North American Maple Syrup Producers Manual

THIRD EDITION

**Produced by
The University of Vermont
in cooperation with
The North American
Maple Syrup Council**

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3rd edition

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North American
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Front cover caption: A maple forest on a beautiful spring day.

Back cover caption: Computerized tomography (CT) scan of red maple wood showing one full and two partial annual growth rings. Vessels (the large open holes) are where the majority of sap flows, rays (the long, thin lines going up/down) provide storage of sugars and starches, and fibers (the majority of small cells surrounding the rays and vessels) are air-filled and help to build pressure in the stem in the spring. Together these tissues produce the sweet sap flow from maple trees during springtime freeze-thaw periods. Photo courtesy of Dr. Craig Brodersen, Yale University.

CONTENTS

Maple syrup production is often a social activity. Like the proverbial groundhog reemerging after the long winter confinement, once steam starts to billow from the sugarhouse, family, friends, neighbors, and strangers alike stop to visit, taste fresh syrup, and renew the bonds of friendship. While the pandemic may have slowed these visits somewhat, there is still a strong desire for people to gather each spring—maple sugaring satisfies that urge. The season is a time of renewal. Good or bad, ready or not, the new sugaring season always seems to energize us in a number of ways.

While society seems to be constantly changing, particularly within the context of the recent health, financial, and other challenges, many have found comfort in the things that stayed the same. At its core, producing pure maple syrup, despite the improved equipment and techniques, has fundamentally changed little over the years and in many ways is essentially the same process used for centuries.

This Third Edition of the North American Maple Syrup Producer's Manual continues in the tradition of previous editions as a compendium for the production of pure maple products. Current information and best management practices are emphasized. While one single publication cannot hope to cover the vast range of topics and the techniques of all practitioners in detail, our aim is to provide a solid foundation of information that will be useful to the majority of producers.

Astute readers will find that many chapters have changed considerably from previous manuals, a few have been updated a little here and there, and some have changed only a little. Some may be disheartened that older techniques and information have fallen by the wayside. While these approaches may still be in use in some sugarhouses, the information is generally unchanged and less relevant to the majority of modern maple operations today.

Rest assured that this material remains available in previous editions of this manual for those looking to explore more traditional techniques.

This work has also been reformatted in ways that will make it easier to update individual chapters in the future. Citations or extensive explanations of some information and techniques have been replaced by internet hyperlinks to source materials, with many of those works available at www.mapleresearch.org, a resource of the North American Maple Syrup Council. This will allow quick and easy retrieval of detailed information if more information is desired. The resources on that website include publications as well as videos, spreadsheets, presentations, calculators, and various other types of media.

These guidelines contained herein should be helpful to producers of all types and sizes, whether you are just beginning or are engaged in tapping tens (or hundreds) of thousands of trees. It should also be of interest to those who simply want to learn more about this unique industry as well as to those who resolve to make maple syrup production a full-time occupation. Although many of the practices involved in collecting and processing sap have evolved to look far different from those of your grandparents and parents, whether you use the latest technology or make syrup with a simple pot over a wood fire, the lure of pure maple remains the same.

ACKNOWLEDGMENTS

Maple producers have benefited from several previous versions of the *North American Maple Sirup (Syrup) Producers Manual*.[1] Rapid advances in sap collection and processing equipment and techniques have occurred since the last edition in 2006. The industry has also expanded rapidly both in number of taps and yield per tap since that time.

The goal with this edition was to update the manual by inviting maple research and outreach professionals and others from the maple industry to address important new aspects of maple production. While not a complete rewrite, several chapters were heavily updated, some were changed more modestly, and a few were only slightly modified. A new chapter on Food Safety was added.

Contributing authors and their affiliations are listed at the beginning of each chapter, however the efforts of many other academic and Extension colleagues working on maple are acknowledged with thanks. While they may not have contributed to the actual writing of this material, their input via discussions, writings, and information presented at conferences has been vitally important to the science and practice and their contributions are incorporated into the content of this manual.

Several people with recognized maple expertise participated in reviewing this manual and its predecessor. Each chapter was reviewed during development for technical content. Appreciation is expressed to those who made suggestions on both the second and third editions, including: Bill Eva, Eileen Downs, Bob and Pat Dubos, Don Giffin,

[1] Willits, C.O. 1958. *Maple Sirup Producers Manual*. USDA Hdbk. No. 134.
Willits, C.O. 1963. *Maple Sirup Producers Manual*. USDA Hdbk. No. 134.
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Special gratitude is extended to the Producteurs et productrices acéricoles du Québec (PPAQ) for granting permission to reprint the technical datasheets on chemistry of maple syrup, sap, and sugar found in the Appendix.

Most of the photos in the manual were provided by the editors and authors of this and previous manual editions and are thus uncited. Many other individuals volunteered photos. These contributions are identified beside those pictures. A special thanks is extended to Mike Girard, former North American Maple Syrup Council Executive Director, and to Mark Isselhardt, Maple Extension Specialist at the University of Vermont. Mike made available his extensive personal collection of photographs. Several of those are found throughout the manual. Mark acted as the unofficial photographer for both the last two editions of the Manual, tracking down or taking pictures to illustrate particular points. Wade Bosley, Brendan Haynes, and Steve "Jed" Abair of the UVM Proctor Maple Research Center also contributed photographs.

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Finally, the editors and authors wish to express their utmost respect and gratitude to the past and present scientists, technicians, Extension and outreach professionals, and all those in the maple industry who have helped to advance the science and practice of maple over the past centuries. We succeed because we stand upon the shoulders of giants.

CHAPTER 1

Introduction

Melvin R. Koelling, Ph.D., *Professor Emeritus,* **Michigan State University, E. Lansing, Michigan, U.S.A.**

To many North Americans the words *maple syrup* and *maple sugar* are synonymous with Currier and Ives images of a simpler, quieter, and more relaxed time in the past. A time characterized by an unhurried pace dominated by a rural, farm-focused lifestyle in which family relationships and "old-fashioned" values prevailed. In general, life in those days was much simpler. Although a great deal of effort was required to complete the farm work necessary to maintain a subsistence level of living, people found abundant satisfaction in the world surrounding them. This was also a time for anticipation of warm, family-focused holiday celebrations as well as the changing of seasons and the opportunities these seasonal changes afforded. For many in the northeastern United States and Canada there was no more anticipated change than that associated with the coming of spring following a long and frequently confining winter.

A harbinger of spring was the arrival of the annual "sugaring" season (**Figure 1.1**). A process that originated with Indigenous North Americans, maple syrup and sugar production is the source of other delectable products such as maple sugar, maple cream, maple candies, and maple taffy. Maple sugar also serves as the principal sugar for other uses such as curing meats and enriching the flavor of baked goods, sauces, and toppings.

Figure 1.1. A harbinger of spring was the arrival of the annual "sugaring" season. (M. GIRARD)

These memories are still alive, and so is the production of pure maple syrup and related products. While substantial improvements have been made in techniques and equipment involved in sap collection and related production and processing (**Figure 1.2**),

Perkins, T.D., R.B. Heiligmann, M.R. Koelling, and A.K. van den Berg (Editors). 2022. *North American Maple Syrup Producers Manual. Third Edition.* The University of Vermont and the North American Maple Syrup Council, Burlington, Vermont. www.mapleresearch.org/manual/

Figure 1.2. While substantial improvements have been made in techniques and equipment involved in sap collection and related production and processing, pure maple syrup is still a natural product, produced largely by the same process used by our forefathers. (M. GIRARD)

pure maple syrup is still a natural product made using the same basic process used by our forebears. Current production techniques are more efficient and attentive to food safety, but the final product is little changed. While nature continues to provide the maple resource and the change of seasons necessary for the sap to flow, dedicated, hardworking individuals still harvest and process this sap into the same delicious product as always. Certainly, modern technology has been applied to the maple syrup industry. Today's sap collection systems involve plastic tubing and vacuum pumps, evaporation systems featuring reverse osmosis (RO) sap concentration units, stainless steel evaporating pans with efficient preheating units, and precision controls and tools to consistently produce the highest-quality product. Contemporary packaging methodology assures consumers of having quality products available in the purest possible condition. While these modifications have resulted in more efficient and productive operations, the heart of maple syrup production is still the collection of maple sap from trees (**Figure 1.3**), and concentration of the sugar in this sap by boiling to produce the unique flavor and character of pure maple syrup.

After a prolonged period of declining production, the pure maple syrup industry has experienced a resurgence and is currently alive, prospering, and growing. It has withstood the test of time and change and continues to occupy a unique place in North American agriculture.

This manual has been prepared to provide current information on all aspects of sap collection and syrup production processes. It contains information that should be helpful to beginning as well as experienced producers whether they are managing small or large operations. This information was obtained from relevant research studies and the experiences of producers, equipment manufacturers and dealers, and others who have dedicated themselves to understanding the processes and techniques involved in producing pure maple products. The pure maple syrup tradition continues; the maple season is greeted with the same anticipation and enthusiasm as always, and the products produced are as valued and treasured as ever (**Figure 1.4**).

Figure 1.3. Maple sap flowing from trees in the spring is at the heart of every operation.

Figure 1.4. Maple season is greeted with the same anticipation and enthusiasm as always, and the products produced are as valued and treasured as ever.

CHAPTER 2

History of Maple Syrup and Sugar Production

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CHAPTER CONTENTS

INTRODUCTION

It is the opinion of many modern consumers that maple syrup producers owe a debt of sincere gratitude to the Indigenous peoples of North America for discovering that sweet sap from maple trees could be collected and consumed. Written accounts from sixteenth-century French and English explorers describe the gathering and consumption of maple sap by Indigenous peoples. Despite early references to the collection and use of maple sap, the actual production of maple syrup or sugar through boiling and concentrating maple sap are curiously absent from early written accounts. The lack of such early historic accounts has led some scholars to question whether Indigenous peoples invented maple syrup and sugar making before the arrival of Europeans. Other scholars point to the difficulties in manufacturing maple syrup or sugar with the technology available to Indigenous populations prior to the introduction of metal containers by Europeans. Historians and archaeologists have yet to find irrefutable evidence from the written or the archaeological record that Indigenous people were making maple sugar or syrup prior to the arrival of Europeans, which is not to say that it did not happen, just that the evidence is lacking at this time.

Similarly, the folklore of maple syrup often centers around the retelling of popular myths and legends of how Indigenous people came to know how to make maple syrup and sugar. As with any legend there is likely a kernel of truth buried somewhere in it, but the telling and retelling over time have embellished and polished the truth to a point where the information that has been passed down is relegated to the category of story or myth. Regardless of the exact timing of their origin or the precise

Perkins, T.D., R.B. Heiligmann, M.R. Koelling, and A.K. van den Berg (Editors). 2022. *North American Maple Syrup Producers Manual. Third Edition*. The University of Vermont and the North American Maple Syrup Council, Burlington, Vermont. www.mapleresearch.org/manual/

process by which the first maple syrup and sugar was made, by the mid-1600s both new European arrivals and the Indigenous peoples of North America were gathering maple sap and boiling it down to create maple syrup and sugar and developing new traditions and a new springtime industry.

EARLY MAPLE PRODUCTION

For early colonists and settlers in North America, life was primarily a subsistence existence. Daily activities were focused on a small family farm that met the family's immediate need for food and shelter and produced a few items that could be either bartered or sold to provide money for things that could not be produced on the farm. All family members capable of working were involved in the cultivation of crops and raising of domestic animals as sources of food and clothing. Where maple trees were present, the collection of maple sap and subsequent processing into syrup and sugar contributed to the family's food supply and often produced some surplus that could be readily sold or bartered for other products.

The rural, farm-centered subsistence lifestyle soon developed into a seasonal pattern. Spring was the time for planting, followed by a period of cultivation and eventually the late summer-fall harvest. This was followed by winter, the time for fuelwood production and anticipation of the coming spring. The maple season in late winter was much anticipated as it signaled the end of a long winter and heralded the coming spring. Most of the maple sap that was collected was reduced to make maple sugar rather than syrup, resulting in custom of referring to the tapping and boiling season as the "sugaring season." Sugaring became an integral part of the farm experience. Occurring at a time of the year when other farm activities of necessity were slowed down by the last vestiges of winter, springtime activities in the sugarbush and sugarhouse caused many to view this as one of the most enjoyable times of the year. The overwhelming majority of maple sugar operations in the 1700s and 1800s were located in the Northeast and Great Lakes regions of the United States, and the adjacent provinces of Canada. However, limited quantities of maple sugar for home consumption were also once produced across the Midwest up to the Plains, and as far south as Kentucky and Tennessee. The harsh winters in northern regions tended to keep people indoors for most of the season, and the opportunity to get out during periods of weather favorable for sap flow was considered a sure indication that spring was "just around the corner." In some communities, maple sugaring was a social event that involved gathering friends and neighbors who provided the many hands needed to run a medium- to large-sized operation. The work required was sometimes tedious and the hours were long, but the fruits of the labor were long remembered as maple syrup and other maple products found their way into many delicious foodstuffs, flavorings, and sweet treats prepared throughout the year. The sugarhouse, known as *la cabane à sucre* in Quebec, also served as a central location where family, friends, and neighbors could gather during the maple season for feasting, music, and dancing. These springtime gatherings and family trips to a sugarhouse remain a cherished cultural tradition in modern-day Quebec.

SAP COLLECTION AND PROCESSING METHODS

Methods of sap collection and evaporation have evolved and gradually improved over the centuries, but the fundamentals of the process remained unchanged. During late winter, temperature-induced physiological processes occur in maple trees such that wounding a tree results in a natural flow of sap that can be collected and processed into maple syrup. Native Americans tapped maple trees by making a rather rough gash through the bark in the trunk of the tree. Sap flowing from this wound was directed through a hollow twig or a flat slat made of cedar or basswood and into a birch bark or wooden container placed on the ground. Sap was collected and placed in large clay pots that were then heated over open fires to concentrate the sugar content of the sap. Occasionally, sap was concentrated by placing heated stones in the sap in the clay pots or hollowed-out wooden vessels. Heat from the stones boiled the sap, concentrating the sugars. Repeating the process several times eventually resulted in a thick syrup that could be poured in molds to cool or be worked with a spoon or paddle as it cooled to form a grained sugar.

Early settlers, both French and English, initially followed the destructive tapping practices of Indigenous peoples by making gashes in the bark to create wounds through which sap would flow (**Figure 2.1**). Sap was collected in wooden troughs placed on the ground. These troughs were made of short, hollowed-out sections of split logs. Within a few years settlers modified their tapping practices so less wounding to the tree resulted. Metal augers were used to make a small hole in the trunk of the tree. In this "taphole" a round tubular wooden spout, or spile, was inserted to direct the sap into a collection container. The word *spile* probably comes from the idea that the spile was used to "spill" the sap from the tree into a container. These primitive spouts were small stem sections of sumac or elder that were hollowed out by removing the central core, or pith, (**Figure 2.2**). In the latter half of the 1800s commercially manufactured metal spouts replaced those made of wood. A variety of different designs were available from several different manufacturers with the earliest made of cast iron and later designs of folded or rolled sheet metal covered with less corrosive coatings like tin or zinc (**Figure 2.3**).[1] A

Figure 2.1. Early sap collection practices used gashes cut into stems and chips of wood or bark and later small pieces of metal to direct sap into containers placed on the ground.

Figure 2.2. Primitive spouts were small stem sections of sumac or elder which were hollowed out by removing the central core or pith tissue.

Figure 2.3. Eventually commercially manufactured metal spouts replaced wooden ones, with a variety of different designs available from a several different manufacturers.

[1] Although hollowed-out elderberry stems were used by settlers and are still recommended in some literature as suitable for maple spouts, they are not recommended. The twigs of elderberry contain a low-level toxin.

shift from wooden to smaller metal spiles led to smaller-diameter tapholes and more effective sap collection. Some incorporated a built-in hook to support either the wooden or later metal sap collection pail at the taphole as opposed to placing it on the ground. Over time the hand-operated brace and bit replaced the large-diameter auger as the standard tapping tool.

For many years the hand-powered brace was the standard tapping tool. However, power tapping units first appeared in the 1940s and 1950s and ultimately found their way into the sugarbush. The first were rather heavy gasoline-powered backpack units with a flexible shaft that drove a small bit held in front of the operator (**Figure 2.4**). Later, backpack units powered with bulky wet cell batteries became available. Though some producers still use a tapper consisting of a lightweight gasoline-powered drill, a high proportion of today's tapping is done with cordless handheld battery-powered drills.

Containers used for collecting sap have progressed from vessels made of bark and hollowed-out logs to wooden buckets (**Figure 2.5**) in the 1600s and 1700s, to metal buckets (**Figure 2.6**) in the late 1800s, and lastly to plastic bags and plastic pails from the 1950s to today. The size and design of sap containers have changed over time; however, all required at least daily visits during the sap season to collect the accumulated sap. In the early 1900s a sap collection system invented by William Brower was introduced using metal tubing that did not require a collection container at each taphole. Known in some locations as the "gooseneck" system for the curved neck-like shape of some of the metal pipe (**Figure 2.7**), the Brower system was laid out in a dendritic pattern with lateral and main lines, like a modern plastic tubing system, carrying sap from the taphole to the collection tank. The gooseneck system did not gain wide acceptance because it was prone to leaks,

Figure 2.4. Gasoline powered tapper. (UVM LIBRARY SPECIAL COLLECTIONS)

Figure 2.5. Early wooden maple sap bucket.

Figure 2.6. Metal sap buckets. (UVM LIBRARY SPECIAL COLLECTIONS)

[2]http://maplesyruphistory.com/category/george-cary/

Figure 2.7. Early "goose-neck tubing system. (GIRARD)

was difficult to clean, required strict attention to grade (slope), and was more expensive than metal buckets, not to mention that it was easily damaged by roaming moose and deer, high winds, and falling limbs.[2]

The availability of new materials following the end of World War II led to the introduction of the plastic bag for sap collection in the early 1950s (**Figure 2.8**). Soon after in the mid-1950s, inventive engineers and sugar makers like George Breen, Nelson Griggs, and Robert Lamb began experimenting with flexible plastic tubing, taps, and fittings to transport sap from the taphole to the collection tank. Like the gooseneck metal tubing system, early plastic tubing used gravity to carry sap downhill directly from the tap hole to either a centrally located collection tank or right into the sugarhouse. This system eliminated the need for daily sap collection at the tree. Plastic tubing significantly reduced both the labor and equipment costs associated with sap collection and improved sap quality and sap yields. The development and addition of vacuum pumps to tubing networks in the early 1970s has since enabled producers to significantly increase sap yields and accelerate the movement of sap through the tubing network. Vacuum pumps

Figure 2.8. Plastic bags for sap collection. (UVM)

[3]A collection of maple history articles can be found at http://maplesyruphistory.com/ and an archive of maple-related research in Vermont from the 1940s through 1970s is located at: https://cdi.uvm.edu/collection/uvmcdi-uvmcdimapleresearch.

also facilitated the installation of tubing in both flat and sloping landscapes.[3] The adoption of tubing combined with vacuum has arguably been the maple syrup industry's most important improvement in the twentieth century.

In the earliest years of sugaring, sap was gathered and transported to the evaporation site by hand. Given that most operations were relatively small and had plenty of family or local labor on hand, this was not an insurmountable task. Gathering equipment often consisted of a couple of large wooden buckets suspended from a shoulder yoke. However, as operations increased in size, it became necessary to collect sap from several trees, empty the gathering pails into a gathering tank, and transport it to the evaporator. Initially this was done with a team of oxen or horses pulling a sledge or sled on which a wooden tub, barrel, or tank was mounted. Eventually many operators replaced the wooden tubs with metal collecting tanks (**Figure 2.9**), and the oxen or horses with tractors or crawlers. Where plastic tubing systems are used it is not necessary to collect sap directly from each tree. Rather, sap moves through the tubing system to a common collection point, preferably the sugarhouse. If it is necessary to move sap, pumping systems are installed to transport sap from one location to another. For large operations, where sap is collected from one or more sugarbushes, trucks equipped with holding tanks are used to transport the sap.

Equipment used for boiling and evaporating sap has changed and improved over the years; however, the requirements of concentrating the sap and applying heat to develop color and caramelization in the syrup has not. Early settlers used metal cauldrons or kettles to boil the collected sap. These vessels were suspended from a pole or tripod over an open fire. As the amount of sap in the kettle was reduced by boiling, more sap was added. Eventually the concentration of sugar in the boiling sap was increased to reach the point of "finished syrup." The syrup produced by this method, although sweet, was strong flavored and dark because of prolonged boiling resulting from the continued addition of fresh sap. An innovation resulting in improved quality of the final product was the use of multiple kettles. Partially concentrated sap was transferred from one kettle to another as it progressively increased in sugar concentration. This process resulted in the production of lighter-colored syrup as the boiling

Figure 2.9. Early sap gathering with a tank on an animal-drawn sledge. (F. TANGUAY)

time required for sugar concentration was reduced. In the 1700s and most of the 1800s most of the sap was reduced to a thick syrup that was poured into molds or wooden kegs and cooled to form cakes, loaves, or block sugar (**Figure 2.10**) that could be broken up and pulverized into granulated sugar or reconstituted into syrup by adding water.

In the mid-1800s the large, shallow, flat-bottomed pan for concentrating sap was introduced. Mounted on a firebox called an arch (so called because of its shape) usually made of stone or brick (**Figure 2.11**), this pan and the arch it sat on greatly increased the rate of boiling and evaporation. Expanding both the boiling surface and the area where heat could be applied made it easier for the operator to control the intensity of the heat generated by the cooking fire. By 1860 the continuous flow evaporator appeared on the scene. This was a modified flat pan equipped with series of maze-like sectional dividers (**Figure 2.12**) that allowed sap to enter at one end of the pan and become increasingly concentrated as it moved through the sections of the divided pan to be become finished syrup that was "drawn off" at the other end (**Figure 2.13**). The advantage was more rapid evaporation and a "continuous evaporation" process that required less mixing of fresh sap and partially concentrated sap. The result was reduced boiling time and a higher-quality final product. This was a major improvement over the batch system used with both kettles and flat

Figure 2.10. Most maple was primarily made into block or cake sugar well into the 1800s.

Figure 2.11. Boiling outdoors on a flat pan setting on a stone arch.

Figure 2.12. Katherine Skinner boils on a continuous flow evaporator on a metal frame wood-fired arch in Westmore, Vermont, in the 1940s. (GAUTHIER)

Figure 2.13. An abandoned early continuous flow flat-pan evaporator with partitions.

pans in which boiling would take place for several hours before removal of the finished syrup.

One of the first evaporators to be patented and used in the maple industry was the Cooks Sugar Evaporator, patented to Daniel McFarland Cook on June 22, 1858. It was originally made to produce molasses or sorghum syrup. However, it was evaluated for maple syrup production and was soon accepted as a sap evaporator without a rival. Cook himself never manufactured the evaporator, instead selling the rights to produce it to several metal fabricators in different states.

Improvements in the efficiency of sap evaporators continued with the addition of flues to the continuous flow pan. This resulted in separating the evaporator into two individual pans, a front, or syrup, pan and a back, or flue, pan. The flue pan was a modified flat pan with several deep corrugations or individual wells in the bottom of the pan that increased the surface area to which heat was applied. The result was much more rapid boiling and evaporation. Partially concentrated sap flowed from the flue pan into the flat surface syrup pan where boiling continued and sap was brought to a proper finishing temperature. The quality of the finished syrup was substantially improved due to the shortened evaporation time.

From the beginning of maple syrup and sugar making up to today, burning wood has been the primary source of heat employed in the boiling process. Wood-fired evaporators continue to be most used today; however, other forms of heat have been introduced in the twentieth century. Oil-fired burners were introduced in the 1940s and have been adopted by maple operations with larger evaporators and sugarhouses with more automated systems. Steam heat systems, requiring an external boiler, are beginning to see use as well.

The basic evaporator has remained unchanged since the development of the flue pan. However, several accessories have been developed over the years to increase evaporator efficiency. These generally attempt to use steam produced during evaporation to preheat incoming sap, thereby reducing the amount of both heat and time required for processing sap into syrup. One of the first such devices was a hood placed over the evaporator to direct the steam away from the evaporating surface. Later the sap preheater was introduced. Initially a series of coils was placed in the smokestack of the arch, and incoming sap could flow through these coils becoming warmed before it entered the evaporator. Improvements in a sap preheating device called a "Steam-Away®" led to placement of pipe sections on a suspended platform within the steam hood, allowing incoming sap moving through these pipes to significantly increase in temperature. These preheating devices have resulted in gains in evaporator efficiency. Modifications to increase the amount of air going into the firebox of wood-fired evaporators have also resulted in an increase in evaporator efficiency, as have modifications such as insulated arches and airtight doors, and preheating oil by running feed lines through the firebox to improve fuel atomization and combustion. Lastly, the electronics and computer age have led to the installation of sensors in evaporators and arches to monitor and automatically adjust temperatures, fuel, and sap and sugar levels and control syrup draw-off.

Evaporators were initially located in the open in the sugarbush, where kettles were suspended over open fires on tripods or log supports. This led to a shift to the use of pans supported on arches constructed of stones or bricks and fueled by wood collected from within the woodlot. Since the evaporators were outdoors, syrup producers were subjected to whatever type of weather was present. It soon became apparent that some type of shelter was desirable; thus the "sugarhouse" came into being. The first shelters were nothing more than crude shacks or lean-tos in the woods built to protect the valuable pans and provide some shelter for the operators. These were followed by the construction of cabin-type structures that over time have come to be identified as sugarhouses (**Figure 2.14**). Initially these buildings were located in the woodlot, and sugarhouses are often still found there today; however, they are increasingly located in more accessible and convenient areas where utilities such as electricity and running water are available. Over time it also became more common to set up sugarhouses near public roads, where modifications in their structure enabled them to serve as not only production facilities but also outlets for marketing the finished product.

EARLY MAPLE INDUSTRY—1700s AND 1800s

Consistent with the subsistence lifestyle of early settlers and colonists in the northeastern United States and Canada, maple syrup and maple sugar were the principal sweetening agents used in the home. The only other locally produced sweetening product was honey, although it was not as commonly available. Together maple syrup and honey found their way into several prepared food products and were increasingly used in preserving, drying, and curing of many staple foods, including meats. Cane sugar, a rare and expensive commodity in the first half of the nineteenth century, was generally unavailable in most rural areas. When it could be obtained it was viewed and treated as a luxury product.

FIGURE 2.14. Early "sugarhouses" were cabin-type structures which, over time, evolved into the modern sugarhouse. This is "Sugar-House No.138." of the Cary Maple Sugar Company in Danville, Vermont, from the early-1920s. (GRAHAM)

In the late 1800s maple equipment, which had been made by general metal workers in local communities, began to be manufactured by specialized equipment companies. While originally there were several such companies located throughout the northeastern United States and Canada, over time several of these companies discontinued production or merged with other operations. Some of these companies continue to operate and supply maple equipment for the industry today.

Maple syrup producers first began keeping reasonably good production records in the mid-1800s.[4] Much of what was produced at that time was maple sugar, with only modest amounts of the maple harvest made into syrup. This was likely due primarily due to ease of storage and transport of a solid compared to a liquid.

Maple products, especially maple sugar, continued their dominance as the principal food sweetener in some regions until after the United States Civil War. Following the war, improvements in production techniques and transportation resulted in larger quantities of cane sugar becoming available and in the reduction of its price. As a result, many urban residents increased their use of cane sugar and decreased their use of maple sugar. The reduced demand for maple sugar forced the industry to find and promote new uses for their products, which led to in an increase in the amount of maple syrup marketed primarily for use as a topping for pancakes, waffles, and other similar foods.

In the latter part of the nineteenth century, syrup packers came on the scene, providing a sales outlet for maple producers. These companies purchased syrup from many maple producers, then

[4]Graham, G. 2016. Maple Syrup Production Statistics—An Updated Report to the North American Maple Syrup Council. Ohio State University Extension. 30 pp. https://mapleresearch.org/pub/grahamstats2016-2/

packaged and marketed syrup under their own brand and label, developing regional and national markets for table syrup in the process. Most of these packers were blending pure maple syrup with corn syrup, then called glucose, and cane sugar to create maple-flavored syrups that undercut the price of pure maple syrup. George C. Cary and the Cary Maple Sugar Company provided another place for maple producers to sell their product when he convinced the tobacco industry to use maple sugar as a flavoring agent. Sales to the Cary Company were especially popular with Vermont and Quebec producers, who continued to make more maple sugar than syrup in the 1890s and early 1900s. For about 50 years the tobacco industry was a large consumer of maple sugar, using it for flavor and aroma enhancement of different tobacco products.

The first of several maple producer organizations were formed in the 1890s. In the beginning the goals and objectives of these state and regional associations were to work together to address their concerns regarding false labeling and the sale of what they called adulterated syrup, as well as to share ideas among members and focus collective efforts on addressing common production problems.

Improvements in evaporator design and sophistication, greater ease of railroad shipping, and the increased availability of sheet metal in the late 1800s enabled the rise of a great number of specialized maple sugaring equipment companies in both the United States and Canada. As the industry progressed into the twentieth century, many of the smaller companies were bought out and absorbed by an ever-shrinking handful of large equipment manufacturers. A few of these large equipment companies continue to operate and supply maple equipment to the industry today.

MAPLE INDUSTRY—1900 TO WORLD WAR II

In the early part of the twentieth century maple production continued much as it had in previous years. Small family-operated farms dominated the rural landscape, and the production of pure maple products was an integral part of the diversified agricultural operation. Higher-grade excess syrup was sold to neighbors or to urban residents who did not produce their own syrup, and lower-grade syrup was sold to packers and syrup buyers for bottling and blending and tobacco flavoring. As something of a precursor of the major maple enterprises that would later emerge, the first large-scale maple syrup operation appeared in the Adirondack region of New York with the Horse Shoe Forestry Company tapping as many as 50,000 trees and making syrup in nearly 20 large evaporators. Other producers expanded their operations to take advantage of the simplicity of selling in bulk to single wholesale syrup or sugar buyer like the Cary Company.

Maple producers were concerned about the adulteration of pure maple syrup and the difficulty of competing with syrup blenders that were selling large volumes of cane and corn syrup mixed with smaller amounts of maple syrup and falsely labeling this more easily and cheaply produced commodity as pure maple syrup. These adulteration concerns were partly addressed with the introduction of the Pure Food and Drug Act of 1906, which resulted in regulations requiring more truthful and accurate labeling of ingredients. This legislation forced the large syrup blenders with national markets to truthfully declare that their syrups were a combination of cane or corn and pure maple syrup. While the Act helped clean up the false advertising of some blenders, it did not prevent the blending of maple with other syrups. Companies and brands like Towle's Log Cabin from St. Paul, Minnesota; Burlington, Vermont's Welch Brothers; and the New England Maple Syrup Company out of Boston continued to manufacture blends with some amount of pure maple syrup, and in doing so, these companies purchased a significant volume of lower-grade maple syrup.

Maple producers recognized the value of coming together as a unified voice when addressing the actions of government that affected them as well as to share ideas and pool resources for sales and marketing. There was also a desire to work together to cut out the middleman syrup buyer and packer and to pool resources for sales and marketing. Some states and provinces simply formed statewide and provincial maple producers' organizations at this time, while others formed formalized sales and marketing cooperatives through which members sold the bulk of their maple syrup and sugar. Most co-ops proved unsuccessful in the end and were discontinued due to insufficient capital, poor management, and low participation; however, others like the Producteurs de Sucre d'érable de Québec, now known by their brand name Citadelle, have survived and continue to operate.

The voices of industry were heard, and support and assistance for maple producers through federal, provincial, and state agricultural departments and university Extension offices appeared in the first half of the twentieth century. The resources and organization of these offices were directed toward practical industry research and testing of new technology. They also provided hands-on guidance and expertise and addressed broader industry issues such as the wider adoption of syrup grading based on federal, state, and provincial color standards.

World War II had a significant impact on the maple industry. With shipping and transportation limited by the war effort, and some commodities redirected to assist in feeding the troops, the supply of cane sugar was limited and eventually cane sugar was rationed. The result of rationing was an increase in demand for maple syrup and sugar. Demand was so great that the government placed price controls on maple syrup, limiting the price per gallon to $3.39. Similarly, production by maple producers for home consumption also increased. The immediate impact of limited supplies was a reduction in the amount of syrup available for the wholesale market. Some markets, such as the tobacco market, were eventually lost, even though rationing was removed following the war.

Manufacturing of maple syrup making equipment, most notably evaporators, tanks, pails, covers, and syrup tins, largely ground to a halt during World War II with sheet metal supplies being diverted to the production of equipment and supplies that supported the war effort. As a result, the maple industry began to experience a gradual shift to bottling syrup in glass containers and smaller, more shelf-friendly sizes for consumers in urban markets. In addition, the improved prices for hardwood lumber in the 1940s, led many sugarbush owners to cut down and sell substantial portions of their maple woods, setting the maple industry back even further.

MAPLE INDUSTRY—WORLD WAR II TO THE 1990S

Following World War II, significant changes occurred in many aspects of both rural and urban life, and technology advanced at a pace unparalleled at any time in the past. Transportation facilities have improved, a significant migration of people from rural to suburban areas has occurred, and a reduction in the number of family-focused, diversified farms typical of previous times has also taken place. Specialization has occurred in many agricultural operations, including maple production, and with it, the number of maple producers has declined. However, many of those remaining have increased the size of their operations and, in more than a few instances, have developed their maple syrup operation into a full-time business with the production of many maple sugar products derived from maple syrup and the establishment of both local and national retail markets.

During World War II and in the years preceding it, maple production in the United States and Canada was relatively equal. In the first few decades following the war, maple syrup production in Canada remained relatively constant while the United States saw an immediate decline to the point of producing half as much syrup as Canada. Overall, the production levels of the entire maple industry were at their historically all-time lows due to changing consumer palates and the loss of formerly profitable markets like the tobacco industry and a drastic reduction in the amount of maple syrup used by the blended table syrup industry.

Packaging maple syrup for retail and direct sales took a giant leap forward in the late 1940s with the introduction of cans in 1-gallon sizes down to single pint sizes featuring attractive color lithographed maple sugaring scenes. Packaging and syrup sales were further improved in the early 1970s with the introduction of food-grade plastic containers shaped and colored like antique ceramic jugs. A third wave of packaging came in the 1990s with the increased availability and variety of fancy glass containers that showcased the color and clarity of maple syrup, becoming very popular for gift giving and with tourists.

The post-war period also witnessed experimentation with new models of production such as the central evaporator plant in which multiple owners of maple groves tapped and sold their raw sap to a single nearby sugarhouse or syrup plant, similar to the model of a cheese factory or dairy cooperative. As promising as this model was, woodlot owners and syrup producers found its administration to be cumbersome and a distraction from the work of making syrup, and it failed to take off.

The continued adoption of new power tools and machinery on the farm spilled over to the development of useful new tools for the maple syrup industry. Gasoline- and battery-powered tapping machines were introduced in the 1940s and 1950s, replacing the centuries-old brace and bit and greatly speeding up the tapping process each spring. By the end of the 1950s tractors and trucks had almost completely replaced the use of animal power for sap gathering in the sugarbush.

Changes were witnessed in the design and location of sugarhouses with the modernization of sap gathering and incorporation of more efficient evaporators and arches. In addition, greater attention to and enforcement of food production and food safety regulations led some producers to make a shift away from the romantic, simple wood framed and sided sugarhouse with a cupola on top nestled in the sugarbush. In its place was a less distinctive industrial or barn-like structure designed to comply with local construction and sanitary codes, equipped with electricity and running water, and situated near the residential dwelling and other farm buildings in a wooded area alongside an improved roadway.

In the last several decades, improvements in technology have greatly affected the maple syrup industry. Many of these technological advancements have originated from research designed to increase production efficiency while conserving energy. Included are such advances as the widespread use of plastic tubing sap collection systems, increasingly sophisticated sap collection vacuum systems, improved spout and tubing sanitation practices, closer attention to tapping techniques, reverse osmosis sap sugar concentration systems, and sap preheaters and similar evaporator modifications to increase heat transfer to incoming sap. Until very recently, little research has focused on the impacts of such changes on flavor development. There have been changes in evaporator design to use forced draft wood-burning systems, automated draw-off equipment for finishing syrup, application of pressure-filtering systems for syrup filtration, and a variety of automated canning and bottling equipment for packaging syrup. New containers for packaging maple syrup for retail market sales have also been developed, including many that are made of food-grade plastic.

While the number of maple syrup operations associated with small subsistence-type farms has declined, another significant class of maple producer has emerged in recent years. The number of individuals who live in rural areas but who do not depend on farm activities as the primary source of their livelihood has increased. Many of these rural residents, although employed elsewhere, have access to a maple woodlot. Each winter they tap a few or several trees to produce their own pure maple syrup. While the total amount collectively made by producers of this type is not large, the actual number of individuals involved is very significant and represents an increasingly common source of pure maple products in many rural areas. With the promotion by the provincial government of a switch from pails to plastic tubing and vacuum systems, the producers in Quebec experienced a significant increase in their maple syrup production in the 1980s and 1990s. With production levels over twice as high as those in the United States, Canada and the Province of Quebec took their place at the head of the table of the maple syrup industry. Efforts at international cooperation and integration of support, research, and marketing in the maple industry gave birth to the North American Maple Syrup Council in 1959 and the International Maple Syrup Institute in 1975, two cross-border organizations working to improve and promote the industry.

In the late 1980s and early 1990s, the government of Quebec took the maple syrup market in a new direction with the decision to mandate that all bulk sales of maple syrup in the province be carried out by a single, centrally run cooperative organization known as the Federation of Quebec Maple Syrup Producers (Fédération des producteurs acéricoles du Québec). With the aim of stabilizing market prices and controlling surplus and overproduction, a strategic reserve of maple syrup was established. Prices paid for bulk syrup in the province were fixed by the Federation and producers were assigned production quotas to better align supply with demand. In the 2000s Federation resources were further employed to push the industry to expand existing markets and develop new markets and maple products.

MAPLE INDUSTRY—2000 AND BEYOND

With the arrival of the twenty-first century, improvements in sap collection and processing enabled maple operations to generate products of the highest possible quality. More sophisticated and knowledgeable consumers now pay greater attention to how the food products they buy are made and where they come from. Consistency in quality, absence of impurities or contaminants, and safety of food products have become primary concerns of many consumers. As demand for pure maple products has increased, production has increased in both the U.S. and Canada (**Figure 2.15**)

The maple industry is not immune from these consumer concerns. In recent years the increased production of and growing demand for pure maple syrup and syrup-derived products has fueled significant advances in research, technology, and materials that continue to improve the manufacture of maple equipment, resulting in the increased production of quality maple products. The possibility of low levels of lead in finished syrup and syrup-derived products has resulted in a change in methods of manufacture for maple sap and syrup production and processing equipment. Much of the older processing equipment formerly used by many producers has been replaced. Stainless-steel evaporators and related sap and syrup handling equipment are now manufactured using lead-free solder or welding. Syrup is packaged in food-grade containers made of materials that will not impart off-flavor or otherwise result in product degradation.

Another concern related to maple products and their production has to do with their classification as "organic food materials." In the past several years increasing concern has developed related to food quality and purity. Among consumers there is a perceived but not necessarily research-proven perspective that "organically produced" foodstuffs are superior in both quality and nutritional value to

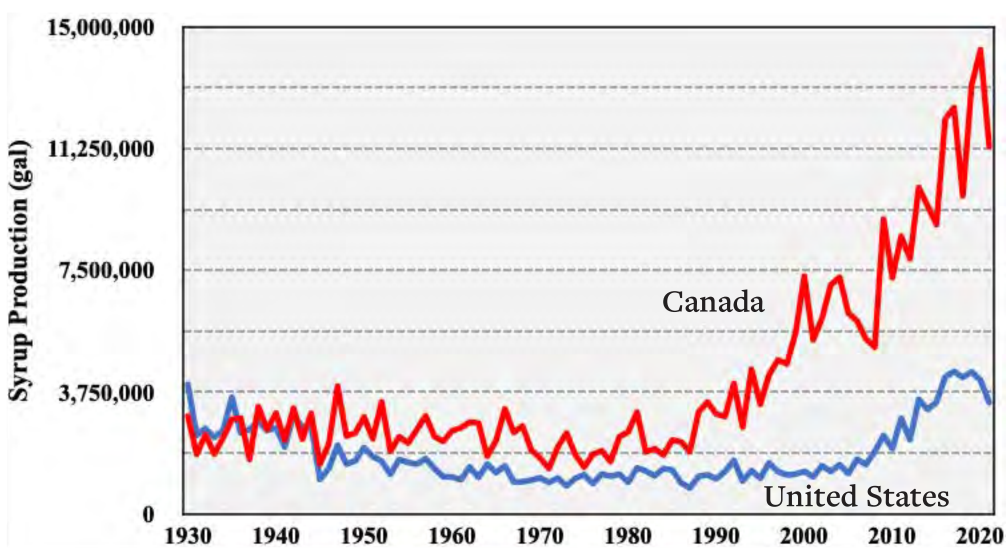

FIGURE 2.15. Production of maple syrup in the U.S. and Canada from 1930 to 2021. SOURCES: GRAHAM, G. 2016. MAPLE SYRUP PRODUCTION STATISTICS. OHIO STATE UNIVERSITY EXTENSION., USDA NATIONAL AGRICULTURAL STATISTICS SERVICE, STATISTICS CANADA.

foodstuffs produced using “inorganic fertilizers or pest controlling products.” In the minds of some, the growing popularity of foods identified and certified as organically produced is more likely a reflection of the power of a marketing that capitalizes on the fact that these products command higher prices rather than a reliable indication of food, safety, quality, or purity. Producers of pure maple products have taken advantage of this marketing opportunity, and many have promoted maple syrup and sugar products through organic food marketing outlets. In so doing, they satisfy a more demanding segment of the population while increasing economic returns.

While many aspects related to sap collection, processing, packaging, and marketing have changed substantially in recent years, the purity and wholesomeness of maple syrup and related products remains the same. It is this same wholesome flavor, quality, and image that will continue to satisfy the needs and wants of maple consumers. With significant improvements in production processes continuing to evolve from technological innovations applied to the maple industry, and the popularity of pure maple products among consumers, the future of “pure maple” would seem certain. Opportunity to produce and enjoy this unique North American product should continue, if not expand, in the future.

CHAPTER 3

The Maple Resource

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CHAPTER CONTENTS

INTRODUCTION

Approximately 132 species of maple (the genus *Acer*) exist around the world, with the vast majority found in the Northern Hemisphere. There are thirteen native maple species in North America (**Table 3.1**). These are distributed primarily in the eastern and central regions of the United Stated and Canada and along the Pacific Coast, reaching the highest concentrations in the northeastern and north-central areas of the U.S. and bordering areas of Canada (**Figure 3.1**).

The commercial production of maple products (other than wood) is almost entirely restricted to North America, in the northeastern and north-central United States and southeastern and south-central Canada, although maple sap is collected as a seasonal beverage/tonic in some Asian countries. While sap will flow from most maple species when tapped during appropriate times, strong sap flows with a reasonably high sugar content will only occur under the proper climatic conditions. Sugar maple (*Acer saccharum*), black maple (*Acer nigrum*), and red maple (*Acer rubrum*) are the most important commercial species for maple syrup production, but silver maple (*Acer saccharinum*) is often tapped along roadsides and in areas where it is the predominant maple species. Other species in the genus are tapped less commonly, such as bigleaf maple (*Acer macrophyllum*) in areas of the Pacific Northwest, and occasionally boxelder (*Acer negundo*) in the prairie states and provinces where it is the only tappable native maple species.

SPECIES SUITABLE FOR MAKING MAPLE PRODUCTS

Sugar and Black Maple

Sugar and black maple are very similar species and, because of their high sugar content, are the

Perkins, T.D., R.B. Heiligmann, M.R. Koelling, and A.K. van den Berg (Editors). 2022. *North American Maple Syrup Producers Manual. Third Edition*. The University of Vermont and the North American Maple Syrup Council, Burlington, Vermont. www.mapleresearch.org/manual/

Table 3.1. Maple species native to North America.		
Common Name	**Scientific Name**	**General Geographic Distribution**
Sugar Maple	*Acer saccharum*	Northeast United States and Southeast Canada
Black Maple	*Acer nigrum*	Northeast United States and Southern Tip of Ontario and Quebec
Red Maple	*Acer rubrum*	Eastern United States and Southeast Canada
Silver Maple	*Acer saccharinum*	Eastern United States and Extreme Southeast Canada
Boxelder	*Acer negundo*	Eastern and Central United States, South Central Canada, Scattered Western States
Mountain Maple	*Acer spicatum*	Northeast United States and Southeast Canada
Striped Maple	*Acer pensylvanicum*	Northeast United States and Southeast Canada
Bigleaf Maple	*Acer macrophyllum*	Pacific Coast of United States and Canada
Chalk or Whitebark Maple	*Acer lucoderme*	Southeast United States
Canyon or Bigtooth Maple	*Acer grandidentatum*	U.S. Rocky Mountains
Rocky Mountain Maple	*Acer glabrum*	Western United States
Vine Maple	*Acer circinatum*	Pacific Coast of United States and Canada
Florida Maple	*Acer barbatum*	Southeast United States Coastal Plain and Piedmont

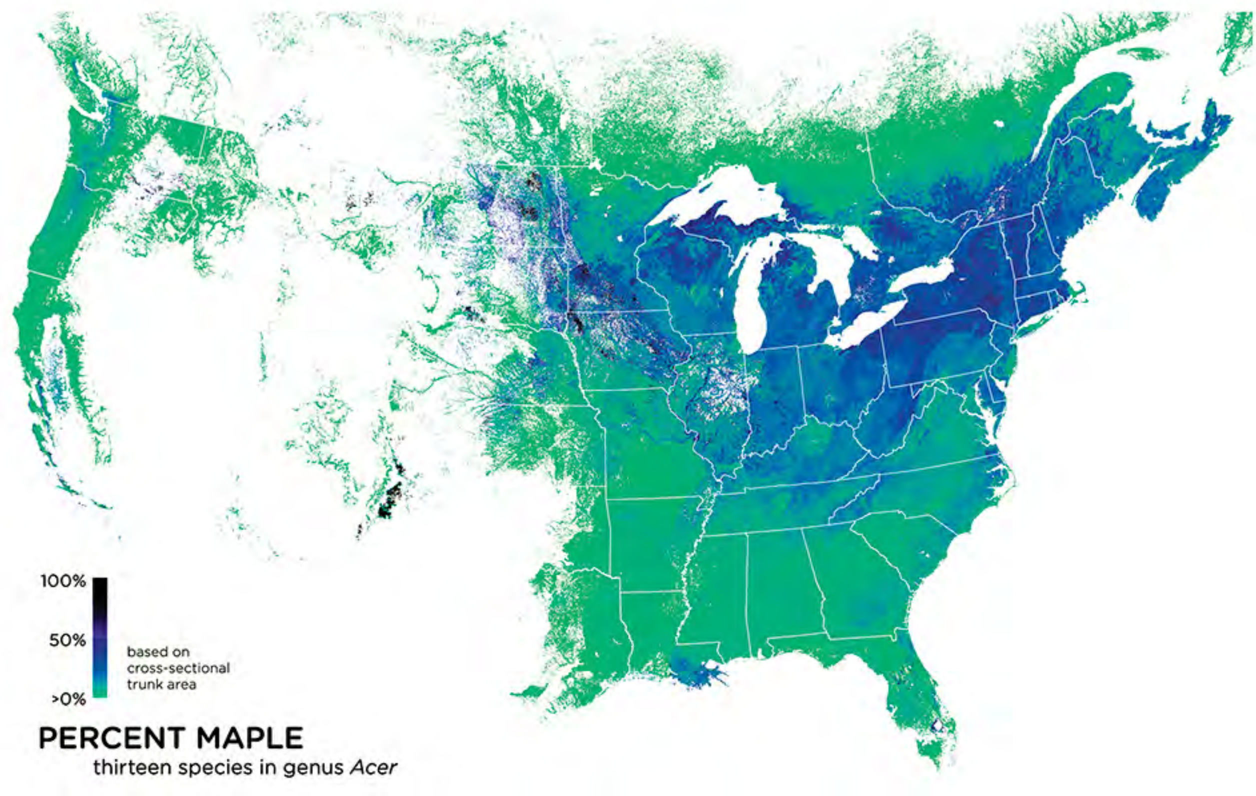

Figure 3.1. Percent maple in the U.S. and Canada based upon cross-sectional trunk area. Data from the U.S. Forest Service (2013) and Canadian Forest Service (2014, 2016). Figure used with permission, Bill Rankin, www.radicalcartography.net/trees.html

most preferred species for harvesting maple sap. Sugar maple occurs naturally throughout most of the northeastern United States and southeastern Canada (**Figure 3.2**). Black maple, on the other hand, occupies a much smaller natural range (**Figure 3.3**), particularly in the north and northeast areas. Distinguishing between the two species may be more of an academic exercise than it is a useful management practice because (1) they are essentially identical in quality as sap producing trees and (2) they are reported to hybridize, producing trees with a range of characteristics, making it difficult to clearly distinguish between them. Identifying characteristics of sugar and black maple are presented in **Table 3.2** and **Figure 3.4** and **Figure 3.5**. The leaves of both species have five lobes, are oppositely paired along the stem, and lack fine teeth along the margin. The bark of older trees has long plates or ridges that often peel away from one side of the trunk but remain attached along the other. The twigs have oppositely paired, pointed lateral buds and a relatively long, pointed terminal bud. The fruit of black and sugar maple is identified by its size and horseshoe or "U" shape.

Distinguishing between sugar and black maple is best done by comparing the leaf structure (particularly the number of lobes, droopiness, and presence or absence of stipules along base of petiole) and by the degree of bumpiness of the twigs. The trunk bark of large black maples also tends to be less platy and has more of a ridge and fissure structure than sugar maple.

Sugar and black maples are found on a variety of soils and site conditions, but neither tolerates excessively wet or dry sites, and both grow best in deep, moist, but well-drained soils. Black maple is more likely to be found along moist river bottoms. Each of these species can be found growing in pure stands, in combination, or with a wide variety of other hardwood species, including American beech, American basswood, yellow birch, black cherry, northern red oak, yellow poplar, and black walnut. Both species have been planted extensively as roadside trees, which are often tapped as part of a sugaring operation. In some instances, plantations of sugar maple have also been established with the

Figure 3.2. Range map of sugar maple in North America. (USGS)

Figure 3.3. Range map of black maple in North America. (USGS)

TABLE 3.2. Identifying Characteristics of Sugar, Black, Red, and Silver Maple and Boxelder.[1]

SPECIES	Leaf	Bark	Twig	Fruit
Sugar Maple	3–6 inches wide: 5-lobed (rarely 3-lobed); bright green upper surface and a paler green lower surface; leaf margin without fine teeth (compare to red and silver maple).	Young trees up to 4–8 inches in diameter with smooth gray bark, Older trees developing furrows and ultimately long, irregular, thick vertical plates or ridges that curl outward.	A somewhat shiny, brownish, slender, relatively smooth twig with ¼–⅜ inch long sharply pointed terminal bud.	Horseshoe-shaped double-winged fruit (called a double samara) with parallel or slightly divergent wings. Winged seed approximately 1 inch long. Fruits borne in clusters and mature in fall.
Black Maple	Similar to sugar maple but usually 3-lobed (sometimes 5-lobed); often appears to be drooping; often with a thicker leaf and leaf stem (petiole) than sugar maple; often with a distinct pubescence or hairiness on the under-side of the leaves; usually with two wing-like or leaf-like growths at the base of the petiole (stipules).	Similar to sugar maple but usually darker and more deeply grooved or furrowed.	Similar to sugar maple but twig surface with small bumpy growths (lenticels—which are not raised much above the bark surface in sugar maple) often more hairy buds.	Similar to sugar maple, with perhaps a slightly larger seed.
Red Maple	2–6 inches wide; 3-lobed (occasionally weakly 5-lobed); sharply "V"-shaped sinuses; small sharp teeth along margin. Sides of terminal lobe converge toward tip. Mature leaves have a whitish appearing underside.	Young trees up to 4–8 inches in diameter with a smooth light gray bark, developing into gray or black ridges and ultimately relatively broad, scaly plates.	Slender, shiny, usually reddish in color; terminal buds ⅛–¼ inch long, blunt, red; odorless if bark bruised or scraped.	"V"-shaped, double-winged fruit about ½–1 inch long. Fruit matures in late spring.
Silver Maple	5–7 inches wide; deeply clefted; 5-lobed with the sides of the terminal lobe diverging toward the tip; light green upper surface and a silvery white underside; leaf margin with fine teeth (but not the inner edges of the sinuses).	Silvery gray on young trees breaking into long, thin, scaly plates that give the trunks of older trees a very shaggy appearance. Considerable red is seen in bark pattern as scales develop.	Similar to red maple but often more chestnut brown in color. Bruised or scraped bark has a very fetid or foul odor.	"V"-shaped, double-winged fruit 1½–2½ inches long, with widely divergent wings. One of two seeds present is often poorly developed or aborted. Fruit matures in spring.

[1] Extensive information on each species can be found in U.S. Forest Service Handbook 654, Silvics of North America. https://www.srs.fs.usda.gov/pubs/misc/ag_654_vol2.pdf

TABLE 3.2 (*cont'd.*)

SPECIES	Leaf	Bark	Twig	Fruit
Boxelder	Pinnately compound with 3–7 (rarely 9) leaflets; leaflets green above and pale below, margins variably toothed or lobed, terminal leaflet often resembling a three-lobed maple leaf.	Young trees up to 4–8 inches in diameter with smooth gray bark, Older trees developing furrows and ultimately long, irregular, thick vertical plates or ridges that curl outward.	A somewhat shiny, brownish, slender, relatively smooth twig with ¼–⅜ inch long sharply pointed terminal bud.	Horseshoe-shaped double-winged fruit (called a double samara) with parallel or slightly divergent wings. Winged seed approximately 1 inch long. Fruits borne in clusters and mature in fall.

FIGURE 3.4. Sugar maple leaves, fruit, twig, and bark. (VPI)

intent of developing efficient, productive sugarbushes. Both species are relatively long-lived, capable of living well beyond 200 years, attaining trunk diameters greater than 30 inches (76 centimeters) and heights greater than 100 feet (30.5 meters).

Sugar and black maple both grow in the shade of other trees (referred to as being shade tolerant), and individuals of many different ages and sizes are often found in a forest. Both species are also found in stands composed of trees that are essentially all the same age (known as even-aged stands) or in stands of mixed ages (known as uneven-aged stands). Healthy sugar and black maple trees growing in dense stands can be expected to achieve tappable size in 40–60 years, depending on site quality. Thinning or release cutting can decrease the time it takes to reach a tappable-size (see **Chapter 5** for more details on stand management).

Sugar and black maple are particularly valued as sap-producing trees because of their high sap sugar

FIGURE 3.5. Black maple leaf, fruit, twig, and bark. (WRAY, VPI)

content. Sugar and black maple have the highest sap sugar content of any of the native maples. While the exact sugar content of tree sap will vary depending on many factors, including tree characteristics (crown size and condition, tree diameter, age, and health), genetics, site, and weather, the sugar content of sugar maple and black maple sap generally averages between 2.0 and 2.5°Brix.[1] It is not unusual to find trees in a sugarbush with sap sugar content significantly greater than 3°Brix. Genetic research on sugar maple suggests that sap sugar content can be increased by selection and controlled breeding; however, a great deal of variability is observed in the sap sugar content of progeny from these selections. Seedlings with comparatively high sap sugar content, often referred to as "super-sweets," are sometimes available from nurseries. Other things being equal, higher sap sugar content translates to lower production costs and higher profits.

Red Maple

Red maple is commonly tapped in areas where it is abundant, particularly in the southern and western portions of the commercial maple production region. Identifying characteristics of red maple are presented in **Table 3.2** and shown in **Figure 3.6**. The leaves of red maple commonly have three lobes (occasionally five) with the sides of the terminal lobe generally converging toward the tip, are oppositely paired along the stem and have small teeth along the margin. The bark of older trees develops long, broad, scaly plates, which often peel away from the trunk while remaining attached at the top. The twigs have paired, opposite arranged buds, a relatively short, blunt, rounded, red terminal bud, and no offensive odor when the reddish bark of the twig is bruised or scraped. The fruit is identified by its severe "V" shape and relatively small size.

Red maple is one of the most abundant and widespread hardwood trees in North America (**Figure 3.7**). Although it develops best in moderately well-drained to well-drained, moist soils, it commonly grows in conditions ranging from dry ridges to swamps. Because of the wide variety of sites on which red maple will occur, it is found growing naturally in pure stands and also with an enormous variety of other tree species, ranging from gray birch and paper birch to yellow poplar and black cherry, as well as sugar and black maple. Its rapid growth and ability to thrive on a wide variety of sites have resulted in its widespread planting as ornamental and street trees, which are sometimes tapped as part of a sugaring operation. Compared to sugar and black maple, red maple is a relatively short-lived tree, rarely living longer than 150 years. Mature trees commonly average between 20 and 30 inches (51 and 76 centimeters) in diameter and 60 and 90 feet (18 and 27 meters) tall. Red maple is relatively shade tolerant and is found in both even-aged and uneven-aged forests. Thinning or release cutting will substantially shorten the time it takes to reach tappable size.

Figure 3.6. Red maple leaf, fruit, twig, and bark. (VPI)

One of red maple's most attractive characteristic for maple producers is its ability to thrive in a wide variety of site conditions. In some areas of the commercial maple range, red maple is the only

[1] In this publication, degrees Brix, ° Brix, and percent sugar are used synonymously to describe sap, concentrate, or syrup concentration.

Figure 3.7. Range map of red maple in North America. (USGS)

maple present. Producers in these regions either tap red maple or they don't produce maple sap and maple syrup. In other areas, red maple is tapped along with sugar and black maples.

Historically, red maple wasn't universally favored for maple syrup production, as the amount of sugar in its sap was thought to be lower than that of sap from sugar or black maples growing nearby. Before the introduction of reverse osmosis to the industry, this lower sugar translated to increased production costs and lower profits. However, because of variations in sap sugar content among trees, the sap of many red maples contains as much or more sugar than the sap of many sugar maples and black maples. Further, red maples can often produce large sap volumes, ultimately resulting in total annual syrup yields comparable to those produced by by sugar maples. A study at the University of Vermont showed no significant difference in the total syrup yields of red and sugar maples of equal diameter in the same stand with vacuum and good taphole sanitation practices. Tapholes drilled into clear wood in red maple resulted in a similar volume of nonconductive wood[2] as observed in sugar maples. However, red maples can often have a large central column of discolored (nonconductive) wood, so extra caution is required with respect to tapping depth to ensure yields are optimized, and that the extensive additional nonconductive wood development that can result from tapping into already discolored wood is avoided.

Red maple may be a good species to encourage in the sugarbush over the long term because it is predicted to maintain or increase its importance in response to changing climate conditions in most geographic areas of current maple production. It is also less affected by some forest pests that favor sugar maple, such as forest tent caterpillar (*Malacosoma disstria* Hübner). The use of red maple as a crop tree is thus an excellent way to add diversity and resiliency to stands used for maple production and will likely continue to increase its importance for maple syrup production in the future.

Dried or wilted leaves of red maple may be toxic to horses if consumed.

Silver Maple

Silver maple is a rapidly growing tree found throughout much of the eastern United States and extreme southeastern Canada (**Figure 3.8**).

Identifying characteristics of silver maple are presented in **Table 3.2** and shown in **Figure 3.9**. The leaves of silver maple have five lobes, with the sides of the terminal lobe diverging toward the tip; a paired opposite arrangement of the leaves; deep sinuses between the lobes; fine teeth along the margin but not on the inner sides of the sinuses; and silvery white underside. The bark of older trees develops small, narrow, scaly plates, which often peel away from the stem while remaining attached at the top. The twigs have paired, oppositely arranged buds; a relatively short, blunt, rounded, red terminal bud;

[2]Nonconductive wood (NCW) is wood tissue that has been compartmentalized as part of the natural tree response to wounds (including tapping). It is no longer functional for water transport or metabolic functions, or viable for sap collection and therefore should be avoided when tapping. NCW is typically discolored (stained) relative to conductive sapwood.

Figure 3.8. Range map of silver maple in North America. (USGS)

Figure 3.9. Silver maple leaf, fruit, twig, and bark. (VPI, WEEKS AND PARKER)

and a fetid odor when the red to reddish-brown twig is bruised or scraped. The fruit, which matures in late spring, is identified by its "V" shape, relatively large size, and often asymmetrical appearance, with one seed and wing visibly larger than the other.

Under natural conditions, silver maple is primarily a bottomland and floodplain species, where it may occur in pure stands but is more commonly found growing among other bottomland species, such as American elm, sweetgum, pin oak, swamp white oak, eastern cottonwood, sycamore, and green ash. Silver maple is among the fastest-growing hardwood species in eastern North America and is certainly the fastest-growing maple. For this reason, it has been widely planted as an ornamental and street tree. However, its use as an ornamental and street tree, at least in urban areas, has been largely discontinued because the wood of silver maple is very brittle and often breaks in severe wind, snow, or ice storms. Some hybrids between silver and red maple have been developed and are increasingly being planted as ornamentals. Nevertheless, large silver maple street trees are numerous in many areas and these are sometimes tapped as part of a sugaring operation.

Like red maple, silver maple is a relatively short-lived tree when compared to sugar or black maple, living perhaps 130–150 years. Because of its fast growth rate, however, mature trees can achieve diameters in excess of 36 inches (91 centimeters) and heights in excess of 100 feet (30.5 meters). On good sites with little competition from other trees, silver maple diameter growth may approach ½ inch (1.3 centimeters) per year. Rates as high as 1 inch (2.5 centimeters) per year have been recorded. Silver maple's growth rate often responds dramatically to thinning or release cutting.

Silver maple is infrequently tapped for maple production except in some instances where it is abundant in forest stands or along roadsides. Sap sugar content is often less than that of sugar, black, and red maple. However, silver maples with sap sugar contents in excess of 4°Brix have been reported.

Boxelder

Boxelder is geographically the most widespread member of the maple genus growing in North America (**Figure 3.10**), occurring naturally throughout much of the eastern and central United States, south-central Canada, and scattered throughout several western states. It is a relatively small, short-lived tree reaching 24–48 inches (61–122 centimeters) in diameter and 40–75 feet (12–23 meters) in height in 60–100 years. Typically, boxelder trees have a relatively short trunk and a bushy, spreading crown.

Identifying boxelder is relatively easy (**Table 3.2**, **Figure 3.11**)—it is the only native maple with pinnately compound leaves. Each leaf is made up of three to seven (rarely nine) variably toothed or lobed leaflets, with the terminal leaflet often resembling a small, three-lobed maple leaf. The bark on the younger twigs is greenish; the bark on the trunk ranges from pale gray to light brown, with shallow fissures separated by narrow ridges on younger trees that gradually develop into much deeper furrows as the trees age. The fruit is a 1 to 1½-inch-long (2.5–3.8-centimeters long) double samara with wings that initially diverge from the seed and then converge slightly near the tips.

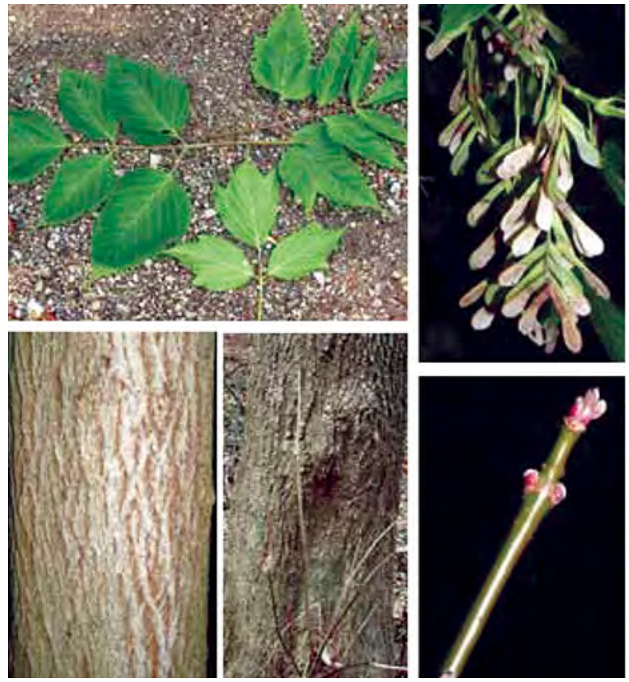

Figure 3.11. Boxelder leaves, fruit, young and older bark, and twig. (WEEKS AND PARKER, WRAY)

Figure 3.10. Range map of boxelder in North America. (USGS)

Boxelder grows in a variety of climatic conditions across the U.S. and Canada from New York to Florida and from Manitoba to New Mexico. Normally most commonly found growing on moister sites such as bottomlands or along water, where it grows in association with a wide variety of bottomland hardwoods including cottonwood, willow, hackberry, and green ash. However, boxelder will grow in an extremely wide variety of site conditions from hot to cold and from droughty to wet and even periodically flooded.

Boxelder is rarely tapped within the commercial maple syrup range, except in some areas with abundant boxelder of tappable size, such as Manitoba. Considerable research is ongoing to determine whether a maple industry based upon boxelder syrup can be commercially successful in the northwestern U.S.

Little information from studies in which the effects of collection and processing conditions are controlled for and the assessment of flavor is objectively assessed using scientific methods is available on the flavor of syrup produced from less commonly tapped species, such as silver maple and boxelder.

Other Maples

Striped maple (*Acer pensylvanicum*) and mountain maple (*Acer spicatum*) are two other native maples that are found growing within the commercial maple range (**Figures 3.12** and **3.13**).

Neither of these species is commonly tapped. Striped maple is a small, slender tree, often with multiple stems that rarely attain tappable size. It is most easily identified by the opposite paired arrangement of its leaves and branches, its three-lobed leaf with fine teeth on the margin and striping on the branches and young trunks. Mountain maple is essentially a shrub. It is most easily identified by the opposite paired arrangement of its leaves and branches and its three-lobed leaf with coarse teeth. If these species occur in a sugarbush it is important to be able to identify them. They should not be confused with the desirable maple species when performing management practices such as thinning or release cuts, although limited testing has shown syrup with excellent flavor can be made from striped maple sap.

Figure 3.13. Range map of mountain maple in North America. (USGS)

Figure 3.12. Range map of striped maple in North America. (USGS)

One exotic maple species, Norway maple (*Acer platanoides*), is commonly planted as an ornamental and street tree and will attain tappable size. A native to Europe and Scandinavia, it is considered an invasive in North America and can be found throughout the northeast and north central U.S.A. and adjacent areas of Canada, with a range similar to, but considerably less expansive than sugar maple. It is recognized by the opposite paired arrangements of its leaves and branches, its large, seven-lobed leaf without marginal teeth, and its 1½–2-inch-long (3.8–5-centimeters long) double samara with

[3]Berger, C. and T. Fegel. 2017. Bigleaf Maple Syrup. Oregon State University Extension Service, EM 9163, 2pp. https://mapleresearch.org/pub/bigleafor-2/.

divergent wings (**Figure 3.14**). The sap sugar content of Norway maple is lower than that of sugar maple, can have a milky appearance, and is only infrequently used commercially to produce maple syrup, most often by urban and suburban hobby producers.

Bigleaf maple (*Acer macrophyllum*), found along the Pacific coast (**Figure 3.15**), is occasionally used to make maple syrup on a limited scale,[3] but is not considered part of the established North American maple syrup industry due to its limited commercial potential and ongoing decline related to climate change. It is readily identified by its very large (6–12 inches, 15–30 centimeters across) leaves with five deeply incised palmate lobes. It typically reaches 50–65 feet (15–20 meters) tall. Sap sugar content is reported to be lower than sugar maple. Sap flows tend to be more sporadic due to long intervals between cold weather and long intervening warm periods, which can result in sap souring in collection systems during the period between sap runs. The result is often low syrup yield and very dark and strong-tasting syrup. Considerable research is ongoing in the U.S. Pacific Northwest to establish best management practices for syrup production in that region.

Figure 3.15. Range map of bigleaf maple in North America. (USGS)

Figure 3.14. Norway maple leaves, fruit, twig, and bark. (VPI, SYDNOR)

CHAPTER 4
Planning a Maple Operation

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CHAPTER CONTENTS

INTRODUCTION

Maple sap and syrup production operations exist in a variety of sizes and levels of intensity, integration, and sophistication. While some are the result of the completion of a series of planned activities, many more began with a small, relatively simple operation using resources that were available and have, over time, evolved into larger ventures involving many more activities than were originally conceived. This is true with respect to both production and marketing. While all producers are advised to evaluate and plan for future changes, small and new operations will benefit most from planning for the long term before making decisions concerning expansion or other changes related to production, processing, and marketing (**Figure 4.1**).

Among the important factors that producers need to consider in order to build a successful commercial operation are the amount of time and level

Figure 4.1. Careful planning based on sound information is crucial to the successful establishment and expansion of any maple operation. Take the time necessary to thoroughly understand and evaluate alternatives before committing resources.

Perkins, T.D., R.B. Heiligmann, M.R. Koelling, and A.K. van den Berg (Editors). 2022. *North American Maple Syrup Producers Manual. Third Edition*. The University of Vermont and the North American Maple Syrup Council, Burlington, Vermont. www.mapleresearch.org/manual/

of commitment they can bring to it, the availability of a suitable, well-managed tree/forest resource, adequate financial resources; their ability to develop appropriate production, processing, storage, and marketing facilities and sound marketing strategies; and their degree of interest in integrating secondary products (e.g., maple sugar, candy, nougat, cream) into their business model.

TIME AND COMMITMENT

Collecting maple sap, processing it into syrup or maple confections, and marketing those products takes considerable time and dedication. Before the first drop of sap is collected, a management plan for the sugarbush should be developed (**Chapter 5**), and a marketing strategy should be designed that identifies the amounts of syrup and other products that will be produced and to whom and how those products will be marketed (**Chapter 10**). These decisions must be made before tapping and processing equipment (**Chapters 6, 7, 8,** and **9**) is purchased and assembled and before a production facility is constructed or developed from an existing structure (**Chapter 12**). Getting ready for the season requires equipment to be cleaned and prepared for use. While repairs and some preparation can be done more leisurely in the off-season, the time just before sugaring season always seems hectic.

While the number of hours spent on sap collection, processing, packaging, and cleanup will vary depending on the size and nature of the operation, these tasks can be quite time-consuming. During the first few seasons, additional time will be needed to learn or relearn how to use the equipment and perform various activities most efficiently. Obviously planning and allocating sufficient time is necessary, but flexibility is also required. Maple sap, unfortunately, does not flow uniformly throughout the season, nor are flows necessarily predictable, and certainly they are not restricted to a typical 8 AM–5 PM workday schedule. Sap flow can and does occur in the evenings and on weekends, and big flows often come without warning. Many producers, particularly if otherwise fully employed, find that assistance, whether from family, friends, or employees, is required if a maple operation of any significant size is to be undertaken. In fact, some new producers have found it wise to sell sap the first couple of years and focus on developing the tapping and collecting portion of their operation before proceeding to processing, if ever.

It would seem appropriate to make one additional observation with respect to commitment, particularly to those new to the maple industry. Developing a maple syrup/product business requires both a significant labor commitment and a substantial capital investment. While the degree of investment certainly depends on the size and nature of the operation, investments made to establish or expand a maple operation will rarely be recovered in the initial year of operation or even within the first few years. Both individuals considering entering the industry or established producers evaluating a substantial expansion need to be sure they are committed to making a long-term investment in the industry.

THE MAPLE RESOURCE

Obviously, maple trees are an essential resource for a maple syrup operation. The number and size of trees available will determine how much sap can be collected and, in turn, how much syrup can be produced. While variations in production may exist among trees and regions of the country, a good rule of thumb related to sap production is to assume that each taphole will produce enough sap (approximately 10 gallons or 38 liters) to make approximately 1 quart or 1 liter of syrup in an average season if gravity collection is employed. Production rates of 15–25 gallons (57–95 liters) or more of sap per tap are achievable with high-yield collection methods, although this requires a somewhat larger investment of time, energy, and money. Keep in mind that this is only an estimate and both smaller and greater production is possible depending on tree size, method of sap collection, sap sugar content, and other variables. More importantly, plan for the occasional poor production year due to weather-related issues or equipment failure. If a larger operation is desired than available tree resources will support, provision could be made for purchasing sap or renting trees or tapholes from nearby landowners.

Once the decision has been made to develop a maple operation, the next step should be the development of a management plan for the sugarbush. It will serve as a road map for developing a healthy, productive sugarbush and will provide information essential to planning sap collection and processing activities and determining equipment needs. Important steps in developing a plan include

- locating property and sugarbush boundaries;
- dividing the sugarbush into manageable compartments;
- inventorying and mapping trees, existing roads and trails, and other features; and
- developing management prescriptions, including the location and development of roads and trails, recommended improvement cuts, tree planting plans, and other activities.

Guidelines for developing a management plan are described in detail in **Chapter 5**.

Don't assume a management plan is unnecessary because the maple stand was used as a sugarbush in the past. Certainly, if the stand has been properly managed in the recent past, the job of getting it up and running may be easier. However, sugarbush management is not a one-time activity. Irrespective of what the former owner/operator did, a current inventory and plan will provide the basis for activities now and in the future that are designed to achieve goals using available technology and existing resources. A written management plan also documents the development of and investments in the sugarbush. This reduces dependence on memory and may provide the information needed for transferring ownership, conducting a property tax assessment, and, if need be, obtaining a loan from a financial institution.

If the management plan includes improvement or harvest cuts, these are best done as soon as possible and certainly before semi-permanent installations such as tubing systems are erected. In addition to improving the health and productivity of the sugarbush, these activities may provide needed income and offer the opportunity to develop additional roads and trails. Again, recommendations and guidelines for these activities are presented in **Chapter 5**. The inventory of trees in the sugarbush also provides critically important information for estimating production, designing a sap collection system (e.g., tubing layout), identifying tapping and processing equipment needs (e.g., how many buckets, how much tubing, and what size pumps, storage tanks, and evaporator are needed and whether a reverse osmosis machine is required); determining the size of the processing facility); and evaluating the profitability of the venture and the potential for future expansion. These topics and decisions are discussed in subsequent chapters in this manual.

LABOR REQUIREMENTS

The amount of labor required for a maple operation is influenced by a variety of factors. Obviously the larger the operation, the more labor is necessary to ensure that it will function efficiently. It may be possible for one person to operate a relatively small operation (perhaps a few thousand taps or less) if he or she utilizes the most efficient sap collection and processing technologies and equipment available. With increasingly larger operations, part-time or full-time help becomes essential. The size of operation where that occurs depends on the amount of time the producer and their family can commit to the maple operation and the nature of the operation, especially the types of equipment employed and the approaches to collecting the sap, fueling the evaporator, and marketing the syrup.

The method of sap collection directly influences the amount of labor required. If a vacuum tubing sap collection system is installed, the amount of labor necessary for sap collection during the season can be reduced, although generally more time is spent in leak-checking if high yields are desired. Installation of the tubing system requires labor, but this can be completed during the off-season. Autumn, when snow has not yet accumulated and fallen leaves allow better sightlines, is often preferred for tubing installation. If the system is left in place throughout the year, minimal labor is necessary to maintain the system between and during seasons, but time should be spent before or during tapping to make necessary repairs. **Chapter 6** provides an in-depth discussion of alternative sap collecting systems.

All maple syrup operations require an evaporator to process sap into syrup. Although all evaporators are similar in design and operation, there are several modifications and accessories that can contribute significantly to labor savings and efficiency increases. These include

- forced-air draft units for wood-fired evaporators;
- sap preheaters to reduce the amount of time necessary to raise the temperature of sap to the boiling point;
- evaporator attachments to utilize the heat present in the water vapor from the boiling sap;
- air injection units intended to produce lighter colored syrup, reduce niter, and shorten evaporation time; and
- reverse osmosis units that significantly increase the sugar concentration of incoming sap, thereby increasing the rate of syrup production as well as reducing the amount of time and energy necessary for evaporation.

These energy-improving accessories used with evaporators are discussed in **Chapter 7**.

Consideration must also be given to the method of fueling the evaporator. Oil-, gas- (both natural and propane), and wood-fueled evaporators are available. Both oil- and gas-fueled units are more automated; however, they entail the additional expense of commercially sourced fuel. Wood-fired evaporators may be more economical to operate if the producer has access to a large enough woodlot and the ability to cut and process the fuelwood. Otherwise, there will be a need to purchase substantial amount of fuelwood.

Cutting, processing, transporting, stacking, and storing wood can and should be done during the off-season (to provide the six to twelve months required for adequate drying/seasoning), but this will require a significant commitment of both time and labor. The advantages and disadvantages of alternative fuels for firing an evaporator are discussed in **Chapter 7**.

FINANCIAL RESOURCES

Establishing and operating a commercial maple syrup/product business requires significant capital investment and adequate operating funds. Capital investments include such things as land (if not owned), a processing facility (sugarhouse), sap collecting and processing equipment, bottling (canning) and packaging equipment, and equipment for making candy and other confections (if desired). Operating funds might include money for such things as sap purchase or tree/tap rental, fuel, bottling and packaging supplies, salaries, insurance, and advertising and marketing expenses. Obviously, the amount of money necessary will vary and depend on several factors, including size of the planned operation, the availability of a maple resource, family labor, and appropriate facilities and processing equipment (both new and used) and its cost; the methods used to collect sap and sell products; and the cost of containers, utilities, insurance, and various miscellaneous items. As noted in the discussion on commitment, whatever expenditures are necessary to ensure a successful operation, it is absolutely certain that they will not all be recovered in the first year of operation, and most likely several years will be required before the investment is fully returned.

Anyone considering starting or substantially expanding a maple syrup/product business would be well served to take the time to carefully evaluate the costs and returns involved in the proposed operation. Development of a business plan is critical once maple activities expand beyond a hobby into a money-making venture. Such an analysis will not only identify the costs and returns involved, and whether the resources are available and the cash flows acceptable, but also may indicate where a slight change in plans (e.g., more or fewer taps, a different combination of equipment, a different mix of products) could increase profits. When performing such an analysis, it is realistic to project anticipated revenues conservatively since significant variations in sap yield and the amount and grade of syrup produced will have direct impact on revenues. The economics of a maple operation are more fully considered in **Chapter 11**.

It is also important to remember that, while there is money to be made in the maple syrup/product business, realistically, it is more likely that only substantial, integrated, and diversified maple syrup operations will provide enough income to support a family solely from the production and sales of maple products. Potential producers are advised to approach the maple syrup–product business as additive to other enterprises, such as agricultural or horticultural ventures. Some operations will involve activities such as tubing installation services, equipment sales, or retail marketing. These and other activities associated with maple operations can expand business opportunities for producers, enabling them to put their time and some of their equipment (e.g., tractors), as well as their highly specialized knowledge and other resources to profitable use during the off-season. Because the capital costs required to establish a new operation are high compared to the value received from the sale of maple products in any one year, a realistic expectation of profitability should not be made for the first few years. Rather, profitability should be calculated as an average per year over a longer period, such as five to ten years.

LOCATION AND DESIGN OF PROCESSING FACILITIES

To process maple sap into maple syrup, it is essential that a structure or building dedicated to this use be available. It may be possible to modify an existing structure; however, it may be more desirable to construct a new building, particularly if processing maple syrup into other products. Maple production facilities should be of such quality and construction that all local requirements for "food processing facilities" are met. These may include the presence of hot and cold water, toilet facilities, adequate electrical service, ample ventilation, washable surfaces in packaging areas, floor drains, exclusion of animal pests, and adequate lighting. If a new facility is to be constructed, it is recommended that local and state building codes relative to food processing facilities be consulted. And, while there may be a great deal of variation among states and provinces about what standards are currently required for maple production facilities, it is important to remember that maple syrup and other products are food. Irrespective of what minimum standards might be, it is important that producers assume the responsibility of maintaining a facility appropriate for the production of a food product. Only equipment and materials suitable for the intended purpose should be used (i.e., unsuitable materials such as DWV plastic line or fittings in systems carrying sap or potable water should be excluded).

Several options should be considered when planning where to locate the sugarhouse. The specific location will largely depend on anticipated use and activities that will be conducted there, including to what extent the public will be allowed access. If the intent is to use the sugarhouse as a marketing location, it should be accessible by a hard surface road with adequate parking, electrical service, sanitary facilities with a potable water supply, adequate product display areas, and sufficient room for visitors. The location also should be as prominent and attractive as possible. Local governmental regulations relating to land use and public accommodations should be consulted. If plans include eating facilities, it is essential that their construction, maintenance, and use complies with all local, state or provincial, and federal regulations regarding food production and service areas.

When planning a sugarhouse that will not involve the public, the situation is less complicated. Local governmental regulations, if any, should be observed. A good access road is still a necessity and electrical service will make operations considerably easier. In the past, sugarhouses were located near or in the sugarbush, often at the base of a hill where sap could flow directly into storage tanks located at or near the sugarhouse. This is not as important a consideration today since sap transfer and vacuum pumps are available to move sap from one location to another more easily. However, if buckets and horse- or tractor-drawn collection tanks are used, the location of the sugarhouse near the sugarbush may be important. If roadside trees are tapped and trucks are used for collection, all-weather access to the sugarhouse needs to be provided. If plans include sap purchases, ensure compliance with road weight limits when trucking sap.

Design and construction of a sugarhouse can depend on the plan for marketing syrup. If intended solely for processing sap into syrup for bulk sale, the type and style of building can be quite simple; however it is a good idea to consult your bulk syrup buyer about any specific limitations they may have (especially in relation to lead-containing equipment). Adequate space for the evaporator and related syrup filtering and packing of containers will be the most important considerations. The size of the building will depend on the type of fuel used for the evaporator. If wood is used, adequate space must be provided for storage. A standard cord (4 by 4 by 8 feet or 128 cubic feet, 1.2 by 1.2 by 2.4 meters or 3.62 cubic meters) will process approximately 20–25 U.S. gallons (76–95 liters) liters) of finished syrup on a standard evaporator with no efficiency-improving devices. The wood storage area should hold enough wood to process anticipated seasonal production. If 100 gallons (379 liters) of syrup are expected, then minimum storage space for four to five cords of wood should be constructed. The wood storage area should be covered and well ventilated. If oil- or gas-fired evaporators will be used, the building can be smaller. Access for the fuel delivery truck during the season is crucial. Oil tanks can be covered to reduce condensation in partially filled tanks. Most producers have observed that the sugarhouse is never large enough. Additional space is needed for equipment storage such as collection and gathering containers, pumps, storage tanks, and empty containers. Additionally, producers should give some thought to the amount of extra space that would be needed if they decide to enlarge their operation in the future. If plans include processing maple syrup into other products, a well-equipped kitchen should be provided. Hot and cold water, electrical lights, a washable floor, and a supplemental heating system will add to the efficiency and comfort of workers. Regarding sugarhouse size, an experienced maple producer once gave very valuable advice, noting that you should "always build the sugarhouse twice as large as you think you will ever need—that way they will only have to add on to it once." **Chapter 12** provides a thorough discussion of considerations and recommendations for constructing a maple production facility.

MARKETING METHODS

Making a profit is an important aspect of commercial maple operations. Unquestionably there are other reasons to "sugar" including tradition, enjoyment, and strengthening of family bonds, but for commercial maple producers and many hobbyists making a profit is an important motivation. If it were not, most producers would undoubtedly satisfy their "maple urge" by producing a small amount of syrup for their own use and for gifts.

The financial success of a commercial maple operation depends on selling the desired amount of syrup and other maple products. To do this requires a marketing plan or strategy. Marketing can be as simple as a small sales counter in the sugarhouse or farmhouse, or as complicated as an expanded wholesale/retail outlet that includes distribution to other retail markets, operation of a full-time retail outlet, or sales through the internet and/or by direct mail. How products are marketed will depend on many factors, including the amount of syrup and other products produced, the amount of local competition, the facilities available, and the vision and effort committed to the operation. If the intent is to generate a quick, short-term income stream each year, the simplest but certainly not most profitable way would probably be to sell the sap wholesale to a processor or neighbor who will package and retail the product. Other marketing methods might include combinations of direct sales from the farm (**Figure 4.2**) or mail-order or internet sales or supplying products to farm markets, farm stands, food stores, or specialty shops.

Regardless of how marketing is done, development of a marketing plan is recommended. This plan should include an analysis of your individual situation, a statement of specific marketing objectives, and a strategy (method) for obtaining your marketing objectives. Producers are urged to think

Figure 4.2. Maintaining an attractive display is a great way to market maple syrup.

through the marketing process just as they think through the establishment and construction of physical facilities. Producers should not expect that simply because a quality product is produced, sales and profits will be forthcoming. Successful marketing is earned through planning and hard work; it is not something that just happens. A thorough discussion of marketing maple products is presented in **Chapter 10**.

PRODUCTION OF SECONDARY PRODUCTS

Maple syrup is the initial product obtained from processing maple sap. While syrup is certainly salable as produced, many producers have expanded their market by processing it into other products or confections such as maple sugar, maple butter (cream), and maple candies (**Figure 4.3**). These products are produced by increasing the sugar concentration in maple syrup through continued boiling, and then treating as appropriate for the desired products. A complete discussion of secondary maple products is contained in **Chapter 9**.

Figure 4.3. Processing maple syrup into secondary products such as maple candy can increase value and access to alternative markets.

The necessary permits and regulations to be followed pertaining to food safety must be planned for. **Chapter 14** outlines some of the primary considerations in that area, but attention to local, state and provincial regulations must also be investigated and well-thought-out.

If other products are to be produced, provisions for their production should be made. When this is to occur in the sugarhouse, an appropriate preparation area or sugar kitchen should be constructed. Production of some of these products is easier if specialized equipment is available, including mixers, stirring machines, cooling facilities, and molds. While these confections will increase the variety of products available and should, under most circumstances, result in increased sales and net income, labor and equipment costs associated with their production should be considered when planning a complete operation.


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CHAPTER 5
Sugarbush Management for Syrup Production and Forest Health

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INTRODUCTION

Maple production is an agricultural activity occurring in a managed woodland ecosystem where sap collection is the primary objective. Central to every maple sugaring operation are maple trees. A land area of woodland with maple trees managed for sap production is called a sugarbush (**Figure 5.1**). Maple producers strive to keep their crop trees healthy and productive, which is important for the long-term sustainability and profitability of their own maple operation and for the success of the entire maple syrup industry. Managing maple trees for sap production is as viable a goal as timber production, and care should be taken to ensure crop trees are tended to maintain tree health.

Figure 5.1. An uneven-aged maple sugarbush with a tubing installation. Typically, such stands contain a range of sizes and three or more age-classes of trees.

Sugarbush management is the manipulation of maple-dominated woodlands and the culturing of maple trees to ensure they remain vigorous and resilient to stress, produce abundant sap high in sugar content, and regenerate as needed. Thus, sugarbush management requires forest science knowledge, ecological skills, and a clear understanding of agricultural principles. This background knowledge enables producers to make decisions that ensure vigorous and abundant maple trees and forests.

In many cases, a producer will choose to work with a forester or other forestry professionals to optimize the desired outcome. As when hiring a qualified contractor or financial planner, there are numerous benefits from working closely with a skilled professional. Experienced foresters and other veteran natural resource professionals who understand sugarbush management are trained to accurately gather the necessary data on current forest conditions, listen to landowner goals for the property, and write appropriate prescriptions to achieve the owner's goals. Unsupervised or inappropriately targeted management activities can adversely affect the long-term health and productivity of the sugarbush. Poor management can lead to damage to residual crop trees, soil compaction, root injury, erosion, lack of diversity, and poor-quality trees. Ongoing and impressive developments in technology over many years have allowed syrup producers to improve production by investing in equipment. However, the long-term sustainability of a maple operation also depends on investments to maintain productive maple trees and healthy forests. Just as a vegetable garden requires an overall management plan and regular tending to ensure the production of abundant, high-quality crops, so too does a sugarbush. In a healthy sugarbush, sap sugar production is limited only by the trees' genetic potential and the effects of topography, weather and soil conditions, and production practices on their physiology.

Tapping of maple trees creates a wound that the tree must compartmentalize and results in the removal of a portion of the tree's carbohydrate (energy) reserves. The annual growth of wood on a maple tree is an indicator of the tree's resilience to these stresses. Strong annual growth in stem diameter is important not only because it directly supports sap and syrup production, but also because stem growth results from multiple factors that are affected by the overall health of the tree. Management activities should therefore promote high levels of wood accumulation. This requires vigorous crowns on crop trees. In addition, trees should be growing in conditions for which they have adapted to achieve optimum health. Vigorous trees will generally produce a greater volume of sap[1] and will be able to recover from stress more quickly than slow-growing or less healthy trees. A sugarbush that includes a diverse range of species and age and size classes is more resilient to a wide variety of stressors and will better support the long-term sustainability of sap collection.

In some cases, sugarbushes are neglected, with producers entering each year only to collect sap. Other than removing dead trees or non-maple trees for fuel wood, these producers may pay little attention to the impact that sap collection has on the trees. This lack of management can reduce the potential of this asset through over-tapping, unnecessary tree mortality, reduced species diversity, poor forest structure, a lack of regeneration potential, and possibly a decline in tree vigor. Fortunately, many producers are aware of the need to properly manage and care for this basic resource. Through regularly conducting a few basic sugarbush management activities producers can:

- maintain sugarbush health and tree vigor;
- improve yield of high-quality, high-sugar sap;
- reduce production costs;
- increase the short- and long-term profitability of their maple operation.

Management and sugarbush improvement activities should be ongoing, conducted regularly, and incorporate thoughtful action in response to any abrupt disturbances, such as insect defoliations or ice storms. Management activities, especially when applied to younger stands of maple, can yield impressive results in a relatively short time. However, management activities also represent a disturbance to the forest, and care must be taken to ensure that actions are executed in a careful and timely manner and do not severely damage or stress the roots, crowns, or stems of the remaining trees. The outcome of forest management is improved growing conditions for the residual trees; avoid actions that might injure or limit growth of your best trees.

SUGARBUSH PLANNING—CREATING A MANAGEMENT PLAN

A forest management plan is an important tool because it describes the maple producer's goals for their woods. The plan identifies the specific objectives, resources, and steps necessary to accomplish those objectives. If needed, the plan identifies people, tools, and strategies to support those actions. This section on planning precedes other sections that describe concepts and activities that may be enacted as an action of management as guided by the plan.

Assessing and Comparing Stands for Commercial Production

Maple producers often begin by assessing the commercial potential of one or more areas for productive and operational efficiency. Several criteria are useful in this analysis. The sugarbush site assessment guide[2] may help producers focus on strategies most applicable to their potential sugarbush. Producers may wish to seek advice and assistance with this task from professional foresters, state or provincial Extension services, local maple producers' association, trained loggers, maple equipment vendors, or various online resources and communities. Key concepts of this assessment phase are described below.

1. The minimum number of taps per acre should ideally be between 40 and 80 (100

[1] Wilmot, T.R., P.W. Brett, and M.T. Tyree. 1995. Vigor and nutrition vs. sap sugar concentration in sugar maples. Northern J. Appl. For. 12(4): 156–162. https://mapleresearch.org/pub/vigorsap/

[2] Childs, S., P. Smallidge, and M. Farrell. 2016. Assessing the Commercial Potential of a Site for Maple Sap Collection, Cornell University Cooperative Extension, Department of Natural Resources. Ithaca, NY. https://mapleresearch.org/pub/sugarbush-site-potential/

and 200 per hectare) for trees >15 inches dbh (38 centimeters) and may be as many as 60–120 per acre (150–300 per hectare). If the stand is dense, but too small for tapping, thinning will increase tree growth and eventually produce stems large enough to tap.

2. Several attributes of the site, including soil fertility and moisture, the amount of organic matter in the soil, and the site's slope and aspect can influence the growth of maples. Ideally, soils should be fertile and moist, but adequately drained. Sugar and black maples are the most demanding maple species in terms of soil nutrition and moisture, preferring moderately drained sites with soil pH tending towards neutral. Red maple will tolerate both slightly moister and drier soils, while silver maple can tolerate periodically flooded soils. It is inadvisable to force a tree to grow in site conditions that it's not adapted to. If the soils are unsuitable, there is generally little potential for remediation.
3. The health and quality of trees are normally the result of a combination of site conditions and past woodland management activities. Tree crowns should be evaluated to ensure there are fine branches, the upper branches are thriving, and there is not a significant amount of crown dieback. Optimally, stems should be free of significant defects that would compromise their structural integrity and lead to premature breakage. Damage to the root flare or root zone could indicate root decay, greater sensitivity to drought, and lowered resilience to stress.
4. The location of the sugarbush relative to the sap collection site impacts the mode and efficiency of sap movement. Sap must eventually move from the sugarbush to a storage tank at the sugarhouse. If the sugarbush is remote from the collection site, the sap must be transported via tubing or in a tank on wheels. Poor access can be improved by building a new trail or woods road or by installing an effective tubing system to move sap.
5. The presence of roads and topographic features influences the ease of tubing installation and other work that must be done during sap season and the off-season. Road and trail access improves efficiency; simplifies the transport of tools, supplies, and people; and increases the likelihood that the owner will monitor the condition of the sugarbush and the operation of the tubing system. Best management practices (BMPs) for designing and stabilizing roads and trails should be identified, implemented, reconstructed if necessary, or maintained as needed. Poor trails and roads may be addressed during a thinning or harvest that incorporates the addition of a road and trail network for maple sap collection.
6. The availability of a source of electricity (e.g., solar power, batteries, or a generator) will determine whether you can easily run a vacuum pump or will need to use buckets or gravity tubing for sap collection.
7. The topography of the area, particularly the steepness and the direction of slope influence the ease and efficiency of production. Topography impacts the design of tubing installation and the potential for a natural vacuum. Slopes of 3–15 percent are reasonable to work with if using tubing, but far more challenging when it comes to deploying and gathering buckets. Recent innovation in sap pumping has allowed areas not previously considered viable for sugarbush development. Careful consultation with equipment manufacturers will help determine if a given area has enough potential to warrant this option.
8. Canopy closure and competition among tree crowns for light will influence tree growth, taphole closure rates, sugar production, and tree vigor. A forester can assess the amount of competition among trees for sunlight and write a prescription

for thinning that is designed to increase the growth, and thus vigor, of maple trees. Most trees respond favorably to moderate thinning, but the results are greatly influenced by tree age and vigor, soil, and site conditions, recent stress events, and management practices implemented previously.
9. Some forest plants behave like weeds in that they interfere with a producer's objectives and ease of operations. These interfering plants can be either native or non-native species, and their growth may be dense enough to complicate your work in the woods, the collection of sap, and the recruitment of future sugar maple. The solution to managing interfering plants depends on the species of the problem plant and the objectives of the owner. Excessive deer impacts can precipitate an interfering plant problem by eliminating desirable species and encouraging nuisance plants. An experienced forester can recommend chemical or organic options for limiting the abundance of interfering vegetation once deer impact is controlled.
10. Invasive pests such as emerald ash borer, Asian long-horned beetle, spotted lanternfly and earthworms can seriously disrupt the healthy and management of a sugarbush. Producers should educate themselves on how to identify these pests and report any detections to the appropriate authorities. Verification of the identification of the pest and appropriate methods of addressing the problem should be sought from the appropriate professional and regulatory bodies.

Parts of a Management Plan

A written forest management plan consists of the following parts:

1. A list of the maple producer's goals
2. An inventory of the forest resources, including the type, number, size, condition, and distribution of trees and the variety and character of soils present
3. A description of the management activities necessary to achieve the landowner's goals
4. A timeline for accomplishing those activities

Essentially, the management plan is a "road map" for transforming the sugarbush from its current condition into the desired condition. It should be noted that some parts of the forest may be unsuitable for maple production due to their unfavorable location or site conditions. These sections should be clearly identified and reserved for alternative uses such as buffer areas, wildlife areas, for recreation, or for the production of timber or wood for fuel. In particular, trees both inside and outside the sugarbush itself may be designated as potential high-value "veneer" trees and managed appropriately.

Many producers also have expectations for outputs from their woods that include more than maple syrup production; some may pursue agroforestry products (e.g., ginseng, gourmet mushrooms), timber, and/or recreational activities or leases. The plan should describe the positive or negative synergies from multiple outputs, the trade-offs and benefits of the outputs, and additional outputs that are possible from the property. A management plan ensures that these activities mesh appropriately. Additionally, some activities such as a timber sale or organic certification may result in tax and other economic outcomes that would benefit from, or even require, a management plan.

To create a plan, you need to go through the following steps:

1. Review the full suite of objectives you have for the property. Beyond maple syrup, what else might you want to produce or make available? What activities are important to you? How might these objectives change in the future?
2. Talk with state or provincial forestry agencies to get a list of private consulting foresters. Other maple producers, Extension, and trained forestry volunteers might also suggest names. Interview those foresters to identify one familiar with maple production.

3. Arrange for the forester to inventory the woodlands and summarize the various resources. The forester can then integrate the objectives and the resources to develop a list of suggested management actions and a schedule for the actions.
4. Consider the list of suggested actions. Decide which you will attempt on your own and those which you will need to find assistance to accomplish.
5. Keep track of your activities. It's great historical information, but also guides the future direction of the plan.

Boundaries

The first step in managing a sugarbush and developing a management plan is to determine the limits of the property. Without an agreement, tapping across the boundary is against the law—in some locales it can result in fines or payments of damages that are triple the loss in affected value to the trees. Locate the property boundaries (find the permanent markers) and be sure they can be easily relocated. Make certain there is agreement with adjoining landowners as to the boundary locations. If no boundary markers exist, or if there is disagreement over the boundary, have a boundary survey done by a registered or licensed surveyor and ensure the results are filed in the appropriate jurisdictional office. Ask your surveyor to clearly mark the boundary line and locate the corners with permanent and substantial markers such as iron rods or concrete posts. In some states or provinces only a registered or licensed surveyor can establish permanent boundary markers and only licensed surveyors or foresters can blaze trees along a boundary.

Dividing the Sugarbush into Manageable Units

A farmer divides a property into fields or compartments to make management activities more efficient. Those fields are management units. In a sugarbush, the management units are called "stands." Stands might be just a few or up to thousands of acres (hectares), but within a stand there is a distinctive mix of characteristics such as the size and age ranges of the trees, the soil conditions, and the effects of past land use and future development goals. All future management activities in the stand can be organized and carried out based upon these characteristics; accounting for all these factors can pose a daunting task for the producer. For example, the effort required to test the sap sugar content of all trees or to thin a large sugarbush can seem overwhelming. However, if the same task is to be completed on a smaller area, such as a stand of 3–10 acres (1–4 hectares), it becomes more manageable and thus more likely that it will be completed. For very large stands, activities can be broken down into sections or partitions. Having some knowledge of the characteristics of each stand allows priorities to be established. Activities such as thinning can be done where the need is greatest instead of in a haphazard disorganized fashion over the entire sugarbush.

The specific size of individual stands will depend upon the variability of the previously mentioned features and total size of the sugarbush. Generally, individual stands of 3–10 acres are the most suitable choice for sugarbush management units, although larger stands are possible on sites where there is similarity of trees and site characteristics or on larger parcels. When and where possible, use existing boundaries, such as roads, trails, drainage features, fences, and fields to separate stands. If natural features are not present to separate stands, some type of permanent boundary marker might be helpful.

Separating some sugarbushes into stands is easy; others are considerably more difficult. Examining topographic maps, aerial photos, satellite images, historic photos, and other property maps may be helpful. Topographic maps, aerial photos, and satellite images are available in the United States at the local Soil and Water Conservation District office or on the internet through Web Soil Survey.[3] In Canada, visit the office of the Centre for Topographic Information of Natural Resources Canada. Hunting apps (onX Hunt©, Huntstand©, Basemap©)[4] can provide a

[3] USDA Natural Resources Conservation Service. Web Soil Survey. https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

[4] Products are listed as examples. Mention here does not imply an endorsement.

wealth of geographical and environmental information and may be useful later in planning and mapping out tubing systems.

These resources will help determine whether stands can be delineated based on visible characteristics such as tree species, tree age, tree size, tree crown size, canopy texture, or other features such as roads, streams, and buildings. Site-sensitive herbaceous plants, such as some ferns and wildflowers, can also help producers separate one stand from another.

Describing the Trees and the Forest—The Inventory

Central to the management plan is a description of the soils, vegetation, and other relevant features of each stand. This inventory provides greater utility when the producer works with a forester to inventory the woods and provides quantitative descriptions of the conditions. While it's possible for producers to conduct the inventory themselves, foresters are trained to efficiently collect and analyze the data required to accurately describe forest stands.

Information from the inventory will guide the producer's priorities and actions. The inventory will result in a summary of the types, number, size, and vigor of trees in each stand. The forester should assess the number and health of maple trees in the active or proposed sugarbush, as well as the potential for revenue from maple production. The inventory might also include descriptions of soil fertility and drainage based on soil maps. Finally, the description should include the potential ability of a given stand to satisfy one or more of the owner's objectives.

Management Recommendations—The Action or Operating Plan

The final section of a sugarbush management plan identifies and describes what actions, operations, or work needs to occur in the sugarbush as a whole and within each stand to achieve the objectives of the producer. Many of the recommendations in the action or work plan will be silvicultural recommendations—recommendations of practices intended to improve the growth rate, mixture of species, health, or quality (such as sap sugar concentration) of the sugarbush, or those actions needed to encourage the establishment of new maple trees. Silvicultural recommendations might include recommendations for thinning treatments, such as improvement cutting, regeneration treatments, pruning, tree planting, and fertilization. Other management recommendations might include road and trail development and maintenance, and activities geared towards protecting the sugarbush from insects, diseases, animal damage, grazing, fire, and weather-related (wind, ice) damage.

SUGARBUSH SILVICULTURE

Strategies for Management—Uneven-Aged vs. Even-Aged

Tree age structure in a sugarbush is a major determinant of how stands are managed. If the sugarbush is relatively homogenous, management may be relatively simple. However, it is possible to have a sugarbush where some stands are uneven-aged (**Figures 5.1**) and other stands are even-aged (**Figure 5.2**). Unfortunately, tree size is not a consistent predictor of age. Tree age is best determined by counting rings on a tree core or from a stump. Beneath a canopy of larger trees, smaller suppressed or intermediate dominance trees that are old will sometimes lose their central single stem and the crown flattens. The bark on these individuals may be heavy or rough, like that of larger trees. Smaller trees that are also young tend to retain their central

Figure 5.2. An even-aged maple stand with bucket collection. Although trees are all within the same age-class, sizes may vary somewhat.

stem and more often have smooth bark like that of trees of the same size growing in full sunlight.

In an uneven-aged stand there may be groups of trees of a single age cohort, and other groups of trees of different ages. Alternatively, stems of various ages may be intermixed. Management strategies need to address all age-classes and ensure that any younger trees meant to remain in the stand have sufficient sunlight to stay generally healthy. Because these younger trees become established in small patches, they need to belong to species that are at least moderately tolerant of shade, such as sugar maple, American beech (*Fagus grandifolia*), and eastern hemlock (*Tsuga canadensis*). While these trees can withstand shade, they grow best with full sunlight. Although there will be greater numbers of the small trees, the goal of uneven-aged management is to ensure that each age-class has the same amount of space within the stand. The management activities that are appropriate for one age class will differ from those suitable for other age-classes.

In an even-aged stand management activities are more heavily focused on those trees that are dominant or codominant (having crowns that make up the uppermost canopy) and ensuring they continue to have sufficient light, space, and other resources required for healthy growth. Less attention can be paid to the vegetation below the main canopy (intermediate and suppressed trees), though interfering vegetation should not be completely ignored. Because the trees became established in a large area with abundant sunlight, a greater mixture of tree species may be found. Even-aged stands are common throughout the maple producing region, often following the abandonment of land from agriculture or by regeneration of a stand after heavy logging. Traditionally, the same management activity will be applied throughout the entire stand, but producers may benefit from the long-term transition toward an uneven-aged stand afforded by creating multiple small open patches that remove clusters of trees with low vigor.

In many ways, the sugarbush can be thought of like a garden, only covering more area, with greater longevity, and representing a far more complex system. Success usually results from monitoring the site conditions to ensure that the desired individuals have adequate sunlight, space to grow, and freedom from injury to allow for vigorous growth. Crowding among young trees is corrected by thinning to ensure adequate sun and soil resources for the crop. Unproductive competitors are removed. If necessary, opening up the canopy and removing interfering vegetation increases space and sunlight reaching the ground, promoting the establishment of natural regeneration or allowing successful tree planting.

Assessing Tree Vigor

Having maples and other tree species that are vigorous is advantageous to producers because healthy trees grow better, produce more sap and syrup, and are more resilient to stresses. Vigor is the ability of the tree to grow wood each year as a percentage of sapwood (i.e., wood conductive to sap, as opposed to heartwood or stained wood which is non-conductive to sap) or relative to the surface area leaves. Improved tree vigor is one of the desired outcomes of management treatments. There are several factors that influence whether a tree can be vigorous and several ways to evaluate the vigor of a tree or of the trees in a stand.

One factor influencing the vigor of a tree is whether it is growing in soils for which it is suited. If the biological needs of the tree are matched by the soil and other topographic features, it is considered to be growing "on site." A preponderance of sugar maple in a stand may result from alignment with site conditions or from past management activities that have heavily favored and retained sugar maple versus other species (**Figure 5.2**). Sugar maple grows best in moist, fertile soils. Soils in stands located on a side slope are often moister and more fertile than soils on the crown of a hill or ridge. Red maple is more tolerant of slightly drier or slightly moister soils than sugar maple but may become less vigorous on excessively dry or swampy soils. Silver maple tolerates moist to seasonally flooded or swampy soils.

A second factor influencing vigor of a tree is the crown position (or crown class). Dominant and codominant trees (**Figure 5.3**) tend to have more foliage and thus are better able to capture the sunlight necessary for growth. Such trees are in a prime situation to expand their crowns into openings created around them due to thinning or space created by natural disturbances (e.g., senescence of neighboring trees, windthrow).

A third factor is competition for sunlight. Trees that are crowded together compete for sunlight. Competition for space and light is generally the largest factor influencing tree growth in northern forests. Trees that are behind in the competition for sunlight tend to have lopsided crowns that are often flattened on one or more sides (**Figure 5.4**). The trees that are ahead in the contest for sunlight generally have uniformly wide and balanced crowns that extend lower down the stem. Because soils and climate in the maple region are conducive to growing trees, the stocking level of trees often exceeds that which is optimal for good growth. Reduced stocking allows for good growth per tree, equating to better production of wood.

Figure 5.3. Co-dominant trees form the majority of the canopy trees and are the primary crop trees in this sugarbush.

Figure 5.4. The tree on the left has a asymmetrical crown due to intense competition with the tree on the right. Thinning at an earlier stage would have prevented such intense competition. Intermediate trees at top and bottom right of photo.

Tree vigor is also related to tree age. The maximum age for sugar maple runs between 300 and 400 years. Red maple is shorter lived, with a maximum of around 150 years. As with the vast majority of biological organisms, the growth rate and growth potential of trees decrease with advanced age. Measuring diameter growth rate is a good way to assess tree vigor (**Figure 5.5**). One way to accomplish this is to measure diameter (dbh) on a representative subset of trees in the sugarbush each year using a forestry diameter tape (alternatively, measure the circumference and divide by *pi*, 3.14 to convert to diameter).[5] The measurement location can be

[5] Tree diameter is measured at 4.5 feet (1.37 meters) above the ground. If on a slope, dbh is measured from the uphill side of the tree. If a tree splits below dbh height, both stems are considered and treated as individual stems.

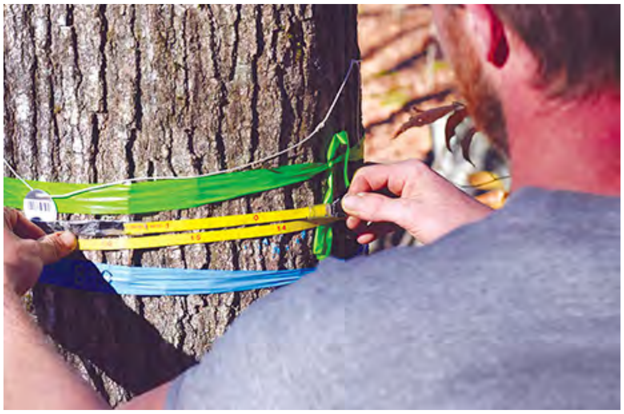

Figure 5.5. Measuring tree size (dbh) using a diameter tape. If a direct reading diameter tape is not available, measure the circumference and divide by 3.14.

marked with forestry paint for annual assessment. By comparing measurements over time, growth rate of trees in the stand can be estimated. Foresters may use increment borers to extract tree cores for assessment of age and growth rates.

An indirect way to assess tree growth and vigor is by looking at the number of open tapholes. Because taphole closure rate depends on a number of other factors including tree age, taphole size, and quality of the site, it should be evaluated by comparisons with the closure rate of tapholes from healthy, vigorously growing trees of approximately the same size growing on the same or comparable sites. Vigorous trees will often fully close a 5⁄16-inch taphole in 1–2 years, and a 7⁄16-inch taphole in 2–4 years or less.

Several measurements of the tree crown can be used to assess tree vigor,[6] although there can be considerable variability from tree to tree and site to site and from one untrained observer to the next. Live crown ratio (LCR, the height of the live crown as a percentage of the total tree height) reflects the amount of competition experienced by a tree over time, and thus is a cumulative indicator of vigor. Opengrown maples may have an LCR of 80 percent, whereas woods-grown maples may have LCR of 15–50 percent. A higher LCR is considered an indication of good vigor. Crown diameter (width of the live canopy estimated in perpendicular directions and averaged) is similar to LCR and may be a better indication of tree vigor within a closed canopy stand. In addition, a high degree of crown fullness or low crown transparency (ability to see through the crown) indicates high vigor. A vigorous maple tree will have a dense collection of foliage in the crown that you can't see through. Trees that lack vigor may produce sparse foliage, smaller leaves, and tend to have shorter branches, and thus have a higher degree of crown transparency. Dieback of fine twigs or larger branches may also indicate reduced vigor. Overall, the utility of crown condition is further reduced by the difficulty in taking such measurements and a lack of understanding of the relationship between crown condition estimates and growth or sap yield.

Signs of injury and decay are indicators that a tree may be prone to stem breakage or loss of crown capacity. Symptoms may include fungal fruiting bodies or conks, visible splitting below a fork, slow tap hole closure, the presence of several open tapholes, and slow healing of wounds. A hollow tree is not necessarily of concern if the tap hole closure rate is good and sapwood thickness is sufficient to prevent drilling into the hollow.

Guidance for Foresters

Forestry professionals (foresters, loggers, and other practitioners) play an essential role in the long-term sustainable production of maple sap and syrup. Sugarbush management is a special case in terms of forest management; the goal is to optimize the site for sugar and sap production as well as for other potential uses such as a timber source or an area designed to accommodate wildlife or recreational activities. Although trees used for sap grow similarly to trees grown exclusively for timber, there are some distinctions for foresters to consider.

Interactions between foresters and woodland owners have traditionally focused on timber production and sales. Historically, the value of trees from a sugarbush was reduced due to tapholes and associated staining of the butt log, rendering it unable for use as a sawlog. Also, the value of syrup enterprises was thought to be less than the value of timber enterprises. Currently, markets for "taphole"

[6] Vermont Forest Health Monitoring Protocol, Vermont Forest Ecosystem Monitoring. https://www.uvm.edu/femc/attachments/project/17/FHM_MethodsManualFullProtocol_2017.pdf

maple sawlogs exist as a specialty product in many parts of the maple producing region. Marketing these sawlogs may require developing additional networks or connections, but the return can be favorable. Furthermore, from a long-term economic perspective, maple production offers recurring annual revenue versus the episodic revenue from timber, and the net present value (NPV) of annual maple syrup and related food products may be more favorable than the NPV of revenue from a typical future timber sale.

Aside from the direct economic value of maple for sap and syrup, many commercial maple enterprises are family based and may span multiple generations. The infrastructure can also be transferred to unrelated businesses in the future. This potential for continuity is a favorable outcome that contributes to a broader natural resource benefit to owners, communities, and society from keeping forests as forests.

Maple producers have a vested interest in the long-term productivity from their trees. Woodland owners that lack a maple syrup production objective may not have this perspective, sometimes due to the scale of disturbance and disruption associated with annual maple production. Singletree selection, group selection, and patch cutting with reserves are more likely to align with the needs of the maple producer. These types of dispersed cutting and treatment will allow for better annual predictability and continuity of sap production. The advantage of consulting a forestry professional lies in the professional's heightened attention to the needs of the producer as a client and in the producer's willingness to be more active in understanding how management activities will impact annual production.

Early sugarbush management guidelines often focused on strategies that removed all non-maple tree species from the sugarbush. While this focused was intended to optimize the productivity of the sugarbush, an unintended consequence was a reduced resilience to insect defoliation, spread of disease, drought, and other stress events in addition to reducing effectiveness of forest nutrient cycling. Specific guidance for the desired species composition depends on the circumstances of the sugarbush, but as much as 25 percent of the basal area in species other than the purely dominant sugar maple within a given stand can increase the vulnerability of the stand to defoliation by native insects. Stand-level diversity is strongly encouraged in most organic maple syrup production. In particular, thinning treatments should favor retention of other species on microsites that are not ideally suited to the needs of sugar maple, such as sites with soil depth limitations or impeded drainage.

Although a maple tree in a sugarbush may eventually be sold as a sawlog, the primary criteria for favorable maple sap, sugar, and syrup production relates to crown size, stem diameter, and structural integrity of the stem. The absence of stem defects and the straightness of stem that are emphasized for sawlog production are not entirely pertinent to sugarbush silviculture; the timber management definitions for acceptable and unacceptable growing stock should be modified for sugarbush objectives. Such flaws do not necessarily disqualify a tree for maple sap production; however, stem defects that reduce structural integrity of the stem can increase the potential for stem breakage or failure. As such, stem defects can play a role when selecting trees for removal during sugarbush management treatments due to the consequences of broken stems blocking woods roads and damaging tubing systems.

Early sugarbush management guidelines were developed when sugarbushes were part of animal pastures or agricultural lands were reverting to forest through planting and natural regeneration. At that time, buckets were the primary method of sap collection and production systems favored fewer trees per acre (or hectare) and large-crowned trees. Early sugarbush stocking charts were typically extrapolated from mature open-grown maples and thus are limited in their usefulness as guides to effective management techniques for many second-growth sugarbush stands. Tubing systems and vacuum can efficiently collect sap from a higher number of trees per acre. Current sugarbushes often have varied management histories that created multiple age cohorts of trees with a wide range of diameters.

In addition to accounting for the heightened pace of activity during sap season, maple producers must eventually deal with need for tubing replacement. Mainline and lateral line tubing may last as long as 10–15 years (or even longer) before it needs to be replaced. It's often best to plan for the work to coincide with scheduled forest harvesting operations.

Ideally, management treatments of a planned sugarbush should begin before the installation of the tubing system. Silvicultural treatments prior to initial tubing design and installation can improve tree growth and vigor and anticipated sap yield. Harvests will allow for the development of well-planned access trails to accommodate future maple production needs. Hazard trees should be removed before there is regular human access. Treatments can regulate stocking, eliminate trees of low structural integrity, balance species mixtures, encourage the establishment and growth of species on their optimal microsites, develop crowns of upper canopy trees, reduce stem density for improved access and efficiency, and adjust age structure where there is low vigor to create areas of low tree density for regeneration. Income from a harvest can also provide necessary capital for tubing and other investments.

Improving Tree Vigor and Productivity—Why Growth and Tree Size Are Important

A casual walk through the sugarbush will typically reveal broken branches on the ground as well as the presence of at least a few defoliating insects. These are simple and minor examples of the injuries that cause stress to maple trees, which at high levels can reduce growth. Trees respond to injury within the wood tissues by internally compartmentalizing (also called "walling off") the wound through the development of internal physical and chemical barriers.

Compartmentalization is the tree's way of preventing the establishment and spread of microorganisms that enter the tree wound.[7] A secondary consequence of this process is the creation of a barrier to the flow of sap through the affected region. Therefore, this area is also unusable for storage or export of tree carbohydrates. The wound caused by tapping will result in a column of compartmentalization that is slightly wider and slightly deeper than the taphole, but due to the vertical orientation of most wood tissues, extends a considerable distance both above and below the taphole. The size of the wound is highly variable but is proportional to the size of the hole and probably to the growth rate of the tree. The affected zone is termed "stain" or "non-conductive wood" (abbreviated NCW).

With adequate access to sunlight, trees maintain uniformly wide and deep crowns. These crowns support more foliage and are thus able to capture more sunlight and transform it into carbohydrate through photosynthesis. Vigorous, fast-growing trees are more likely to have the stored resources necessary to withstand light to moderate stresses.

Early research identified characteristics of trees that reflect their potential for growth and sap and syrup production.[8] Crown diameter and live crown ratio were the variables that best predicted the production of sugar, volume of sap, and syrup production per acre. Stem diameter is important because it reflects the volume of wood available to store and redistribute water and carbohydrates. Diameter is also positively related to syrup yield (**Figure 5.6**) since growth adds new conductive sap wood to the tapping zone. In general, if collecting with vacuum, for each inch of tree diameter there is an increase of approximately two gallons more sap or 0.67 pounds more syrup.[9] Because sap yields depend on the availability of clean, conductive wood for tapping, annual growth rates strongly impact yields over the long term.

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[7] Shortle, W.C. and K.R. Dudzik. 2011. Wood decay in living and dead trees: a pictorial overview. General Technical Report; NRS-97, U.S. Department of Agriculture, Forest Service, Northeastern Research Station, Newtown Square, Pa. https://www.nrs.fs.fed.us/pubs/gtr/gtr_nrs97.pdf or in French at https://mffp.gouv.qc.ca/les-forets/services-entreprises-et-organismes/martelage/

[8] Jones, C.H., A.W. Edson and W.J. Morse. 1903. The maple sap flow. Burlington, VT, University of Vermont and State Agricultural Experiment Station. Bulletin No. 103: 45–183. http://cdi.uvm.edu/book/uvmcdi-80192#page/1/mode/2up

Morrow, R. 1955. Influence of tree crowns on maple sap production, Cornell University Agricultural Experiment Station Bulletin No. 103: 1–24.

Note that the research studies cited above were conducted primarily on open-grown individual maple trees, so the relevance to woods-grown trees may not be particularly high.

[9] Isselhardt, M. T. Perkins, and A. van den Berg. 2018. Tree size and maple production. *New England Society of Amer. Foresters News Quarterly* 79(2): 5–6. https://mapleresearch.org/pub/treesize-2/

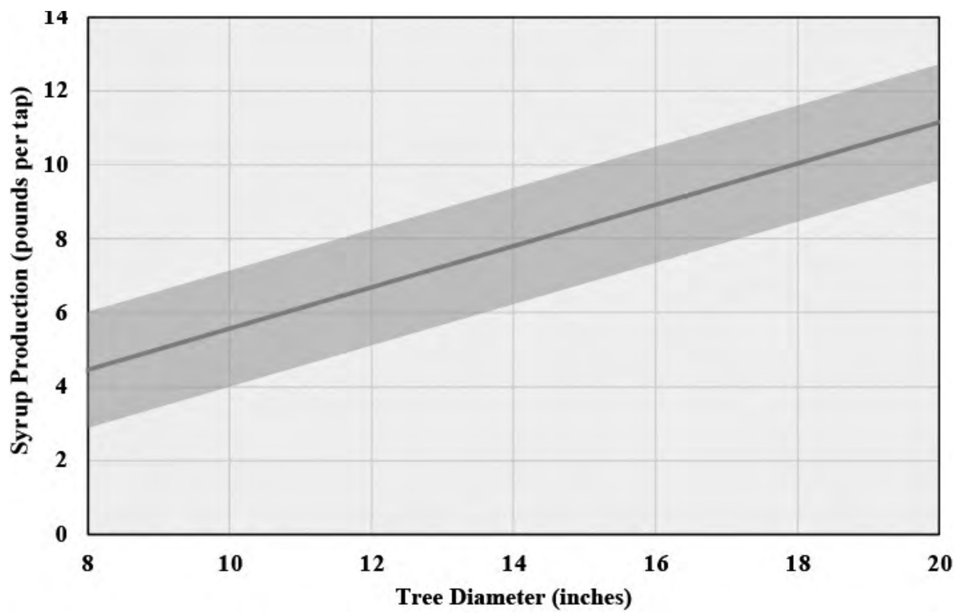

Figure 5.6. The general relationship between maple tree diameter and syrup yield under vacuum and good tubing/spout sanitation conditions. The actual relationship varies somewhat from year to year, by stand conditions, and there can be high variation observed from tree to tree. Data are generalized from multiple sources: Grenier. 2007. https://gestion.centreacer.qc.ca/fr/UserFiles/publications/13_Fr.pdf, Isselhardt, Perkins, and van den Berg. 2018. https://mapleresearch.org/pub/m0218treesize/, van den Berg unpublished, and Smallidge unpublished. Yields under gravity sap collection methods will be considerably lower. The trendline levels off above 20 inches diameter.

Determining Whether Trees Are Competing for Sunlight

Excessive competition between trees for sunlight impairs their growth, vigor, and ultimately sap and syrup production. Managing the competition for sunlight among trees requires that some trees will be removed from a stand. This process is known as thinning, and it allows more sunlight to reach the crowns in the residual trees in the stand to accelerate growth. There are visual signs and mathematical tools and charts that can be used to assess the extent of competition and the need for thinning. Visual symptoms relate to the way trees grow and respond to competition for space and sunlight. Tree symptoms that indicate excessive competition include the following:

- Flattening of the sides of the tree crown due to competition from the crowns of adjacent trees (**Figure 5.4**)
- Death of lower branches (**Figure 5.7**)
- Slow or decreasing growth rate
- Reduction (over time) of sap yield or sap sugar concentration

In addition to visual symptoms of competition, there are mathematical relationships, often displayed

Figure 5.7. Dead branches in the lower crown of maple are typically a symptom of canopy closure and limitations in sunlight. The canopy closure indicates the crowns are competing for sunlight.

Measuring Stand Basal Area

The basal area of an individual tree is the cross-sectional surface area a tree's stem measured 4.5 feet (1.37 meters) aboveground. The sum of the basal area of all trees over a unit of land area is reported in square feet per acre or square meters per hectare. This value is an indication of the stocking level. The basal area of a stand can be calculated from the diameters of trees present in the stand or estimated using the diameters of trees present in one or more sample plots in the stand, or by using an angle gauge or basal area prism.

Angle gauges and basal area prisms are common forestry tools that are used to quickly estimate basal area from point samples without having to measure the basal areas of all the individual trees in a stand. Both these tools can be readily purchased from forestry equipment and supply companies. In some states, the forestry agency or Cooperative Extension may have angle gauges available. Several Extension publications provide detailed descriptions of how to estimate basal area and density of trees per acre with angle gauges and prisms.

Using an angle gauge (or prism) is relatively simple. Hold the gauge directly in front of your face at a distance of approximately 25 inches (63.5 centimeters), and slowly turn your body around in a complete circle, keeping your feet centered over the same spot. A prism can also be used, but the prism is held over the center as you complete the circle. As you rotate with the angle gauge, compare the gap width of the gauge with the width at dbh of each tree that is visible (no matter how large or small, no matter how near or far), and count the number of trees that appear as large as or larger than the width of the gap. Multiply the number of trees counted (those as wide as or wider than the gap) by 10 (or the appropriate basal area factor [BAF]) for the angle gauge or prism being used. The resulting number is an estimate of the stand's basal area in square feet per acre. Angle gauges and prisms calibrated in metric units, often with a basal area factor of 2 (e.g., each counted tree represents 2 square meters of basal area per hectare), are available. As an example, using a gauge of BAF 10, if eight trees cover the width of the gap, the stand's basal area would be estimated as 80 square feet per acre (18.4 square meters per hectare) based on that point sample.

More information is available at https://blogs.cornell.edu/cornellmaple/files/2016/06/Sugarbush-site-potential-assessment-and-tap-count-12vmdl4.pdf or https://mapleresearch.org/wp-content/uploads/Tubing-Notebook-6th-edition.pdf

An angle gauge being used to estimate stand basal area.

as charts, that can help assess the level of competition in a forest stand. Basal area per acre (hectare) is a good indicator of the amount of competition for sunlight and, when used in conjunction with the number of trees per acre (hectare) will assist in evaluating and guiding decisions regarding thinning. A stocking chart shows basal area per acre (hectare), and the density of trees (**Figure 5.8**).[10] The basal area and density measured in a forest inventory can be compared with the chart to describe its stocking level and average tree diameter. The nearly horizontal lines on the chart delimit when the stand is overstocked (A-line); fully stocked (between the A-line and B-line); achieves a balance of utilization of growing space and optimal growth for timber (B-line); or at a level where the stand would be expected to grow to the B-line within 10 years (C-line). Most stocking charts were developed to assist with timber production objectives. Overstocked stands have excessively high levels of competition for sunlight, elevated levels of mortality, reduced tree growth, reduced production per tree, and a lower resilience to stress. Trees in understocked stands have ample sunlight, but because it is underutilized, production per acre (hectare) does not meet the site potential.

Once the current stocking level is determined via an inventory, the maple producer and forester can identify the desired residual level of stocking that will correspond to a proper level of competition, and which will encourage the fastest growth of individual trees and highest rate of production per acre (hectare). The difference between current stocking and desired stocking is the number of trees and volume of wood to be cut (if so indicated). Because maple trees are sensitive to rapid changes in exposure, thinning treatments should not remove more

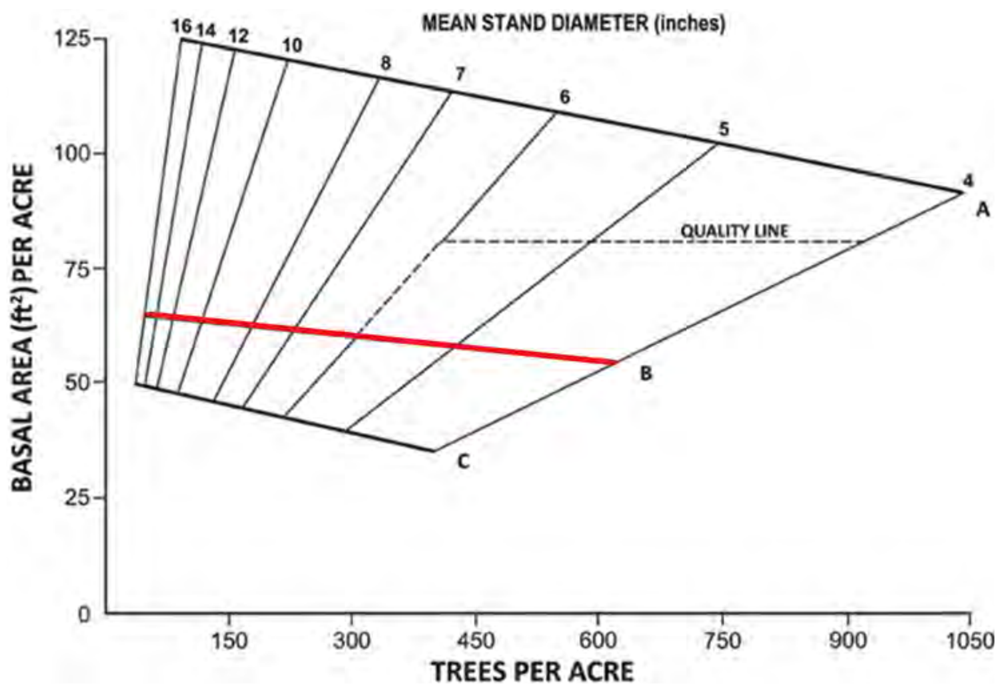

Figure 5.8. Northern hardwoods stand stocking chart. Stand stocking reflects the relationship between the number of trees per acre (density) and basal area per acre. Stands near or slightly below the B-line (in red) are most highly optimized for maple syrup production. From USDA Forest Service GTR-NRS-132. https://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs132.pdf

[10] Adapted from Leak, W.B., M. Yamasaki, R. Holleran. 2014. Silvicultural guide for northern hardwoods in the northeast. General Technical Report. NRS 132. U.S. Department of Agriculture, Forest Service, Northern Research Station, Newtown Square, Pa. https://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs132.pdf *Note that for this stocking chart, only trees greater than 4.5 inches (11.4 centimeters) dbh are included.*

than 30 percent of the main canopy's basal area in any 5–10-year period, and thinning should be performed this aggressively only if the stand is vigorous. Delay thinning treatments or retain higher residual stocking if the stand is stressed by drought or defoliation located on thin or infertile soils, or recently impacted by ice storms or any other adverse events that might limit the growth of foliage or roots. Additional basal area beyond the calculated basal area reduction may be removed from lower canopy position trees.

While the amount of canopy basal area removed will depend on the type of regeneration system used, it's important to bear in mind that the chief goal of any regeneration treatment is to increase sunlight to the forest floor rather than to distribute sunlight among upper crowns.

It should be noted that stocking charts used for sugarbush management were developed to optimize timber production or were calculated based on idealized notion of open-grown maple trees. The guides aimed to strike a balance between maximizing individual tree and stand-level growth, so they did not necessarily maximize diameter growth across all trees in a stand. Therefore, given the lack of specific recommendations for thinning in an established, closed-canopy sugarbush and the relative shade tolerance of sugar maple, it would seem most prudent to retain some level of residual stocking via one or more thinning treatments at or slightly below the stocking level recommended for sawtimber production (i.e., the B-line on the stocking chart).

An interesting feature of stocking charts is their ability to predict the change in average tree diameter based on changes in the number of trees per acre. This relationship is important and useful given the influence that tree diameter has in predicting the production of sap and sugar. On average, for each 1-inch (2.5 centimeters) increase in average diameter in an overstocked stand, there would need to be a 20 percent reduction in the number of trees (i.e., at the A-line) to maintain the same stocking level. Thus, 20–30 percent (one out of five to one out of three) of the trees in such a stand would need to be removed for each inch (2.5 centimeters) of tree diameter growth. Assuming maple syrup production (sap yield and sap sugar content) improves with growth, removing trees by thinning treatments will improve productivity.

Identifying Trees to Retain and Trees to Cut

Without management intervention, natural processes of competition and tree genetics determine which crowns can grow large enough to collect adequate sunlight and survive versus those trees whose growth stagnates and will eventually die. How and when trees are removed from competition through forest management is both an art and a science. Although thinning is a beneficial and needed practice, as the saying goes, "a little is good, a lot is not necessarily better."

There are two main silvicultural approaches to identifying specific trees to cut when thinning: crop tree release and residual basal area. Irrespective of the approach used, the characteristics desired in the trees retained in the stand after cutting are the same:

- Retention of maple species best suited to the soil and site conditions. High-value sawtimber trees that do not compete with productive maple sap trees also benefit from release and may eventually produce valuable timber revenue.
- Stand diversity, resilience, and efficient site nutrient cycling. To that end, reserve up to 25 percent of the remaining stand basal area for species other than sugar maple if those species are not significantly competing with upper canopy maples having good form.
- Removal of trees with significant evidence of insects, disease, physical damage, or stress. Exceptions may be made for legacy trees.
- Retention of single-stemmed crop trees with well-developed crowns without acute branch forking. Branch forks that are "U" shaped are stronger in storms than branch forks that are ″V″-shaped and have included (buried) bark.
- In even-aged stands, retention of crop trees with crowns located in the upper canopy

of the sugarbush. In uneven-aged stands, crop trees should have a main branch or branches that point upward rather than being flat-topped.

- Where possible, retention of crop trees that originated from seed as opposed to trees that developed from stump sprouts.
- Because of the highly dynamic nature of sap sugar concentration, it is difficult to select trees based upon this factor, but with careful measurements over time, it could be used as a deciding factor after other considerations have been met.

When thinning trees, it is important to minimize cutting within a 50-foot (15-meter) border on the windward side(s) of the sugarbush if the stand abuts non-forest lands. In these circumstances, maintaining a higher density of trees along the windward borders will act as a windbreak, conserving moisture in the sugarbush and reducing potential wind damage. Stand treatments that significantly disturb soils and root systems may cause higher levels of windthrow. For young stands, planting a windbreak on the windward side may be desirable.

A third silvicultural approach based upon tree spacing is occasionally possible. The appropriate spacing interval in feet (or meters) is selected to achieve a desired number of trees per acre (or hectare). This is most useful in sapling or pole-sized stands heavily dominated by maple or when done several years after planting trees.

Approaches to Thinning

Each of the methods described below may be employed alone, but frequently achieve better results if they are somewhat integrated with each other; the degree of integration will be dictated by the circumstances. These guidelines should not be applied without continual critical assessment of their impact on the stand. In most cases, a forester should be involved with tree selection, negotiating a sale contract with the buyer and providing administration/supervision of the logging crew. The forester can be retained to ensure that the contract terms are fulfilled properly.

CROP TREE RELEASE The concept behind crop tree release is to give the crowns of the trees selected to remain (crop trees) space for canopy growth. In this approach, current or potential crop trees are selected for release from the surrounding competing trees based on the selection criteria identified previously. Selected trees are released by cutting adjacent trees whose crowns crowd or closely approach the crown edge of the crop tree, or in the case of smaller trees, to obtain a gap of 10 feet (3 meters) from the edge of the crop tree's crown. Neighboring trees whose crowns do not impinge within 10 feet (3 meters) of a crop tree need not be cut, nor do trees whose crowns are completely under the crown of a crop tree. In sugarbushes containing larger trees that have never been released, the initial release of crop trees should be done on only one or two sides of the crown to avoid removing too many trees at one time, which might stress the crop trees (**Figure 5.9**). Higher levels of release, on three or four sides, often shock the tree, triggering significant issues such as crown dieback, sunscald, and windthrow. The only consequence of a conservative thinning approach is a subdued increase in growth. The number of trees released depends on the size of the trees, with

Figure 5.9. The sugar maple tree crowns in the center of the picture show dieback in the upper branches, likely resulting from shock caused by excessive thinning. These trees are located off site in a poorly drained depression that limits their health and vigor.

allowances being made in younger stands for loss of some of the potential crop trees. The goal of a typical release is to achieve 40–120 tappable trees per acre (100–300 per hectare), and up to 300 per acre (740 per hectare) for stands with smaller-diameter trees that will be subject to another later release. When using the crop tree release approach, it is important to clearly mark both the crop trees and the trees to be removed, using markings that can be easily told apart, to avoid confusion.

THINNING TO RESIDUAL BASAL AREA Stands that have 100 trees per acre (250 per hectare) of sufficient quality to be crop trees might be better thinned using a residual basal area approach. The target residual basal area is likely at or slightly below the B-line of the stocking chart (**Figure 5.8**). Measure the current basal area at a point in the sugarbush using an angle gauge. Determine the amount of excess basal area versus the target residual basal area. Select and mark trees to cut using criteria of the previous list that will reduce the basal area after cutting to near the residual basal area. Select the least desirable trees (candidates for removal) first and stop marking when you get near the target residual basal area. Move to a point a short distance away, ensuring there is some overlap of trees in the angle gauge, but disregard any trees already marked for cutting. Sometimes, especially as you start marking, the actual basal area may be lower than the desired residual basal area, in which case no cutting is required and the "extra" trees retained at some other points will result in the correct average residual basal area. At some points, all the trees in the actual basal area are desirable, even though stand-level basal area exceeds residual levels. In these cases, cutting at each point is not required, but choosing not to thin will result in the development of highly competitive conditions (tight crowns with little growing space between them) over time. As difficult as it may be, sometimes it is better to cut a few maple trees, particularly when considering the long-term health of the best sap-producing trees in a stand. At points where all trees seem of equal quality, aim to make spacing between trees more uniform.

Tree selection and marking takes time and decisiveness to measure basal area at multiple points, inspect trees for crown and stem quality, and strategize the spacing of selected trees at present and as the stand will respond and take shape in the future. There is significant complexity in the process to inventory and mark a sugarbush to optimize sugar and sap production while also accounting for tree revenue, native plant diversity, stem quality, crown vigor, minimized stand damage, harvest trail layout and design, and future harvest considerations. Working with a professional forester throughout the process of inventorying, plan development, and implementation of silvicultural prescriptions can help reduce this complexity of the process and optimize outcomes.

Removing Competing Vegetation

In general, herbicides are not recommended for use in areas of maple sap production. In particular, maple producers seeking or maintaining organic certification are highly restricted in their use of herbicides. Herbicide injection in weedy lower canopy, sapling-sized or smaller stems of species (e.g., hophornbeam, American beech) can be more efficient than cutting, but carries a risk that herbicides may carry over to crop trees and to syrup. Do not inject herbicides into maples in the sugarbush to avoid transferring it to crop trees via root grafts. Some clonal shrubs, such as prickly ash (*Zanthoxylum americanum*), or invasive shrubs such as multiflora rose (*Rosa multiflora*) can be controlled with foliar herbicide sprays, but these may also tend to affect crop trees via soils. In general, if herbicides are used in a sugarbush, great care should be exercised to avoid problems.

IMPROVING THE SUGARBUSH—LIMING AND FERTILIZATION

As a tree species, sugar maple has a relatively high demand for calcium. Liming (adding calcium carbonate or calcium/magnesium carbonate to soil) and fertilization have long been of interest to maple producers as possible method to increasing the health and productivity of their maples. Liming raises soil pH, stimulates microbial growth, and tends to increase nutrient availability. Over the years, researchers and producers have experimented with both liming and fertilization, often with mixed results. In some instances, these treatments increased tree vigor, growth, sap volume, and sap sweetness; in other instances, they did not. Some research, especially on poor soils and high application rates, have documented cases in which the positive response of trees to an initial round of lime treatments lasted as long as 20 years.

There are at least two reasons for these mixed results: First, there are frequently failures to evaluate the soil and plant nutrient status prior to amendment so that lime is applied only to soils having low calcium saturation and base cations, and second, an insufficient quantity of lime was applied to the soil due to incomplete knowledge of the nutritional requirements of maple trees and how to best meet them. In soils with adequate pH, base saturation, and nutrient availability, liming is unlikely to have any beneficial effect. In recent years, research and experience have demonstrated that when indicated, and when used properly, liming and/or fertilization can be valuable tools for improving the vigor, growth, and productivity of maple trees growing in some geographic areas and under certain site conditions, particularly where soils are deficient in calcium and/or magnesium, and where soil pH is quite low (acidic).

Sugar maple responds favorably to lime additions on sites where a detailed soils analysis has identified poor soil fertility as an obstacle to optimal development. In Quebec, improvements in sugar maple basal area growth and sap sweetness have been well demonstrated in areas where liming was indicated by soil testing. A positive effect of liming is generally not observed on sites with good existing soil fertility. Application rates should be dictated by soil (and perhaps foliar) testing. Gains in syrup production in response to amendments are generally thought to be a result of increased growth rates. Applying lime in a sugarbush without damaging the residual stand takes careful planning and execution.

Sugar maple seedling survival and sapling growth often respond favorably to lime additions. Sites where sugar maple regeneration is lacking may be low in calcium. Treatments to favor sugar maple saplings on sites with poor fertility should include sufficient lime additions plus release from competition for sun by removal of competing vegetation such as American beech.

It should be cautioned that forests are not like annual crops on cultivated soils. Besides being a waste of time and money, errors such as over-applying or incorrectly adding fertilizer can adversely affect the forest for a long time. Putting on too much fertilizer is not better than putting on the right amount or the right type. Some nutrients are antagonistic to others (reduce uptake), so adding the wrong fertilizer can make matters worse. Adding nitrogen fertilizer, a common way to spur growth in crops is NOT generally advisable for forest soils. Forests are adapted to be nitrogen limited, and thus will gluttonously take up nitrogen whenever it is available in the root zone. This can be detrimental to trees, reducing their ability to "harden" for winter. There is also some evidence suggesting that excess nitrogen can promote metabolism off-flavor in maple syrup. Adding soil amendments will not help appreciably if trees have no room to grow. In some cases, the producer may be better served to thin their sugarbush or to lease a sugarbush on lands that have better soils and need less investment to improve productivity. In general, the rule for liming and fertilizing forests is to do testing and proceed (if indicated) slowly and cautiously.

Before proceeding with liming or fertilization, the reader is strongly advised to investigate the large body of research and practice developed over the past 20 years, much of it originating and in use in Quebec.

Evaluating the Potential Benefit of Liming or Fertilization

Throughout the maple region, deficiencies in calcium, magnesium, and potassium and the negative effects of strongly acidic soils are the most common tree nutrition/soil fertility problems reported. Producers and others evaluating the potential benefit of liming and/or fertilizing maple trees should rely on a variety of tools and indicators. Knowledge of the nutritional status of the maple trees (determined from a foliar sample) and the soil characteristics (e.g., pH and buffer pH) is required to develop a proper diagnostic recommendation. For producers who have not formally evaluated the soil characteristics and nutritional status of their sugarbush, characteristics of the trees or the site can sometimes be informative. Certainly, trees and stands that exhibit slow growth and low vigor, including thin crowns, branch dieback, and slow-closing tap holes, should be evaluated. While such symptoms can be caused by other factors (e.g., crown competition for light, too much or too little soil moisture, soil compaction), soil pH and/or fertility may be an important variable responsible for observed symptoms.

Most nutrient deficiencies, when severe, produce visible discoloration patterns in leaves (**Table 5.1**). Such foliar symptoms are most easily observed on smaller trees (e.g., a planting) or on roadside or yard trees where the crowns and leaves can more readily be seen and during the growing season well prior to the onset of fall color. The absence of symptoms, on the other hand, does not indicate that the trees' nutritional needs are being adequately met. Asymptomatic trees may harbor deficiencies that are not yet severe enough to manifest as foliar discoloration. Conversely, symptoms may result from other factors such as damaged root systems or extreme soil or environmental conditions, so careful diagnosis is important. Knowing the cause of the symptom is a critical first step toward fixing the problem.

TABLE 5.1 Visible foliar symptoms of nutrient deficiencies in maple

Nutrient	Foliar Deficiency Symptom
Nitrogen	Chlorosis (yellowing) of leaves.
Phosphorus	Bronzing or purpling of leaves; leaves often smaller.
Potassium	Yellowing or death of leaf edges (margins).
Calcium	Yellowing of leaves similar to nitrogen deficiency.
Magnesium	Bright yellowing or oranging of all or part of leaves.
Manganese	Yellowing of leaf between veins, veins remain green, marginal scorching when severe.

Knowledge of the bedrock present in a geographic area may suggest whether liming or fertilization could be beneficial. In many areas of the commercial maple region, particularly parts of New England and portions of New York, Pennsylvania, Ontario, and Quebec, the bedrock and soils are granitic, schist based, or otherwise problematic because of their formation from rock low in calcium or magnesium. Soils produced from the weathering of these parent materials are often fairly acidic and low in calcium or magnesium. Research and experience in many of these areas have demonstrated improvement in sugar maple vigor, growth rate, and even total sugar production after liming. Even if the sugarbush is located in one of these areas, the producer should not invest in liming or fertilization until soil and foliar testing verify the diagnosis. Otherwise, amendments may be selected to treat a condition which might not necessarily exist.

While some maple producing regions were unglaciated (generally mid-Pennsylvania southward), many northern areas have been partially or completely glaciated. The material deposited by the glaciers can substantially modify the soil conditions in these locales. Throughout much of the rest of the commercial maple region, limestone is present in the soil parent material, resulting in soils with higher pH and higher calcium and magnesium levels. Parent material, soil pH, and nutrient levels may have been greatly modified since being deposited as a result of site history, weathering, and acid deposition.

Another qualitative indicator of the nutritional character of a sugarbush can be judged by observing the types of herbaceous and woody plants growing in the stand.[11] While there are no foolproof "indicator" plants that can positively specify whether a sugarbush will benefit from liming or fertilization, there are plants that show the relative pH and nutritional richness of the site and thereby suggest the potential of that the stand to benefit from liming or fertilization. Although qualitative indicators provide some

[11] Wilmot, T. and T.D. Perkins. 2004. Fertilizing a Sugar Bush. Proctor Maple Research Center, University of Vermont. Miscelaneous Pub. https://mapleresearch.org/wp-content/uploads/fertsugarbush.pdf

information, given the cost and effort to lime or fertilize and the potential long-term effects of treatment, analysis of soil and foliar samples is prudent.

Soil Testing and Analysis

Soil test reports commonly provide information on the pH, buffer pH (lime test index) and cation exchange capacity, as well as estimates of the available phosphorus and exchangeable potassium, calcium, and magnesium. This information is used to evaluate the need to adjust soil pH, an index for determining how much lime to apply if the soil pH is to be raised, and a basis for prescribing additional lime applications if necessary.

Like foliar testing, soil sample analysis can be performed by many agricultural testing laboratories. The soil sample should represent as uniform an area and condition as possible (e.g., same soil type, same topography, similar drainage). If a stand being evaluated contains two dissimilar areas with respect to soil characteristics, soil samples should be collected that are representative of each area. The soil sample should consist of 15–20 subsamples collected throughout the sample area, approximately one sample per acre or two per hectare. Detailed guidelines for obtaining, handling, and submitting soil samples are available from individual testing labs and many universities and agencies that work with the agricultural community. Often this information is provided online.

Most maple species thrive in a pH range from 5.0–7.0. Outside that range they may survive but can suffer from reduced vigor or low productivity. If the pH is below 5.0, tree vigor and productivity might be improved through the application of lime or dolomitic lime (which contains both calcium and magnesium). If lime is to be applied, buffer pH provides a guide to determine how much lime or dolomite should be applied to raise the pH to a desired level. Where possible, it would be desirable to raise soil pH to the 5.7–6.0 range for all maple species. In many situations, however, where pH is highly acidic, moving pH upward slightly may be all that is easily feasible. The decision on whether to use calcite lime (calcium only) or dolomite (calcium and magnesium) should be made based on the foliar test results for magnesium—if the magnesium level is satisfactory, calcite lime can be used; if the magnesium level is low, dolomite should be used.

The amount of lime to be applied should be correctly determined by laboratory analysis to achieve the desired pH and ensure balance with micronutrients. High levels of calcium and magnesium from heavy applications of lime may reduce the availability of potassium in the soil and/or interfere with the ability of the tree to absorb potassium. It is prudent to perform a follow-up foliar test about 4 years after liming to confirm the efficacy of the treatment. When heavier rates of lime are used, verification after 3–4 years is highly recommended. Finally, liming may increase the risk of damage by invasive earthworms.

Fewer generalizations can be made with respect to using soil test results to interpret the sufficiency of soil phosphorus and potassium for growing maple. This is not to say that the results of a soil test are not valuable, but that the heterogeneity of soil characteristics (e.g., texture, pH, moisture content, organic matter, cation exchange capacity, parent material) make generalization all but impossible. Further, soil test interpretation as a basis for fertilizing agricultural crops is based on volumes of research and decades of experience—research and experience that is at an immature stage for maple in forest settings. That said, a soil test can still be a valuable tool in aiding someone familiar with maple stand management and the soils in a particular geographic area in assessing the need for or potential benefit of fertilization, particularly if used in conjunction with a foliar test.

Figure 5.10. Lime or fertilizer can be spread in the woods in many ways. A simple way is to divide each acre into four roughly equal parts and spread the proper amount by hand.

Lime is best applied in the spring or in the fall after the leaves have dropped. Depending on the amount of lime to be applied, material can be spread by hand (**Figure 5.10**) or with appropriate spreaders if site access allows. Many sugarbushes have been limed by distributing the bags evenly throughout the application area and then uniformly distributing the lime by casting it throughout the sugarbush with a shovel. More uniform distributions can be obtained using spreaders. If pelletized lime or fertilizer is used, a handheld spinner spreader is well suited for applications in a sugarbush stand. A drop spreader can be used if lime is in powdered form. Incorporation into the soil will be considerably faster with powdered lime than pelletized lime. Spreaders should be calibrated to ensure they are distributing lime at the desired rate. This can be accomplished by measuring the amount spread over an area of known size and adjusting the spreader opening until the desired rate is achieved. Calibrations for each piece of equipment should be performed for each applicator, as two individuals walking with different gaits will apply substantially different amounts of fertilizer. Tractor- or ATV-drawn spreaders can be used in larger areas, with appropriate attention to minimizing soil compaction damage to young trees, lower tree trunks, and roots. Tractor- or ATV-drawn spreaders must also be calibrated to operate at the speed at which they will be driven. In some situations, aerial spreading may be cost-effective.

MAINTAINING A SUGARBUSH—GROWING NEW MAPLE SEEDLINGS

In some sugarbushes, canopy maple trees are old and have reduced growth rates and vigor or the tops

(a)

(b)

(c)

(d)


Figure 5.11. Various types of wounds can impact vigor and sap yield from maple trees. Root wounds from animal gnawing (a), basal wound and fungal infection (b), stem wound (c), and cluster tapping (d). Tapping should take into account such wounds by reducing diameter to an "effective" or functional tree diameter by subtracting out that portion of the tree affected by the condition.

of the crowns are dead, taphole closure is slow, or stem integrity is compromised by significant previous wounds (**Figure 5.11**). These conditions can be exacerbated by damaging biotic (living) factors, such as insects or diseases, and abiotic (physical) factors, such as wind, temperature, or other extreme weather events. In these cases, the producer and forester may determine there is a need to focus attention on regeneration within a section of the sugarbush.

Regeneration requires an increase in sunlight on the forest floor (**Figure 5.12**). Sunlight needs to pass through the main canopy and any additional layers of subcanopy trees, shrubs, and lower vegetation such as ferns or grasses to provide fuel for the photosynthetic process of the leaves of seedlings. Small openings of 0.3–1.5 acres (0.1–0.6 hectares), even if retaining some trees, are generally sufficient to initiate maple regeneration (**Figure 5.13**). Although maples tend to be relatively tolerant of shade, they will most successfully compete with other species in larger openings if given more sunlight. Be continuously alert from the time of seedling establishment until regenerating individuals reach the sapling stage to the presence of interfering vegetation. An initially low frequency of undesired species can rise quickly and overwhelm a site when the canopy is opened.

Figure 5.13. Copious maple regeneration in an opening in a maple stand.

Figure 5.12. Successful maple regeneration requires moderate light and moisture. Adequate available calcium is strongly related to sugar maple seedling survival and tree growth. Sugar maple produces seed sporadically (called masting) so new seedlings will not be observed every year.

Protecting maple seedlings from animals is essential in some parts of the maple production range. The complete absence of maple seedlings or the presence of heavily browsed maple seedlings may indicate high levels of deer impact. Sugar maple is often a preferred browse species (**Figure 5.14**). Deer impacts in many areas are sufficient to prevent or severely curtail efforts aimed at tree regeneration. The producer might consider options such as individual tree cages or tubes in small areas where establishing regeneration is critical. There are resources on the internet for small-scale and low-cost fencing designs intended for uses in sugarbush regeneration efforts. New research on the use of slash walls to exclude deer is encouraging. Note that all the options for protecting seedlings need to be monitored and maintained until seedling height is well beyond the reach of deer.

Figure 5.14. White-tailed deer can have a significant impact on maple seedlings. Browsing removes the terminal buds, which stimulate lateral shoots and eventually produce a stunted maple seedling with slow growth and an increased risk of mortality.

Working with a local forester can help in planning and implementing a specific strategy to regenerate your sugarbush.

There are several practical benefits to assessing the need for sugarbush regeneration and taking action if deemed necessary. Reproducing declining portions of a sugarbush today will provide healthy, vigorous, high-yielding trees of tappable size on fertile sites with adequate protection from deer within a time frame of 25–35 years. The amount of time required to achieve this goal falls within the planning horizon of many producers. Also, in the future, the sugarbush may pass to succeeding generations within the family or be sold. In either case, a healthy, vigorous sugarbush is of more value than one consisting only of old, over-mature trees. It is also much more resilient and will recover more quickly from natural disturbances such as ice or windstorms.

ESTABLISHING A NEW SUGARBUSH—TREE PLANTING

Planting provides the opportunity to use easily accessible and suitable sites to establish a rapidly growing and vigorous stand of maples that may reach tappable size within 25–35 years depending upon the size of stock and tending. This option enables producers to achieve their goal in a considerably shorter time than that required for shaded maples in unmanaged sugarbushes, but is also considerably more expensive, labor intensive, and time-consuming. Plantation establishment requires considerable planning and many years of dedicated effort to ensure success. Focus on small areas of the highest quality that, ideally, are near the existing sugarbush.

Select the maple species best suited to the site based on the soil and site characteristics. Sugar or black maple are the species of choice for optimal sugar yields and tend to have longer life spans than other maple species. While sugar maple grows on a variety of sites, planting should be done only on better sites characterized by deep, medium-textured, fertile, moist, well-drained soils. Red maple can be planted in slightly drier or moister soils than sugar maple, and silver maple thrives in riparian areas. Avoid dry sites, poorly drained sites, and low areas that form frost pockets.

Like naturally established stands, plantations should include a mixture of species or be surrounded by forests containing a mixture of other species. Monocultures (stands containing a single species) are more vulnerable to damage or destruction from species-specific insects or disease. While such a concern is certainly valid for large-scale plantings, most sugarbush plantings are relatively small. There is little information about what constitutes a "small" plantation, but plantings that cover more than 2–3 acres should likely include at least 25 percent of the stems among two or three additional species.

Maple plantings are commonly established either by planting young seedlings (2–3 years old) from a nursery, by transplanting larger, older, wild-grown trees that are already established in the sugarbush or at another location or by planting larger, nursery-grown transplants. Nursery seedlings are relatively inexpensive but must be rigorously culled to favor those with larger stem diameters and good root development. Wild-grown seedlings can be larger, but require considerable effort to collect, risk damage to the root system, and may require more watering. Wild-grown seedlings over 6 feet tall (~2 meters) should be excavated and moved with machinery. Without a moderately high level of post-transplanting care, transplanting large seedlings or saplings can result in low survival rates.

The following guidelines are useful if planting is to be established using young seedlings:

- Order seedlings as early as possible (in early fall for planting the following spring) to ensure availability. If desired, check with your local, state, or provincial resource professional concerning the availability of genetically selected "super-sweet" seedlings.
- Plant in the spring unless you have been advised differently by a resource professional experienced in planting in your region. In some situations, fall planting is also an option.
- Before planting, eliminate any undesirable woody or herbaceous vegetation, such as vines, brambles, trees, shrubs, grasses, or goldenrod from the planting area.
- If possible, arrange for delivery of seedlings as close to the date of planting as possible. Seedlings are commonly packaged in Kraft-paper bags containing moss or some other moisture holding medium. If kept cool, seedlings can be stored in these shipping bags for 4–5 days provided the moss or other medium is kept moist (not wet). Effective storage for longer periods generally requires refrigerating the bags or temporarily "heeling in" the seedlings in a soil filled trench.
- Keep the seedling roots moist at all times prior to planting. Once the planting process has begun, this is best done by keeping moist moss around the roots and keeping the seedlings shaded. Do not store sugar maple seedlings in a bucket of water—roots of tree seedlings are damaged by extended submersion.
- Consider planting seedlings at spacings between 8 feet by 8 feet (2.4 by 2.4 meters) and 16.5 feet by 16.5 feet (4.8 by 4.8 meters). Stands planted within this spacing range do not require excessive numbers of seedlings per acre yet provide ample opportunity for equipment maintenance and thinning as the planting matures and the crowns close. Allow enough spacing for mowing equipment.
- Carefully measure and lay out the location of planting rows and trees within rows. Careful tree placement will make trees easier to locate, reduce damage and loss from mowing, and establish proper spacing for future thinning. Many techniques and aids can be used to achieve proper spacing such as poles cut or marked to the spacing length, rope with knots or fingernail polish marks at spacing intervals, and survey flags to mark rows or planting locations. Sight down and along rows and across diagonals to straighten rows.
- Plant only healthy, vigorous, well-formed seedlings, free from damage, defects, or signs of insects or disease (e.g., mold infections). Acquire enough seedlings to discard at least 10–20 percent with the smallest stem diameter at the root collar. Handle and plant carefully to avoid damaging the seedlings.
- Bear in mind that planting technique is critical. Use a shovel or planting auger or learn how to use a planting bar to ensure correct root orientation. Soil should be firmly packed to eliminate air pockets that dry the roots.
- Plant seedlings at or very near the same depth at which they grew in the nursery. This depth is the tree's root collar, the area where stem changes to root. The location of this area is indicated by changes in the color and surface texture of the bark. Trees planted too deep or too shallow will do poorly.
- If water is available and soils are dry, gently pour a couple of gallons on the soil after planting to help hydrate the plant and

settle the soil around the roots. Do not water the seedling until the hole has been completely refilled with soil. Watering during dry periods for at least the first year will help with survival and growth. A bark or hardwood chip mulch can help with moisture retention.

When planting larger, wild-grown transplants, the following techniques are suitable:

- When possible, select transplants a year ahead and root prune with a trowel or planting spade to reduce the length of unwieldy roots; be careful to minimize damage to the transplant.[12]
- Look for healthy, vigorous trees up to approximately 1 inch (2.5 centimeters) in diameter from open areas within or along the edge of the sugarbush. Select straight trees that are free from stem defects and that have a strong terminal leader (avoid flat-topped trees lacking a single strong terminal leader). When possible, avoid digging trees in dense areas of the sugarbush, as they will be more difficult to remove, will not have as vigorous root growth, and may be sensitive to sunscald when moved to a more open area.
- Transplant wild-grown maples in either spring (before buds begin to swell) or fall (after leaf drop). These trees can be successfully transplanted with either bare roots or a soil ball around the root. The use of a soil ball is recommended whenever possible to minimize stress on the tree.
- Follow current recommendations for the minimum root spread, which are based on the stem caliper (trunk diameter 4 inches or 10 centimeters above ground level) and tree height for maple seedlings and saplings collected from native locations without root preparation prior to digging (**Table 5.2**).[13]
- View the spread diameters in the table as the minimum amount of space required. Larger stems will need burlap around the roots to create a ball. A serious challenge in moving maples with a root ball is holding the root ball together, particularly as ball diameters get above 18 inches (46 centimeters) and weight increases. Soil weighs approximately 84 pounds per cubic foot (50 kilograms per cubic meter). The recommended soil ball for a 1-inch (2.5 centimeter) basal diameter transplant weighs slightly less than 300 pounds (136 kilograms). For best results, stems should be 6–8 feet (1.8–2.4 meters) tall.
- To create a root ball, drive the shovel downward and slightly inward in a complete circle around the tree. Go around the tree

TABLE 5.2 Recommendations for minimum root spread of maple seedlings and saplings collected from native locations based on stem caliper (trunk diameter 4 inches or 10 centimeters above ground level) and tree height without root preparation prior to digging.

Trunk Diameter 4 inches Above Ground	Root Ball Diameter	Root Ball Depth
½ inch (1.3 cm)	14 inches (36 cm)	9 inches (23 cm)
¾ inch (2 cm)	16 inches (41 cm)	10.5 inches (27 cm)
1 inch (2.5 cm)	18 inches (46 cm)	11¾ inches (30 cim)
1¼ inches (3.2 cm)	20 inches (51 cm)	12 inches (31 cm)
1½ inches (3.8 cm)	22 inches (56 cm)	13¼ inches (34 cm)

[12] Root pruning involves driving a spade into the ground completely around the tree at a distance from the trunk equal to the size of the root ball or root mass to be dug. The tree is then left in place for one or more growing seasons during which time it will develop additional roots within the root ball area.

[13] Adapted from American Nursery and Landscape Association. 2014. American Standard for Nursery Stock. https://cdn.ymaws.com/americanhort.site-ym.com/resource/collection/38ED7535-9C88-45E5-AF44-01C26838AD0C/ANSI_Nursery_Stock_Standards_AmericanHort_2014.pdf

several more times, prying upward with the shovel to sever and/or break the remaining roots. Be careful not to shatter the root ball. Using a shovel, pry the root ball up and work burlap under and around the ball. Draw burlap up over the top of soil ball and bind tightly, fastening with nails or wrap with twine. With larger root balls, the process of positioning the burlap under and around the ball may require several steps, working from opposite sides of the soil ball. Also, larger soil balls may require trenching around the soil ball to adequately form, wrap, and lift the ball. Do not discard the tree if the root ball shatters; plant quickly and treat as a bare-root transplant.

- When bare-rooting wild-grown maple transplants, excavate the root systems to a depth of approximately 12 inches (30 centimeters) and a minimum root-spread diameter that is 20 to 24 times the stem's diameter. The minimum stem caliper (diameter at base) should be greater than 0.007 times the tree height. Excavation of bare-root transplants can proceed in a manner similar as that for balled transplants, except that a ball of soil is not retained around the root systems.
- Balled transplants should be planted in a hole deep enough to accommodate the root ball. The burlap need not be removed, but any twine used to bind the ball should be removed. Plant bare-root transplants in a manner similar to that used for small seedlings—in a hole with a cone of soil in the center over which the roots are draped. Position the transplants (balled or bare rooted) at the same depth as they previously grew (see discussion on locating root collar included in the guidelines for planting young seedlings).
- Refill the hole with the soil that was removed, packing the soil firmly as it is returned.
- Give each transplant artificial support to prevent excessive swaying and breaking. This can be done by driving a 6–8-foot (1.8–2.4-meter) stake into the ground near the base of the tree and securing the tree to the stake with a short length of wire running through a garden hose (to protect the tree's bark). Where prevailing winds are a salient factor, place the stake on the windward side of the tree. Where winds are strong and variable in direction, a two- or three-stake system may be preferable.
- If water is available, gently pour several gallons on the soil after planting to help settle the soil around the root ball or roots. Do not water the seedling until the hole has been completely refilled with soil. Watering during dry periods for at least the first year will help with survival and growth. A bark or hardwood chip mulch can help with moisture retention.

If the planting is to be established using nursery-grown transplants, follow planting directions provided by the nursery or the previously listed guidelines for larger transplants.

Because of the time and labor involved with transplanting large saplings, they are often spaced at least 25 feet (7.5 meter) apart—at the desired spacing of the trees when grown. They can, however, be spaced closer together, perhaps 10–15 feet (3–4.5 meter), with the intention of removing poorer performing trees as the canopy closes. If wider spacing is used, interplanting of "nurse" species can help suppress weeds and provide some wind protection. Because sugar and red maple often seed into sparse conifer plantations, species such as white pine (*Pinus strobus*), red pine (*P. resinosa*), Scots pine (*P. sylvestris*), or European larch (*Larix decidua*) as appropriate for the particular site might be more suitable. Consult local resource professionals for recommendations of nurse tree species suited to the area. As the maples begin to close canopy, the nurse trees should be removed. Alternatively, annual cash crops such as u-pick raspberries or pumpkins can supplement income for a while. Nurse crop plants can help buffer the site from some of the environmental extremes that can challenge maples during the critical establishment period.

To perform well, planted maples require good weed control for several years after planting. This reduces competition for light, moisture, and nutrients. More than 10 years is generally required for maples to produce enough shade to suppress competing vegetation. Following planting, grasses and broadleaf weeds should be eliminated from around the base of the trees with a registered herbicide (producers with or desiring organic certification should check guidelines regarding the use of any herbicides), shallow cultivation (no deeper than 1–1½ inches (2½–4 centimeters), or by frequent mowing. Do not strike maple bark with the string of a string mower as it can girdle the tree. Rodents such as mice and voles can damage seedlings. Bare soil around the tree discourages their activity, as would basal wraps or wire mesh. Minimize favorable rodent habitat such as dense weeds by using deep and coarse mulch (e.g., straw) or weed mats. Chemical repellents have shown limited success and often must be applied every 5–6 weeks if feeding damage persists. The best approach is to use wire or plastic mesh tree shelters, or perimeter fences. Wire fencing with 1-inch (2.5-centimeter) mesh formed into a circular guard will prevent deer, rabbit, and porcupine feeding—be sure to remove it as the trees attain sufficient size. Where deer are active, fencing will need to be extended to at least 5–6 feet (~2 meters) above ground or snow level (**Figure 5.15**). For rabbits, the guards need to reach at least 20 inches (50 centimeters) above ground or snow level.

Solid plastic tree shelters and tight mesh shelters should be avoided as these can adversely affect the environment around the seedling. Plastic tubes with sufficient vents will mitigate some of these problems. Solid plastic shelters also provide a good environment for wasps, Japanese beetles, and other insects that can damage the plants. Also, in some areas, solid plastic tubes installed around seedlings may cause them to emerge from dormancy early, thus putting them at risk of frost damage.

Ideally, sugar or other maple species should be planted on sites where the native soil can support vigorous, healthy trees without fertilization or liming. Where possible, soils with a pH between 5.5 and 7.0 are most desirable. If maples are present on the site, an analysis of their foliar nutrient content may indicate how well the site is meeting their nutritional needs. If amendments are considered, soils should be tested prior to planting. Applications of liquid or granular fertilizer should normally not be made during the first year after planting. If fertilizer is applied after that, it should be within the area of the tree crown. If fertilizing in response to a specific nutrient deficiency identified with a soil or foliar analysis, apply the appropriate fertilizer at the

Figure 5.15. Deer exclusion fencing around sugar maple plantations must be sufficiently high to prevent entry.

recommended rate—if done simply to improve seedling health, vigor, and growth rate, use a complete 10-10-10 (N-P-K) fertilizer at a rate of 3–4 pounds per 100 square feet (1.4–2.0 kilograms per 10 square meters) of soil surface. Operations with organic certification should always first consult regulations for permissible fertilizer products.

The form and shape of young maples should be examined each spring and pruned as necessary. The chief goal is to develop a tree that has a single trunk clear of branches up to at least 8 feet (2.5 meter) and that then branches into a full crown. Sugar production results from a full canopy of leaves having maximum exposure to sunlight. Use the following guidelines to achieve good pruning results:

- Retain only the straightest, most central leader.
- Cut laterals with excessive growth to keep the crown balanced.
- Remove dead or damaged branches.
- Leave lower branches unpruned unless they interfere with access to the trunk or with mowing.
- Do not remove more than 25–30 percent of the tree's crow in any one year.
- Ensure that at least the upper 50 percent of the tree's trunk contains live branches.
- Prune branches at the outer edge of the branch collar, not flush against the trunk.
- Prune in the fall or winter when the trees are dormant, or, if necessary, in the late spring or summer after the sap has stopped running.

MANAGING ROADSIDE TREES

Many producers find roadside trees to be above-average sap producers. Better production is presumably a result of their larger crowns and root systems due to lower competition and better light exposure and because they commonly receive better care than individual forest trees. As with forest trees, the management objective is to maintain a healthy, vigorous, large-crowned tree (**Figure 5.16**). The approach, however, is more like that used to maintain an ornamental tree rather than a forest tree.

Figure 5.16. Vigorous maple tree with expansive crown.

Protecting roadside trees from destructive agents is as important as protecting forest trees. Because of their location and easier access, it is typically easier to keep an eye out for roadside tree problems. One major concern with roadside trees that is not a concern with forest trees is road salt. Every effort should be made to eliminate or at least reduce use of road salt near tapped maple trees. Extensive exposure to road salt can lead to the rapid decline and death of maples. The use of gypsum as a soil amendment has shown some promise in treating road salt-stressed trees. Roots of maple trees absorb a small amount of the sodium and chloride present in salt. Gypsum application can sometimes help alleviate salt stress. Under extreme conditions this may impart an off-flavor to the syrup produced. Where roadside salt is used near tapped maples, be sure the sap is not off-flavored before it is processed into syrup.

PROTECTING THE SUGARBUSH

Sugarbushes are vulnerable to a variety of factors that can affect their health and productivity or, at the extreme, kill some or all of the trees. These factors, or stressors, include wild and domestic animals, insects and disease, fire, weather, and human activities that damage the soil or trees. An important responsibility of sugarbush management is to be continually alert for these problems and to act promptly to reduce or eliminate their impact. The accumulation of stressors is noteworthy. Trees can often tolerate a single stress event, but multiple stressors, sometimes acting years apart, can have compounding negative effects on tree health. For example, drought experienced by a healthy, vigorously growing sugarbush is not the same as a drought experienced by a sugarbush that has had 30 percent defoliation by insects during the last two years. Evaluation of the effect of any stressor on a sugarbush must be done in the context of the overall health of the sugarbush and all the stressors affecting it. A healthy and vigorous sugarbush is best equipped to recover from stresses.

Livestock Grazing

While grazing of sugarbushes is still common in some areas, uncontrolled livestock, even for modest time spans, do not belong in a sugarbush. Uncontrolled grazing will reduce the health, vigor, and productivity of the stand. Certainly, continued grazing can destroy most or all of the young maples present. Specific damages likely to result from prolonged livestock grazing in a sugarbush include the following: (1) injury to lower trunks or roots, providing a point of entry for disease, and reducing the crop trees' ability to absorb nutrients and moisture; (2) compaction of the soil, thereby decreasing soil moisture and air available to crop trees while increasing the risk of erosion; (3) feeding on and trampling of young maples, thus eliminating maple reproduction and encouraging other less desirable species; and (4) elimination of leaf litter and snow cover that insulates the soil and reduces the amount and depth of freezing.

Whereas uncontrolled livestock grazing will impair the health, vigor, and productivity of a stand and destroy most or all young maples present, controlled and rotational grazing through the deliberate use of the principles of silvopasture in sugarbushes may be compatible with sap and syrup production (**Figure 5.17**). Silvopasture goes beyond merely "putting cows in the woods." It requires deliberately maintaining a grassy understory and involves frequent (often daily) rotation of the herd or flock among designated paddocks. Producers should consult a silvopasture expert (preferably one with experience working with maple producers), and then proceed with caution and careful monitoring. Cattle and goats have been used successfully, and sheep might also be acceptable. Horses and pigs should never be allowed to graze or feed in a sugarbush.

Other Animal Damage

Damage by wildlife to mature crop trees is not common. Occasionally, porcupines will gnaw on the bark of maples, partially or completely girdling the trees.

Figure 5.17. Livestock can be used with the principles of management intensive grazing (MIG) for silvopasture systems that control understory vegetation and provide an additional source of income. This process is very different than the destructive practice of "putting cows in the woods."

When this occurs, the offending animal should be located (often in their den nearby) and relocated or destroyed. Damage to maple reproduction from deer (as noted previously), rabbits, squirrels, and other animals can be extensive at times. Several strategies may be used to control such damage. The best strategy depends on the animal causing the problem, the features and extent of the area that needs to be protected as well as the amount of time the producer can devote to monitoring and maintaining the protective structures. Several approaches were outlined in the previous sections.

Under most circumstances, wildlife has little impact on maple equipment aside from damage resulting from squirrels gnawing on tubing. Squirrel damage can sometimes be abrupt and extensive and is always frustrating. The problem may be avoided or minimized by reducing trees that produce nuts or seeds supporting squirrel populations. To deal with this problem hunting or trapping, repellants (typically capsicum based) on the tubing, metallic wrapped tubing or tubing protection sleeves, and changing to an alternative cleaning solution (avoiding sodium hypochlorite bleach) have all been tried with varying degrees of success. There is no uniformly successful option. The use of poison bait is not recommended because of the potential for the contamination of sap. Repellants on the tubing have included commercial preparations and a variety of homemade concoctions, but none of these options have sufficient evidence of success to warrant endorsement, and many would be illegal in some jurisdictions. Furthermore, extreme care is needed to ensure that none of the collected sap is contaminated with the repellant, and their use makes handling and repairing tubing more difficult and is likely incompatible with organic certification.

Insects

The sugarbush is home to many insects, most of which are important parts of the forest ecosystem and do little or no significant damage to the maple trees. There are, however, several insects that can cause substantial economic loss in a sugarbush. These include a number of defoliators, such as spongy (formerly gypsy) moth (*Lymantria dispar*), forest tent caterpillar (*Malacosoma disstria*), fall cankerworm (*Alsophila pometaria*), Bruce spanworm (*Operophtera bruceata*), saddled prominent caterpillar (*Heterocampa guttivitta*), greenstriped mapleworm (*Dryocampa rubicunda*), orange-humped mapleworm (*Symmerista leucitys*), maple leafcutter (*Paraclemensia acerifoliella*), pear thrips (*Taeniothrips inconsequns*), and lecanium scales (*Lecanium* sp.); and several wood boring insects including the sugar maple borer (*Glycobius speciosus*) (**Figure 5.18**). Some of these insects are native and follow cyclical patterns over time; others are not native and may become established and a chronic problem.

Fortunately, these insects are usually present in relatively low numbers in most years. They are kept in check by habitat conditions, weather, and natural enemies. Under certain conditions however,

Figure 5.18. Among the insects that have the potential to cause serious economic loss in the sugarbush are spongy moth (a), orange-humped mapleworm (b), pear thrips (c), forest tent caterpillar [larva (d) egg clusters (e)], lecanium scale (f), and sugar maple borer damage (g). (a-OSU; b,d,e-Boggs; f-Shetlar)

insect populations can grow abundant enough to cause considerable damage. One need only recall the devastating impact of recent spongy moth, pear thrip, forest tent caterpillar, and lecanium scale outbreaks on maples in the northeastern United States to grasp the extent of the threat that uncontrolled insect populations pose to a sugarbush. Fortunately, keeping sugarbushes diverse and maple trees healthy and vigorous through regular thinning will normally reduce the long-term impact of many of these insects. Boring insects tend to occur less commonly in maple regions than defoliating insects, and the impact of the latter on maple operations is usually minimal, except for rare instances of spectacular and potentially disastrous infestations.

The first step in dealing with potential insect problems is to learn to identify the insects or to seek out a professional to assist in the identification. Many universities have diagnostic laboratories to assist with identification, and Extension professionals often know the local species that cause problems. Once a potentially serious insect problem has been detected and verified, the possibility of treatment strategies can be assessed. These will vary with the pest and the level of infestation. With some insects, such as the sugar maple borer, which commonly infests weakened or damaged trees in overstocked stands, the best treatment may be by removal of infected trees along with improving the health and vigor of remaining trees by thinning. With other insects, such as the defoliators, the decision often comes down to deciding whether insects are present in large enough numbers to cause unacceptable economic loss or permanent damage to the sugarbush. If the anticipated loss is severe, an appropriate control should be selected. At present, control generally involves the use of some form of insecticide spray. The specific insecticide and time of application must be determined for the particular insect pest present. Very few insecticides, perhaps only Bt (*Bacillus thuringiensis*), are approved for use on maples producing a food product, and pesticides are largely prohibited for certified organic producers. To be effective spraying must be done by a qualified aerial applicator under the correct conditions and must occur at early stages of leaf and larval development. The weather must also be considered, with good visibility for flying and low winds to ensure the product reaches the intended target area. If done correctly, spraying can be effective in reducing the severity of damage in a treated sugarbush. A single treatment may suffice, but in some cases multiple treatments are necessary.

One common defoliator of maple warrants further comment. Forest tent caterpillar (FTC) populations appear to reach outbreak levels in syrup-producing region every 10–20 years with regionally variable presence. While the precise timing of outbreaks is not predictable, the impact, when widespread defoliations occur, are foreseeable. Individual stands can be monitored after leaf fall to assess egg masses on twigs in the upper canopy. This information is vital to planning any control treatments in the spring. Most affected trees, after an early season defoliation, will attempt to flush a new set of leaves within the same growing season. The new leaves often appear stunted, discolored, and oddly shaped and will have a reduced area and photosynthetic capacity relative to the first set of leaves (**Figure 5.19**). In general, trees have sufficient stored energy to handle a single defoliation in the same growing season. Among the worst consequences of defoliation for maple producers are significant reductions in both the radial growth and the sap sugar concentration of their crop trees during the outbreak years and possibly for a year or two following the defoliation. Occasionally, when multiple stresses are involved, there can be isolated areas of tree mortality. Trees growing on marginal sites and with inadequate soil moisture appear to be at highest risk. Baseline maple mortality in healthy forests averages less than 1 percent annually. During FTC outbreaks that number might rise to 2 percent on a regional level with isolated pockets reaching far higher. It is important to understand that the vast majority of trees (even those with significant defoliation) will survive but that the impact on tree growth may linger for years beyond the defoliation event.

Whether tapping should be avoided after insect defoliation is unclear. There is insufficient research to make good recommendations, however extensive defoliation is clearly a moderate to severe stress on

(a)

(b)

Figure 5.19. Tattered foliage (a) and reduced foliar area (b) following forest tent caterpillar defoliation. Healthy trees will typically put out new leaves, but this can be very stressful to maple trees and uses up sizeable portions of the carbohydrate reserves of affected trees.

trees. Common sense would suggest that not tapping might allow a quicker recovery of trees, particularly if several stresses are interacting to impact tree health and survival. If it is not possible to skip tapping for a season or to use non-affected trees, a lighter tapping intensity or shallower tapholes might be worth considering.

There are three invasive insects every maple producer should be familiar with because of their potential for devastation: the Asian longhorned beetle (*Anoplophora glabripennis*), emerald ash borer (*Agrilus planipennis*), and spotted lanternfly (*Lycorma delicatula*). All three have the potential to significantly alter a sugarbush; the Asian longhorned beetle (ALB) and spotted lanternfly (SL) by attacking maples, and the emerald ash borer (EAB) by attacking native ash trees (*Fraxinus* spp.), which are a significant component of many sugarbushes.

ALB (**Figure 5.20**) is a non-native pest believed to have been introduced to North America in 1996 in cargo packing materials from Asia. It currently threatens a variety of hardwood trees in North America, with maples among its preferred host species. At the time of publication, significant outbreaks have been identified in New York City; the Jersey City and Carteret areas of New Jersey; areas in and around Chicago, Illinois; rural woodlands near Worcester, Massachusetts; southwest Ohio; and Toronto, Ontario, Canada. Adult ALB are large, glossy black beetles with irregular white spots and very long, black and white–banded antennae. They can be seen from late spring to fall. Larvae, which can reach 2 inches (5 centimeters) in length, are found from fall to spring feeding initially under the bark and later into the sapwood. It is the larvae that are the destructive form of this insect, due to their potential to form galleries throughout the inner bark and sapwood of the tree, thus destroying the tree's ability to conduct food and sap (**Figure 5.20**). The presence of these galleries; egg-laying niches; and ½-inch (12.7-millimeter) circular emergence holes are signs of ALB infestation.

The spotted lanternfly (SL, **Figure 5.21**) is a recently introduced pest. As of 2022 populations have been reported in Pennsylvania, New York, New Jersey, Delaware, Virginia, Connecticut, Massachusetts, Ohio, West Virginia, Indiana, and Maryland, with isolated individuals found in other states. It has not yet been detected in Canada. The danger of spread is very high given the potential of large portions of the north-central and northeastern regions of the U.S. and some eastern regions of Canada to serve as suitable habitat. The adult is about 1 inch (2.5 centimeters) long and ½ inch (1.3 centimeters) wide, with a black head and grey-brown forewings with small black spots. The hindwings are

(a)

(b)

(c)

Figure 5.20. Adult Asian longhorned beetles (a) are large, glossy black beetles with irregular white spots, and very long, black and white banded antennae. Larvae (b), which can reach 2 inches (5 centimeters) in length, can be found from fall to spring feeding initially under the bark and later into the sapwood. (Harrington, U.S.F.S.). Red maple heavily infested with Asian longhorned beetle (c). (M. Smith, USDA ARS)

Figure 5.21. An adult spotted lanternfly (center of photo with wings) along with red-and-white nymphs. (S. Ausmus, USDA ARS)

red, and the abdomen is yellow. Although it favors grape vines, stone fruit, and apples, it sometimes chooses maple, birch, or walnut as an alternate host. SL feeds upon the sap from the phloem of the trunk or branches. Infestations are typically signaled by the presence of congregations of adults, sticky honeydew, pests attracted by weeping sap attracts, or black mold growing on the dripping sap at the base of the plant. Due to its relatively recent introduction, relatively little is known about this pest and the level of threat it presents.

Emerald ash borer (EAB) (**Figure 5.22**) is also a non-native insect, believed to have been introduced sometime during the 1990s and was first detected in southeastern Michigan in 2002. Since that time, EAB has killed tens of millions of ash trees throughout the geographic range of ash in most eastern U.S. states and some Canadian provinces. The USDA is working to identify and release parasitoid wasps as biocontrol agents for EAB infestations. EAB results in the unplanned loss of trees in the sugarbush, a loss of forest diversity, and a significant safety hazard to workers in affected forests. Unlike the ALB, whose poor flying abilities limit its dispersal potential, EAB can rapidly spread over large areas, complicating the maintenance and undermining the effectiveness of established quarantine zones. The adult EAB is a metallic green beetle approximately ½ inch (12.7 millimeters) long and $\frac{1}{16}$ inch (1.6 millimeters) wide. Depending on the year and location, it can be seen from about

(a)

(b)

Figure 5.22. The adult emerald ash borer (a) is a metallic green colored beetle approximately ½ inch (12.7 millimeter) long; the larva is white, segmented, and flattened, and can grow to 1 inch in length. (s. ausmus, usda ars). Emerald ash borer galleries and emerging adults (b). (d. miller, u.s.f.s.).

mid-May until early August. The white, segmented, flattened larvae, which reach 1 inch (2.54 centimeters) in length when mature, are found from fall to spring feeding on the inner bark and very outer layers of the sapwood. As with ALB, the destructive form of the insect is the larvae, which limits or prevents the flow of foot and water throughout the tree by forming "S" shaped galleries in the bark and sapwood (**Figure 5.22**). The presence of these galleries; the occurrence of ⅛ inch (3.2 millimeter) diameter "D"-shaped exit holes; and the death of all or part of the tree accompanied or followed by the development of shoots or sprouts arising below the dead portions of the trunk are all possible signs of an EAB infestation.

ALB, EAB, and SL are often transported long distances in firewood or other plant material containing the mature insects, larvae, or egg masses. With any of these invasive pests, producers observing either the insect or its signs should immediately report the sighting to their state or provincial Department of Agriculture, local or state Extension office, state or provincial Departments of Forestry or Natural Resources, or the nearest office of the USDA Animal and Plant Health Inspection Service or Canadian Food Inspection Agency.

Diseases

Disease in a sugarbush may be caused or exacerbated by a variety of factors including environmental extremes and biological agents. The most important maple diseases are caused by fungi, including several leaf diseases such as the leaf spots and anthracnose, cankers such as *Nectria* spp. and *Eutypella* spp., and stem and root rots such as *Ganoderma applanatum* (*Fomes applanatus*) and *Armillaria* sp. (**Figure 5.23**). Again, as with insects, producers need to become familiar with the major diseases that affect maples.

Diseases and disease-causing fungi are present in all sugarbushes. Disease impact, however, is far less in a healthy, vigorous sugarbush. Therefore, developing and maintaining a healthy sugarbush is the first step in dealing with diseases. Healthy, vigorous trees are more resistant to many diseases and are better able to survive if infection occurs compared to trees that are weak and stressed. Every effort should be made to minimize injuring tree stems or roots, as injured trees are less vigorous, and the injury provides an entry point for many fungi. Trees that become infected with stem cankers or stem or root rotting fungi should be removed

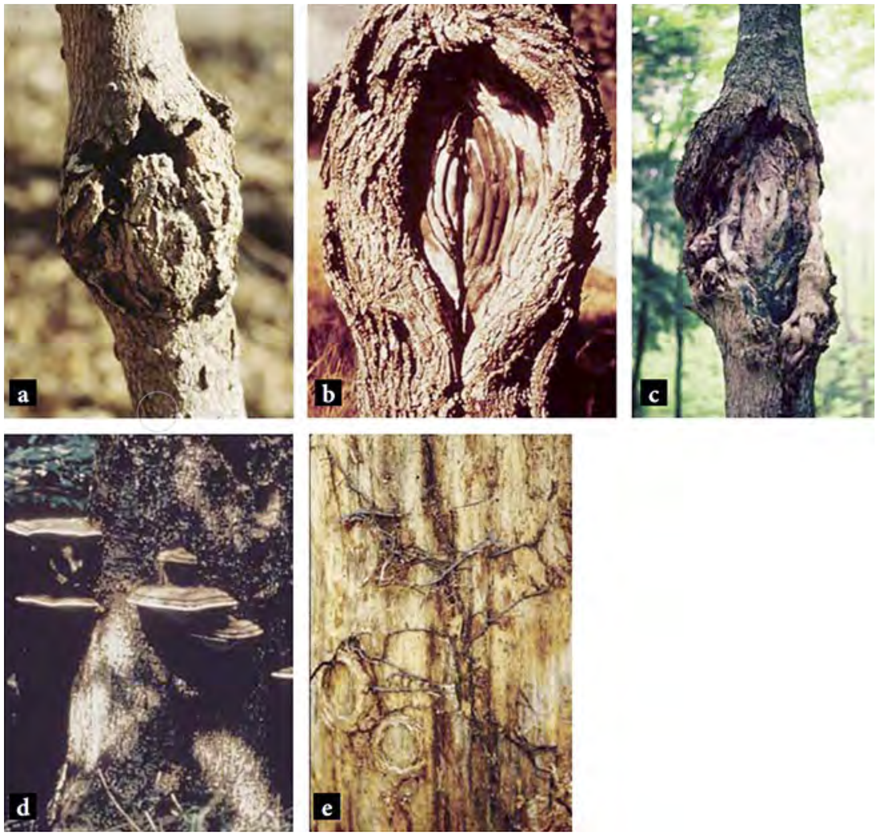

Figure 5.23. *Nectria* canker on small maple (a) and older *Nectria* canker on black walnut displaying characteristic "target" appearance (b); *Eutypella* canker on young maple (c); *Ganoderma applanatum* (formerly *Fomes applanatus*) conk or basidiocarp (d); and the characteristic rhizomorphs that develop between the bark and sapwood of trees infected with *Armillaria*, and from which the fungus gets the name shoestring root rot (e). (RHODES, OSU, BERRY)

to eliminate the opportunity for spread. In cases of severe sugarbush infection, a forest pathologist or other specialist should be consulted.

Maple decline is a category of diseases that deserve special mention. Maple decline, or maple dieback as it is sometimes called, is a progressive loss of vigor and deterioration of maples caused by a combination of several sequential stressors. Some of these agents include repeated drought or insect defoliation, often in stands with relatively low levels of soil calcium and magnesium, followed by infection from a fungus such as *Armillaria* spp. (root rot). Symptoms of dieback, or decline, often begin with abnormal (sparse, stunted, or off-color) foliage high in the crown, and progress to dead twigs and branches. Affected trees usually grow more slowly than healthy trees. Eventually the entire tree may die. Preventing or minimizing dieback involves both increasing tree vigor and eliminating or reducing stress-causing factors in the sugarbush. The reduction in acidic deposition in the past 20 years has reduced the incidence of maple dieback, especially on nutrient-poor sites; however pockets of dieback can almost always be found somewhere in the maple region. Other stress reduction measures that can help lessen the risk of dieback include the following:

- Avoiding heavy intermediate cuts that can severely stress trees
- Refraining from leaving high stumps from harvested trees in which root rot diseases such as *Armillaria* can develop
- Taking appropriate action against major outbreaks of defoliating insects before severe stress occurs
- Avoiding tree injuries especially to roots and lower areas of the stem during thinning

operations or when using machinery in the sugarbush to gather sap
- Using the correct number of taps for the size and vigor of the tree
- Reducing (number or depth) of tapholes or not tapping during years of severe stress (e.g., drought)

Fertilization with calcium and magnesium on sites where they are particularly low may eventually become more widespread for addressing the early symptoms of maple decline, but not enough is known at the present to justify that recommendation.

Invasive Worms

Most earthworms in the northeastern U.S., and other areas that were glaciated, are exotic and some are invasive.[14] Their arrival in a northern hardwood forest can set off a cascade of changes beginning with a transformation of the forest soil. Earthworms accelerate the rate of decomposition in forest soils, increasing the rate of nutrient loss from the site. Typically, the leaf litter layer including the seed bank, is severely reduced or entirely eliminated. The reduced organic layer limits germination of desirable understory plants and amplifies the impacts of deer. The action of invasive earthworms has also been associated with sugar maple dieback in the midwestern U.S. Troublesome worm species include snake worms (*Amynthas* spp) from Japan and Korea, and European species, such as night crawlers (*Lumbricus terrestris*) and the red worm (*L. rubellus*).

No recommended practices for managing established earthworm populations are available at present. Prevention is important. Avoid bringing soils, mulch, compost, plants, and fishing bait onto the properties. Efforts at natural regeneration in the presence of worms may be favored by larger canopy openings to allow faster growth of maple seedlings and fences or other structures to exclude deer or other browsers.

Fire

The adage that "an ounce of prevention is worth a pound of cure" is certainly true when considering fire in a sugarbush. Fortunately, in the commercial maple region, fires are generally infrequent because of regional climate and typically much smaller than in western coniferous and Canadian boreal forests. However, fires can happen and can destroy all or part of a producer's investment of time, money, and resources. Everyone working in the sugarbush during periods of fire danger should be aware of fire hazards, including improper installation or handling of equipment and careless smoking. Wood-fired evaporators should have an effective spark arrester, as should any other potential spark-producing equipment such as wood-burning stoves. Dry spring seasons before leaf emergence can be particularly problematic given the large amount of dry leaf litter present. Sparks from wood-fired evaporators can easily ignite fires near the sugarhouse or in the woodshed.

The telephone number of the fire department or other responsible agency should always be posted beside the phone. If a fire occurs, getting it under control as quickly as possible is critical. The first action is to contact the local fire department. Every sugarhouse should have a source of water under pressure (install a pump if necessary) and a hose, along with backpack pumps, shovels, rakes, and brooms. However, note that fighting a forest fire requires certain skills as well as physical fitness and can be very dangerous. Maintain a current map of roads and trails accessible to vehicles. An annual practice fire-control exercise is good preparation. Everyone should know their responsibility and how to use each piece of equipment.

Weather/Climatic Factors

Severe weather or adverse climatic conditions can result in heavy damage in a sugarbush, and additional physiological stress on trees not damaged. High winds break branches and cause windthrow, particularly in sugarbushes growing on wet and/or

[14] The authors of this chapter appreciate the contribution of Dr. Josef Görres, Associate Professor, University of Vermont, Department of Plant and Soil Science, regarding the impacts of worms on forest ecosystems. More information is available at: https://www.uvm.edu/~entlab/Forest%20IPM/Worms/NAMSC%20UVM%20Worm%20Presentation.pdf

shallow soils, especially following recent heavy thinning. The impact of wind can be substantially reduced by maintaining a dense 50-foot-wide (15 meter-wide) border of trees on the windward side(s) of the sugarbush or planting a windbreak along the windward edge(s). To maintain tree vigor, branches damaged by windstorms should be pruned, if possible, to create a clean wound that will heal in minimum time. Windthrown or trees damaged by other weather events that don't impede other operations can be left on the ground to minimize labor and reduce damage to residual trees.

Ice storms are relatively common in the maple-producing region, with an estimated frequency of one large ice storm somewhere in the region every 7–10 years. Fortunately, maple and other trees are fairly well adapted to the challenge of dealing with ice damage. Indeed, on close inspection, most sugarbushes will show evidence of previous ice storms, such as unusual branching patterns occurring at the same height across several trees or the entire stand. Producers must learn to distinguish between visually dramatic and physiologically significant ice damage. The impact of ice storms is visually dramatic because it entails the breakage of many branches from a large number of trees in an area by a single event. (**Figure 5.24**). However, every year trees experience a certain number of broken branches from the individual and combined effects of ice, snow, and wind. This damage is not fundamentally problematic for the physiology of the tree, except when it affects more than 50–75 percent of the crown. Previously damaged root systems caused by poorly conducted logging will exacerbate crown damage. Healthy trees with uninjured root systems can often lose 50 percent of their crown without appreciable change in long-term capacity for growth and production, although short-term impacts may be significant. Often the most important issue following an ice storm is the risk to the producer and crew from working under suspended broken branches or stems tensioned under stress loads. The second most important issue is damage to the tubing system. Damage to trees is frequently a distant third. The longer-term risk of ice damage to the tree comes from the open wounds and thus the potential spread of stain and decay microorganisms. Stain does not weaken the tree, but rather predisposes the stained wood to decay fungi. Trees at greater risk from ice damage to crowns are those that are older or otherwise compromised by other stresses (e.g., drought, insect defoliation, disease) that reduced their vigor. Mortality can be heavy if high winds follow ice storms.

After the 1998 ice storm, Canadian and U.S. researchers conducted numerous studies to assess the storm's impact on tree vigor, sap characteristics, and production. In the first growing season after the storm, damaged trees showed evidence of recovery that included increased radial growth and increased starch reserves. Tree mortality resulting from that event was rare (in the short-term) regardless of the extent of crown loss. Trees with greater crown loss showed greater losses in diameter growth, and red maple suffered more growth reduction than sugar maple. Sap, sap sugar content, and syrup production in moderately and heavily damaged trees tended to be reduced for at least four years. In trees that lost less than 25 percent of their crown, decreases in productivity were minimal. The output of trees that lost 25–50 percent of their crowns was somewhat reduced, and trees with more than 50 percent crown loss were more severely compromised. The favorable growing seasons and lack of compounding stresses in the years immediately after the ice storm may have muted seriously deleterious effects.

Over the course of the first year following an ice storm, producers should monitor taphole closure rates and crown condition and use their observations to inform tapping decisions during that period. Vigorously growing trees with limited crown loss can likely be tapped as normal in the first year. Trees with less vigorous growth and with more extensive crown loss should be tapped conservatively or not at all. Sap sugar concentrations in the first year after winter ice damage may be unaffected (since the carbohydrate reserves were produced prior to damage) but could be reduced for some time as trees use reserves to rebuild lost crowns. Damaged crowns and reduced foliage will mean less competition for light, so growth responses and canopy closure may be fairly rapid if other stresses remain low.

Figure 5.24. Broken twigs and branches, snapped stems, and damaged tubing systems are the result of heavy ice storms. (s. williams, uvm pmrc). Although the damage appears to be devastating, even heavily impacted trees can sprout new branches and survive if growing conditions are good in the next few succeeding seasons.

Extreme cold that results in deep freezing of sugarbush soil can damage tree roots, although freezing of forest soils beyond a few inches is unusual except where the snow is removed or packed down by vehicle travel. Normally, the litter on the forest floor and snow cover serves as natural insulation that prevents deep freezing. In some cases, however, uncontrolled grazing of livestock in a sugarbush or the presence of invasive earthworms destroys the litter cover. Likewise, if the animals are kept in the sugarbush during the winter, their presence may reduce or pack snow and permit deeper soil freezing and more root damage.

Frost cracks in the trunk of a tree are caused when the trunk cannot withstand the expanding and contracting forces created by heating and cooling. While not common in a forest, they can be a problem in a sugarbush with lower stem or root injuries, or along the forest edge. The relatively smooth bark of previously shaded maple trees is quite sensitive to sudden exposure to direct and prolonged sunlight. The result frequently is sunscald, the death of areas of bark on the south and southwest sides of the trunk. Excessively heavy intermediate cuttings, which open large holes in the tree canopy, should be avoided.

Either too much or too little water can be a problem. Drought can be a major problem that often goes unnoticed but can have significant consequences especially if it coincides with other stressors. Water is necessary for photosynthesis, so drought may impact sugar production, limiting energy available for tree physiological processes, and result in reduced sugar yields in the future. If drought occurs during the summer when the trees are storing carbohydrates, it can impair the health and reduce the vigor of the trees. With forest maples, there is commonly little that can be done directly to alleviate the effects of drought. Drought should be evaluated together with other tree stresses (e.g., insect defoliation) to determine whether tapping should be reduced or suspended. Keeping a healthy layer of organic material on forest soils can help retain moisture in the short term.

Too much water can also be a problem, particularly in sugarbushes with soils prone to oversaturation (**Figure 5.25**). Because oversaturated soil can lead to severe tree stress and mortality by interfering with the ability of roots to obtain oxygen and release carbon dioxide, too much water can be just as detrimental as too little. Although changing the hydrology of an entire sugarbush may not be the goal, careful design of water diversion structures (e.g., water bars, broad-based dips, drainage ditches, and culverts) on roads and trails can lessen the impact of severe rain events. Activity on adjoining lands can also impact the soil moisture conditions of a sugarbush.

Figure 5.25. Poor drainage in this woods managed for sugar production has resulted in stag-headed trees with dieback, loss of fine branches, and poor growth. These trees have slow growth and low resilience to stressors.

Future Climate and Its Impact on Sugarbush Management

Increased temperatures, changes in growing season length, more frequent ice storms, and a greater frequency of extreme precipitation events (droughts and downpours) have been observed over the past several decades throughout the maple-producing region of North America. These changes are expected to continue in the future as the impacts of climate change are further realized, creating challenges to long-term sugarbush management for many areas. If temperature and precipitation regimes change significantly, the competitive ability of sugar maple relative to other species could be altered. In some cases, suitable growing conditions could shift for sugar maple and other species, resulting in "species migration" or at least changes in the distribution of suitable habitats. Rather than denoting a literal movement of individual trees, species migration describes the anticipated change in forest species under a different climatic regime as tree species more sensitive to higher temperatures and altered moisture regimes become less abundant, and tolerant species from warmer (more southerly) climates become more numerous as they expand their geographic range.

The extent to which these projections or forecasts might affect sugarbushes and other forests is often expressed in terms of "vulnerability," which is a function of both the expected effects of future climate change on a given forest and the ability of the forest to respond and adapt to those changes. These projections rely on complex modeling of climate change and generally assume (probably incorrectly) that management activities will not modify the presence, vigor, or diversity of species present. Maple producers rely on one or two species from which they collect sap. Historically they have strongly favored the presence and growth of maple trees at the expense of other (non-maple) species, which could increase vulnerability of these systems to the impact of climate change and other stressors like invasive insects and diseases. The anticipated changes in the species composition of the sugarbush will also need to factor into their thinking the prior management actions in the sugarbush.

It is important to recognize the potential positive aspects careful sugarbush management has on issues related to a future with changed weather patterns and increased storm severity. Sugarbush management by and large strives for intact forest cover as part of a working landscape. As a productive and profitable use of the land, it helps to retain forests as forest. Forests sequester carbon, reduce soil surface temperature, reduce the severity of flooding, improve water quality, and promote cooler air and water. Sugarbush management practices can bolster tree health, vigor, and resilience to changes in response to weather and climate.

In the case of sugarbush management, at least three factors influence the degree to which future change might influence vulnerability.

1. *Location within the range of sugar maple.* Sugar maple is a temperate species adapted to cool, moist climates. Projections of suitable climate conditions for sugar maple growth suggest these conditions will become less common in the southern portion of sugar maple's geographic range. While there is no current evidence that the contraction in the southern limit of its range has begun, a detectable shift of northern hardwood species upslope has been found. A larger temperature shift may be needed before significant compositional changes will be observed in the range of sugar maple.[15] Predictive modeling suggests that sugarbushes located in southern areas may experience greater declines in sugar maple health over time than those in the northern portion of the commercial range, where the impact of climate change on maple vigor is expected to remain relatively insignificant in the near future. Some evidence suggests an increase in recruitment of sugar maple along its northern range.
2. *Site conditions.* Site plays an important role in affecting vulnerability. Sugarbushes on north-facing slopes with deep soils are less likely to experience climate impacts relative to those on warmer, drier sites. Because of red maple's broader tolerance to site conditions, its role in future sugarbushes may become more important. Site conditions may interact within the geographic range such that, for example, north and east slopes in the southern parts of the range may experience less impact, while western and southern slopes in the northern regions may experience more.
3. *Management activities.* Producers can use and adopt technologies that reduce climate-related impacts. Employing best practices for vacuum and tubing technologies (see **Chapter 6**) and knowing how to keep the system leak-free and clean will help offset annual variability in season length. The use of buckets to collect sap is as reliant on good weather today as it was when humans began collecting sap in wood and bark vessels. Producers should also bear in mind that a sugarbush with vigorous trees that have ample access to site resources can also help buffer the impact of climate extremes, such as droughts. Following the thinning and stocking guidelines described herein will help improve tree vigor and maximize the defenses of trees to these future changes. Harvesting activities should avoid reducing stand

[15] Hart, J.L., C.M. Oswalt, and C.M. Turberville, 2014. Population dynamics of sugar maple through the southern portion of its range: implications for range migration. *Botany* **92:** 563–569.

diversity and damaging roots or lower stems of residual trees. Retaining slash and other residue after harvests will help replenish the soil's organic layer, promote regeneration by decreasing browsing, and reduce residual stand damage associated with wood removal.

Human Activities

Throughout this chapter, the importance of minimizing the negative impact of all activities in the sugarbush has been emphasized. Sugarbush management activities need to be done correctly to minimize physiological stress. In all sugarbush activities, best management practices advise the avoidance of injury to trees and limiting soil compaction. It is also extremely important to remember that tapping the tree is a human activity that directly affects the health and well-being of the sugarbush. Tap correctly, tap conservatively, and adjust tapping protocols according to the condition of the trees.

Interfering and Invasive Plants

A variety of native and non-native woody and herbaceous plants can dominate a woodland, excluding or limiting the regeneration of desired plant species, restricting producer access, and reducing biodiversity. Many jurisdictions include "non-native" or "non-indigenous" as part of the definition for an "invasive species." Because both native and non-native species can interfere with sugarbush management goals, both are included here under the label of "interfering species." Typically, these interfering species gain dominance because of excessive deer browsing of desired and palatable plant species. Prolonged heavy deer pressure can create a legacy effect that persists for decades even if deer impacts are eventually brought under control. A variety of online resources are available to help identify locally abundant non-native interfering species such as multiflora rose (*Rosa multiflora*), European buckthorn (*Rhamnus cathartica*), glossy buckthorn (*Frangula alnus*), bush honeysuckle (*Lonicera* spp.), autumn olive (*Elaeagnus umbellata*), European barberry (*Berberis vulgaris*), Japanese barberry (*B. thunbergii*), pale/European swallow-wort (*Cynanchum rossicum.*), black/Louise's swallow-wort (*Cynanchum louiseae*), pricklyash (*Zanthoxylum* american, and garlic mustard (*Alliaria petiolata*). Many other native woody and herbaceous plants can also interfere with the goals of the maple producer. American beech (*Fagus grandifolia*) often develops thickets of young saplings that crowd out maple regeneration. Several types of ferns, notably hayscented fern (*Dennstaedtia punctilobula*) and wood fern (*Dryopteris* spp.), provide dense understory cover that can interfere with maple seed germination and early seedling growth either through direct shading or through allelopathic (chemical inhibition) means.

Successful control and management of interfering vegetation starts with a plan that details the interfering species, the desired plant species, the costs, how the interfering vegetation will be treated, and how the site will be revegetated. The word *treatment* as used here describes the approach to dealing with the vegetation, which in many cases focuses on killing the stems that are causing the interference. However, annihilation of the interfering species is neither possible nor often desirable. Treatment has two aspects: the method and the mode. Method is typically mechanical or chemical, and mode is either broadcast or selective. Every treatment can be described by a combination of method and a mode (e.g., selective mechanical, broadcast chemical).

Both mechanical and chemical methods may have useful applications. Often the choice depends on the objective and attitude of the owner. Relevant considerations include the producer's level of interest in organic certification, the jurisdiction's policy on the use of chemical treatments, the time of year, the terrain, and the equipment necessary and available. In some circumstances, an integrated approach that combines a mechanical intervention with a subsequent chemical treatment may be appropriate.

The decision about whether to use chemical methods may be decided by the owner's attitudes and comfort with the use of herbicides. In the U.S., herbicides are regulated by the EPA through authority given to the state-level regulatory agencies. The Health Canada Health Management Regulatory Agency (PMRA) regulates pesticides throughout

Canada. If owners use an herbicide, they should carefully follow the label and all applicable laws. The use of herbicides in active maple production stands should be avoided.

Producers should carefully study their situation and review online and print information about forest vegetation management with Extension specialists and/or with their state or province forestry agency. Some plant species warrant prompt attention, but others may allow for a delayed response. Treatments can be expensive, especially if a particular invasive species has become well established. Some mechanical and chemical treatments can be personally or environmentally dangerous. Use appropriate methods, equipment, and precautions, and strive to limit the use of materials or techniques that can have unknown or uncontrolled impacts beyond the target species.

SUGARBUSH ACCESS

The sugarbush road system plays an essential role in sugarbush management and access in collecting and transporting sap (**Figure 5.26**). Well planned and constructed roads provide access to all parts of the sugarbush, while minimizing impacts on the health and productivity of the trees. However, some sugarbushes have existing road systems that do not function well and can even produce negative impacts on soils and make traveling on the roads dangerous for maple producers. Sometimes the best decision is to discontinue the use of a problem road and redesign the system to avoid wet areas or significant impediments such as ledge. As with any other disruptive activity in the sugarbush, the best approach is often to strive to keep any disturbance to a minimum. Agency-based soil conservationists and many private sector foresters and other resource professionals are trained to identify where and how to install and maintain road systems that support access and reduce disturbances.

Figure 5.26. An example of an acceptable sugarbush road. The road has a ditch on the uphill side, is crowned and slightly sloped to the downhill side, and enough light is currently available to maintain vegetative cover on the road.

Roads and trails can limit tree health and productivity through impacts to soil drainage and root damage. The upper 5–12 inches (12–30 centimeters) of soil contains 70–80 percent of a sugar maple's roots, and most of the roots important in water and nutrient absorption and gas exchange. For this reason, sugar maples are particularly sensitive to soil compaction. A tree in severely compacted soil may exhibit poor diameter and crown growth and crown dieback and would be more prone to windthrow as a result of impaired functioning or loss of portions of its root system. However, long before these symptoms are visible, maple trees subject to soil compaction typically exhibit reduced vigor and increased susceptibility to insect and disease problems and other environmental stresses that may decrease their yield.

The critical root zone of a maple tree is the soil area under the crown and beyond that contains a high proportion of the tree's feeder roots. While we commonly think of this critical root zone as being primarily under and extending a limited distance beyond the tree's crown, it can extend across an area of three to five times the crown radius, yet only extends about 6 inches (15 centimeters) deep in the soil. In a typical sugarbush it is almost impossible to avoid standing in the critical root zone of one or more sugar maples. Understanding this fact clarifies the potential far-reaching effects of soil compaction on sugar maple health and productivity. A correctly designed system of sugarbush roads and trails will minimize the number of roads that will meet production needs, and ensure roads are built correctly and located and managed to minimize their impact on crop trees (**Figure 5.27**).

Producers are generally advised to avoid developing extensive, heavily compacted graveled roads in the sugarbush (**Figure 5.28**). An exception to this would be a main road to the sugarhouse to support delivery or transport vehicles, or customers in passenger cars. Another set of exceptions would comprise roads required for important "non-sugaring" uses of the sugarbush. If, for example, the main road through the sugarbush is a frequently used access road, it should be developed to support the type and frequency of vehicles that use it for that purpose.

Location and Design of Roads and Trails

The location and design of sugarbush roads depends upon the topography, soil characteristics, drainage, the kinds of vehicles used, and the purpose of the roads. Wherever possible, roads should follow slope contours and avoid wet areas. Tools to help decide the best location for roads are aerial photographs, topographic maps, and local county soil surveys.

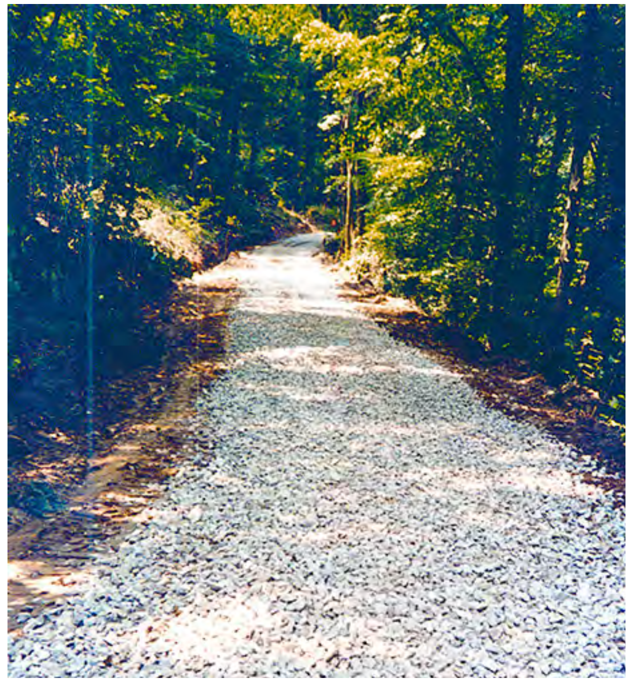

Figure 5.28. As a general rule, producers are advised to avoid developing large, heavily compacted, graveled roads in the sugarbush. Exceptions to this would be the need for a main road to the sugarhouse to support delivery or transport vehicles or customers in passenger cars. Under those circumstances, both the main road and the parking areas around the sugarhouse should be finished for access in all types of weather and conditions."

Figure 5.27. Woods roads and trails for tractors and ATVs should be designed to minimize impact to the sugarbush and soil.

Aerial photos will reveal natural drainage areas, while topographic maps reveal the slope increases and decreases to avoid in road placement. County soil surveys, available online for the U.S. through Web Soil Survey, will detail the characteristics of the soils in the sugarbush and commonly contain tables rating the suitability of those soils for road construction. When considering where to place a road, be sure to visit the proposed location several times during sugaring season, and any other time of the year the road will be used, to avoid placing the road in an area dry in the summer but wet during times of heavy use. Roads that are incorporated into steeper grades require the use of appropriate water diversion and drainage devices.

The pattern of the road system will also be influenced by its purpose. Most sugarbush roads are used to inspect, tap, gain rapid access in case of fire, and accomplish forest management activities.

Bucket systems generally require a more extensive road system than tubing operations. Nevertheless, roads and vehicle traffic for collection of sap in buckets should be kept to a reasonable minimum. Roads should be located to minimally impact tree root zones. Minimize the amount of off-road travel by the gathering vehicles. Traditionally, the gathering vehicle travels close to each sugar maple production tree to shorten the distance sap has to be carried. While some off-road travel is undoubtedly necessary, for many vehicle types this extra travel will result in soil compaction and possible further damage of roots due to rutting.

The type of transportation and gathering vehicles used in the sugarbush will also affect the type of roads required and the impact of off-road travel. Of particular importance are the vehicle weight and type and number of tires. Other things being equal, the greater the vehicle weight, the "harder" or more developed the roads need to be, and the greater the risk of compaction with off-road travel. For a vehicle of any given size, the more tires it has, the wider the tires, and the lower the tire pressure, the lower the risk of soil compaction. Large flotation-type tires would seem ideal for the sugarbush. Moreover, the wider tires, or tracked machines, are less likely to cut ruts in the soil, resulting in less damage to tree roots and less erosion. These factors help explain why ATVs with flotation tires are gaining popularity as transportation and tow vehicles in the sugarbush. They are relatively small, require less road development than most other forms of transportation, and have comparatively low off-road impact.

Managing Small Amounts of Slow-Moving Water

Proper construction and maintenance are critical to a successful road system. Sugarbush roads are almost always unsurfaced forest roads. The greatest concern with such roads is water erosion that can result in impassable sections requiring expensive repairs. When dealing with surface water flow and its potential to cause erosion, it is the volume and the velocity of the water on exposed soils that cause most road problems. The larger the volume of water and the faster its moves over the surface of the road, the more erosion will result. The prime objective when managing water on roads is to reduce the volume and flow rate of the water; get the water off the road as frequently as possible and in small quantities.

On slopes, water management is accomplished by crowning or sloping (in-sloping to a ditch on the uphill side of the road or out-sloping to the downhill side) the road surface to facilitate water runoff (**Figure 5.29**). Exposing the road to sunlight by thinning adjacent trees will also help dry the road surface, if such tree removal is appropriate with the management plan.

Controlling the rate and volume of surface flow of water on roads in areas of gently rolling to steep topography is accomplished by using a combination of road construction and water diversion structures within the roadbed. Water is directed off the road through modifications to the roadbed, including crowning or out-sloping water bars and broad-based dips; and physical management practices such as open or closed culverts and roadside

Figure 5.29. A broad-based dip (foreground) is a low, relatively flat, out-sloped diversion in the roadbed designed to intercept water flowing down the roadbed and drain it to the side, off the road surface. Note the crowned aspect to the roadbed on the rise in the background to facilitate drainage to both sides.

ditches. Check with your state forestry agency for specific recommendations on the type and spacing of water diversion structures.

The most common structure to direct water off roads and trails is a water bar. Water bars (as well as reinforced water bars) are relatively small, appropriately spaced channels dug by hand or small machine to intercept and direct surface water off the road. Generally speaking, a water bar should be constructed to span the entire road and be at a 30-degree angle relative to the road (**Figure 5.30**). The lower end of the water bar should channel the water to a ditch or area that can accommodate the influx of water. Angles less than 30 degrees will result in water sitting in the water bar rather than draining and can require more frequent cleaning due to increased sedimentation. The spacing of water bars is adjusted based on the steepness of roads. The steeper the road, the shorter the distance between water bars. Charts for spacing of water bars are available from the local forestry agency or online.[16]

A broad-based dip is a low, relatively flat, outwardly sloping diversion in the roadbed designed to intercept water flowing down the roadbed and drain it off the road surface to the side (**Figure 5.29**). Broad-based dips should be sufficiently gentle to allow vehicles to proceed through them with only a slight reduction in road speed.

Open-top culverts are structured openings at a down-slope angle across a road that intercept water and carry it off the road (**Figure 5.31**). Open-top culverts can be made from a variety of materials but

Figure 5.30. Hand-dug water bars on this low-use ATV trails are oriented approximately 30 degrees to the downhill side. Spacing depends on the steepness of the slope of the trail.

[16] Note that precipitation amount and variability are expected to increase in some regions due to climate change. This should be factored into decisions on the size of culverts designed to be in place for an extended period.

Figure 5.31. Two examples of open-top culverts. These are installed at a down-slope angle across a road or trail to intercept water and carry it off the road. Culverts require regular maintenance to clear debris.

are most commonly made from treated lumber or a combination of logs and treated lumber. Open top culverts need to be cleaned out regularly to prevent the accumulation of organic and mineral debris.

Closed culverts, sometimes called cross-drainage culverts, are conduits to move water from a drainage ditch on the upslope side under the road to the down-slope side (**Figure 5.32**). These can be made of a variety of materials, but the most common are plastic, metal, or concrete. Closed culverts must be properly sized and set. If they are too small, water will back up, causing erosion and a surface water hazard. If improperly installed, they may not drain effectively or can easily become blocked with debris. Culvert size guidelines are available online and are typically based on the size of the land area to be drained. If there is uncertainty about the size of culvert needed or the proper method of installation, consult a detailed reference on forest road building or contact a local soil conservation/management agency or forestry consultant for assistance.

Figure 5.32. Closed culverts are conduits that move water from one side of the road to the other without it flowing across the road surface. A closed culvert would be used, for example, to move water from a drainage ditch on the up-slope side of a road to the downslope side.

It is important to note that most future climate predictions include an increase in short-duration, high-intensity (also known as "flashy") storms. The volume of water generated by these types of events may exceed water diversion systems that have historically been sufficient. It is a good idea to take stock of the structures in place and areas of concern and develop a plan to correct issues before more expensive road repairs become necessary.

Road and Trail Maintenance

Once roads and trails are established it is essential that they are regularly maintained. Well planned and constructed roads and trails will have lower maintenance requirements than those built without such attention. Water bars, diversions, and culverts should be inspected regularly and cleaned as necessary to ensure the unimpeded redirection and flow of water. Water bar cleaning may be nothing more than running a hoe or shovel down the length of the bar and removing and accumulated leaves and sediment. Not cleaning bars regularly can lead to failure of the structure and costly road repairs (**Figure 5.33**).

Snow is an excellent insulator, and roads covered with heavy snow are insulated from cold temperatures, preventing them from freezing as deeply as they would otherwise. Where feasible, removing the snow (e.g., by plowing) exposes the soil to colder temperatures, resulting in deeper freezing. Such freezing will result in later thawing of the roadbed in the spring and, depending on the year, can often result in a firmer roadbed (or parking area) that is less subject to damage during sugaring season.

Also, where feasible, the seeding of infrequently used sugarbush roads, work areas, and parking areas with some cover crop can reduce erosion, rutting, the frequency and intensity of maintenance, and be more visually appealing and will play an important role in minimizing the amount of surface water runoff and erosion. Recognize that most cover crops require a reasonable amount of sunlight to thrive. For recommendations of appropriate cover crops

Figure 5.33. Failure to maintain water bars, open-top culverts and similar water control structures can damage the road or render it less functional. This open-top culvert was installed at the correct angle, but lack of maintenance allowed the road to wash out on the lower side of the culvert.

and seeding rates, consult the local, state/provincial, or national soil and water management agency.

Controlling Access

A final consideration is control of access to and through the sugarbush. The sugarbush represents the primary resource on which the maple enterprise is based, and it includes considerable capital investment. While it is impossible to completely prevent someone who truly wants access to the sugarbush from getting in, it is possible to strongly discourage entrance. This can be done with gates or logs across primary access roads, and most certainly a "No Trespassing" sign. Often a simple rope or chain across the road—well flagged for safety reasons—will keep most people from entering. If security is a problem, wireless internet (if available) or cellular game cameras may give an extra layer of protection by providing evidence of trespassers.

The planning and construction of a woods road system is not something that most producers are trained to do. Fewer still have the necessary equipment. Individuals without experience in designing and constructing woods roads are encouraged to seek the advice of experts, including governmental agencies or private consultants or contractors with appropriate expertise.

SUMMARY

Maple producers will benefit from giving deliberate attention to their sugarbush. Working within and managing the complexity of the forest requires a breadth of talents and skills. Many lessons from gardens will apply nicely to the sugarbush, but this knowledge is unlikely to cover every issue a maple producer will encounter. Given the complexity and scale of the sugarbush in terms of area, species diversity, ages, soils, topography, management objectives and potential benefits, and other factors, most maple producers stand to gain major advantages from the involvement professional foresters and other qualified practitioners in the development and execution of their sugarbush management plan. Sugarbush management is never a once-and-done effort, but rather a sustained and thoughtful process that builds on previous actions.

CHAPTER 6

Maple Sap Production—Tapping, Collection, and Storage

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CHAPTER CONTENTS

Perkins, T.D., R.B. Heiligmann, M.R. Koelling, and A.K. van den Berg (Editors). 2022. *North American Maple Syrup Producers Manual. Third Edition*. The University of Vermont and the North American Maple Syrup Council, Burlington, Vermont. www.mapleresearch.org/manual/

INTRODUCTION

Maple sap is the raw material from which pure maple products are derived. It is a completely natural product that is obtained from the wood tissue of several species of maple trees.

Most of our understanding of sap flow and collection methods has been derived from research and practice from the northeast and north-central regions, particular those areas around research centers located in New York, Vermont, and Quebec. Many of the factors affecting flow can be expected to produce very similar results in areas farther from these regions given similar climatic conditions since the physiology of maple trees can vary only to a certain degree and the physics that affect vacuum and flow don't change from place to place. However, there may be some differences that could change recommended practices and affect production. As more research and production occurs in these far-flung regions, a more nuanced understanding of how alterations in practices might develop on how to improve production there.

MAPLE TREE PHYSIOLOGY AND SAP FLOW

The sugar found in maple sap is the product of photosynthesis that occurred over several preceding growing seasons. The process of photosynthesis converts light energy to chemical energy and uses it to form carbohydrates (sugars). These carbohydrates are then used in the normal growth and life processes of the tree during the active growing season to maintain the tree throughout the dormant period, and to occasionally produce seed. Some photosynthetic products are stored in the tree, predominately in the form of starch (a relatively stable, insoluble form of carbohydrate), located primarily in ray tissues found throughout the wood in the stem, the branches, and the roots. This starch gets converted back to soluble sugar as needed to serve as an energy source to maintain the life processes necessary for survival during the long dormant period when there are no leaves on the tree. The energy to resume growth the following spring also comes from these stored photosynthetic products. During the winter some of the starch that is converted back to sugar (mainly sucrose) is dissolved in the sap. The amount of sugar in the sap depends on several factors including the genetics of the individual tree, the tree's diameter and crown position, the size of the crown relative to the diameter, environmental conditions in the current and previous growing season, the quality of the site on which the tree is growing, tree health and nutritional status, the time of season, and the occurrence of freeze/thaw cycles. The general trend in sap sweetness across the dormant season follows a regular pattern (**Figure 6.1**).[1] Sap sugar concentration is usually considerably lower in the fall than in the spring. Sap sugar concentration starts to rise rapidly to a peak level in early spring as sugar is mobilized to fuel the upcoming metabolic demands of spring growth. This rise is followed by a slow decline as the season progresses (perhaps related to microbial activity), with occasional small, short-lived increases in sugar concentration following freeze/thaw cycles. However, the quantity and timing of changes in sugar content are influenced by current weather conditions as well as those present during the previous growing and dormant seasons. Research is ongoing to understand the contribution of various influences on springtime sap sugar.

The age of the sugar in sap flowing from tapholes, and thus the age of the sugar in maple syrup, varies considerably since trees produce, store, and

[1] Perkins, T.D., A.K. van den Berg, and W.T. Bosley. 2020. Sap sugar within, between seasons at UVM PMRC. *The Maple News.* Nov. p.25. https://mapleresearch.org/pub/mn2020sapsugar/

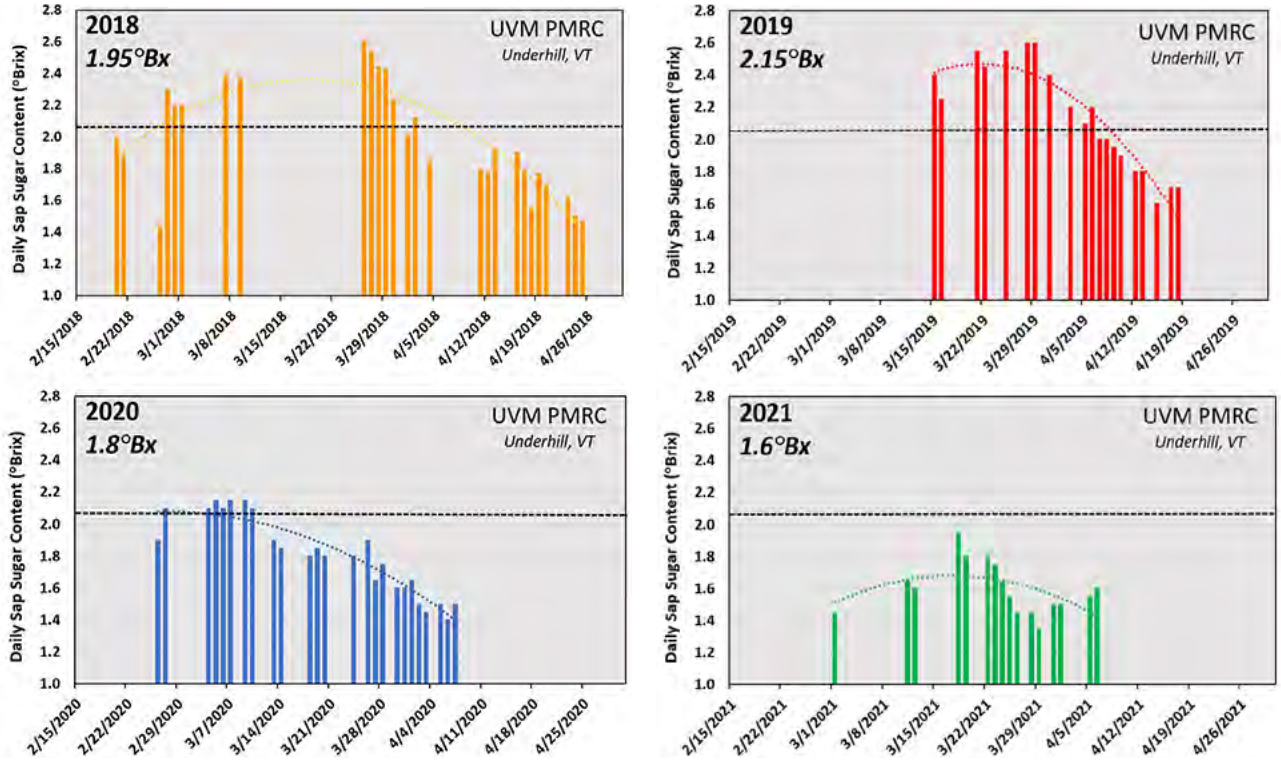


FIGURE 6.1. The typical trend in sap sugar content each spring is to start off slightly low, then rise quickly to a peak level before tailing off over the remainder of the season with slight ticks upward after freezing weather. This figure shows the sap sugar level in sap collected during each flow period at the University of Vermont Proctor Maple Research Center in Underhill, Vermont, over four recent seasons.

mobilize sugar dynamically over time. It averages about 3–5 years old, but this varies with the depth of the taphole, the tree's growth rate, and the technology used (gravity or vacuum), as well as with changes in hydraulic conductivity (the ability to move liquid) of wood vessels as they age. A good deal of the carbohydrate (sugar and starch) in the tree is eventually locked away in tissues and not used or mobilized but is only released again when the tree dies and decays or is burned as fuel.

In the United States and adjacent areas of Canada, sap exudation can occur anytime during the leafless season; however, the largest and strongest flows take place in late winter through early spring, typically during the months of February, March, and April. During this time winter begins to lose its grip in many parts of the maple region. Colder days and nights give way to periods when temperatures during the day frequently rise above the freezing point. When these warmer daytime temperatures are followed by below-freezing periods, usually at night, strong sap flows can be expected upon warming (**Figure 6.2**). In the early part of the season, sap flow is often less predictable, probably due to the large thermal inertia[2] in trees and due to low recharge of stems resulting from deep snow or frozen soils. As the season progresses, sap flows tend to become longer and stronger, often spanning several days. Near the end of the season flows tend to be weaker as tapholes begin to dry out and freezing weather become less frequent.

The Sap Flow Mechanism[3,4]

Water or sap (water mixed with sugar and other plant-derived substances) moves within plants in response to different driving forces. These forces

[2] A measurement of the degree to which an object will resist a change in temperature.

[3] Tyree, M. 1984. Maple sap exudation: how it happens. *Maple Syrup Journal*. 4(1):10–11 https://mapleresearch.org/pub/sapexudation

[4] Wilmot, T.R. 2009. Maples under pressure. *Farming*. Mar. https://mapleresearch.org/pub/wilmot_underpressure-2/

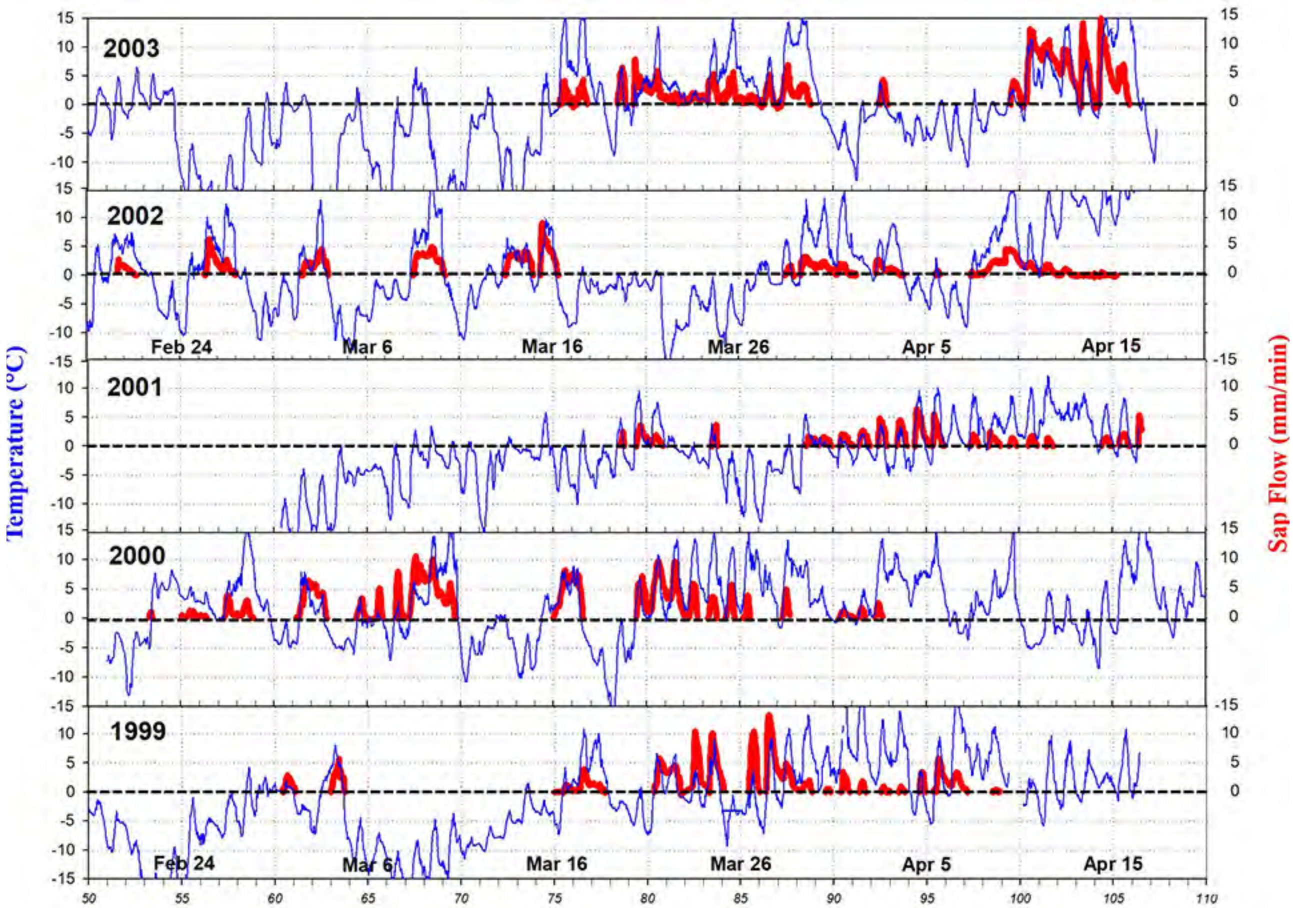


Figure 6.2. The relationship between temperature (blue) and gravity sap flow rate (red) over several spring seasons at the University of Vermont Proctor Maple Research Center in Underhill, Vermont. Dashed black line indicates freezing. When temperatures rise above freezing enough for the stems to thaw, sap will flow from wounds. Each season is made up of several sap flow periods (sap runs) spanning a few hours to several days. The variability in patterns of flow within and across individual seasons is evident. Adapted from T. Wilmot (unpublished).

include gravity and internal pressures, driven largely by physical phenomena (e.g., gas expansion due to temperature changes) and biological/chemical processes (e.g., osmosis).[5] In addition, two properties of water are important in sap transport: cohesion and capillarity. Cohesion refers to the tendency for water molecules to "stick" to each other. Water is slightly polar, meaning one end of the molecule has a slight positive charge and the other a slight negative charge. Because of this, water molecules attract each other. This behavior is illustrated by the way that water poured onto a flat surface forms droplets instead of spreading out evenly. Capillarity of water is the ability of water to flow in narrow spaces due to intramolecular forces between the liquid and surfaces. The result of these properties of water is that within small spaces such as wood fibers and vessels, water is pulled or pushed by different driving forces due to physical, chemical, and biological forces, and that as water is moved around, that force is transferred to other water molecules, which result in water or sap flow within the plant. Like water flowing in a stream from a high point to a low point, sap within the stem flows along a gradient from areas of higher pressure to areas of lower pressure.

[5] Graf, I. and J. Stockie. 2014. A mathematical model for maple sap exudation. *Maple Syrup Digest*. Dec. pp.15–19. https://mapleresearch.org/wp-content/uploads/sapmath.pdf
Perkins, T.D., A.K. van den Berg, and M.L. Isselhardt. 2021. Sap flow, wounding, and compartmentalization in maple. *The Maple News*. Mar. pp.10–11. https://mapleresearch.org/pub/mn2021wound/

Fluctuations in wood temperature above and below freezing during the dormant season are responsible for development of stem pressure, which results in sap flow in maples. These temperature changes, which occur predominantly in the spring and fall, but which can also occur during winter thaws, create periods of alternating negative (below-atmospheric) and positive (above-atmospheric) pressures within the stem. At these times of the year negative pressures can develop when the air temperature falls below freezing, resulting in water uptake through the roots. Positive pressures develop when the temperature rises above the freezing point. This results in sap exudation if there is a wound (such as a taphole) in the stem because the pressure inside the stem is higher than atmospheric pressure. Under some conditions, the positive pressure may reach levels that are significantly higher than normal atmospheric pressure. The level of pressure of the sap column at the interface of the wood and the open space of the taphole is due mostly to gravitational pull. It is due in large part to the head (height) of the column of sap from the taphole to the top of the tree branches). These changes in pressure are the result of certain properties of maple wood, which, although not unique in the plant world, are uncommon.

Most of the liquid-conducting tissues (xylem, photo rear cover, the wood beneath the bark) in the maple tree are considerably longer in the vertical axis (up-down) than in the horizontal (side-side) axis or radial (in-out) axis, so the predominant direction of sap flow is therefore also up and/or down. We can think of vessels within a maple tree as small pipe segments stacked (approximately) end to end. While these vessels average about 0.016 inch (0.4 millimeters) in red and sugar maple xylem, the rare individual vessel can reach a maximum of up to 12 inches (30 centimeters). Surrounding and supporting the vessels is a matrix of many wood fibers. During the growing season, water is pulled through the xylem vessels upward from the soil into the roots and up through the stem and out through the leaves, driven by the evaporation of water from the leaves. During the dormant season, when there are no leaves, a similar uptake of water occurs in maple trees, driven by the freezing of water instead its evaporation. In maple the central part (lumen) of fiber cells is air filled, whereas in most other tree species this space is sap filled. When freezing conditions are present in late winter/early spring, small ice crystals begin to form inside each of these air-filled fiber cells, much like frost forming on a windowpane. As the ice crystals form, the humidity within the fiber cells falls rapidly, causing a rapid water vapor deficit, which results in moisture being drawn in from adjacent vessels. As liquid and water vapor are pulled into the fibers, the layer of ice crystals within each fiber thickens, and the air bubble becomes increasingly compressed. The movement of sap into fiber cell pulls water in from the adjacent vessels, and this pull is transmitted throughout the branches and the trunk down to the roots (due to the cohesiveness of water molecules). Strong negative pressure (suction) propagates throughout the tree. At the same time, other weaker forces caused by the contraction and the dissolving of air bubbles in the cooling sap further intensify the suction. The suction results in water being taken up by the roots (if the soil is not frozen) and pulled upward through the stem. This process continues until all the sap in the tree is frozen, effectively blocking the pathway for water uptake. Uptake is best when cooling takes place slowly over many hours and the resulting accumulation of sap in the fiber cells and throughout the tree is more complete. Rapid drops in temperature can result in freezing of the twigs and the stem. When this occurs, the ice blocks the full recharge of the stem with water, and subsequent sap flows will be reduced.

When the temperature next rises above freezing and the frozen branches thaw, the pressure in the tree at the taphole transitions rapidly from negative to positive. Typically, the small branches thaw first, followed by the larger branches, and then the stem. Once a complete column of sap is thawed, positive pressure spikes. Thawing of the ice in the fiber cells allows the compressed gas bubbles to expand and push the sap back into the vessels. Coupled with the pressure from bubble expansion are two additional forces: gravity and osmosis. Since the sap accumulated as ice in branch fiber cells that are located high above the taphole, this additional sap, once returned to the vessels exerts a downward force similar to that of a standing column of water, with the greatest pressure at the base of the tree. In addition, it is believed that osmosis contributes to sap pressure because the movement of water into the fiber cells during the cooling period excludes sucrose (the sugar molecules cannot pass through the fiber cell walls). The transition from below- to above-freezing temperatures stimulates the conversion of stored starch to sucrose, which is loaded into the sap in vessels. Once ice crystals in the fibers have thawed, osmotic pressure created by the sucrose in the sap in the vessels draws water out of the fibers. These combined forces can result in a positive pressure as high as 40 pounds per square inch (psi) near the base of the tree. This helps explain the observation that a tree whose sap contains a higher concentration of sugar than its neighbor's typically is subject to higher sap pressure and yields more sap.

If there is a taphole or other wound through the bark in the tree, then sap will be exuded, because the pressure inside the tree is higher than the atmospheric pressure outside of the tree. Keep in mind that this phenomenon is present in maple trees not to benefit maple sap collectors but to refill portions of the wood that became filled with air during the winter. The sap flow rate will be proportional to the pressure inside the tree, and pressure will almost always be highest at the beginning of the thawing period before dropping off over several hours or even days depending upon how quickly the tree warms. The amount of sap exuded during a flow is related in part to this pressure, as well as other factors such as the length of the flow, the extent of vessel refilling in the previous freeze event, the tree diameter and size of the crown, and sugar content. Larger trees will typically produce more sap, and often sweeter sap, over a season than smaller trees.

As time passes during a sap run, other forces in the maple tree will begin to counteract the positive sap pressure and lessen it. These forces include evaporation of water from branches on sunny days, which exerts a pull on the sap toward the point of water loss and away from the taphole, as well as various internal leaks throughout the tree's sap system. The result is that sap pressure begins to dissipate within a few hours after the thaw has begun. Without a new freeze-thaw cycle, the pressure inside the tree will eventually subside and equal the pressure outside. At this point, sap would cease to flow from the hole in response to gravity. How long it takes before this occurs may vary greatly from sap run to sap run, depending on factors such as the length of the previous freeze, the rate at which freezing and thawing occurs, the temperature the wood reaches, the availability of soil moisture, and the size of the tree.

It is important to recognize that freezing and thawing does not happen throughout the entire tree at the same time or at the same rate. At the beginning of the sugaring season, a portion of the tree trunk deeper inside the stem or on the north side of the stem is often frozen during early sap runs.[6] The sap in that portion is thus unavailable and does not contribute materially to stem pressure or sap flow during that time. When the temperature remains above freezing, the sap run may last half a day or it may last several days, and flow may be rapid or slow during this period depending upon the rate and extent of thawing. A taphole on the south side of the tree may run early in the day or flow earlier in the season due to solar warming, but the north side could thaw later in the day and continue to freeze and thaw and to produce sap somewhat later into the season. In general, sap flow will become slower the longer the run lasts. Cooling (as opposed to freezing) of small branches during spring nights can sometimes marginally renew the pressure in the tree enough for sap to resume flowing for a few hours the next morning when the temperature warms. However, only freezing of the small branches will fully reestablish the initial sap flow rate by stimulating the uptake of water from the soil, starch conversion to sucrose, and the pressure development mechanism.

To put this phenomenon in other terms, fresh maple wood during the spring has a moisture content in the 65–70 percent range. Given that the aboveground dry biomass (weight) of the wood and branch tissue of a mature tree with a diameter of

[6] Perkins, T.D., A.K. van den Berg, and B. Haynes. 2021. Why sap may not always flow well in early season. *The Maple News*. May. pp. 6–7. https://mapleresearch.org/pub/mn2021earlyflow-pdf/

12 inches (30.5 centimeters) typically amounts to over 1,500 pounds (680 kilograms), the tree's fresh weight (dry biomass plus water) can be estimated to be over 4,600 pounds (2,090 kilograms). The loss of a gallon (3.8 liters) of sap (weighing 8 pounds or 3.6 kilograms) represents a change of only about 0.02 percent in weight for any one individual flow period. The liquid loss is subsequently replenished by water uptake as the tree enters the subsequent freeze period. If that taphole produces 5 pounds (2.3 kilograms) of syrup consisting of 3.3 pounds (1.5 kilograms) of sugar and 1.7 pounds (0.7 kilograms) of water, or 0.45 gallon (2 liters) of syrup equivalent per tap over the entire season, the tree has only given up about 0.22 percent of its total dry biomass in the form of sugar. Compared to an annual loss of 28 pounds (12.8 kilograms) or nearly 2 percent of the tree's total dry biomass in foliage alone, this sacrifice of sugar to the maple producer each year is a relatively small difference for the tree overall and amounts to a far lower percentage of biomass than that harvested from many other crop plants, while constituting a substantial gain for maple producers and consumers.

If we calculate it another way by looking at the average amount of sucrose in maple wood tissue in the springtime compared to the amount of sucrose in a gallon of sap, we eventually find that sap collection typically removes about 4 percent of the total sucrose in the stem during a typical run. That sugar is replenished by the conversion of starch (an insoluble form of carbohydrate) into sucrose (a soluble form) during the season.

Ideal Conditions for Sap Flow

Most sap flow events can be predicted reasonably well from air temperature alone. For strong sap flows to be repeated, a suitable temperature cycle above and below freezing must occur to allow strong positive sap pressure to develop. Maple producers should be aware that the nighttime air temperature measured a few feet off the ground is often several degrees lower than the temperature in the tree canopy, particularly on nights with minimal wind, and branches may not have frozen even if puddles on the ground are covered with ice. Early in the season or after very low temperatures during the season, one or more days of above-freezing temperatures may be required for the wood around the taphole to thaw enough so that sap flow can occur. Similarly, air temperatures only slightly below freezing may not be cold enough to cause tree branches to freeze all the way through. It is important to recognize that the temperature within a sugarbush can vary substantially due to elevation, aspect, and local microclimate. Given that sap flow is the result of very slight fluctuations in temperature near freezing, it is not always easy to gauge when a freeze (or thaw) has occurred, or how far across the woods it extended.

When to Tap

Although sap will flow in maple trees any time there are alternating freeze-thaw periods, the largest and most consistent sap flows typically occur in late winter and early spring during the months of February, March, and April. This period constitutes the commercial maple syrup season. Fall tapping has seldom proved economical because of low sap sugar concentrations and shorter periods of sap flow. So far it has not been possible to maintain a viable taphole that continuously delivers high sap yields from fall through spring.

Exactly when the season begins and ends in a particular year depends on geographic location and local temperature patterns. There is no clear answer for the question of when to tap—it depends on a combination of inexact science, the vagaries of weather, microclimate, intuition, and luck. The challenge for the maple syrup producer is to determine when to begin tapping in a particular year. Tapping that is completed late may miss early sap flows—these can never be recovered. On the other hand, tapping very early may expose the producer to an increased risk of lost production later in the season due to plugging of the xylem vessels by microbial growth and the way the tree responds to the taphole wound by walling off the injured tissues (taphole "drying"). However, it should be remembered that the quality of syrup produced early in a particular season is usually higher than that of syrup produced nearer the end of the season. Therefore, producers want to capture the majority of sap flows that produce the greatest amount of sap per flow within the window of time their tapholes remain productive. Repeated studies in the U.S.A. and Canada have shown that when using vacuum, it is generally more favorable to tap early as long as good spout/tubing sanitation practices are maintained and producers are prepared to process early sap into syrup.[7] Sap flows missed in the early season can rarely be made up in the late season, and then only with lower quality sap.

Taphole "drying" is a term that refers to the cessation of sap flows, even if weather conditions are appropriate for good sap runs. Tapholes do not actually dry. Instead, the natural wound response process resulting from exposure to air and microorganisms elicits plugging of wood vessels and walling off (compartmentalizing) of the injured area, the tree's mechanism for preventing entry and spread of infection and the subsequent development of decay. When vessels are plugged, sap flows diminish and eventually cease. The walling-off process begins immediately after a taphole is drilled in a tree, and the effect is visible within just a few weeks (**Figure 6.3**), although full development of the stained nonconductive wood takes a year or more.

Figure 6.3. Developing stain is already visible in a stem cross-section 0.5 inches (1.3 centimeters) above the taphole only two weeks after tapping (Isselhardt, unpublished).

The method of collection and level of spout sanitation are very important in determining tapping date. Producers with buckets or bags should only tap shortly before sap flows are expected to begin, as tapholes that are exposed to air will dry considerably faster than tapholes on a vacuum system. Expected taphole viability is generally about 4–8 weeks with buckets or bags. Because microbial growth is strongly influenced by temperature, hot weather during the season will result in seasons that are short. Tubing systems with tapholes closed to the air produce better results, particularly if good spout and tubing sanitation practices are observed. Tubing systems with vacuum can remain reasonably productive for 3–4 months, but again, temperature plays a major role in determining season length due to its influence on microbial growth.

Because of the effect of microorganisms on taphole drying, the amount of time a taphole remains viable in a tubing system is also greatly influenced by spout and dropline sanitation and on the weather during the season. Highly sanitized systems will often produce strong sap flows up through the end of the season and even past the time sap turns buddy, whereas less well sanitized systems experience sap flow declines partway through the season, with yields that are greatly diminished. Warm spells during the season, particularly when wood temperatures begin to exceed 55°F (13°C) later in the spring, can cause rapid sap flow cessation both due to rapid microbial growth and lack of proper conditions for water uptake in stems.

The current understanding of the sap flow process and improvements in weather forecasting allow better prediction of when sap flow is likely to occur. In most areas of the maple region, 5-day weather forecasts are reliable enough to help producers determine when to start tapping. Longer-range weather forecasts are generally less reliable than a record of the long-term average temperatures for your location. New producers are advised to communicate with experienced producers in their area

[7] Wilmot, T.R. 2008. The timing of tapping for maple sap collection. *Maple Syrup Digest*. June pp. 20–27. https://mapleresearch.org/pub/m0608tappingtiming/
Wild, A. 2021. Spout selection and timing of tapping and its impact on production. *The Maple News*. Sept. pp. 1,10. https://mapleresearch.org/pub/wildtaptiming-2/

to gain information on when sap flow has started and ended in previous years. In some areas, researchers or producer organizations survey producers and maintain records of maple season starting and ending dates. These, together with following local weather forecasts, will provide an approximate guide to when it is time to tap. A common mistake that new producers with only a few trees make is to tap too early when they see or hear of others who are using tubing with a vacuum system tap. This practice will lead to premature flow cessation. It is more advisable to be prepared for appropriate conditions and tap when weather for good sap flow is predicted. If uncertain, and enough trees are available, small producers can tap a subset of their trees early and tap the remaining trees later. Practices that attempt to extend the viability of tapholes or rejuvenate them (drilling the taphole slightly larger in diameter and/or deeper, drilling a new taphole slightly above or below the original taphole) are not recommended, as research has documented that internal wound development is significantly increased, greatly reducing tapping sustainability. Producers should refrain from placing more than one tap in a tree in one year unless the tree is large enough to accommodate additional taps.

Producers are encouraged to keep records of weather and sap flow at their location to aid in relating regional forecasts to their location. Larger producers with thousands (or tens or hundreds of thousands) of taps typically cannot wait for appropriate conditions to approach but must begin tapping early to complete the process by the time appropriate conditions are likely to appear. While there might be some sacrifice of sap due to reduced flows toward the end of the season, this approach lessens the danger of missing early sap runs or of not completing tapping before optimal conditions for flows occur.

It was once thought that tapping frozen wood might lead to the development of small splits around the taphole when the spout is set. Practice has shown this not to be the case, or at least that the danger is relatively low. Smaller, less strongly tapered spouts, thinner walled spouts, and improved bits for frozen wood seem to have reduced the wood's tendency to split. When larger (7⁄16-inch)[8] spouts are used and frozen wood must be tapped, the use of a sharp tapping bit and gentle seating of spouts is recommended.

CHARACTERISTICS OF TAPPABLE TREES AND FACTORS AFFECTING SAP YIELD

There are a number of factors that make trees suitable for sap collection and that affect the yield (sap quantity and sap sugar content) from maple trees. These include

- tree characteristics such as diameter, vigor, crown position and size, and genetics;
- weather/climate before and especially during the sap flow season;
- tapping specifics (e.g., taphole size, number, quality);
- vacuum level;
- spout and tubing sanitation;
- soil type, fertility, and moisture; and
- tapping history (the amount of nonfunctional wood from previous tapholes in the tapping zone).

Generally, any healthy maple tree larger than 9–12 inches (22–30 centimeters) in diameter at breast height (dbh, 4½ feet, or 1.4 meters, above ground) may be tapped. Specific tapping guidelines can vary from place to place and be regulated more stringently if an operation is certified in some way (organic) or enrolled in a tax abatement or conservation program. The stipulations regarding tapping might also be defined by either formal contract or by verbal agreement with the owner of the trees. In cases where the producer doesn't own the trees, having a written agreement in place is a good idea to prevent misunderstandings.

Characteristics of superior maple trees and criteria for selecting them are discussed in **Chapter 5**. It should be reemphasized that greater economic returns will be achieved by tapping healthy trees that produce large volumes of sap with high sugar

[8] Spouts, lateral line, and mainline used in the maple industry are normally sized in English units; thus no metric equivalents are given.

concentration as opposed to tapping unhealthy trees or those with small crowns. Select dominant or codominant trees unless their location is too far from other trees or from a good collection point for buckets or is too far to connect to the tubing system. In general, trees under optimal conditions (healthy, high vacuum,[9] good spout sanitation) will produce approximately 0.5 pounds of syrup for each additional 1-inch (2.5 centimeters) of diameter.

It is not generally recommended that unhealthy, low-vigor, or subdominant (suppressed) trees be tapped. Often sap production from such trees will be low; furthermore, the rate of growth and taphole closure on nonvigorous or subdominant trees is usually retarded, thus increasing exposure for the entrance of decay causing organisms and reducing tapping sustainability through an enhanced accumulation of nonfunctional wood from previous tapholes in the tapping zone. Sometimes producers will tap small trees intended to be culled within a few years to get some amount of sap from them (the so-called "thinning with a tapping bit" approach). The low sap yield and sugar content from these individuals makes this practice questionable in terms of added sugar production and economic gain. It is likely that a better approach would be to remove these individuals to reduce competitive pressure and allow faster growth of remaining crop trees.

Tapholes in healthy trees usually close in 1–3 years (**Figure 6.4**); those in unhealthy trees may take longer. Slow-closing tapholes may result in increased insect and disease problems and a reduced tapping surface on the tree trunk due to more open tapholes, increased cambial dieback, and increased sapwood staining. Additionally, sap collected from unhealthy or low-vigor trees or subdominant trees may be low in sugar content and, according to anecdotal reports, can produce off-flavored syrup. Given that subdominant trees produce less sugar overall through photosynthesis, the amount of carbohydrate removed by tapping smaller trees represents a higher proportion of their energy reserves than that removed from larger dominant or codominant individuals, potentially further compromising growth and vigor in small stems.

As noted in the discussion of conditions for sap flow, weather plays a very strong role in sap yield. This is readily apparent when looking at season-to-season variation. Some years have numerous days with conditions conducive to strong sap flows. Other years have fewer good sap flow days. Poor seasons often occur when temperatures exceed 55°–60°F (12.8°–15.6°C) for several days, as this promotes explosive microbial growth and hastens taphole drying.

Preliminary research has shown that environmental and biological factors such as high temperature and drought during the preceding growing season, or high temperatures in the fall and lack of snowfall during the early winter preceding the subsequent sap flow season, can produce discernible impacts on sap sugar content and sap flow, although these tend to be fairly small in comparison to the effects of weather during the season. Because sap sugar is derived from many individual tree rings (often spanning 20 years or more), the influence of any one especially good or poor year is generally moderated. Optimal environmental and biological conditions generally produce sap sugar content at a peak level determined mostly by tree genetics and crown position; suboptimal conditions drive sap sugar content downward from that peak. More research may help to illuminate the complex and interactive effects of different factors controlling sap sugar content.

Vacuum level (within tubing systems) strongly affects sap flow. When vacuum (either pumped or natural) is pulled inside tubing, the pressure the tree experiences at the taphole is artificially lowered, which heightens the pressure gradient between the inside and outside of the tree. The steeper gradient increases both the sap flow rate and quantity exuded from the taphole. The effect is essentially linear—the higher the vacuum level, the greater the sap flow produced. Research has demonstrated that the amount of sap produced increases by about 5–7 percent for each inch of mercury (hereafter ″Hg) of vacuum, that the sap produced is typically comparable in sap sugar concentration to that produced

[9] By maple industry convention, vacuum is referred to as a positive number (rather than a value below atmospheric air pressure).

(a)

(b)

(c)

(d)

Figure 6.4. Fresh taphole (a), taphole early in the subsequent growing season a few months later (b), taphole at end of one growing season (c), taphole after two growing season. Tapholes that are $\frac{5}{16}$ inch or smaller in healthy trees will generally close in 1–3 years, depending on the age of the tree, the quality of the site, and the growing seasons.

without vacuum and that there is no additional damage inflicted on the tree from the use of vacuum.

Soil fertility plays a significant role in determining tree health and growth, and thereby affects sap yield and sap sugar content. Adequate available soil moisture, particularly during the summer growing season and during the spring sap flow season also influence sap yield and sugar content.

Yet another important factor in determining sap yield is sanitation. In bag or bucket systems, spout sanitation is very important, and yields can almost double by use of new or well-sanitized spouts. The impact of sanitation of the tubing system on sap yield becomes increasingly significant the closer a system component is to the taphole.[10] Therefore, spout sanitation is of highest importance and dropline sanitation is also fairly important; however, lateral line and mainline sanitation has only a minor influence on sap yield. Sap yields from tubing systems with excellent sanitation can be 100 percent or higher than those from systems with poor sanitation. More discussion of spout and tubing sanitation appears later in this chapter.

TAPPING

Although tapping is a seemingly simple task, it is one of the most critical steps in achieving good yields from maple trees. The selection of trees to tap and the tapping techniques employed can affect the amount of sap produced and the economic success of the operation. Putting a drill, a hammer, and a bag of spouts in the hands of an inexperienced and untrained person can result in very low sap yields. Mistakes that occur during tapping are often unfixable.

The objective of tapping is to create a taphole that will produce large volumes of high-quality sap with a good sugar content in an economical manner, while at the same time, maintaining the long-term production potential of the tree. Correct tapping will minimize taphole damage to the trees, lessen microbial contamination of the sap, and ensure a high level of sustainability of tapping. Sap that is free of microbial contamination has the highest potential to become syrup of the best quality. Microorganism contamination of sap is also a major contributor to the production of darker grades of syrup. Furthermore, off-flavors sometimes occur in syrup made from contaminated A contaminated taphole will produce less total sap during a season due to blockage of the sap producing vessels in the wood.

The techniques of correct tapping include observing the following:

- Using appropriate equipment and maintaining it in good condition
- Choosing the right time to tap
- Selecting appropriate crop trees
- Identifying the proper number, size, depth, and placement of tapholes for each tree
- Drilling a good taphole
- Seating the spout properly

Tapping Equipment

The basic equipment required for tapping maple trees include a drill, an appropriate drill bit (with stop), spouts, and a small mallet or hammer.

Battery-operated drills (18 volts or more) work well for drilling 5⁄16-inch holes that are commonly recommended for vacuum tubing systems. These drills are lightweight and easy to operate, and one to two freshly charged batteries will typically last through an entire day of tapping. Lithium batteries typically function better at cold temperatures than Ni-Cads.

Battery-operated drills can be used to make larger diameter (7⁄16-inch) tapholes; however, it will be necessary to change the battery more frequently. Use of a sharp bit helps prolong battery life.

It is important that a clean, sharp tapping bit appropriate to the size of spouts is used (a 5⁄16-inch bit for a 5⁄16-inch spout, a 19⁄64-inch bit for a 19⁄64-inch spout, etc.). Bits should be tightened firmly straight into the drill chuck. Even a slight misalignment will lead to oval tapholes. Only bits designed specifically for tapping maple trees for sap production should be used as they are designed for rapid cutting through wood tissue and extraction of wood shavings (**Figure 6.5**). Regular drill bits have a much shallower angle, less twist, and smaller flutes and are designed

[10] Perkins, T.D. and A.K. van den Berg. 2012. Relationships between tubing system component age and sap yield—a preliminary assessment. *Maple Syrup Digest*. Feb. pp. 11–16. https://mapleresearch.org/pub/m0212tubingagesapyield/

Figure 6.5. A clean, sharp drill bit designed for tapping maple trees (left) is different from a standard wood bit (right). Tapping bits are made for rapid cutting of fresh wood in live trees and fast removal of wood chips from the taphole. Bits should be replaced if damaged or after about 2,500 tapholes.

for a variety of materials. Be sure to choose the right bit for the spout being used as even small differences can be important. Dull bits are more difficult to use, create ragged tapholes that may impede sap flow, provide additional surfaces within the taphole for microorganism growth, reduce the number of holes able to be drilled, and are more likely to produce oval tapholes, which can allow sap leakage, compromise vacuum, and enhance contamination by microorganisms. Drill bits should be kept as clean as possible to minimize contamination of the taphole. An effective way of cleaning drill bits is to wash them in a detergent solution, thoroughly rinse following washing, and allow them to soak for a few minutes in a bleach solution (1 ounce commercial [5 percent] standard strength household bleach in 1 pint of water, or 30 milliliters bleach to 470 milliliters water), or soak them in alcohol. If bleach is used, the bits should be immediately rinsed with clean water then dried before use to avoid contaminating the tapholes with the bleach solution and to prevent rapid oxidation (rusting). If decayed or rotting wood is encountered while tapping, bits should be rewashed with bleach or alcohol to prevent transferring possible microbial contamination to other trees. Avoid allowing the drill bit to touch the ground or other unclean surfaces while in use. A supply of clean, sharp bits should be available for changing as needed. Bits sometimes break. There are few things more annoying than to be a good distance out in the woods without a spare when this happens. It is good practice to consider replacing bits after no more than every 2,500 tapholes (or fewer) to ensure they are sharp. A sharp bit is your first assurance of a productive taphole, which will save you time when tapping and help increase the probability of a sustainable sap flow, both of which make you money in the long run.

Spouts have three important functions: (1) transfer sap from the taphole into a collection container or tubing, (2) provide support for holding a sap collection container or connection for tubing, and (3) provide a seal to minimize leakage around the taphole. Minimizing leakage is important in the maintenance and operation of vacuum tubing installations as well as to reducing the likelihood of contamination of the taphole by microorganisms and retarding the initiation of the wound closure process. Spout design and construction has changed significantly over time. Early spouts were sometimes made from flat chips of wood or hollowed-out sumac or elder stems,[11] but over the years have evolved into a wide variety of metal and plastic spouts available in different sizes and designs. A variety of spouts for tubing or bucket/bag operations are currently in use (**Figure 6.6**), and an even greater assortment of spouts are made for tubing (**Figure 6.7**). Each has its perceived advantages and disadvantages. Either 5⁄16-inch, 19⁄64-inch, or 7⁄16-inch spouts are standard for non-vacuum systems, with 7⁄16-inch spouts being used less frequently. Results from research have indicated that spouts with a 5⁄16-inch hole size will yield approximately the same amount of sap in vacuum systems as can be expected from larger spouts in most years. Sap yields with 5⁄16-inch spouts without vacuum are generally close to those from 7⁄16-inch spouts, but a small reduction in yield may be observed in some years. The smaller diameter holes associated with 5⁄16-inch spouts will close significantly faster than larger 7⁄16-inch holes. Also, less wood is removed

[11] The use of sumac or elderberry stems is highly discouraged as they can impart toxic substances into maple sap.

Figure 6.6. A wide variety of types and sizes of spouts for collection with buckets or bags.

Figure 6.7. Tubing spouts come in many different styles, sizes, and colors.

from the tree during tapping, and the size of the column of stained, nonfunctional wood is considerably smaller. Some equipment manufacturers offer even smaller diameter spouts. The ¼-inch (or 17⁄64-inch) spout is sometimes recommended, especially for smaller or slower-growing tree; however, it should be appreciated that these spouts will produce about 10–12 percent less sap than a 5⁄16-inch spout. An even smaller spout that is 5⁄32-inch is also available—research has demonstrated that these produce only about 60–65 percent the sap yield of a 5⁄16-inch spout under the same conditions, although they do have the advantage of producing a smaller internal wound.

When buckets are used for sap collection, spouts are removed from the trees at the end of the season and taken to the sugarhouse or other location where they should be cleaned with a detergent or bleach solution, thoroughly rinsed, and allowed to dry. Following cleaning they should be stored in a clean and dry location. Before use the following year, it is a good idea to wash them with boiling water or a bleach solution (but do not use bleach for aluminum buckets or soak metal spouts longer than 10–15 minutes in bleach) to make sure all possible sources of contamination are removed. Once spouts are cleaned and dried, every effort should be made to keep them clean by storing them in plastic bags in a dry location. Spouts should be transported to the sugarbush under conditions that will keep them clean. Do not allow spouts to touch other surfaces where possible contamination could occur before they're placed in the taphole.

With tubing systems, spouts can remain connected to the tubing after they are removed from the tree or are replaced annually. Dirty spouts are a source of microbial contamination for a new taphole, and seriously compromise sap yields. Sanitation strategies for spouts and tubing and related collection equipment are discussed later in this chapter.

Taphole Number, Size, and Location

How many taps to place in a tree and where is dictated by the concept of the "tapping zone."[12] The tapping zone is an area of a crop tree that is a potential source of conductive (unstained) wood where you can place a taphole and spout for convenient high-yield sap collection with buckets or a tubing system. The tapping zone extends from the lowest to the highest spot on a tree that can be tapped (using the particular collection technology employed), and all around the stem. Typically for a tree where a bucket or sap bag is used, this extends from about 2–4 feet above the ground/snow level. It is very tempting to always tap in an area that is convenient for sap collection with the bucket. Termed cluster tapping, this practice typically results in a high concentration of tapholes in a small area

[12] van den Berg, A.K. and T.D. Perkins. 2014. A model of the tapping zone. UVM Proctor Maple Res. Ctr. https://mapleresearch.org/pub/tapzonemodel-2/

and eventually leads to the development of a large wound and the creation of a nonproductive tapping zone that blocks sap flow. With tubing systems, the tapping zone is delimited by the area where it is possible to place a taphole and reach it with the dropline. Thus, dropline length effectively controls tapping zone size. For that reason, longer droplines (30–36 inches minimum, 76–91 centimeters minimum) than those used historically (15–18 inches, 38–46 centimeters) are recommended.

It is critical to have a tapping zone large enough so that there is a low probability of hitting a former tapping stain. This internal wound within the tree results from tapping, visually indicated when a tree is cut as a tan or brown stain. This zone of stained wood is nonconductive of sap.[13] Normal functional wood is light cream colored. Typically, the stain is just a little wider and a little deeper than the taphole but extends up and down in the tree for 12–18 inches (30–46 centimeters) or more above and below a taphole (**Figure 6.8**). Generally, the total size of the stain is proportional to the size of the taphole—bigger diameter and deeper tapholes result in bigger columns of nonfunctional wood. However, the size of the stain can vary considerably depending upon the growth of the tree, genetics, and the presence of other areas of internal staining. While this stained area is usually structurally stable, it is no longer physiologically functional—it is no longer conductive to sap and is also no longer useful for storing carbohydrates. There is some evidence that a nonfunctional "ghost" zone extends slightly beyond the visually affected area of stain, increasing the affected wound area by up to 25 percent. Further research is needed to understand this phenomenon.

Tapping into stained wood can substantially reduce sap yields, with the amount of sap loss directly proportional to the amount of stain that is hit. Proper sustainable tapping practices focus on spacing tapping wounds to minimize the likelihood of tapping into old tapholes or stained wood. If tapholes close in 1–2 years, determining where previous tapping has occurred is nearly impossible unless there is an organized approach to taphole placement. Stained wood never recovers functionality. New wood eventually grows over and encapsulates the stained wood, and the stain will eventually be buried deep enough to permit tapping over the same area. The length of time it takes for this to happen depends largely upon the growth rate of the tree, which is why proper management is important (see **Chapter 5**). Because tapping decisions such as taphole depth and diameter determine how much nonfunctional wood is added to the tapping zone annually, producers should base them on all the factors, including the growth rate of the tree, that contribute to the impact of tapping on the tree to minimize the chances of tapping into unproductive wood and thus jeopardizing future sap yields. For this reason, it is important to choose tapping practices that balance current desired yields with the amount of internal wounding they will result in, as this will ultimately optimize future yields.

Good practice when tapping is to periodically inspect the wood shavings from a taphole, particularly in those portions of the sugarbush that have

Figure 6.8. Internal staining in section of maple stem cut vertically resulting from tapping. Tapholes themselves will never fill in, but the wood above and below the taphole is rendered nonfunctional (it will no longer transmit sap) and discolored (stained) as a result of the natural tree compartmentalization process.

[13] For the purposes of this chapter, "stain" is unused synonymously with "nonconductive wood" or "NCW." Many maple producers refer to this as a "scar." More information on NCW and tapping sustainability can be found in: van den Berg, A.K. and T.D. Perkins. 2014. A model of the tapping zone. *Maple Syrup Digest*. Feb. pp. 18–27. https://mapleresearch.org/pub/m0214tappingzonemodel/

been tapped for a long time, especially if $\frac{7}{16}$-inch spouts and multiple buckets per tree were in use for some time or if the woods is slow growing for some reason (lack of management, poor site or soil nutrition, poor tree health). Catch the wood shavings in your hand as they come off the bit and inspect them (**Figure 6.9**). While there will always be some amount of dark material from the bark, most of the wood should be a light cream colored, and somewhat moist. It should not be crumbly-dry or punky and wet. Slightly moist, unstained wood indicates productive wood that will produce good sap flows. If the taphole produces an abundance of brown-tan colored wood it was drilled into stained wood, and sap yield will be low. By keeping track of the number of tapholes and the amount of stained wood in each taphole, producers can judge whether to make changes to tapping practices. If stained wood is encountered more than 5 percent of the time, producers should consider altering their tapping practices in affected areas and conducting management activities (such as thinning or fertilization, see **Chapter 5**) to increase the growth rates of crop trees. Tapping higher or lower on the stem, reducing taphole diameter, depth, and number of taps per tree will, over time, allow the tree to put on new wood over the stained areas, and slowly decrease the amount of stain encountered while tapping. Depending on the degree of internal staining and the tree growth rate, these changes might require several decades to be effective.

Figure 6.9. Drill shavings should be inspected frequently when tapping to ensure that functional sapwood was tapped into.

There are no set rules for the number of taps to place in a tree. Tapping guidelines can vary depending upon the size of spout used, the technology used for collection (gravity or vacuum), the health or stress level of the tree, tapping history, and whether there are any overriding conditions (organic or lease related). Over the years, tapping guidelines have been developed that use tree diameter as a way to determine the number of allowable taps. Traditional tapping guidelines permitted up to four buckets on large maples. Research has shown that this intensity of tapping is unsustainable in the long-term both in terms of the ability of the tree to grow new wood fast enough to compensate for losses due to compartmentalization and due to reductions in sap yields over time. Many maple trees in sugarbushes are older and are affected by a variety of stresses including overcrowding, broken branches, pockets of decay, defoliation by insects, adverse weather (such as drought), soil compaction, and air pollution. As a result of this, and because high sap yield production can be achieved with good vacuum and spout/dropline sanitation practices with fewer tapholes, tapping guidelines have become more conservative in some ways and less restrictive in others.

Modern tapping guidelines (**Table 6.1**) are more nuanced, varying based not simply upon tree diameter, but also on the technology used (spout size and vacuum levels) and whether the tree is under stress or might be growing slowly. Tapping should optimally be adapted based upon the growth levels; however this is difficult to monitor directly.

It is thought likely that wounding a tree by tapping has a greater potential impact on tree health and

TABLE 6.1 Tapping guidelines based upon tree diameter,[1] tree condition, and sap collection method.

Tree Conditions[2]	Collection Practices[3]	Spout Diameter (inches)	Tapping Depth[4] in / cm	Minimum Tree Diameter[5] in / cm	Number of Taps
Conservative					
Optimal	Gravity	7/16	1–2.5 / 2.5–6.4	12+ / 31+	1
Suboptimal	Gravity or Vacuum	1/4–5/16	1–1.5 / 2.5–3.8	12+ / 31+	1
Standard					
Optimal	Gravity or Vacuum	1/4–5/16	1.5–2 / 3.8–5	9–12 / 23–31	1
				18–22[6] / 46–56	2

[1] Tree diameter should be adjusted downward to an "effective" diameter if there is evidence of stem defects (insect or animal damage, logging wounds, trunk cracks or scars, cluster tapping, etc.).

[2] *Optimal* conditions include trees that are healthy, with good growth rates, no history of overtapping, and NCW (stained wood) is not frequently encountered during tapping. *Suboptimal* conditions are trees that have slower growth rates, are in a "suppressed" position in the forest canopy, have been recently stressed or are exhibiting signs of stress (dieback, fine twig mortality, slow wound healing, etc.), have a history of overtapping, or if NCW (stained wood) is frequently encountered during tapping. Conditions are a range—the more *"Suboptimal"* conditions that are observed, the more conservative the practices (shallower depths, smaller-diameter spouts, larger minimum tree diameter for first or second tap, etc.) that should be selected. Likewise, the more *"Optimal"* conditions that are observed, the less conservative tapping practices can be selected.

[3] All practices assume a dropline length of 36–42 inches (92–107 centimeters) for collection with tubing.

[4] Tapping depth includes bark. If the stand has a preponderance of older, thickly barked trees, up to an additional 1/2 inch of depth may be added.

[5] To convert diameter to circumference, multiply the diameter by 3.14.

[6] The lower portions of the diameter range should be used with gravity and vacuum collection at less than 20″Hg. The upper portion of the diameter range should be used with vacuum collection greater than 20″Hg since the additional yield from a second taphole is negligible in trees of smaller diameters at high vacuum levels. In many cases producers using high vacuum will only use one tap per tree regardless of size.

maple production sustainability than the amount of sap collected. Concerns about tree health and the impact of too many tapholes on tree vigor provide the basis for following conservative tapping guidelines. Furthermore, it has been observed, both from controlled research studies and from field observations, that the volume of sap per taphole can increase substantially when fewer tapholes per tree are used, especially when sap is collected using vacuum. Using more taps per tree does not necessarily mean obtaining proportionally more sap. In fact, as vacuum level increases, the amount of additional sap produced by a second (or third) taphole decreases considerably. While a second taphole in a 19-inch (48 centimeters) tree under non-vacuum conditions might produce nearly double the amount of sap, a second taphole in the same tree at 28″Hg vacuum will only produce approximately 30–65 percent more sap. This is because vacuum will move sap further within the tree, so as vacuum level increases, the zone from which sap is collected increases, and a second taphole cannibalizes sap from the first at an ever-increasing level with higher vacuum. Therefore, two tapholes under high vacuum will not produce double the sap yield but will still produce double the amount of internal wounding, ultimately affecting future yield potential. For this reason, as vacuum levels increase the distance between two tapholes in one tree should be increased.

Organic and other types of certifications and programs may place certain restrictions on tapping diameter, number of taps per tree, and/or collection methods or may have other tapping rules. Leasing of land or trees often involves written or verbal agreements requiring the producer to follow a given set of tapping guidelines. In these cases, such agreements are no longer "guidelines" but rather enforceable rules and tapping should strictly comply with the rules agreed to.

Tree diameter can be easily measured using a special diameter tape or by measuring circumference and dividing by 3.14, or estimated with a Biltmore stick (a yardstick-like scale), or simply by using a piece of string or dropline cut to the proper length. Diameter tapes and Biltmore sticks (or tree scale sticks, but not to be confused with a "log" scale stick) can be purchased from forestry equipment supply companies (see **Chapter 5** for more detail).

Actual tree diameter should be adjusted downward if there are any stem wounds due to logging, lightning, insect or animal damage, or evidence of stress.

To avoid having to measure or estimate tree diameter each year, some producers who use bucket sap collection equipment will use permanent marking paint[14] to mark a dot code on the tree indicating the number of taps (e.g., 1 dot = 1 tap, 2 dots = 2 taps). If trees are marked, it is suggested that all trees be marked on the same side, so the number of taps is easily determined at a glance. Note that some methods of marking are not allowed by organic certifiers and that some lease agreements may specify the number of taps allowed by the landowner.

Tapping guidelines have traditionally suggested that tapping rates be reduced or tapping suspended for severely stressed trees. Producers are urged to evaluate the health and overall condition of each tree, being particularly aware of symptoms or causes of tree stress, such as severe weather conditions (e.g., drought), major trunk wounds, slow healing wounds, substantial insect or disease problems, defoliation, fewer and smaller leaves than normal, and branch dieback. From a tree health perspective, subjecting stressed trees to the additional impact of tapping may slow the recovery of unhealthy or otherwise low-vigor trees, and such trees might benefit from a reduced tapping rate. However, from a practical perspective, the decision may be one of balancing tree health with the potential lost production resulting from the reduced tapping rate. Certainly, where few trees are involved, or where there are alternative trees to tap, it is advisable to temporarily reduce or suspend tapping of stressed trees. In other instances, such as the severe ice storm of 1998 in the northeastern United States and adjacent regions of Canada, where economic factors strongly influenced decisions to tap severely damaged trees that same season, tree condition should be continually monitored to ensure the best chance of tree recovery, even though it may occur at a slower rate. Scientific evidence supporting the continuation of tapping at the same intensity or the use of restricted tapping practices after severe tree damage is lacking; however, it is probably best to exercise prudence if trees have been damaged by weather, disease, or insects or show other obvious signs of stress.

Although tapping guidelines have been developed to balance sap yield and internal wounding in maple trees, it is important to recognize that sap collection also removes a portion of the trees' energy reserves that might otherwise be used for metabolism, growth, or reproduction. Research on the effects of sugaring on trees from a carbohydrate removal perspective is limited. The few studies comparing tree health and growth in stands that have been tapped with those nearby that are untapped show mixed results. Some work suggests a possible impact of sugar extraction on growth, particularly on lower quality sites or otherwise stressed trees; other studies show no effect. Currently ongoing long-term experiments will provide more information on this question. Regardless, if there is any impact of sugar removal it is likely to be found to be more pronounced in suppressed or otherwise impaired individuals that are living closer to the carbohydrate balance point where they barely make enough carbohydrate to meet internal needs. Larger trees with crowns that extend into the canopy generally produce excess carbohydrate reserves, which are stored throughout their woody tissues and can be mobilized as needed. The amount of carbohydrate reserves typically increases as tree size

[14] Paint or other marking materials must be chosen to conform to specific regulations if used in certified organic operations.

increases, so removal of sugar via tapping removes a smaller proportion of the reserves in larger trees than from smaller trees.

Taphole depth generally should not exceed 2 inches (5 centimeters) including bark; many producers who use vacuum tubing systems only tap to a depth of 1.5 inches (3.8 centimeters) or sometimes even as shallow as 1 inch (2.5 centimeters), particularly for smaller or slow-growing trees. Under vacuum a 1.5-inch-deep (3.8-centimeter-deep) taphole will produce about 80 percent the amount of sap as a 2-inch (5-centimeter) taphole, while a 1-inch (2.5-centimeter) taphole will yield only about 55 percent of a taphole drilled 2 inches (5 centimeters) deep. Shallower tapholes may produce marginally sweeter sap, but this does not compensate fully for the volume loss. It has been demonstrated that when vacuum is not used yields will increase with increasing depth of the taphole up to about 2 inches (5 centimeters) or more. Deeper tapholes do not produce proportionately greater amounts of sap. The risk of penetrating previously tapped wood or heartwood increases as tapholes are drilled deeper. Because bark thickness of tappable maples varies between about ¼ and 1 inch (0.6 and 2.5 centimeters), adjustments to total tapping depth may be necessary in older stands with a preponderance of large trees so that tapholes will extend the desired depth into the wood. When tapping trees of low to moderate vigor, shallower tapping may reduce the amount of physical injury to the tree.

Tapholes, particularly with bucket or bag collection, are often drilled 2–2.5 inches deep (5–6 centimeters), often with a slight upward angle (going inward) so the back of the hole is slightly higher than the front by approximately 10 degrees (**Figure 6.10**). This is done to ensure that sap drains out of the taphole rather than collecting behind the spout, where it's at risk of being pushed out during a freeze. In vacuum systems using small (e.g., 5/16-, 19/64-, ¼-inch) spouts, tapholes are often alternatively drilled straight in. This practice is supposed to reduce the production of oblong tapholes, but research has shown that the two drilling methods (straight or slightly angled) yield indistinguishable results. The creation of oval or oblong tapholes should certainly be avoided, but drilling at an angle does not create oval tapholes—movement of the drill while drilling tapholes does. Spouts will not seat properly in oval tapholes, which leads to leakage of sap. Leakage also results in loss of vacuum, the possibility of increased microorganism growth in the taphole, taphole drying, and the loss of sap. The chances of drilling oval holes can be minimized by using sharp drill bits, not tapping too fast, ensuring you have a stable stance before starting the drill, and holding the drill firmly with two hands so the bit does not rest on the front of the taphole. Be aware that reaching over the head to make tapholes at higher locations on the trunk or tapping while on snowshoes will increase the likelihood of making irregular-shaped tapholes that are more prone to leakage. A special drill attachment is available (Precision Tapper™), aimed to help maple producers consistently drill good tapholes. Some people find this device to be very useful, others do not. One drawback is the extra weight it adds to the drill. Proper and adequate training of those doing the tapping is probably the most important factor in achieving good results.

Figure 6.10. Tapholes used with gravity collection are generally drilled at an angle with the bit going slightly upward (approximately 10°) as the bit goes into the tree. This is done to minimize sap pooling and freezing in the taphole between runs, which can result in spouts being dislodged. On tubing systems with vacuum, tapping either at a slight angle or straight into the stem is acceptable and has no effect on sap yield.

If the trees have been previously tapped, new tapholes should be at least 1.5–2 inches (3.8–5 centimeters) and preferably 4 inches (10 centimeters) or more to the side of and at least 6–8 inches (15–20 centimeters) or more above or below the previous season's tapholes, although more research is needed to delimit optimal spacing. When vacuum levels are very high, even wider avoidance of tapholes from the previous few years is recommended to avoid possible microleaks. Tapholes drilled in successive years should not be placed in a straight line close together horizontally around the tree to avoid creating a weak zone in the tree and to prevent vacuum leaks from tapholes that are too close together. A useful pattern is to drill each new taphole to the side and slightly above or below old tapholes each successive year, always moving to the side in one direction. This results in a spiral or zigzag pattern of tapping around the tree that, over many years, uses the entire tapping face of the trunk. Often this approach is accompanied by the practice of marking above the previous taphole with a small dot of paint (a new color every year) or wood crayon to make identifying the previous taphole very easy as a way to hasten tapping. Moving in a predetermined direction around the trunk avoids retapping a previously tapped area before the tree has enough time to grow new wood over the old tap hole. Both pattern tapping and selective tapping have advantages and disadvantages, and the use of one or the other is largely a matter of personal preference and previous tapping history. Care should also be taken to locate the tapholes least 6 inches (15 centimeters) from old branch scars, cracks, or other wounds, even if they appear to have healed. Hydraulic connections of tree vessels carrying sap become restricted and can vary greatly in direction at branch junctions, so tapping near them is not advised.

Maple folklore suggests tapping preferentially on the south side of stems and above a large root or below a large branch. These practices should be avoided as there is substantial evidence that no one aspect produces higher sap yields over the long term. Although tapholes located on the south side of a tree trunk may produce sap a few days or weeks earlier than those on the north, or might run better in one particular season, typically all sides and positions on a stem will produce similar amounts of sap when averaged over several years. In bucket operations, the side of the tree trunk on which tapholes are located should be governed more by taphole spacing and minimizing collection time and costs, although care should be taken to avoid repeatedly tapping the side of the tree easiest to get to or from while collecting a bucket. This practice leads to over-tapping one face of the stem and increases the likelihood of hitting stained wood. Likewise, there is no indication that tapping over a large root or under a large branch will increase sap yield. Furthermore, if such a practice is continued over a long period of time, cluster tapping with an attendant loss of tappable wood (and reduced sap yield) in that area will result.

A recent innovation in expanding the tapping zone with vacuum systems is to tap below the lateral line.[15] This approach essentially doubles the size of the tapping band. It should only be used in systems with good vacuum and when excellent spout sanitation practices are employed. Tapholes should be drilled as normal, and the spout placed so that there is a small loop downward to allow an air gap to form, reducing the chances of microbial contamination of the taphole (**Figure 6.11**). A Leader

Figure 6.11. When tapping below the lateral (recommended on vacuum systems only), a small loop upward is used to create an air-gap so the taphole does not remain constantly full of sap. (SILVA)

[15] Perkins, T.D., M.L. Isselhardt, and A.K. van den Berg. 2016. Is Tapping Below the Lateral Line a Good Idea? *Maple Syrup Digest*. Dec. pp. 9–16. https://mapleresearch.org/pub/m1216belowlateral/

Evaporator Co. Check-Valve spout is generally recommended when tapping below the lateral.

Taphole Cleanliness and Sanitation

Tapholes should be kept free of wood shavings or bark fragments. This can be achieved with the drill running in either high-speed or low-speed settings as long as a sharp bit is employed. Experienced producers may prefer a high-speed setting but switch to a lower speed near the end of the day when they are fatigued. Inexperienced tappers may want to start with a lower drill speed. If sawdust or shavings remain in the taphole after it is drilled, they should be removed using a small, clean twig or a metal wire; a nail driven into a small dowel also works well. Do not "blow the taphole clean," by mouth as this may contribute to microorganism contamination.

Several different approaches have been tried to kill or prevent the growth of microorganisms in the taphole. These include using a dilute bleach solution, ethyl alcohol, hydrogen peroxide, and paraformaldehyde. Solutions sprayed into the newly drilled taphole have a very short-term effect and produce widely varying results, sometimes positive and sometimes negative, and thus and are not considered worth the effort and expense. Furthermore, some of these sanitizing materials may have the potential to interfere with taphole closure when the tap is removed at the end of the season or to increase the size of internal staining. In addition, some research evidence suggests that using such solutions can hasten taphole drying, resulting in reduced sap yield.

For many years, small pills or pellets containing paraformaldehyde (PFA) were routinely placed in tapholes to retard the growth of microorganisms and thereby increase both the yield and quality of sap. Because the pellet dissolved slowly, PFA was released in the taphole, thus reducing microbial populations throughout the entire season. However, PFA was subsequently found to produce significant increases in the size of wounds in maple stems that resulted in increased susceptibility to wood decay and reduced tree health. In 1999 the U.S. EPA revoked tolerance exemptions for residual formaldehyde in maple syrup. Accordingly, the use of these pellets has been discontinued, and it is presently illegal to use paraformaldehyde in tapholes in Canada and the United States. Screening and laboratory tests are now available to detect the use of paraformaldehyde in maple sap and syrup.

While direct application of sanitizers to the taphole does not result in net positive outcomes, there is tremendous value in using sanitized spouts.[16] Spouts that have not been adequately treated with a sanitizing solution are a likely source for introducing undesirable microorganisms into the taphole. The abundance and type of microbes that trigger the wound response determine the the speed of this process and the extent of its impact on sap flow and taphole drying. Considerable research has demonstrated that sanitation of spouts, as well as droplines, is critical.[17] In general, sanitation strategies tend to produce sap yield improvements in the following order compared to nonsanitized systems (estimated annual net profits shown in parentheses following, assuming a sap yield of 15 gallons/tap (57 liters/tap) and sap value of $0.51/gallon):[18]

- Cleaning of spouts and droplines with bleach (15–30-minute contact time) ~76 percent ($2.04/tap)
- Check-Valve spouts or adapters ~69 percent, ($2.10/tap)
- Spout and dropline replacement on a 3-year rotation ~65 percent ($1.68/tap)
- Isopropyl alcohol ~63 percent ($1.52/tap)
- Zap-bac spouts ~42 percent ($1.48/tap)
- New standard spouts ~32 percent ($1.03)

Since annual replacement of spouts and droplines is costly both in terms of materials and the labor involved in construction and deployment of new droplines (in this case the dropline includes a new tee fitting as well since cutting a dropline off a tee will often result in a microleak), most producers

[16] It is the responsibility of producers to ensure that the sanitizer they choose to employ is registered with the appropriate U.S.A. or Canadian authorities for the intended use.

[17] Perkins, T.D., A.K. van den Berg, and S.L. Childs. 2019. A decade of spout and tubing research summarized. *Maple Syrup Digest*. Oct. pp. 8–15. https://mapleresearch.org/pub/1019sanitation-2/

[18] All currency values are in U.S. dollars as of 2022.

utilize a 3-year rotation of replacing droplines, with new spouts being used each of the next 2 years.[19] This practice results in a slightly lower average sap yield, but is more economical and practical. Often this approach entails dividing the sugarbush into three sections and replacing drops in one section each year. Old spouts are cut off at the end of each season and new spouts are placed on all droplines each year. Alternatively, spout adapters are used and replaced each year. This approach requires less time to implement in any one year and also minimizes the risk of a poor year impacting all the new drops simultaneously. This strategy results in relatively high sap yields (65 percent) over the 3-year rotation, but a slightly lower net economic profit (~$1.68/tap annually) than the latter two choices. Producers with very high sap yields of 20 gallon/tap (76 liters/tap) annually or above or those selling more of their product in retail (rather than bulk syrup) may be better served by switching to a 2-year rotation of droplines.

Check-Valve spouts were introduced into the market in 2010. This type of spout or adapter incorporates a small ball that serves as a one-way valve. When vacuum occurs in the tree, either in response to a vacuum pump or as a natural development in a tree during the freeze cycle, sap can move from the spout and dropline back into the taphole. Small pulses of sap backflow can also occur during the dump cycle of mechanical releasers when air is allowed into the system (hybrid and electric releasers are less prone to this problem). Also, when tubing system leaks occur, sap will often move up to tens of feet backward toward the tree. When these episodes of sap backflow happen, microbes within the spout and tubing are deposited within the taphole, where they elicit the wound response process that results in taphole drying. The use of a spout with a built-in check valve prevents this backflow of sap into the taphole. By maintaining highly sanitary conditions in the taphole, the valve promotes stronger and longer-lasting sap flows throughout the entire season. Use of Check-Valve spouts/adapters largely eliminates the need to periodically replace droplines—although new Check Valve spouts need to be used each year. When used, Check-Valve spouts produce sap yields only about 6–9 percent less than with dropline replacement; however the cost of materials and labor is substantially lower, thus net profits are slightly higher (~$2.10/tap, same assumptions as above) with this strategy than that found with a 3-year rotation of droplines and new spouts.

Cleaning and sanitizing of droplines, with or without the use of new spouts, can also provide improved sap yields. To be effective, the sanitizing solution must be in contact with the dropline/spout for a minimum of 5–10 minutes, and preferably 20–30 minutes. Therefore, sucking a sanitizing solution into the tubing system under vacuum is ineffective due to the lack of adequate contact time. Effective approaches are to either pump a bleach solution (200–400 parts per million [ppm]) into the tubing system from the bottom and allowing it to run out of each drop sequentially before capping it OR injecting 0.5–0.7 ounces (15–20 milliliters) of solution into each spout/dropline and allowing it to stand in place for a while before letting it drain. Draining as much of the residual sap as possible prior to application is also key to the effectiveness to these approaches. Sanitation is best done in the fall or early winter as it will help prevent recolonization and regrowth of microbes before the spring sap flow season. To prevent a salty off-flavor in the sap caused by bleach formulated with sodium hypochlorite, it is necessary to either flush the lines with potable water/permeate OR to allow the sap produced the first day to flow onto the ground when sodium bleach is used. Care should be taken to prevent bleach from getting on the outside of tubing to reduce the attractiveness of tubing to squirrels. The use of calcium-based bleach (calcium hypochlorite) rather than sodium hypochlorite might help to prevent animal problems. In general, bleach sanitization of tubing systems with adequate contact time produces excellent sap yield results (~76 percent), although the labor involved in cleaning and rinsing, or the loss of sap from allowing the first sap to run on the ground, reduces the net profit (~$2.04/

[19] Perkins, T.D. 2014. How often should you replace droplines? *The Maple News.* Feb. pp. 4–5. https://mapleresearch.org/pub/mn214drop-2/

tap) below that achieved with Check-Valve spouts. An alternative to treating the spout and drop in the sugarbush is to remove the spout and drop from the lateral line using a quick connect. Take them to the sugarhouse, where they can be submerged in the chlorine solution, rinsed, dried, and returned to the sugarbush during cool weather prior to tapping. This can be done with the same spout and drop for many years and first run sap does not need to be lost. To reduce the potential for vacuum leaks, care must be taken to ensure quick connects used are of high quality, mated with pieces from the same lot, and not placed under tension.

Isopropyl alcohol (IPA) is widely used as a sanitizing solution in maple tubing systems in Canada. When used for this purpose, IPA is injected into the spout/dropline and allowed to remain in the lines during the off-season, largely reducing microbial population and preventing regrowth. A second treatment in the fall is often employed. The first run of sap during the next season is allowed to run onto the ground to flush the alcohol from the tubing. IPA used in this way generates good sap yield results (63 percent improvement), but net profits (~$1.52) are somewhat lower than with the use of bleach or Check-Valve spouts/adapters, primarily due to the higher cost of the sanitizing solution, the increased labor expenses, and the cost of lost sap. It must be noted that IPA is not permitted for use in tubing systems in the United States since it is considered a pesticide by the U.S. EPA, and there is currently no registration in place permitting its use.

Other sanitizers tend to produce sap yields and net profits below those mentioned above—some of these are so ineffective that their use results in net revenue losses after material and labor costs are factored in.

Replacement of spouts annually is a common strategy for some maple producers. New spouts, being very clean and very close to the tree, have a strong influence on taphole sanitation. If new spouts are used each year, producers can expect a potential increase in sap yield on the order of 32 percent, resulting in an annual net profit (~$1.03), or about half the gain typically achieved with Check-Valves or bleach. Regardless, spout replacement is a simple approach that is less costly to implement and less labor intensive than other methods. Timing of spout and/or drop deployment does not seem to have any discernable impact on subsequent yield once temperatures have dropped below freezing in the fall.[20]

Another sanitization strategy relies on a spout lined with antimicrobial metals to prevent microbial growth in the taphole. The Zap-Bac™ spout or spout adapter (generally green in color) incorporates silver into the spout as an antimicrobial and should be replaced every 3 years. Efficacy appears to fall off over time. When this device is used, sap yield compared to that of a nonsanitized system, averaged over the 3 years, typically increases about 42 percent, resulting in an annual net profit (~$1.48/tap) somewhat lower than that achieved with the top-tier approaches, but within the same range as IPA sanitation. It should be noted that the use of antimicrobial silver is not permitted in most organic certifications, not due to the silver component, but rather due to the use of a nanoceramic carrier. The use of antimicrobial metals other than silver has not yet been extensively explored in the maple industry.

In summary, any type of effective spout and dropline sanitation strategy will produce increases in sap yield and tend to produce increased net profits; however the importance of sanitation varies considerably from year to year, largely as a result of temperature patterns during the season. Producers should evaluate the different approaches and choose the method that works best for their own operation.

Seating and Removing Spouts

Once the taphole is drilled, the spout must be placed in the hole and tapped securely in place. It is important to remember that spouts are "tapped" in, not pounded in like a nail. For that reason, tapping in of spouts is best accomplished with a small wooden, plastic, or rubber tapping mallet (**Figure 6.12**) designed

[20] Perkins, T.D., A.K. van den Berg, and W.T. Bosley. 2021. *Timing of spout and dropline deployment has no effect on sap yield. Maple Syrup Digest.* Sept. pp. 9–12. https://mapleresearch.org/pub/timing0921/

Figure 6.12. A hammer made for tapping maple trees will produce the best results. Heavy hammers, especially in inexperienced hands, often result in overdriving of spouts, reducing sap yield.

specifically for maple use rather than a carpenter's framing hammer. Regardless, care must be exercised during the process to get the spouts in securely, but not overdo it. The best indicator of when a spout is correctly seated is when the sound of the hammer hitting the spout changes to a lower pitch. At that point stop, or perhaps give the spout one final light hit to confirm the position is secure. The change in pitch is caused by the spout moving or not moving, it can be made to happen at any depth depending on how hard you hit it and how big your hammer is. It works when you hit the spout consistently and can be different for every person.

Overdriving the spout beyond the recommended amount can lead to poor results. Sap yields can be severely reduced by overdriving,[21] particularly if the spout is pounded in well beyond the correct point, and even more so if shallow tapholes are used. Overdriving of spouts may also split the wood, creating sap and vacuum leaks, and may lead to difficulties and damage to the tree when pulling spouts. Taking the time to teach new members of the tapping crew the proper way to tap will reap positive outcomes in terms of additional sap.

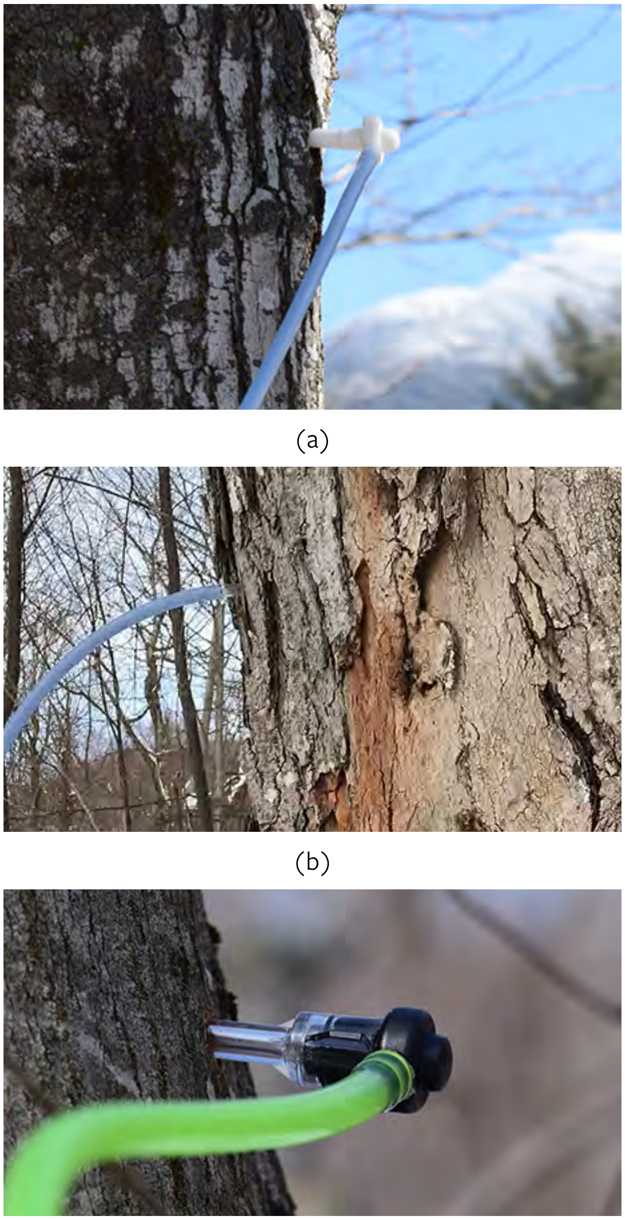
Older 7/16-inch spouts, have a pronounced taper. Seating of such spouts can be problematic as they must be snug enough in the taphole to hold the weight of a full bucket or bag or to stay in place if hit by a falling branch, but not pounded in so hard that they split the wood. Older plastic nylon spouts may deform over time, making seating of affected spouts problematic. If you observe spout deformation or frequent heaving from tapholes, replace them. It has been reported by some producers that 7/16-inch polycarbonate spouts do not hold well in tapholes, perhaps because they are too rigid and thus don't conform to tapholes well. It is suggested that producers using 7/16-inch spouts, whether plastic or metal, should consider tapping only when temperatures are above freezing to avoid these problems.

Smaller (5/16-, 19/64-, 1/4-inch) spouts have a much more gradual taper and are considerably easier to seat properly and appear to provide a tighter seal compared to 7/16-inch spouts. Some producers have found twisting these spouts in by hand with a quarter turn into the taphole will effectively seat the smaller spouts, but most producers using vacuum will use a hammer to ensure good seating and prevent air leakage.

While it is important to avoid damaging the tree by using excessive force to seat the spout, it is also necessary, particularly with vacuum sap collection, to maintain a good seal between the tree and the spout. A tight seal will prevent air from leaking in and will reduce spout heaving. Such loosening of spouts can occur when the trunk freezes and thaws repeatedly, leading to vacuum leaks, and reduced amounts of sap collected. Producers should check their spouts during the sugaring season, in particular after hard freezes, by looking for rapid sap movement through sap lines that indicates leaks caused by spouts loosening.

Spouts come in a wide variety of designs. For the most part there is little actual difference in performance as measured by sap yield (with a few exceptions). There are three basic types of spouts: standard spouts, straight-through spouts, and stub spouts with spout adapters (**Figure 6.13**). Standard spouts comprise the entire spout, both the part inserted into the tree and the end that connects to tubing. These spouts have a 30-, 45-, or 90-degree bend before the barbed end for tubing connection. Straight-through spouts have no bend—the tubing is merely pushed

[21] Perkins, T.D., W.T. Bosley, and A.K. van den Berg. 2020. The Goldilocks touch: overdriving spouts reduces sap yield. *The Maple News.* Sept. pp. 1,26. https://mapleresearch.org/pub/overdrive2020/



(a)

(b)

(c)

Figure 6.13. Standard 90-degree spouts (a), straight-through spouts (b), and stub spouts with spout adapters (c).

onto the hammer end of the spout after it is tapped into the tree. The advantages of straight-through spouts are simplicity and low cost. The disadvantage is difficulty in reseating if the spouts heave from the taphole. Stub/spout adapters are two-part: the spout adapter end is inserted into the tree and the stub is connected to the tubing. After the spout adapter is inserted into the tree, the stub is mated to the adapter and lightly tapped into place. The two-piece stub spout/spout adapter facilitates easy annual spout replacement and eliminates the shortening of droplines caused by cutting and replacing a one-piece spout, while the single-piece spout has fewer possible places where a leak could develop and eliminates the potential source of microbial contamination from the stub that remains in place. Spout adapters tend to be slightly cheaper than standard spouts, but do require the initial purchase of stub spouts. Often personal preference dictates the choice. Note that not all spout adapters will fit on all stub spouts.

Spouts also are now available in a wide array of colors. Studies have shown that without knowing whether it will be a hot or cold season there is no particular advantage to one color over another. Dark-colored spouts can heat up more during sunny periods without wind and thaw out faster. However, the dark color can be a disadvantage later in the season as these spouts may warm up to 30°F (15°C) above air temperature, resulting in rapid microbial proliferation in the taphole. Light-colored or clear (polycarbonate) spouts do not thaw as quickly, but also do not get overly hot. Moderately tinted spouts are intermediate. Over several years, sap yields from different color spouts tend to be about the same. Light-colored spouts may be of use in particularly warm sugarbushes or in southern maple producing areas, whereas dark-colored spouts may improve flows in cold sugarbushes or northern edges of the producing range. In general, however, spout color has little or unpredictable effects in any one season.[22]

Spouts should be removed from the tapholes shortly following the sugaring season. Care during spout removal will reduce injury to the cambium (the delicate layer of tissue below the bark that is responsible for new wood growth) and facilitate taphole closure. Spouts left in tapholes during the growing season will prevent or delay taphole closure and may cause additional injury when eventually removed. Plugging of tapholes after spout removal is not recommended as the plug could interfere

[22] Perkins, T.D., A.K. van den Berg, M.L. Isselhardt, B. Stowe, and W.T. Bosley. 2018. Does color matter? *The Maple News*. June/July. p. 9. https://mapleresearch.org/pub/spoutcolor-2/

with the tree's natural wound closure mechanisms as well as contribute to increased decay in the vicinity of the taphole.

Retapping or Reaming Existing Tapholes

Early tapping, a long maple season, or a prolonged warm spell during the maple season can result in excessive microorganism growth in tapholes. These conditions can cause a sharp reduction in sap flow as well as the production of lower quality sap. Practices that attempt to address this problem include redrilling the earlier taphole deeper, reaming it wider, or making new tapholes in the tree. Any potential sap yield lost by not retapping must be weighed against the costs of retapping (time, materials, etc.). It is also important to remember that retapping, even if done with fewer taps, increases the number or size of tapholes and therefore the number and size of wounds in the trees. Thus, the impact of these practices on sustainability is questionable at best.

Recent research has documented that the size of internal wounding from reamed or redrilled tapholes is significantly larger, sometimes double or more, than from single tapholes of the same size. A second taphole, even if immediately above the first, will generate a full, second staining column. Drilling close above or below a taphole drilled earlier in the season will generally not result in good sap flows since the wounding response happens relatively quickly (see **Figure 6.3**). In addition, the stain is often not perfectly linear (up and down), so while missing the staining column may generate more sap, it also creates another new wound column. For these reasons, none of these taphole rejuvenation practices are recommended.

Reaming tapholes that have become blocked by the growth of microorganisms is a method that has been used by some producers to rejuvenate sap flow in the taphole. While reaming, also called "freshening" or "bumping," may have less impact on the tree than creating a new taphole, it usually does not remove sufficient microorganisms, and those that remain grow back quickly, contaminating the sap and again quickly reducing or blocking flow. Success in increasing sap yield by reaming is largely a matter of timing. If tapholes have dried, but good weather will occur soon, reaming may produce a reasonable gain in sap. Whether it is economically beneficial depends mostly upon the cost of labor to ream and the amount of additional useable sap gathered. Renewed sap flow after reaming will usually be fairly short lived, and the quality of syrup produced will not necessarily improve. As a generalization, reaming of existing tapholes is not recommended. Related methods of inducing higher flow near the end of the season include drilling tapholes slightly deeper or placing a second taphole slightly above or below the first. Either method will produce a wound in the tree that can exceed by double or more the original taphole wound. The amount of additional sap gained depends on the weather occurring immediately after this procedure. Again, none of these approaches are recommended.

SAP COLLECTION AND TRANSFER

The methods of collecting and transferring sap to the sugarhouse vary significantly among maple syrup operations. These variations reflect size of the operation; purpose and/or objectives for tapping trees and producing syrup; equipment and financial resources available; availability of labor; and, perhaps most important, personal preference. Many maple operations rely on buckets or bags for collecting and transferring sap. Others use a tubing collection and transfer system, with or without the application of vacuum to increase sap yield. More recently, $\frac{3}{16}$-inch tubing systems have been introduced to enhance development of natural vacuum and reduce or eliminate the need for pumped vacuum. There are certainly advantages and disadvantages to each system; the choice between them depending on a great many factors, including size of operation, capital resources and planning horizon of the producer, characteristics of the sugarbush, and personal objectives of the producer.

Tubing systems significantly reduce the labor and time required during the sap season, and additionally have the potential to yield significantly more sap when vacuum is used. While tubing is the principal method of collecting sap in large maple operations, some small to moderate size producers continue to prefer buckets. Reasons given include a desire to maintain the traditional approach, the affordability of using existing equipment rather than investing in a new collection system (tubing), and the ease of monitoring the production of each tree with this method. One of the main advantages of using buckets is less maintenance—the whole system is taken down at the end of each season. Buckets and spouts can also be cleaned and sanitized easily, and there are generally fewer problems caused by animals. However, it must be emphasized that considerably more labor is required to collect sap during the season than that required for a well-designed and functioning tubing system. Further, older metal spouts and buckets can be a significant source of lead in maple syrup and must be replaced with new, lead-free, food-grade materials if their use is to be continued.

Sap Collection and Transfer with a Bucket/Bag System

Traditional sap collection systems use a bucket or bag suspended from a hook (**Figure 6.14**). Spouts designed for buckets incorporate a hook or other means for this purpose. Some producers instead will use tubing spouts with drops leading to buckets placed on the ground. Obviously, all sap collected in a bucket/bag collection system exudes from the tree due only to the pressure difference between the inside of the tree and outside air developed through freeze/thaw cycles (i.e., gravity flow) and not with the application of vacuum. Buckets must be emptied periodically; collected sap is transferred to larger gathering tanks for transport to the sugarhouse. The frequency of gathering will depend on the size of the collecting container and the rate of sap flow. A major requirement for producing syrup of the highest possible quality is to gather and process sap as quickly as possible. To minimize microbial growth (particularly during warm periods), sap should normally sit no more than a few hours in the collecting container. Buckets are the most common collecting container, and 16-quart galvanized buckets are the type most commonly used. However, sap buckets constructed of different material such as aluminum and plastic are available as well. The popularity of galvanized buckets is related, at least in part, to their historically low cost and perceived germicidal properties. Some believe that the minute quantity of zinc dissolved from the galvanized coating by the sap

(a)

(b)

Figure 6.14. Traditional systems collect sap in buckets (a) or bags (b) suspended on the spout. Some producers use plastic buckets placed on the ground with a tubing spout and dropline emptying into the bucket.

reduces microbial growth. While this may be true, any germicidal effect is nullified if the zinc coating is overlain with a film formed from the sap.

As a general rule, only buckets specifically manufactured for maple collection should be used. Many older buckets (including some galvanized) contain lead, either in the galvanizing coating, in the solder, or in the metal itself. These buckets are not acceptable for maple production and should not be used. Old terneplate or tin buckets also contain excessively high levels of lead and should not be used for sap collecting. No container capable of rusting should be used, and containers with thin galvanized coatings should be avoided as the coatings may quickly wear exposing a surface that will rust. Under no circumstances should a container that has ever contained a hazardous material be used for collecting sap. Non-food-grade plastic containers, including plastic trash containers and stock tanks (plastic or galvanized), are never suitable for sap collection. The formulations used in these containers may be made of materials that are unsuitable for food contact. For small producers, bakery pails that once contained icing or filling can be suitable, although these tend to be somewhat smaller than the typical maple bucket. Caution must be used to avoid reusing containers originally employed for strongly flavored materials such as pickle, pepper, or raspberry containers; otherwise syrup can develop "interesting" off-flavors caused by concentration of the sap during processing (jalapeno-flavored syrup does not typically make a good impression on contest judges or customers who are not expecting it). For very small home producers, 1-gallon (3.785-liter) milk jugs can be adapted, although they will quickly overfill. Many modest-sized producers will use spouts and droplines and have two or more taps run into one bucket. Note that the standard 5-gallon (19 liter) buckets found in hardware stores often come in food-grade and non-food-grade varieties. Always choose the former for maple sap or syrup. Any container, either new or formerly used, used to collect maple sap, should be washed well and copiously rinsed.

Sap buckets of different sizes are available. Caution should be exercised, however, in selecting smaller buckets as they may not have adequate capacity to hold the total amount of sap produced during a large sap run, and thus will require more frequent emptying. Large buckets, in the 20-quart range, are occasionally used in "cold" sugarbushes (higher altitude, north-facing slopes) where the cold temperatures and ice accumulation in the buckets may permit less frequent gathering.

Each bucket should have a cover to keep out rain and falling debris. Rain dilutes sap resulting in a lower sugar content that requires more sap, time, and fuel to produce the same amount of syrup. Debris is a physical contaminant that must be filtered out; additionally, it has the potential to introduce off-flavors or microorganisms. Covers also help to maintain cooler sap. Bucket covers come in two general types, those that attach with a wire pin to the spout and those that clamp to the bucket top. Note that covers that attach to the spout require spouts with a ring on the top for attachment. Also, if buckets are to be emptied by rotating (spinning) them on the spout, covers should be the kind that clamp to the bucket top.

While not as popular as buckets, plastic bags provide alternative sap-collecting containers that are used by some producers. Often-cited advantages of sap bags over buckets include the following:

- Their small bulk and weight mean they require less storage space and make them easier to transport and hang.
- They provide the spout and taphole greater protection from microorganisms.
- Bags are easier to empty; they can be rotated on the spout and dumped with one hand.
- They do not require a separate cover.
- The formation of ice during cold spells as well as exposure to sunlight may reduce microbial development.

Frequently cited disadvantages of sap bags include the following:

- They may break at the seams, particularly if the bag is full and the sap freezes.
- They may tear or be damaged by rodents.
- They are difficult to empty when filled with ice.
- The bag may be too small to hold a large run.

- Washing and rinsing bags may be difficult.
- Sap may warm rapidly in the sun.

Gathering and Transporting Sap—Bucket or Bag System

Gathering sap from a bucket or bag operation can be expensive and laborious unless an inexpensive labor source is available. It is essentially a hand operation, typically involving transferring sap from buckets or bags into a 3-to-5-gallon (11-to-19-liter) gathering pail and emptying this pail into a large collecting tank mounted on some form of carrier such as an ATV/tractor-drawn trailer or wagon. Buckets may be removed from the spouts and the sap dumped into the gathering pail, or an individual bucket may be dumped by rotating it on the spout. Care should be taken to minimize spillage and dislodging spouts, particularly when spinning buckets. Most plastic bags are emptied by rotating the bag on the spout so the collected sap flows into a gathering pail. Most sap collectors will carry two gathering pails to minimize the number of trips to the collecting tank and to balance out the load. Gathering pails should be clean and constructed of food-grade metal or plastic.

To reduce the effort of carrying pails, some producers use a suction pump to transfer sap from buckets to a larger tank mounted on a trailer or wagon. Food-grade hose should be employed for this practice, and care should be taken to use pumps that will not accidentally transfer lubricants or fuel into sap. A small number of producers use horses to pull the gathering tank.

As mentioned, sap should remain in the bucket, bag, or gathering pail for only a few hours before it is collected and processed, particularly during periods of warm temperature. During sap flow periods that produce insufficient volumes of sap to justify starting the evaporator, buckets should still be emptied even though this is time-consuming and expensive. Sap left standing in buckets for even short periods of time in warm weather will deteriorate in quality. Low-quality or spoiled sap that remains in the bucket or bag will contaminate the sap produced in subsequent runs, and any sap in storage tanks to which it is added. This sap should be dumped on the ground if not collected to boil. If spoiled sap is present in collecting, gathering, or storage tanks, these containers should be thoroughly cleaned and sanitized before they are again used for collecting or storing high-quality sap.

Sap collection or gathering tanks vary substantially both in design and size. Producers use sap collecting and transporting systems that take into consideration personal preferences, budget, available equipment, and the size and characteristics of the sugarbush. However, regardless of these limitations, only tanks constructed of materials appropriate for handling food products should be used. Commercial maple collecting (gathering) tanks are available in a range of sizes, and many have desirable features including a dumping port or drainpipe, splash-reducing baffle system, and a straining or filtering system. Tanks are commonly mounted on a trailer with runners (for snow) or wheels. Small collecting tanks should be mounted as low as possible to minimize the labor and effort required to dump the gathering pails and for stability. When large collecting tanks are used, some form of vacuum pumping system is desirable to lift the sap from a low sump tank into the collecting tank. Power for the pump can be supplied by a takeoff from the tractor or truck engine or from a portable gasoline engine. Transport power to move the collecting tank throughout the sugarbush can be provided by animal, tractor, truck, ATV, snowmobile, or other suitable vehicle.

Sap should be passed through a coarse filter before being transferred to storage tanks to remove debris (**Figure 6.15**). This filtering can be done either

Figure 6.15. Sap collected in buckets should be filtered or screened before it is transferred to the storage tanks. Depending on conditions and handling, a variety of debris can collect in the sap.

as the sap is poured into the collecting tanks or as it is being transferred from the collecting tanks to the storage tanks.

CLEANING AND CARE OF COLLECTION EQUIPMENT Sap collecting equipment should be kept as clean as possible, and ideally should be used only for collecting and holding maple sap. At the end of the maple season, buckets and reusable plastic bags should be thoroughly washed with hot water and bleach or a small amount of (unscented) detergent and thoroughly rinsed with potable water to remove all traces of the detergent. Available in a variety of sizes, bucket-washing brushes will markedly improve the speed and thoroughness of bucket cleaning. If bleach is used, thorough rinsing is a must. An acceptable alternative is to clean and sanitize buckets at the end of the season with high-pressure steam. Some producers also rewash buckets/bags during the season with a water/ bleach solution and triple rinse them thoroughly with water to remove any built-up film of sugar and microorganisms. While time-consuming, this practice can, particularly during maple seasons with a prolonged warm period, result in the production of much higher quality syrup during the latter part of the season.

After rinsing, buckets/bags should be drain dried and stacked for storage. It is important that this post-season cleaning not be postponed. The thin layer of dried sap on the surface of the buckets/ bags will support the growth of microorganisms. If washing is delayed, it becomes increasingly difficult to remove sap and debris accumulations. Prior to use in the spring, buckets should be washed with hot water, sanitized with a 200 ppm bleach solution (0.55 ounces of 5 percent bleach per 1 gallon water), and thoroughly rinsed with hot water to remove all traces of the bleach solution.

At the end of the season and prior to first use, gathering pails and collecting tanks should be cleaned in the same manner as buckets. In addition, they should be rinsed with hot water at the end of each workday to remove the coating of sap. If this is not done, microorganisms can grow on the surface of these containers and contaminate subsequent sap during collection. Thorough washing followed by extensive rinsing will be helpful in maintaining sap quality. Clean sap, free from any contaminants, is necessary to produce syrup of the highest quality and best flavor.

Sap Collection and Transfer with Plastic Tubing

The introduction of relatively inexpensive plastic tubing for maple sap collection in the 1950s has been recognized as one of the major factors in maintaining the economic viability and overall significance of the pure maple industry. The use of tubing has greatly reduced the amount of labor required for sap collection during the sugaring season and has enabled maple operations with thousands of taps to operate effectively with a minimum of personnel. While buckets and bags are effective in collecting sap, their use is highly labor intensive, requiring frequent emptying and collection by hand. Plastic tubing with accompanying spouts permits sap from all the tapholes in a sugarbush or section of a sugarbush to flow into a network of conduits, and from there, directly to a collection tank. Benefits of collecting using tubing are several, and include reduced traffic and soil compaction in the sugarbush; the ability to more easily bring sap across swampy areas, ravines, or other barriers; the convenience of having a collection system set up year-round, ready to go in the spring (this can also be a hindrance, as sections of tubing are sometimes damaged during the off-season); and potentially higher sap yields if vacuum is employed with the tubing system. Since the introduction of plastic tubing systems, several improvements in their design, manufacture, and application have been made. The plastic tubing networks used today are highly efficient, and those using mechanical vacuum pumps are considered state-of-the-art sap collection systems in the commercial maple industry.

Originally lateral lines in plastic tubing systems were ¼-inch nominal inside diameter (I.D.). The majority of plastic tubing used in current maple lateral lines is 5⁄16-inch I.D.; however a fairly recent innovation is the use of 3⁄16-inch I.D. tubing (**Figure 6.16**). Due to the capillarity and cohesiveness of water molecules (the major constituent of sap), a natural vacuum can develop in this smaller diameter tubing when it is filled with sap running downhill.

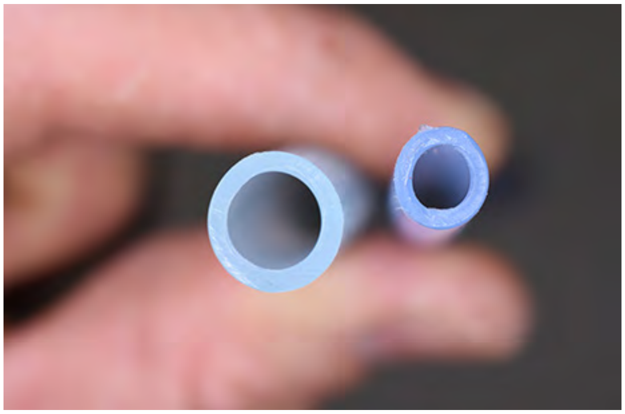


FIGURE 6.16. Two common sizes of lateral and dropline maple tubing are currently in use; 5/16-inch tubing (left) is used for gravity tubing on level ground and for most pumped vacuum systems; 3/16-inch tubing (right) is used on sloped ground for natural vacuum systems and in hybrid pumped/natural vacuum applications.

While it is possible to create natural vacuum within 5/16-inch tubing, achieving and maintaining vacuum in such tubing systems is difficult and has some drawbacks. In a leak-free system, maximum vacuum levels can be achieved in 3/16-inch tubing given sufficient elevation drop. Interestingly, pumped vacuum and natural vacuum are additive, so that the use of a small pump (such as a diaphragm pump) can be used to create a low base-level vacuum, which along with a modest drop in elevation will result in maximum vacuum (as determined by site elevation and barometric pressure), often higher than that able to be reached by the best pumps.

TUBING SYSTEM CONCEPTS In order for a tubing sap collection system to operate efficiently, it is essential that a few basic concepts be understood and followed. These are relatively simple, but if not followed can lead to installation difficulties and operational inefficiencies.

1. Tubing systems should be designed to handle anticipated peak sap flows, but not oversized to the point where sap gets highly overheated during low flow periods.
2. All systems should be designed so gravity will passively move sap through the system. When tubing is properly installed, it is generally tight and straight and slopes continuously downhill (**Figure 6.17**). Lateral lines in particular should have a constant downhill pitch as steep as practical. Mainlines should run generally along the contour, but with a slight continuous downhill pitch, typically under 5 percent.
3. Sags and abrupt turns or changes in pitch in tubing systems, particularly in mainlines, impedes the smooth flow of sap (and air in pumped vacuum systems) and should be eliminated to the extent possible. Turbulence in mainlines is to be avoided.
4. Tubing systems for vacuum are constructed differently than systems that rely

FIGURE 6.17. Schematic of a typical tubing system on a slope. Tubing systems should be installed tight, straight, and generally downhill. The primary (trunk) mainline (dark blue) runs straight up the hill. This mainline would be either larger in diameter or a dual conductor system. Secondary (spur) mainlines (green) run across slope, at a slight uphill angle and are connected to the primary mainline with fittings or via a manifold (if the primary is a dual conductor system). Secondary mainlines are spaced as tree density dictates, but typically 100–150 feet (30–45 meters) apart. Lateral lines (light blue) run mostly uphill, deviating slightly to intersect one to ten crop trees if 5/16-inch tubing is used with a maximum length of 150 feet (45 meters). If 3/16-inch tubing is employed, far fewer secondary mainlines are used and lateral lines can be very long (up to several hundreds of feet), intersecting twenty to thirty-five taps. Local topography and tree locations dictate tubing system layout.

on gravity alone for sap movement, both in terms of the number of taps on each $\frac{5}{16}$-inch lateral line (*strive for five, no more than ten* on vacuum, up to thirty-five without vacuum) and on $\frac{3}{16}$-inch lateral lines (fifteen to thirty-five taps per lateral with or without supplemental mechanical vacuum), and also in mainline tubing sizing.

5. Pumped vacuum system mainlines are designed to move air rapidly from the system in addition to moving sap, so more air space is needed at the top of pumped vacuum mainlines than at the top of gravity mainlines. Therefore, mainlines for vacuum systems are generally larger in diameter than gravity mainlines.
6. Generally, tubing systems should be as simple and direct as possible, with the fewest fittings possible (fittings reduce the internal diameter of lines and may restrict efficient sap movement and provide locations for potential leaks) and should incorporate the minimum number of mainline diameters feasible, to facilitate easy repair.
7. Tubing systems can contaminate fresh sap unless they can drain fully and can be kept clean. Sap sitting in lines between runs or moving slowly during low flow periods (especially on low slopes or open areas) can heat up and ferment, producing sour sap and off-flavor syrup.
8. Tubing systems must be regularly inspected and maintained to minimize sap leaks and vacuum loss and are often cleaned in some manner after each sap season.
9. Vacuum tubing systems should incorporate ways to facilitate leak checking such as saddle loops, valves, gauges, and/or electronic sensors to facilitate rapid detection and correction of leaks or other problems.
10. Although the longevity of new installations has not been adequately established (and can vary widely with tubing quality), it is thought that tubing systems typically need to be replaced every 15–20 years to accommodate aging and deterioration of the plastic, as well as in-growth of new trees and mortality of old trees. Droplines, fittings, and lateral lines typically do not last as long as mainlines.

A properly designed, installed, and operating tubing system will substantially reduce the amount of labor associated with sap collection and produce higher sap yields. Designing and installing an efficient sap collection system can be challenging. Consulting nearby producers who have achieved good sap yields or drawing on the knowledge and experience of local maple equipment dealers is well worth the time. Often employing the services of a professional tubing installer is a good idea (ask for and check references from recent customers). Although the cost for a good tubing installation might seem high (averaging $7.50–$20/tap U.S. as of the time of this writing, depending greatly upon the number of taps per lateral line), the gain in sap production from a well-designed and installed system can result in a fairly rapid payback time. Deviations from good practices do not necessarily mean that you won't get any sap, but rather that the cumulative effect of small errors can add up to significantly reduced sap flows and lower-quality sap. Additionally, it is possible to obtain larger sap yields from properly installed and maintained systems.

The trend in $\frac{5}{16}$-inch vacuum pipeline systems over the past decade has been toward shorter lateral lines with fewer taps. New installations often average three or fewer taps per lateral line. This necessitates more mainline since the shorter lateral line runs mean more frequent mainline spurs. These systems regularly achieve yields of more than 0.5 gallons/tap (1.9 liters/tap or 5.5 pounds/tap) of syrup if high vacuum and good sanitation is maintained. Conversely, some new systems with long laterals and higher tap counts per lateral can also realize high yields. The primary determinant is how well vacuum is transferred from the releaser to the end of the mainline (releaser vacuum minus end-of-mainline vacuum). High vacuum and a small difference in vacuum between these two points is desirable, with good results typical for systems that attain those goals.

DESIGN OF TUBING SYSTEMS A tubing system consists of a network of plastic lines of various diameters, resembling a number of small streams flowing into a larger river and ultimately into a reservoir. The trees, with spouts and droplines (vertical) attached can be thought of as the individual springs from which the liquid is derived. The smallest "streams" are the lateral lines of 3⁄16-inch or 5⁄16-inch tubing that pass (horizontally) from tree to tree. Sap from the lateral line "streams" flows into mainlines, the larger "rivers," which are generally ¾-inch in diameter or larger. Sap from these mainlines may flow into larger mainlines, sometimes called conductor systems, that transfer sap to storage tanks. In most pumped vacuum systems, sap would flow through a releaser, usually located near the storage tanks "lakes."

To design an efficient tubing collection system for a particular sugarbush, it is necessary to plan carefully before installation begins. Since most tubing systems are not taken down each year, before starting a new installation, completing any necessary forest management activities (thinning, road building, etc.) is generally recommended (see **Chapter 5**). The tubing network should be designed to accommodate the number and distribution of tappable trees as well as the prevailing topography. Planning can often be facilitated using a topographic map of the sugarbush or satellite images and a thorough inspection of the property to be tubed. The tubing map that is created should show the location of the sugarhouse or sap collection point, roadways, streams, topological details, property lines, and other significant features. Many producers have found it helpful to locate individual or groups of maple trees on the map as well. It will be helpful if the finished map is drawn with good detail.

One purpose of a sugarbush inventory and resulting map is to assist in planning the location of collection tanks and main tubing lines. The most critical first step for a tubing collection system is determining the location and height of the collection tank or releaser. Normally these will be at or near the lowest point in the sugarbush with good access. In some sugarbushes it is possible to locate the collection tank near or at the sugarhouse; however, in many cases, sap will need to flow to a collection station some distance from the sugarhouse and be pumped or transported by truck or tractor from there to a tank at the sugarhouse.

TYPES OF TUBING SYSTEMS There are four major types of maple tubing systems based primarily upon the types of lateral lines used:

- Pumped vacuum tubing systems (generally 5⁄16-inch I.D. lateral lines)
- Gravity tubing systems (generally 5⁄16-inch I.D. lateral lines)
- Natural vacuum tubing systems (generally 3⁄16-inch I.D. lateral lines)
- Natural/pumped vacuum hybrid systems (3⁄16-inch I.D. lateral lines)

Each of these systems has certain characteristics and advantages and disadvantages outlined in **Table 6.2**.

Many producers who set up a tubing system intend to use vacuum to maximize sap yield. Increases of 50–100 percent (or more) in sap yield may be achieved with a well-designed, installed, and maintained vacuum system. Some sugarmakers may choose to collect sap using tubing without a vacuum pump using either a 5⁄16-inch gravity system or a 3⁄16-inch system with natural vacuum. There are many similarities, but also some key differences in the way each type of tubing system should be set up. Even if a pump is not employed initially, it is often wise to consider preparing the system for the incorporation of vacuum if there is any possibility that a it might be added in the future. Such obstacles as the lack of electrical service or the need for remote starting of pumps can often be overcome with technology and equipment available through many maple equipment dealers. For those producers who are certain that a vacuum pump will never be added to the tubing system, the installation of 5⁄16-inch lateral lines on gravity or 3⁄16-inch lateral lines installed to

TABLE 6.2 General characteristics of different types of tubing systems.

Tubing System Type	Pumped Vacuum Tubing 5⁄16″	Gravity Tubing 5⁄16″	Natural Vacuum Tubing 3⁄16″	Natural Pumped Hybrid 3⁄16″
Relative Cost	Mod–High	Low	Low	Moderate
Relative Sap Yield	High	Low	High	High
Vacuum Pump Needed	Yes	No	No	Yes
Slope Required[1] (%)	2+	2+	5+	5+
Number of Taps per Lateral Line	1–10	10–75	15–35	15–35
Maximum Length of Lateral Lines (ft)	150	500+	500+	500+
Releaser Needed[2]	Yes	No	No	No
Installation Difficulty	Moderate	Simple	Moderate	Moderate
Degree of Maintenance	Moderate–High	Low–Moderate	High	High

[1] Although slopes of 2 percent or higher are optimal, tubing installations are possible on slopes as low as ½ percent if extreme care is taken during installation to avoid sags and sap lifts/ladders are employed as necessary. Tubing installations for natural vacuum perform best on slopes of 5 percent or more and are not indicated for flat ground.

[2] A releaser may not be necessary with certain types of pumps (diaphragm, peristaltic), but is with most other pumps.

maximize natural vacuum may be better choices. Otherwise, designing a tubing system that can accommodate expanded operations and the addition of vacuum in the future might be a better option.

LOCATING MAINLINES AND LATERALS "Mainlines" in a tubing system are the larger pipes (typically ¾ inch or larger) used to transfer sap to the collection tank in as direct a path as possible. Mainlines must be installed on a fairly consistently downward slope, without dips, sags, or abrupt changes in pitch or direction, and are usually supported on wire and strung tightly along the mainline path and often supported with posts (**Figure 6.18**). An alternative configuration called Rapitube™ available from CDL Sugaring Equipment (Les équipements d'érablière CDL) does not require mainline wire and thus can be faster to install. The tubing must be stretched to 10 percent more than its slack length during installation and supported with posts and tie-backs at frequent intervals with side ties (**Figure 6.19**) to prevent sagging when the pipe is full of liquid.

Figure 6.18. Standard maple mainline supported on wire and kept in position with posts. The three lines represent wet and dry conductor lines and a pump line.

Figure 6.19. An alternative to standard mainline wire installations, CDL Sugaring Equipment Rapitube™ allows quick installation with minimal infrastructure. Proper tensioning is required with this product. Frequent side ties or posts should be used to prevent sagging when the pipe is filled with liquid.

Mainlines are not easy to relocate once installed and are hence considered a permanent part of the tubing system; thus their location must be carefully chosen. Location of mainlines depends on the location and density of tappable trees present in the sugarbush, and often follows the natural surface drainage pattern in the sugarbush. Where a uniform slope is present, line location is somewhat arbitrary as long as all tappable trees are nearly equally accessible and their location facilitates the proper layout of the lateral lines.

Where natural slope exists, lateral lines ($\frac{3}{16}$-inch or $\frac{5}{16}$-inch I.D. tubing) branching off mainlines should run up the slope from the mainlines, rather than across the slope. This arrangement will produce the best flows and maximize natural vacuum, which can be readily developed in $\frac{3}{16}$-inch tubing and sometimes achieved in $\frac{5}{16}$-inch lateral lines when they are full. Some producers may be tempted to put out fewer mainlines than are necessary, as mainline installation is more time-consuming and expensive than installation of $\frac{5}{16}$-inch (lateral) lines. Too few mainlines will result in wide spacing between mainlines, which will necessitate long lateral lines. Long $\frac{5}{16}$-inch lateral lines with many taps on each line are inefficient for moving sap or transferring vacuum from a distant pump; furthermore, long lateral lines are prone to sagging. Additionally, if mainlines are far apart, they need to be of large diameter for good movement of sap and vacuum. Large diameter mainlines are more expensive and bulkier to move through the woods, as well as more difficult to install. For these reasons, present practice holds that the most efficient system is one with many mainlines that are located fairly close together. Vacuum transfer and sap flow are most efficient when there are no more than five to seven taps (maximum ten) connected to each $\frac{5}{16}$-inch lateral line. To limit taps to this number, most producers with vacuum systems have the mainlines installed about 150 feet apart from one another. Density of trees is also an important factor to consider in the overall system design.

An alternative viewpoint, more common in Canada than in the U.S., suggests that fewer mainlines and longer lateral lines can also be effective. This approach offers several possible advantages: lateral lines are quicker and cheaper to install than mainline and wire, woods roads are easier to install and maintain, tubing system maintenance is simpler, particularly if a tree falls, and sap may not heat up as much during warm spells with low flow. Drawbacks include somewhat lower sap yields and a higher degree of effort required when leak checking.

Unless one has considerable experience in setting up a tubing system, it is best to mark out the location of mainlines as part of the inspection and planning before they are installed. Plastic flagging or tree-marking paint is useful for this task (note that organic certification or lease arrangements might restrict permanent marking methods). A slope of 2–4 percent is ideal for a mainline: a slope of 1 percent is considered the minimum requirement, but great care needs to be exercised to avoid sags along the entire length of the flat area. With extreme care, experienced installers can set up tubing systems in areas with slopes as low as ½ percent. Slope is best determined using a sight level, Abney level, or transit. The length of mainline sections should be measured to determine the length and sizes of mainline and the fittings required.

MAINLINE SIZE The size of the mainline plays a critical role in determining the efficiency of sap flow and vacuum transfer. The line must be sized to accommodate peak flows while allowing adequate vacuum transfer. In a gravity system, mainlines should be a maximum of two-thirds full at peak sap flows. A good guideline is to assume 3–5 gallons per minute (11–19 liters per minute) per 1,000 taps at peak sap flow. For vacuum systems, mainlines should never be more than one-half full when sap is running hard—one-third full is even better. This is because in vacuum systems sap moves across the bottom half of the lines and air (from leaks and tree gases) moves across the upper portion of the mainline. Air naturally moves about ten times faster than liquid in a pipeline. If both air and liquid move within the same space, mixing of sap and air results in turbulence and movement of both is impeded. Smaller diameter mainlines are very susceptible to restrictions and turbulence. Most mainlines range from ¾ inch to 2 inches in diameter. Mainlines smaller than ¾ inch are not recommended because of their reduced ability to transfer sap and vacuum. In fact, it is questionable whether producers using vacuum should install ¾-inch mainline if they wish to achieve high yields. For example, consider a 1-inch mainline under gravity conditions. If the lower two thirds of the pipe is full of sap and the upper one third is filled with air, a sag of only ¼ inch will reduce the ability to move air by 76 percent. Likewise, in a 1-inch mainline that is half full of sap and half filled with air, the same sag will reduce air removal via the pump by 50 percent. Clearly, pipes sized too small will suffer if sap loads are high or if there are sags or other installation/maintenance problems that introduce turbulence.

The number of taps entering a mainline from the collection of lateral lines determines how much sap will be in the mainline. The more taps on a mainline and the longer the length of tubing, the larger the tubing diameter must be. How large should a mainline be to accommodate both sap and air? If the secondary mainlines are approximately 150 feet (46 meters) apart, then an area of the sugarbush that is about 150 feet (46 meters) by 1,000 feet (305 meters), or about 3.5 acres (1.4 hectares), will drain into each mainline. At a normal density of 70 to 90 taps per acre (170 to 220 taps per hectare), a ¾-inch or 1-inch mainline (considering the slope and potential size of runs as discussed below) that is no longer than 1,000 feet (305 meters) will be adequate size for handling the sap from this number of taps during periods of maximum flow. In larger operations (> 2,000 taps), 1-inch mainline is typically the smallest size employed, with runs of 3,000–4,000 feet found. If the line is placed at the bottom of a drainage, and lateral lines feed into it from both sides, the area of sugarbush feeding this one line could be as much as 300 feet by 1,000 feet (92 meters by 305 meters) and a 1-inch mainline should be used. As secondary mainlines are joined, the size of the downstream mainline will need to be increased, perhaps to 1–1½ inches in diameter. A wet/dry conductor system, described in a later section, should be considered for very long runs of mainline and areas with a high density of taps. Maple equipment dealers or Extension educators should be consulted about recommended mainline sizes as research on proper sizing continues.

Recommendations of the appropriate number of taps for mainlines of different sizes vary somewhat throughout the maple region, and occasionally among knowledgeable producers and tubing installers within a region. Some of this variation may be due to tradition, but some is certainly the result of different producer or installer experience and differences in the peak sap flows that are expected. These differences can be the result of geographic location, tree size, tree health, and tubing system design, including the number of taps per tree and the amount of vacuum, and other factors. Keep in mind that a tubing system on vacuum could produce twice the amount of sap as a system without vacuum.

MAINLINE SYSTEMS ON SLOPES The number of taps commonly recommended for different size mainline on three slope conditions—slopes of less than 5 percent, slopes of 5–10 percent, and those greater than 10 percent are provided in **Table 6.3**. Note that a range of tap numbers is provided for each combination of mainline size and slope. This range reflects the variability described above. It is suggested that producers planning on upgrading a tubing installation discuss mainline sizing with those familiar with successful tubing installation in their area. Note also that the appropriate number of taps for a mainline in a specific situation should rarely exceed those recommended in the table but could often be less than the maximum number recommended due to local conditions, particularly the expected size of the larger sap runs. It is often better

TABLE 6.3 Simplified chart of number of taps by mainline diameter and slope. For more complex installations, consultation of mainline sizing worksheets available through maple equipment dealers, Extension personnel, or the *New York State Maple Tubing and Vacuum System Notebook*[1] or *Cahier de transfert technologique en acériculture*[2] is highly recommended.

Mainline Diameter (inches)	Percent Slope		
	<5	5–10	>10
	Number of Taps		
¾	<400	300–500	300–600
1	<700	400–900	600–1,100
1¼	<1,100	900–1,400	900–1,800
1½	<1,600	1,200–2,000	1,200–2,600

[1] Childs, S.L. 2015. New York State Tubing and Vacuum System Notebook. Cornell Maple Program. 283pp. https://mapleresearch.org/pub/tubing-notebook-6th-edition-2/

[2] https://www.craaq.qc.ca/Publications-du-CRAAQ/cahier-de-transfert-technologique-en-acericulture/p/PEDI0190

to slightly upsize and maintain a constant diameter of mainline for an entire system than to start small at the far end and increase size as you get closer to the tank or releaser. This approach standardizes the size of fittings and required tools and makes repairs on the system far easier.

Although sap moves faster as slope increases, and therefore more sap can be moved through a mainline on a steep slope than can flow through the same-sized mainline on a shallow slope without filling the pipe more than one-third full, steep mainline installation is not recommended. Where the mainline levels out following a steep section, it is likely to fill with sap or become excessively turbulent. In either case, the removal of air from the upstream sections will be blocked and the vacuum at the taps will be reduced. A maximum mainline slope of 4 to 5 percent should be the goal of installations even on steep land; with the lines placed across the slope rather than straight up and down. An option that can be used where slope changes are unavoidable is to install a second line or dry line over the area where the slope flattens out to allow vacuum air flow to pass over the turbulent area.

MAINLINE SYSTEMS ON FLAT GROUND When a tubing system is installed on very flat ground, it may not be possible to achieve the ideal or recommended slope in the mainline; but it is critical that there is at least enough pitch to allow the sap to drain by gravity. A slope as low as ½ percent for the mainline can work, as long as the line is very tight with no sags (when the line is full) and the grade is consistently downhill. Installations generally are more successful however with 1 percent or more grade. Where the ground is flat, slope can be artificially introduced by installing the line higher off the ground at the far end of the sugarbush, up to a practical height of about 6 feet (1.8 meters). Mainlines on very flat ground may have to be shorter than 1,000 feet (305 meters), necessitating dividing the woods into compartments with several remote tanks, each serving a group of mainlines. Care should be taken in measuring the slope of the line to ensure that there are no flat spots or dips. Line slope should be remeasured periodically, as even small changes in ground level that occur naturally from soil freezing and thawing can eliminate or reverse the slope of mainlines in areas with little pitch. Mainlines on very flat land may need to be larger than ¾ inch, particularly as the lengths approach 1,000 feet long. Lines that are 1–1¼ inches in diameter are usually the smallest that sugarmakers should use on flat ground, especially if mechanical vacuum is used.

MAINLINE TUBING TYPES AND COLOR Currently commercially available maple tubing and black water pipe approved for potable water are both commonly used for mainlines. Black water pipe is quite rigid and totally opaque; some producers prefer a softer, translucent (usually blue) mainline. This material is more expensive than water pipe but somewhat easier to work with, and it is possible to see sap movement through the walls of the tubing. Dark green or orange pipeline should be avoided in most cases, as these plastics may not be suitable for food applications.

Use only plastic tubing that has been appropriately tested and labeled. All plastic tubing contains chemical plasticizers that affect the pliability of the tubing. With untested tubing, there is no assurance that the plasticizers or other chemicals in the tubing will not leach into the sap at levels that may present a health hazard.

Mainline color will affect the heating of the sap within the pipe. In colder, north- or east-facing sugarbushes, or in the lower parts of very deep valleys, it may be preferable to have all black lines, so that any sun striking them will help thaw sap that may be frozen inside. On south- or west-facing slopes, where mainlines cross open areas, or in regions where daytime temperatures are often well above freezing during the sap collecting season, light-colored tubing may be preferable to prevent heating and fermentation of sap within the lines, especially during slow flow periods, to increase the potential for producing high-quality syrup. Excessive fermentation of sap in mainlines is more frequent during the late season, leading to sour off-flavors in affected syrup. Producers used to paint black tubing with white latex paint to reduce solar heating—this is no longer recommended. White pipe can take a long time to thaw without direct sun. With high vacuum, mainline tubing, particularly dark-colored water-pipe, may collapse when exposed to the sun or high temperatures—a thicker-walled pipe with a higher pressure rating should be used in these settings.

MAINLINE SUPPORT—WIRE INSTALLATION

Mainlines must be tied to a rigid support wire in order to support the mainline without sags when it is filled with liquid. Producers typically use either 9- or 12.5-gauge high-tensile wire for this support. Both are about equal in regard to strength; 12.5-gauge wire is less expensive and will not stretch over time, but is somewhat more difficult to handle, kinks more readily, and can be more difficult to install. Use care when installing mainline wire, as tensioned/stretched wire is dangerous if it breaks. In particularly flat areas the use of 9-gauge high-tensile wire can be helpful.

Once the location of mainlines has been determined, the support wire should be installed. There are two basic methods for installing mainline support wire: (1) making the wire initially very tight with a fence wire tensioner (**Figure 6.20**) and (2) installing it somewhat loosely and then pulling it tight with side ties (**Figure 6.21**). While the first method usually requires the least maintenance over time and results in the shortest possible mainline, the second method can be useful if one needs access to the woods with a vehicle for thinning or other activities, as the line can be laid on the ground without disconnecting the pipeline once the side ties are loosened. Many producers employ both methods in supporting and tensioning mainlines. The object of each of these methods is to erect a wire that does not sag and can support a mainline full of sap.

Figure 6.20. Tightening mainline support wire with a fence wire tensioner

Figure 6.21. Tightening mainline support wire with side ties. This approach allows relatively easy adjustment of mainline grade if necessary.

To begin wire installation, the wire is first pulled into the sugarbush on a predetermined path, played out from a wire spooler (**Figure 6.22**) or by a helper who is unspooling the coil to avoid kinks (see "Installing Lateral Tubing" below). Some producers prefer to install a single length of wire to the point where the mainline will end, while others prefer to install wire in approximately 500-foot (152.5-meter) sections so that a break in the wire will not affect the whole line. If the latter method is used, one wire can be ended and the next one started at the same tree, and the mainline passed from one wire to the

Figure 6.22. A wire spooler is a useful tool for avoiding kinks when pulling mainline support wire through the sugarbush.

(a)

(b)

Figure 6.23. J hook (a) and mainline wire looped and secured around a tree (b) can be used to anchor mainline support wire to a tree or post.

next without interruption. The wire must be firmly anchored at the last tree or to another stable support such as a post or ground anchor. This can be done by mounting a "J"-shaped or closed end hook on the tree (select a non-crop tree if possible) or post (**Figure 6.23** top), or by forming a loop around the tree (post) (**Figure 6.23** bottom) and anchoring the wire to itself with some form of wire splice (e.g., Gripple, **Figure 6.24**) or a knot (**Figure 6.23** top). If it passes around the tree, the wire should be encased in a short section of tubing to protect the tree. Even with this protection, the loop around the end tree should be moved up or down every year or two to prevent damage to the tree. Slats of pressure treated or decay-resistant wood between the tree and this protective tubing will allow the wire to be moved up and down more easily. The wire is then cut and fastened at the other end. If a fence wire tensioner is used, it is usually attached at the lower end of the wire.

The wire should be supported in such a way that it maintains as uniform a grade as possible. If there are small trees along the path of the wire, these can be used for support, or the wire can be pulled to trees with side ties. However, the support wire should not zigzag excessively. If adequate support trees are not available, cedar posts, pressure treated lumber, or steel posts can be used (**Figure 6.18**). Wire that follows a 4–5 percent grade needs support about every 40 feet (12 meters). Wire that extends over a flatter grade needs supports placed more closely to prevent sagging. On flat land of 1 percent or less slope, support is critical because even slight sagging could cause a failure of the sap to drain, resulting in sap freezing in mainlines and transient blockages. Supporting these installations at intervals of 10 feet (3 meters) may be necessary. For tying to trees or side-tying to tension the main wire, #12 or #14 soft wire is usually used. This size wire will usually break before the mainline wire gives way if a large branch or tree falls

Figure 6.24. Wire splice (Gripple) being applied to tensioned mainline support wire.

on the mainline, thus sparing the producer a major repair. Side-tying wire is looped around the mainline support wire and twisted around itself, then looped around a tree inside a short piece of tubing (¾-inch mainline works well) to protect the bark and brought back again to the mainline wire (**Figure 6.21**).

MAINLINE TUBING INSTALLATION Mainline tubing is installed following the path of the support wire. As mainline comes in large rolls, it is best not to carry the whole roll into the woods, but instead to pull the free end while the coil is unrolled by a helper (**Figure 6.25**) or set on a spooler that can turn smoothly (**Figure 6.26**). If there is snow on the ground, mainline can sometimes be unrolled by setting the whole coil on the ground and driving wooden stakes through the center of the roll into the ground; the coil turns easily on the snow and is unrolled as if it were on a spooler.

At the end of the support wire, the tubing is plugged, or a valve installed and fastened to a hook, or by some other method to the tree (**Figure 6.27**). Some producers like to install a valve at the end of the line as an aid in washing the mainline or for use as a tool in leak detection. The line is initially secured to the support wire using a wire tie about every 10 feet (3 meters). At the end of the support wire, the tubing is passed through a tubing grip and pulled tight by hand (**Figure 6.28**). Using a mechanical tensioner to tighten the tubing is not recommended (except in the case of Rapitube, which does require tensioning). The tubing may need to be retightened in a few days if it becomes loose on the support wire, particularly if the air temperature rises after installation. Once the tubing is tight, installation of wire ties every 10–12 inches (25–30 centimeters) should be completed so that the mainline tubing is firmly attached to the support wire.

Fittings, either plastic or stainless steel, are used to attach lengths of mainline tubing together. Stainless fittings are generally preferred since the

Figure 6.25. An effective way to distribute mainline in the woods is for one person to pull the free end while the coil is unrolled by a helper.

Figure 6.26. A mainline spooler can be used to easily uncoil tubing as it is pulled into the woods. These are sometimes mounted on ATV-towed trailers for easy transport and maneuvering in the woods.

(a)

(b)

Figure 6.27. At the upper end of the mainline a plug (a) or a valve (b) can be installed. The valve is more versatile since it can be used during tubing cleaning.

Figure 6.28. Tubing grip on end of mainline used to pull tubing "hand-tight."

reduced thickness creates less turbulence and are less likely to form ice dams.

Quick disconnects may be helpful where the mainline (but not mainline wire) crosses a road so it can be uncoupled when not in use. To prevent sagging across the gap, side ties or bungees can be used to add tension when the tubing is in use, or a short length of wire tightened with a load binder can be used to bridge the gap. Good-quality disconnects are recommended to eliminate vacuum leaks—lower-quality disconnects will leak under tension.

With most mainline materials, particularly black water pipe, it is not possible to push fittings on by hand. The recommended installation method is to use a mainline installation tool, which grips the tubing and holds it in place, then pushes the tubing over both sides of the fitting as a crank that closes the tool is turned (**Figure 6.29**). The tubing does not need to be heated when using this tool. Alternative methods used by some producers involve heating the end of the tubing, either with hot water (carried in an insulated thermos) or a propane torch, although this risks deformation of the tubing and potential leaks, especially with high vacuum. A stainless-steel hose clamp should then be tightened around the cut end of the tubing to prevent leaks. Use a nut driver to tighten mainline hose clamps, as simply tightening the clamp using a screwdriver will not tighten the clamp sufficiently. Very frequently producers and tubing installers will double-clamp fittings as an added security measure to prevent tubing from pulling apart. Alternatively, a tubing expansion tool can be used.

LATERAL LINE TUBING Tubing for the maple industry is made via extrusion of melted plastic through a metal die plate. Although this process is quick and inexpensive, continuous and precise control of the tubing size (diameter) can be difficult to maintain, so small variations in size can sometimes occur. Similarly, fittings made by different manufacturers can vary slightly in size. For these reasons, producers should verify that the tubing and fittings they wish to use are compatible, and that tubing size is relatively consistent so that tubing goes on the fittings and remains tight. Information, comments,

Figure 6.29. Mainline installation tool, which grips the tubing (top) and holds it in place while it is cut (center), then pushes the tubing over both sides of the fitting by turning a crank that closes the tool (bottom).

and cautions concerning food-grade mainline tubing also apply to lateral line tubing.

Buying tubing can be confusing as maple equipment manufacturers have used a variety of names for similar products. Until the 1990s, all lateral line was made from polyvinyl chloride (PVC). Most lateral line tubing used now is polyethylene (PE, or poly). Varying amounts of metallocene catalyst are used to introduce flexibility, resulting in the different tubing properties. Food-grade pigments and UV stabilizer packages are also added to tubing to produce various colors and to enhance resistance to the development of UV-induced brittleness over time.

The PVC tubing used up until the 1990s was very flexible and could be found in a wide variety of colors and different wall thicknesses and was either ribbed or smooth. PVC tubing was readily workable, meaning that fittings could be pushed on fairly easily without a tool, and fittings remained relatively tight. It coiled easily for producers who wanted to disassemble the tubing system after the sugaring season. The primary disadvantages of PVC tubing included a tendency to stretch, which demanded constant upkeep to remove sags. Removing sags would decrease internal diameter of the remaining tubing over time, reducing flow. PVC was also somewhat difficult to clean as bacteria can penetrate its more porous (compared to polyethylene) interior walls. This combination of issues tended to result in greatly diminished sap yields over time necessitating periodic replacement of PVC lateral lines.

In the 1990s, polyethylene tubing formulations became available in the maple industry. It is currently available in two forms: rigid (also called stiff), and semi-rigid (or semi-stiff, or soft, as a result of adding metallocene catalyst), although there are other terms (Flex, Grip, Innovations, 4-Seasons, Flexiflo, etc.) that different maple equipment manufacturers use to produce slightly different properties in the tubing and to distinguish their products. PE tubing is far less stretchy than PVC. Although microbes can adhere to and form biofilms on the interior tubing surface, they are unable to penetrate the PE plastic as readily. This makes cleaning somewhat easier and more effective. Many producers prefer rigid tubing because it has minimal stretch and a very smooth inner surface. Additionally, it is lighter in weight and less expensive than other types. Other producers prefer the semi-rigid form, suggesting that it is easier to handle, forms a better seal on fittings, and is easier to unroll and roll up. Producers will sometimes use stiff tubing for lateral lines and a semi-rigid for droplines, which are handled more frequently and therefore more prone to develop leaks; however, the current trend is to use one type of lateral line tubing throughout to facilitate easier repairs. The useful life span of polyethylene tubing systems has not been well established but is the subject of ongoing research. In some cases, tubing is sold with a guarantee specifying a life span, which is determined by the amount of UV stabilizers in the plastic formulation. More frequently the life span, particularly of rigid PE tubing, is dictated by loosening of fittings on tubing as tension on the tubing and shrinkage during very cold weather rounds off the sharp edges of barbs, eventually allowing fittings to rotate or be pulled off tubing. Often the tubing itself is fine if a small length (½–1 inch) of tubing is cut off and a new fitting installed. In other cases, tubing can become brittle due to solarization, and start to develop fine cracks. In cases of extreme solarization, tubing can become so brittle that it shatters into small pieces when hit. When this occurs, repairs are impossible, and all the lateral line tubing of that type and vintage should be removed and replaced.

Lateral line tubing color has not received much research attention. Different colors are mainly used to indicate age of dropline. Some colors such as grey are less visible in the woods than the standard blue or green tubing. Oftentimes producers prefer translucent tubing because it allows them to visually monitor sap movement and air bubbles.

TUBING FITTINGS In addition to rolls of tubing, a maple producer setting up a sap collecting system will need a variety of fittings to connect the tubing to the mainline, to the tree, and for other purposes. These fittings must be constructed of food-grade materials, often nylon or polycarbonate (typically polycarbonate is only used for spouts and not for other types of fittings). In addition to reading information and suggestions provided here, it is recommended that new producers read one or more maple equipment catalogs or consult an equipment dealer and personally examine the various fittings that are available. For high vacuum (> 25″Hg) use, fittings are frequently designed and molded without a parting line (the fine line separating the two halves of the mold used to form fittings) to reduce microleaks at the fitting/tubing connection.

There are several possible fittings for connecting $\frac{3}{16}$-inch and $\frac{5}{16}$-inch lateral line tubing to mainline. A star fitting has multiple (usually four or six) ports for connecting multiple lateral lines to one point in the mainline. This type of fitting requires cutting the mainline. It has been largely supplanted by the newer "saddle-type" mainline fitting (**Figure 6.30**), also called "multi-fittings" or "mainline entrances", that connects only one or two lateral lines at a time to the mainline. Saddle fittings do not require cutting the mainline; instead, a small hole is drilled through the top of the mainline during installation and a gasket is usually placed between the saddle fitting and the mainline. These fittings

Figure 6.30. A saddle fitting(also called a mainline entrance or multi-fitting) is installed by drilling a small hole in the mainline and placing the fitting (right in picture) over the hole and clipped to the mainline. In some cases, the multi-fitting is installed first and the hole drilled afterward. The hook connector (left in the picture) clips onto the mainline support wire to help relieve the tension on the multi-fitting and forming a lateral line loop near the mainline which is used in leak detection. Note the wire ties crossing over, under, and around the saddle and mainline to ensure a tight connection.

are attached to the mainline via some type of strap or ratcheting plastic cuff and are often secured with a screw or bolt through the saddle fitting or a clamp around it. A newer style produced by DSD International Inc. requires only a stainless clamp and tubing attachment. Yet another new entrance fitting is the Lapierre FLEXClip™, designed for rapid installation and self-adjustment to variations in mainline size. The design is interesting, but the product hasn't been on the market long enough for a full assessment of its benefits and pitfalls to become available. Early reports are of both these DSD and Lapierre mainline entrances are favorable.

To further ensure a good seal of the fitting two wire ties are often attached around the entire fitting, crossing above and below the entrance (**Figure 6.30**). It is very important to ensure that the saddle is installed properly since a microleak at this point will result in freezing under vacuum, which at best will affect that one lateral line, but at worst might block sap flow in the entire mainline at that point.

The mainline entrance is currently one of the weak points of the system. With high vacuum, pinhole leaks at the entrance cause mainline freeze-ups (due to reduced pressure in the tubing causing a localized temperature drop, akin to carburetor icing in engines). A new type of mainline entrance designed to eliminate leaks is the SpinSeal™ fitting available from CDL Sugaring Equipment. The fitting is pressed against the mainline while a special tool spins it, welding or fusing it to the mainline. A hole is then drilled through the barbed fitting into the mainline. Advantages of this system are lower cost (once the tool has been purchased), quick installation time, low leak rate, and the ability to easily recycle all the mainline without removing entrances. Disadvantages are cost of the tool, the inability to use the system on black water pipe, and the learning curve involved. The SpinSeal™ entrance should be used only on thicker-walled HDPE maple mainline or Rapitube™ and not on standard black water pipe. Because of these factors, SpinSeal™ is mostly used by installers and maple producers with very large operations.

When using any type of mainline entrance, strain relief should be employed on the lateral line to keep the tension of the lateral line from torquing the fitting to the side and possibly causing a vacuum leak. Straight connectors with hooks are available for this purpose (**Figure 6.30**). The hook connects to the mainline wire; the lateral line attaches to one end of the hooked connector and a short piece of tubing (termed the "loop") connects to the other end of the hook connector and to the saddle fitting. This loop is useful in leak checking as described later. A less common method is to use a 3-foot (1 meter) length of hollow braid, ¼-inch (6 millimeter) diameter poly rope. The braids of the rope are opened up and slid over the end of the tubing; the other end is tied to the mainline wire and pulled tight. The advantage of this latter method is that tension adjustments in the sap tubing can easily be made.

As the lateral line passes by each tree that will be tapped, a tee fitting is installed, which allows a dropline to connect the taphole to the collecting system. The dropline is a segment of tubing 30–40 inches (75 centimeters or more) long that contains one spout (or stubby spout) at the end. The length of the dropline is important because it prevents sap from being reabsorbed from the line into the taphole when sap is not actually flowing, and it allows the sugarmaker to place the tapholes across a wide portion of the tapping band on the tree. The tee fitting is usually manufactured with either a peg or a cup built into it for closing off the spout during the non-sap flow season when it is not in the taphole. Droplines with tee fittings and spouts can be assembled prior to installation.

Spouts for tubing come in a variety of forms, sizes, and materials, and it is suggested that new producers visit with experienced sugarmakers or equipment suppliers regarding recommended types. Designs evolve fairly frequently, so it is difficult to ascertain whether a spout from a manufacturer is exactly the same from year to year.

Special fittings anchor the lateral line to the tree at the end of each line, so that the line can be stretched tight and hold its position. There are several fittings that perform this function, including various ring and Y fittings. A ring fitting allows the producer to take up slack in the lateral line, if necessary, without cutting it. Producers are advised to experiment with different types to determine what works best in each situation, but generally it is best to choose an end fitting that does not allow sap into the tubing encircling the end tree. A plug-tee or dead-end tee fitting works well for this purpose. Another option is to use a straight fitting (connector) to connect lengths of tubing together. Careful planning is necessary to minimize the number of pieces that need to be connected to make up each lateral line, as each junction creates a small restriction to sap and vacuum transfer, a potential leak, as well as a dead spot for microbes to accumulate.

INSTALLING LATERAL TUBING There are several different approaches to installing lateral lines. The one a producer chooses largely reflects the amount of help available as well as personal preference. The basic objective is to stretch the tubing between the mainline and the last tree in a fairly straight line (some weaving is permitted as long as the line is generally straight, tight, and downhill), so that it receives about five taps (*strive for five, no more than ten*) and extends no more than about 150 feet (46 meters) in length, although shorter is better. The fewer taps on a $^5/_{16}$-inch lateral line under vacuum, the higher the sap yield. Droplines at each tree are best spliced in after the lateral line is installed. Most producers find it easier to run lateral lines from the most distant tree toward the mainline, although some prefer to work out from the mainline. If working out from the mainline, a hooked fitting or hollow braided rope can be used to hold the lateral line to the support wire at the mainline while the line is being stretched. The lateral line should pass against the outside of each tree or tensioned against saplings so it will be supported when full of sap and not sag. In a cluster of trees, it is better to use a second lateral line than to zigzag back and forth trying to connect all taps on one line. When available, a co-worker can follow and hold the line tight against the tree just passed. At the last tree, the line is anchored by a loop of tubing that goes around the tree using an end-ring or plug-tee fitting as noted earlier. Lateral lines should not branch off, but rather should remain as a single line, with droplines and spouts, to the mainline. Branch lines using Y or tee fittings should be avoided as these will impede the steady movement of sap from the branches. If the mainlines are located no more than 150 feet (46 meters) apart, and if each lateral line is limited to five to seven taps, the need for branch lines can be eliminated. It is important that a relatively uniform downhill slope be maintained in the lateral line so sap will rapidly move to the mainline.

Unwinding a roll of wire or tubing can result in the wire or tubing retaining an undesirable spiral. These spirals can be minimized if a commercially available tubing or wire reel (spinner) is used or, if the tubing or wire coil is unrolled by hand, switch the side of the roll from which the wire or tubing feeds every three or four coils. Simply hold the roll of wire or tubing over one arm and let out about four coils, then transfer the coil to the other arm so that the wire or tubing feeds from the opposite side of the roll.

CONNECTING FITTINGS TO THE LATERAL LINE Virtually all fittings used with maple tubing have two or three barbs or ridges where tubing is attached. Care must be taken to install the tubing over these barbs, so that the fitting is tight, and will not pull off or allow air into the lines during the sap season. When using soft tubing it may be possible to press fittings on by hand, but in most cases a tubing tool should be used to connect the fittings or they are likely to leak air. Tubing tools of different designs are available; some can be used with one hand and some require two hands. The basic principle of either tool is to grip the cut ends of the tubing in a small vise and push the tubing onto the fitting as the tool is closed (**Figure 6.31**). With a bit of practice,

Figure 6.31. Single-handed tubing tool being used to install a spout onto $^5/_{16}$-inch tubing.

assembling fittings in this manner becomes quite easy. It is possible to use hot water, a disposable cigarette lighter, or small propane torch to soften tubing to insert fittings; however this is generally not recommended as heating the tubing can cause a loss of memory or distortion and result in leaks. Do not soften the ends of tubing by placing it in the mouth and chewing on it. Even with the tubing tool, care should be taken not to damage the barbs. When removing a fitting for later use, care should also be taken not to score the barbs with a knife or clippers, as this will lead to an air leak. Tiny score lines in tubing can be particularly problematic when high vacuum is employed. The fine grooves created by cutting free a fitting from tubing will frequently leak, necessitating replacement. Producers running high vacuum will generally not bother attempting to reuse fittings due to the extra labor costs of cutting off fittings, searching for microleaks this can create, and the subsequent replacement of leaking fittings. In systems using high vacuum, replacement of all fittings is generally more economical in the long run. When using rigid polyethylene tubing, fittings once installed should not be rotated around on the tubing as this may also create small leaks that are extremely difficult to locate, but that cumulatively can negatively impact vacuum levels achieved.

Once the lateral line is in place, the droplines are installed. Droplines should be 30 inches (75 centimeters) or more in length to allow the tapholes to be well spread out on the tree from year to year. Droplines are frequently constructed (or purchased pre-made) and grouped into conveniently sized bundles prior to their installation in the sugarbush. The two-handed tubing tool (**Figure 6.32**) makes it easy to install or replace droplines without losing tension in the lateral line.

When locating each dropline, the tee is most often placed 4–6 inches (10–15 centimeters) downhill from the tree to discourage squirrels and other rodents from chewing on the fittings. If rodents are a frequent problem, the use of specialized protective sleeves over tubing or metallic-wrapped tubing can reduce the damage. The use of substances on tubing to deter rodent activity is not recommended, as it can potentially migrate into sap, and no research

Figure 6.32. Double-handed tubing being used to install a tee with dropline onto $^{3}/_{16}$-inch tubing.

evidence exists that demonstrates it is an effective practice. If tubing must be tightened (toward the uphill end tree side) periodically, the tee will be pulled closer to the tree.

CONNECTING THE LATERAL LINE TO THE MAINLINE In the past, four-way or six-way manifolds were commonly used to attach multiple lateral lines to the same point on the mainline. This method can result in unnecessarily long lateral lines if the fitting is not carefully located, since several lines must be directed to the fitting rather than following the shortest distance to the mainline. It can also lead to suboptimal lateral line placement and lines running slightly upslope to reach the fitting. The use of multiple manifolds also adds more internal restrictions to the mainline. Finally, if the lateral lines do not go in exactly the proper direction, there can be a tendency for manifolds to back out slightly from twisting, creating leaks. Using saddle-type fittings overcomes many of these concerns. Depending on the type of saddle used, a saddle fitting will connect lateral lines singly (preferred for leak checking) or in pairs, at any point in the mainline. Single saddles allow the installer to choose the shortest path from the mainline to the first tree, which results in the shortest possible lateral line with the greatest possible slope. The saddle has the advantage of easy installation, because the mainline does not need to be cut, but only drilled. This is best done with a drill-type device called a mainline punch (**Figure 6.33**),

Figure 6.33. Mainline punch used to drill hole in mainline when installing saddle fitting.

which will make a smoother hole than an electric drill (and is designed to prevent accidentally drilling entirely through both sides of the mainline). A punch also helps prevent the formation of an oval hole, which creates leaks. Care should be taken to place the fitting exactly over the hole, and to lay the rubber gasket flat on the mainline. The ratcheted cuffs should then be closed firmly using adjustable pliers. When installing a saddle, use a hooked fitting or similar device to provide strain relief on the mainline. When using a hook on the support wire or a length of hollow-braid rope, the hole for the saddle should be 9–12 inches (23–30 centimeters) from the hook or rope knot (**Figure 6.30**). The hooked fitting is then connected to the saddle with a short loop of tubing. This loop, which will force the sap to move uphill briefly before entering the mainline, can be used to quickly check the rate of sap movement through the lateral line when searching for leaks.

USING TUBING WITHOUT A VACUUM PUMP

While many producers who set up a tubing system do so with the intention of connecting it to a vacuum pump, tubing systems without vacuum pumps have some of the same advantages as the system described above. Properly installed, a closed (non-vented) tubing system can greatly reduce the labor of sap collection.

In most respects, tubing systems set up for gravity sap collection are very similar to tubing systems set up for vacuum. The primary difference is that lateral lines designed for gravity can be longer and support a higher number of taps per lateral. The result of this change is that mainlines can be spaced further apart.

Under certain conditions, tubing can develop natural vacuum that will increase sap yield over that found in gravity (bucket) collection or older vented tubing systems. Natural vacuum develops when a column of liquid (sap) fills the tubing and moves downhill toward the mainline. Air in the tubing system (from gases produced by the tree or from leaks) can be removed by this moving liquid column, forming vacuum in the line. In some situations where 5⁄16-inch lines are well graded or the natural slope of the land is fairly steep, the level of natural vacuum achieved can be considerable. In order for vacuum to be developed, the tubing must be primarily full of liquid and the system be maintained airtight. These conditions occur during heavy sap flow periods. When attempting to maximize natural vacuum in 5⁄16-inch tubing, each lateral line should have twenty-five to fifty taps. This will result in mainlines located about 250 feet (76 meters) apart to allow for longer lateral lines passing by more trees. Care must be taken to keep the lines tight, and sloping downhill at all points, as any dip will slow the flow of sap (and the removal of air) at that point, reducing the potential for vacuum.

A fairly recent development exploiting the development of natural vacuum in maple tubing systems has been the introduction of 3⁄16-inch lateral and dropline tubing. Because of the smaller line diameter, air is less able to move past the liquid in the tubing, and thus is carried out of the system more readily, generating natural vacuum much faster and maintaining it better than in 5⁄16-inch tubing systems. Tubing systems set up to take advantage of natural vacuum using 3⁄16-inch tubing should have ten to twenty-five taps per lateral and can be very long. The key requirement of a 3⁄16-inch natural vacuum system is that it should only be applied on sloped land (5+ percent is optimal). A 3⁄16-inch tubing system is usually not appropriate on low slopes or flat land—the smaller line diameter produces too much friction in these settings, negating any positive benefit, and in some cases, resulting in sap yields lower than those from 5⁄16-inch non-vacuum systems. If there is a stretch of flat land after a slope, transitioning to 5⁄16-inch lateral lines or even larger mainline would be better. The amount of vacuum generated by a 3⁄16-inch tubing system is proportional to the amount of drop from the taphole to where the sap emerges from the tubing (into a tank or into a larger tubing). For that reason, vacuum levels will vary as one moves upslope from the sap outlet. Trees low on the slope will experience a lower level of vacuum than trees higher up (assuming the system is uniformly leak-free). In most installations, producers can expect to achieve 0.6–0.8″Hg of vacuum for each foot (0.3 meter) of drop.

A great deal has been written about the relationship between 3⁄16-inch tubing systems and natural vacuum over the past 10 years,[23] but there is certainly more to learn. Recommendations developed from decades of research and experience with 5⁄16-inch tubing systems do not always translate to 3⁄16-inch tubing systems. Questions about whether it is better to use a 3⁄16-inch or 5⁄16-inch drop, as well as how much slope is enough, how much slope is too little, or how to properly sanitize 3⁄16-inch tubing systems remain. Recent findings strongly indicate that 3⁄16-inch tubing systems are susceptible to microbial plugging at tees and unions over time, and that good sanitation (200 ppm bleach solution) or frequent (every 2–3 years) replacement of drops and all fittings in 3⁄16-inch systems is critical in maintaining good vacuum and high sap yields from these installations over several years. If sanitizers are used to clean 3⁄16-inch tubing, it is best done in the spring after the season ends in order to prevent clogs developing.

In the past, venting of spouts has been used in some 5⁄16-inch tubing installations. This was supposedly to prevent airlocks and was most common when tubing was laid on the ground. Venting serves no useful purpose, will eliminate the benefit of natural vacuum from a gravity tubing system, and will reduce sap yield over a closed tubing system by increasing introduction of microbes, which cause taphole drying. Eliminating sags in tubing will prevent air locks and frictional back pressure in the tubing system. Unfortunately, venting persists because when producers pull a spout to check for airlocks, sap will run rapidly out of the tubing system, producing the illusion that venting produces far more sap. Multiple studies with measurements conducted over a longer time period have all shown that the fast-moving stream of sap very quickly slows, and that the sap yield from a vented system will total considerably less over a full season than the yield from an unvented system.

THE CONDUCTOR SYSTEM If the suggestions regarding installation of mainlines have been followed, it is not uncommon that in some situations the 1,000-foot (305-meter) maximum mainline length is not sufficient to reach the collection tank. If this situation exists, it is recommended that a larger diameter mainline be used. If a single conductor line is used it needs to be large enough in diameter to accommodate a heavy sap flow of all the trees in the sugarbush while still allowing for good vacuum transfer. As has been mentioned, individual mainlines that are more than one-third full are less efficient at moving air (vacuum) because of turbulence created in the line. Thus, in a large system, mainlines of 1½–2 inches in diameter or larger might be needed (**Table 6.3**). Equipment dealers, experienced producers, or consultation of tables designed for sizing of mainlines[24] can aid in choosing the correct diameter for mainlines.

THE DUAL CONDUCTOR OR WET LINE/DRY LINE TUBING SYSTEM Another approach to increasing the rate of sap and air movement through longer mainlines is the dual conductor or wet line/dry line system. This entails having two parallel mainlines, usually arranged one above the other, to independently carry sap (lower conductor or wet line) and to transfer air (upper conductor or dry line) in order to increase the vacuum level. While the construction of such a system is more complicated than a single pipe system, it has advantages over the latter,

[23] https://mapleresearch.org/search/?_sf_s=3%2F16

[24] Childs, S.L. 2015. *New York State Tubing and Vacuum System Notebook*. Cornell Maple Program. 283pp. https://mapleresearch.org/pub/tubing-notebook-6th-edition-2/

including potentially higher vacuum at the trees and cooler sap arriving at the sugarhouse.

Conceptually, the dual conductor system is similar to the road network. If each spout is a house and the dropline a driveway, the lateral lines are akin to local roads, the mainlines that lateral lines enter are state (provincial) highways, and the dual conductor is the interstate system. In this case, the dual conductor lines represent the slow lane (sap) and the fast lane (air), both moving downhill (towards the vacuum pump). When air and liquid are mixed within the same pipe, particularly at bends or slope changes, movement of both is slowed down. Air will naturally move far faster in a tubing system than liquid, but when they are mixed by changes in direction or slope that causes turbulence, liquid movement is impeded, and the pipe can become overfilled with liquid. If the pipe is too full of liquid, air removal is slowed, and vacuum level may be compromised due to inadequate air removal. Separation of the sap and the air allows both to move at their best speed, maintaining the highest vacuum levels to the far reaches of the pipeline. Although there have not been a lot of good measurements under controlled conditions demonstrating this, producer experience clearly shows the advantages in vacuum levels, and producers employing dual conductor systems report an average of a 10 percent improvement in sap yields compared to those using single-pipe systems.

The dual conductor system is particularly advantageous where mainlines are very long and where sap from many (over 700) taps is collected into one conductor line. Using the dual line system, the pair of lines extend into the sugarbush, from which single mainlines less than 1,000 feet (305 meters) long branch off. At the point where a mainline branches off (a "branch mainline" or "spur mainline"), a manifold (sometimes referred to improperly as a "vacuum booster") connects the dual lines (**Figure 6.34**).

In the past, most manifolds were fabricated from PVC or stainless-steel fittings in the general shape of a large "U" turned on its side, with another entrance at the bottom of the "U" (**Figure 6.34**). These manifolds, if made of plastic, were subject to breakage when the sap inside them froze. The design of each manifold often required slight modifications

(a)

(b)

(c)

Figure 6.34. Manifolds are used in dual-conductor (wet/dry) mainline systems. A PVC manifold (a), a "whip" style manifold (b), and a transfer tank manifold (c). Manifolds direct sap from one or more spur mainlines down into the wet (lower) mainline, while air is pulled up and into the dry (upper) mainline. Separation of the liquid and air allows both to travel more efficiently. (transfer tank photo courtesy of hering's maple, waterville, mn)

depending on its location in the woods, which made standardization and repairs more difficult. Manifolds of this type that are made of stainless-steel fittings are heavy and very expensive. Despite these issues, some producers still use this style of manifold. The more modern method involves using mainline and PVC or (preferably) stainless steel Y or tee fittings as shown in **Figure 6.34**. This design is called the "whip" manifold. They are simple and relatively inexpensive to build and easy to maintain since they use all the same materials and construction as mainlines themselves. In this style of manifold, the single conductor line comes in from the woods, first through a valve, then into a tee fitting. The dry line from the dual-conductor stack is connected to the vertical arm of the tee fitting with another Y or tee fitting, and the wet line is connected to the horizontal arm of the tee on the single conductor. The valve on the single conductor is used in leak checking on that single conductor or to isolate it until repairs can be made if there is a problem.

A third, less common version of a manifold, is to use a transfer tank (**Figure 6.34**). This style is most often used when two or more spur mainlines come together to join a dual-conductor system, but is sometimes used with single spur mainlines or even to collect several lateral lines at a convenient point to a mainline. Wet and dry lines are connected to the transfer tank with short pieces of mainline at the top and bottom respectively, and the spur mainline is connected on the sides opposite where the dry line connects. Connections to these tanks can sometimes be difficult to make leak-free, cost is considerably higher than using a whip manifold, and maintenance can be more difficult.

By using a dual conductor system, vacuum transfer is very efficient, as air (vacuum) moves through the upper, dry line from the pump to the manifold. As sap is drawn from lateral lines connected to trees in the sugarbush into the manifold, it nearly fills the wet line, which is smaller in diameter than it would have to be if the line was transferring both air and sap. Since smaller diameter line can be used for the pair of conductors, for example a 1-inch dry line and a ¾-inch wet line for 1,000 taps compared to a 1¼-inch single line, the price of the dual lines often does not greatly exceed that of a single line system, although there is considerably more labor involved in setting up the two lines. An additional advantage of the dual line system is that the sap stays cooler on a sunny day when traveling through the wet line, because it is nearly full, than it would in a single conductor system where the sap fills only one third of the line. Still another advantage to a dual conductor system is that sap can start to flow through the dry line early in the morning when the wet line is frozen, thus acting as a backup wet line until the wet mainline has thawed to allow normal flow to occur. While not desirable, and efforts should be made to correct the situation if it occurs often, it does provide some system redundancy.

One mistake that is commonly made is to connect lateral lines directly into a dual conductor system. This should NEVER be done, as an air leak on the lateral or at the saddle can create a localized spot where the mainline will freeze, compromising all sap flowing down the wet line from above that point. It is not worth picking up a few more taps on a single lateral line when it can jeopardize the sap coming in from a large segment of the entire system. According to the logic of our "road" analogy above, local roads (lateral lines) do NOT connect to directly to the interstate system. Instead, a single pipe (branch or spur) mainline should be connected via a manifold near the base of the dual-conductor system and run in parallel to the dual-conductor lines, and any lateral lines near the conductor stack are connected to this single pipe. Lateral lines should always enter branch mainlines, not the wet line or dry line. A dual line system is intended to accommodate the fact that the wet line will be full of sap and not an effective conductor of air. In fact, the sap in the wet line moves downhill primarily by gravity. Connecting laterals to a wet line will leave those laterals without a reliable source of vacuum.

Assuming that a reasonable slope (4–5 percent) can be achieved, suggested line sizes for a dual line system, with the smaller wet pipe on the bottom and the larger dry pipe on top are as follows: ¾ inch and 1 inch for 1,000 taps; 1 inch and 1¼ inches for 2,000 taps; 1¼ inch and 1½ inch for 3,500 taps; and 1½ inch and 2 inches for 6,000 taps. These numbers are for the lower end of the system that carries the most sap; pipe size can be reduced for lines located toward the upper end of the system. In a dual line system, the wet line is strictly a conductor line that receives the flow from the branch mainlines.

It should be emphasized that each line is supported independently. The manifold, which can be constructed in a variety of ways, usually includes a valve that can close off the branch mainline, as well as a vacuum gauge slightly beyond that valve for determining the vacuum level of that part of the system. These are useful for checking the system for leaks.

When building and using a dual line system, keep in mind that the dry line is not always dry; when sap is frozen in the wet line, or during times of very heavy flow, some sap may move through the upper line. This line needs to be graded just as carefully as the wet line, and it must be thoroughly cleaned at the end of the season.

MECHANICAL VACUUM SYSTEMS As discussed in an earlier section, sap flows from wounds in trees when there is a higher pressure inside the stem than there is outside the tree in the atmosphere. The flow rate and amount of sap exuding from the taphole is proportional to the difference in pressure (the pressure gradient) from the inside to the outside of the tree, not unlike what happens when you puncture a car tire. At first the air flows out quickly, but as the tire flattens and its pressure decreases, the flow rate slows, and eventually stops. Using a vacuum pump moves air out of the tubing system, thereby lowering the pressure within the tubing at the taphole. In so doing, the steepness of the pressure gradient between the inside of the tree and the tubing network is increased. The higher differential pressure gradient created by the vacuum permits sap to flow out of the taphole beyond the time when the atmospheric pressure outside the tree and the internal hydraulic sap pressure within the tree are the same. This pressure differential also results in faster and more sap removal from the tree when conditions *are* favorable for sap flow. Research has demonstrated that an appropriately configured and effectively working vacuum pump attached to a tubing system can increase sap yield by 100 percent or more. The higher the vacuum level is, the greater the yield of sap. In general, a 5–7 percent increase in sap yield is found for each 1″Hg vacuum in the tubing system at the taphole.[25]

This increase in yield occurs for a number of reasons. Partly it is because vacuum creates a stronger gradient so sap is "pulled" from a larger zone within the tree. It is also due to the nature of the flow and the timing of freeze/thaw cycles. During short duration thaws there is only so much time for sap to flow out of the taphole. With a stronger gradient there is a faster flow rate, so that even during a short sap run a tree will produce more sap in response to vacuum than a tree of the same size with sap flowing only by gravity. During extended thaws, sap flow from trees on strong vacuum systems will continue to flow long after trees under gravity conditions ceases. Under vacuum, sap flow rate will drop off during a long thaw, and will eventually reach a steady-state flow; however sap sugar content will continue to fall. At this point, liquid is being pulled directly from the soil, up through the roots and stem and out of the taphole. A freeze is necessary to both recharge the stem pressure in the tree and to stimulate the conversion of starches to sugar.

In each sap season, there are a number of days when conditions are not ideal for a good sap run (e.g., no significant difference exists between internal pressure within the tree and outside atmospheric pressure). When this condition is present, sap flow can be induced or prolonged by the use of vacuum.

Taken together, these individual increases in sap flow quantity can increase total seasonal sap yields substantially and may turn an average or below-average season into a good sap season. For producers with greater than a few hundred taps at one location, and with access to electrical power (although gasoline vacuum pumps are available), the payback time for adding a mechanical vacuum system is generally quite short.

[25] Wilmot, T.R., T.D. Perkins, and A.K. van den Berg. 2007. Vacuum sap collection—how high or low should you go? *Maple Syrup Digest*. Oct. pp. 27–32. https://mapleresearch.org/pub/m1007sapcollectionvacuumlevel/

It is commonly thought that vacuum does not get "into" the tree—this is false. Vacuum is not anything magical, it is simply pressure below atmospheric pressure. When vacuum is applied to a taphole for a long enough time, the pressure within the tree in the area around the taphole does fall below atmospheric. If a thaw lasts long enough, a vacuum (pressure below atmospheric) gradient will develop and spread within the tree itself. Most of that gradient extends in a vertical direction, following the path of the large vessel elements that carry sap, but the gradient will also extend horizontally in the tree. The stronger the vacuum in the tubing system and the longer the thaw period, the larger the gradient and the larger the "zone" of sap movement becomes. Although pressure in the tree can fall well below atmospheric pressure when tubing systems are connected to vacuum, research has clearly shown that high vacuum does not increase internal wounding of the tree, nor does it significantly change the concentration of sap sugar or mineral nutrients in the sap compared to sap collected by gravity.

VACUUM PUMPS The basic mechanical vacuum system consists of a vacuum pump (**Figure 6.35**) and a mechanically or electrically operated extractor or releaser (**Figure 6.36**), which transfers sap from the tubing network into a collection chamber and then to a storage tank. While this sap transfer is occurring, an extractor is necessary to maintain vacuum within the tubing system.

At its simplest, a vacuum pump "grabs" air molecules and pushes them OUT of the tubing system. A compressor on the other hand grabs air from outside the pump and shoves it INTO a chamber, increasing the air pressure. This reduces the air pressure within the tubing system. Within the maple industry, air pressure below that of the atmosphere is measured in inches of mercury and abbreviated as ″Hg using vacuum gauges with a "gauge" pressure scale. A vacuum gauge with this scale will read 0″Hg at atmospheric pressure. As more air is pulled from the tubing system, air pressure inside the tubing goes down, but by convention, we say that vacuum is "increasing." As the pump continues to run, vacuum continues to increase to the point where the maximum amount of vacuum is achieved based upon the capabilities of the pump and the amount air leakage into the tubing system.

Another important consideration when talking about pumps is CFM, which stands for "cubic feet per minute," which refers to the volume of air the pump can move in one minute. As you might expect, this number varies depending upon the vacuum level at which it is measured. As the vacuum level increases, there are fewer air molecules available in the tubing system for the pump to grab and push out, so CFM typically drops off at higher vacuum levels. The higher the vacuum, the harder the pump has to work to remove even more air. An excellent discussion of pumps and vacuum transfer can be found in *The New York State Tubing Notebook*.[26]

It is important to recognize that while it is the gradient in pressure from the inside of the tree to the pressure within the tubing system that drives sap flow from the tree into the tubing, it is the rate of removal of air from the tubing system as a function of the maximum CFM the pump can evacuate and the tubing system can transport, as well as the maximum vacuum level the pump can achieve that produces the "pull" to drive that gradient. If the tubing system is very tight, a low CFM removal rate is sufficient. If the tubing system is leaky, a large CFM removal rate is needed and, even then, may not generate much vacuum at the end of the tubing system far removed from the pump.

Pumps are rated in HP, the maximum vacuum level that can be achieved, and/or in CFM. In general, what producers are interested in is the latter two measurements, but HP is a reasonable indicator of what can be achieved with a pump. It is always important to know the vacuum level at which the CFM of the pump is rated.

A vacuum pump produces a vacuum in the tubing system by removing air from the tubing lines. If the tree-tubing system were a totally airtight system, once the vacuum was developed it would remain without the need to remove additional air.

[26] Childs, S.L. 2015. *New York State Tubing and Vacuum System Notebook*. Cornell Maple Program. 283pp. https://mapleresearch.org/pub/tubing-notebook-6th-edition-2/

(a)

(b)

(c)

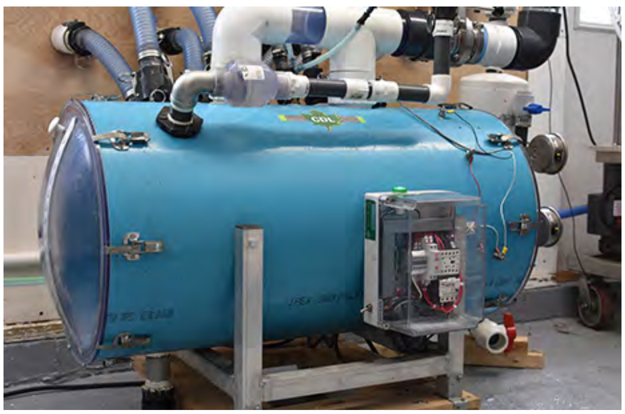
(d)

(e)

(f)

Figure 6.35. A variety of different mechanical vacuum pumps used in the maple industry. Dairy pump (a), Sap Puller dual-diaphragm pump (b), Airablo vane pump with oil flood cooling (c), oil-cooled liquid-ring pump with moisture trap (d), two Busch rotary claw pumps with moisture traps and VFDs (e), and Becker rotary vane pump with moisture trap (f).

(a) (b) (c)



(d)

Figure 6.36. Vacuum extractors (releasers). Single-vertical mechanical releaser (a), double-vertical releaser (b), single-vertical electric releaser (c), horizontal electric releaser (d).

However, the tree-tubing system is not completely airtight. Air enters from the taphole through leaks in the tubing and from small amounts of gases that are dissolved in the sap. As a result, a tubing system must have the proper pump capacity to maintain the desired vacuum level. A common rule of thumb suggests that pump capacity should range from 1 CFM minimum for every 100 taps at 15″Hg (e.g., 1,000 taps would have a pump of 10–15 CFM). If tubing systems are maintained very tight, a reduced pump capacity is acceptable, although vacuum might be somewhat lessened during warm periods when trees release large amounts of gas. These guidelines assume that mainlines are properly sized so that there is little reduction in pumping capacity (CFM) to the lateral lines. Ultimately it is the vacuum level at the taphole out in the sugarbush, as influenced by the pumping capacity, that directly affects sap yield.

The vacuum at the pump is immaterial if either the pipeline system cannot adequately transfer air to the pump or if there lots of leaks. It is analogous to having a car with a monster engine running at top engine RPM while up on jacks—your speed (sap production) will be terrible. Obviously, regular maintenance of the tubing network to minimize leakage is extremely important if optimal vacuum levels are to be achieved and maintained. The best way to have confidence that a vacuum pump and tubing system are properly designed and sized is to measure vacuum level at the tap at the end of the line during a strong sap run. Dividing this number by the reading at the pump will produce a "tubing system tightness ratio," a good indicator of the leakiness of a system. This indicator can be used to help determine the effectiveness of repairs and to compare different types of equipment on similar tubing systems. Maintaining as high a tightness ratio as possible will improve yield. The closer the ratio is to 100 percent, the better. This reading should be made at average or above-average sap flows. Taking this reading when there is little or no sap flow will not give a true reading of the performance of the system during peak sap flow.

TYPES OF PUMPS Several different types of mechanical vacuum pumps are available, with different approaches to moving air and different capacities to do so. It is preferable that vacuum pumps be electrically powered since electric units lend themselves to increased automation as well as requiring less daily maintenance. Gasoline motors can also be used, although more time is required for refueling and maintenance, there is a much higher incidence of sap backflow when stopping the motor, and operating costs are considerably higher than electric pumps.

Very small sugaring operations that wish to use mechanical vacuum may use Sap Pullers (diaphragm pumps) or Sap Suckers (peristaltic or positive-displacement pumps). These pumps can, under the right conditions, generate more than 20″Hg of vacuum, but because they were designed as liquid pumps and not specifically designed to move air, the CFM rating tends to be modest. Therefore, these pumps are highly susceptible to tubing leaks and can also suffer when tree gas production is high on warm days. They must also be protected from freezing with liquid in them by propping them up at an angle or using an ice strainer. It is a good idea to have spare diaphragms and flexible tubing as replacements. One considerable advantage to these small pumps is that they do not require releasers (extractors) or moisture traps. They can give excellent results when combined with a natural vacuum system where they provide a base level (15″Hg) of vacuum and the 3⁄16-inch tubing provides additional vacuum. Vacuum levels are additive in such systems (natural vacuum + pumped vacuum = total vacuum).

A common type of vacuum pump designed for maple systems uses a rotary-vane impeller. Some rotary vane pumps used in the maple industry were originally designed and used in dairy applications and operated either in that configuration to a max of 13–15″Hg or modified (typically by oil cooling) to achieve higher vacuum levels (18–25″Hg). If these types of pumps are used it is important to remember that they must not be allowed to run dry of oil, and that some pump damage is possible if they overheat during extended periods of operation at higher vacuum levels. Larger rotary vane pumps, termed "flood pumps," have an oil-reclaiming unit for lubrication and radiator and cooling to allow somewhat higher vacuum levels. Flood pumps typically move a lot of air (CFM), but their maximum vacuum level is generally more limited than other types of pumps.

Liquid-ring pumps, either oil or water cooled, can achieve vacuum levels of 26–28″Hg as long as the temperature of the cooling liquid stays low, but tend not to move as much air as vane pumps. Water-cooled liquid ring pumps must be protected from freezing. Oil-cooled liquid-ring pumps do not have to be protected from freezing, but are unable to pull quite as high a vacuum as water-cooled models. One benefit of liquid-ring pumps is that they are not seriously damaged if sap should enter the air side of the pump. Other types of pumps may suffer some amount of damage from sucking in sap, ranging from slight but repairable damage to serious or irreparable damage.

The newest types of pump, rotary claw, rotary vane, and rotary screw pumps, typically provide high vacuum levels with good CFM but tend to be somewhat more costly and more sensitive to sap damage. Once operating, these pumps require relatively little monitoring aside from routine and end-of-season maintenance.

In general, most pumps designed to move air that are used for maple sap extraction should always be used with a moisture trap and/or protection valve to safeguard the pump from liquid intrusion (**Figure 6.37**). It is commonly recommended that a vacuum gauge, vacuum regulator, and a relief valve be installed at the pump to ensure the desired level of vacuum is maintained.

Many higher-end pumps can be operated using variable frequency drives (VFD). These systems monitor the vacuum level in the tubing system and reduce motor speed (and power consumption) when desired vacuum levels are reached or, if equipped with an


(a)


(b)

FIGURE 6.37. Moisture (also called vapor) traps help to protect vacuum pumps from ingesting liquid that can cause damage. Two moisture traps used in series (a) and a larger single moisture trap (b).

auto start/stop mechanism, when the temperature falls below a low temperature setpoint or rises above a high temperature setpoint. This feature significantly reduces wear-and-tear and total energy use of pumps in well-designed and well-maintained tubing installation. In some areas, energy efficiency programs may help fund the use of VFDs on agricultural motors.

OPERATION AND MAINTENANCE OF MECHANICAL VACUUM SYSTEMS All electric pumps should be wired properly using adequate circuits and properly sized wire to achieve efficient operation and ensure safety of personnel and property. Vacuum pumps should be monitored and maintained daily to check fluid level and make certain the pump is operating properly and is adequately lubricated. Gasoline-powered motors and generators require regular service to maintain fuel levels, check oil levels, and complete oil changing as recommended by the manufacturer. To avoid breakdowns during sap flow periods, drive belts should be regularly checked and replaced when they show signs of wear and tear. Safety should always be uppermost in mind when personnel are working near vacuum pump equipment. Units with drive belts should have appropriate guards in place, and on/off switches should be placed in a prominent location. All personnel should be instructed regarding proper use. If pumps are placed in a building, provision must be made to make certain the exhaust exits outside the building. It is often advantageous to locate the vacuum pump in a separate insulated small room within a building or the sugarhouse. It is also critical to keep pump exhaust far away from any air intake used with the evaporator, such as the air intake for a steam pan or for air injector pipes in the flue pan.

To achieve the maximum benefit of a vacuum system, the pump should remain in operation any time the temperature is above freezing and the sap is flowing. With the proper equipment (VFDs and appropriate vacuum pumps), some producers turn on the pump during or immediately after tapping and don't turn them off again after spouts are pulled. During freeze periods, as long as there are no leaks, the VFD will throttle the pump down to a low level of power consumption. These cold periods are also good times to do any required routine maintenance (checking fluid levels, changing oil). Some systems are not compatible with this approach either because they do not use VFDs or because they require air moving through the pump to aid in cooling. Similarly, some systems are more susceptible to ice than others. In this case, pumps should be turned on when extractors are free of ice and mainlines are running at the very beginning of a sap flow event. If vacuum pumps are activated too early, ice can clog the extractor valves and delay thawing of mainlines. Ice crystals can also accumulate at the locations of couplers or any other restriction in the mainline such as a lateral manifold. When sap flow ceases because air temperatures have dropped, such as occurs towards the end of the day, the vacuum pump should be shut off. If freezing temperatures do not occur (e.g., during periods of weeping flows), the vacuum pump may be operated night and day if desired. The pump can be operated manually with an on/off switch, or a temperature sensing switch with auto start/stop functions can be installed to start or stop the pump at predetermined setpoints. A sensing switch can also be installed in the extractor to turn the pump on when sap starts to flow or off when flow stops for a period.

One important note is that freezing can occur near vacuum leaks in tubing. Water vapor inside the tubing system freezes due to the rapid change in pressure even air temperatures well above freezing. The higher the vacuum level, the higher the outside air temperature at which this can occur. This leads to ice blockages within the mainline (**Figure 6.38**). When the leak is sealed by ice, thawing subsequently occurs, and the leak reforms. This causes the vacuum level to fluctuate over minutes to hours. Plastic mainline fittings seem to be more prone to microleaks than stainless fittings. These small leaks can be very difficult to find and correct. Because of this, tubing maintenance and rigorous leak checking, particularly for microleaks, become ever more important with increasing levels of vacuum.

Figure 6.38. Transitory intermittent ice formation (frost on mainline to the left of the band clamp) caused by microleaks can occur in mainline systems at above freezing temperatures. This leads to loss of vacuum in sections of the woods until the frozen section thaws. These types of leaks are extremely difficult to find and correct.

EXTRACTORS/RELEASERS The vacuum pump is connected to an extractor (**Figure 6.36**) or dump unit attached to the mainline system. Extractors (also called releasers) are available in a variety of sizes ranging from those designed for several hundred taps to those designed for many thousands of taps. The purpose of an extractor is to collect sap from mainlines and move it to a larger storage tank without interrupting the vacuum. Extractors are either mechanical or electrical (or more rarely, hybrids of the two types).

Mechanical extractors empty by gravity, most often directly into a storage tank. When the sap in the extractor rises to a set level, a float opens a valve to the atmosphere, allowing air in, which permits the flapper valve on the bottom to open and drain the releaser. For this reason, mechanical releasers often are placed directly on top of the sap tank. With this approach the incoming mainlines must be higher than the top of the tank to function. When the vacuum pump is off, any free-flowing sap will trickle through the extractor or from open valves from the mainline, reducing the risk of freezing.

Electric extractors operate with an internal or external liquid pump that removes sap from the collector to a storage tank. The storage tank can be located above or at some distance from the extractor. The pumps must be capable of overcoming the vacuum in the chamber to pump the sap. Air leaks in these systems can be very challenging, and rapid rushes of sap when mainlines first thaw can overwhelm the pump temporarily, creating a backup of sap. Because these releasers use pumps, losses of power are extremely problematic unless contingency plans are in place. Some releasers now have an electric pump as the primary sap removal mechanism but incorporate a float and valve as a backup for sap removal should the power fail. These styles of extractor must also be placed above a tank. As higher vacuum levels are achieved, more capable pumps are required to evacuate sap from an electric releaser.

Introduction of air into the tubing system when extractors dump sap causes pulses of sap backflow in the entire tubing system. Although the amount of air that enters the releaser may seem small, 1 gallon of atmospheric air (0″Hg) will expand to ten times the volume at 27″Hg. This introduced air pushes the sap back up the lines. The extent of these backward (toward the taphole) pulses of sap varies depending upon the amount of air introduced, the vacuum level of the system, and the overall size of the tubing system. Typically, these pulses result in the periodic movement of sap backward from the tubing into the taphole on the order of 1–2 inches, which is about the length of many spouts. This is the reason that spout and dropline sanitation is so critical: this backflow of sap carries microbes from the tubing system back into the taphole, where they can induce taphole drying processes. Therefore, reducing backflow pulses from releaser dumps or leaks is one critical factor in maintaining proper taphole sanitation. Mechanical releasers are generally far more prone to this problem than electric releasers. To help address this problem with mechanical extractors, continuous vacuum mechanical extractors have been developed. These employ two independent chambers that work together to minimize the introduction of atmospheric air, thereby substantially lessening backflow of sap.

Yet another option is to use a large tank capable of withstanding vacuum to serve as both a releaser (of sorts) and sap storage (**Figure 6.39**). These so-called "Zero" tanks are repurposed bulk milk tanks. Tanks have a certain vacuum rating that should not be exceeded. Typically, this rating is stamped on the tank itself somewhere near the lid (T20 means rated for 20″Hg). The indicated vacuum level should not be exceeded; otherwise the tank may implode—frequently catastrophically. Damaged Zero tanks should not be subject to vacuum as their integrity could be

Figure 6.39. "Zero" tanks in which a vacuum is pulled serve as both extractor and sap storage. These tanks typically have a vacuum rated stamped on them. Exceeding this level can lead to tank collapse.

compromised. Not all Zero tanks are vacuum rated. The advantage of a Zero (or other large vacuum vessel) is that no releaser is necessary and the tank itself serves as sap storage. Periodically these tanks are drained, either with a pump built into the tank, or by shutting off the vacuum line and allowing air into the tank and transferring the sap to another container. The quality of the sap in these enclosed tanks is often somewhat lower than that of sap in open tanks due to excessive heating and attendant microbial action as well as the inability to totally drain the tank (depending upon the tank design and installation).

MOVING SAP UPHILL AND LIFTING SAP VERTICALLY IN TUBING SYSTEMS Sometimes the lay of the land in a sugarbush necessitates moving sap uphill from the mainline or collection point. Mechanical vacuum can, with the proper equipment and in the appropriate situation, provide the energy to move sap "uphill" if necessary. It should be recognized that moving sap uphill using vacuum consumes or "uses up" CFM from the vacuum system to accomplish the lift. This will often mean that CFM is reduced systemwide and that vacuum levels and available CFM will be lower (sometimes substantially) beyond the lift point. These systems are appropriate in mechanical (pumped) and in pumped sections of hybrid vacuum systems, but generally are not used in natural vacuum or gravity tubing settings.

One approach is to use a mechanical extractor (often called a reverse flow extractor in this application) placed at a low point in the sugarbush where sap can be collected and then transferred uphill to a collection point (**Figure 6.40**). The system has fairly substantial CFM requirements for operation. The reverse flow extractor system allows sap collection from a larger number of taps situated at a lower elevation than a collection tank. Specific models are engineered for different numbers of taps, height of lift, and flow rates. Maple equipment manufacturers should be consulted if this approach is being considered.

A sap ladder is a simple and relatively inexpensive method used for lifting sap in situations such as over an access road or obstacle such as a small hill by using an existing vacuum sap collection system. A rule of thumb is that you can lift sap 4 feet (1.2 meters) less than your vacuum level in ″Hg (for example, 24″Hg vacuum could lift sap 20 feet, or 6.1 meters). Individuals have reported lifting sap up to 14 feet (4.25 meters) from areas with a few hundred taps. There are two main types of sap ladders: the pipe ladder and the star (or spider) ladder. The star ladder is commonly used with mainlines serving less than 500 taps and a two-pipe (or double pipe) ladder with mainlines serving more than 500 taps.

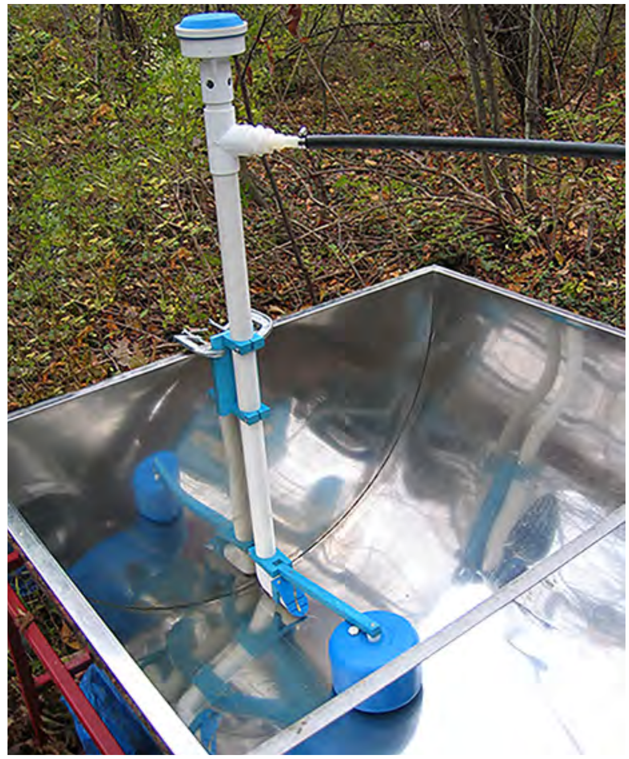


Figure 6.40. A reverse slope extractor can be used to transfer sap collected from taps situated at an elevation lower than a collection or storage tank.

In a two-pipe ladder (**Figure 6.41**) a shut-off valve is sometimes placed in one of the pipes allowing the ladder to be used as a one-pipe ladder during periods of low sap flow.

In a star ladder (**Figure 6.42**) configuration the two mainlines are attached to threaded mainline manifolds (star fittings), with the manifold on the lower mainline inverted (e.g., placed with the manifold below the mainline). Sap flowing in the lower pipeline is lifted by vacuum to the upper line through the $\frac{5}{16}$-inch sap collection tubing lines. Sap

FIGURE 6.41. Pipe sap ladder in foreground. Producer has hand on shut-off valve that can be used to convert two pipe sap ladder to a single pipe sap ladder.

in the upper line then flows under vacuum and gravity in a graded pipeline to the collection point.

The efficiency and performance of sap ladders will vary depending on the number of taps, volume of sap, sufficiency of vacuum, volume of air introduced, and height of the vertical lift. The upper mainline may be larger than the lower mainline but should never be smaller.

It is important to note that while sap ladders offer a comparatively inexpensive method of lifting sap, they do have drawbacks. They can be a source of contamination (bacterial growth) as they do not drain daily. Also, because they do not drain, they can freeze and block an otherwise open mainline.

More recently, an alternative strategy for lifting sap has been developed. Rather than using any type of ladder, for small lifts, individual lateral lines on mechanical vacuum systems can be sloped upward to the mainline or brought sloping down to a point below the mainline; then a short lift is accomplished using a vertical piece of 5/16-inch tubing. Relatively little research has yet been done to determine the advantages or disadvantages of this "mini-lift" approach compared to a more traditional ladder; however it is very simple to install and maintain, only single lateral lines are impacted by freezes, and sap production seems to remain high. In some cases, 3/16-inch tubing can be used instead of 5/16-inch, which will help hasten the movement of sap up the line.

A variant of this approach can be used in 3/16-inch natural vacuum systems. If the 3/16-inch tubing is coming off a steep slope, the weight of the sap moving down can "push" sap up and over a road or obstacle if the lift height is less than the slope height, and there is some amount of slope after the lift.

If the area of the woods cannot be served with a lift due to it being too low in elevation (the maximum suction lift is around 33 feet [10.1 meters],

FIGURE 6.42. Star sap ladder. Sap flowing from right to left in the lower mainline (on the right) is raised to the upper mainline on the left. Note the orientation of the star fittings on the upper and lower mainlines.

under optimal conditions) or if a large number of taps is too high, the alternatives are to either move the sap load by load using a tank on a truck or tractor/sledge or, if electricity is available, by pumping the sap up the hill. Pumping sap uphill is considerably more efficient than suction lifting so the height that can be overcome is far higher, but generally requires having power (either mains or generator or gasoline powered pump) at the pumping location. Vacuum-powered sap pumps/lifts are also available from some maple equipment suppliers. It is also important to know the distance and height the sap needs to be pumped and the volume of sap to be pumped within a set amount of time. Because of the variables involved, enlisting the assistance of those familiar with sap pumping is a good idea.

Based on the anticipated maximum volume to be collected and the time frame within which it needs to be pumped, a calculation of the pumping rate can be made. Often there is no need to pump faster than the reverse osmosis machine or evaporator can process sap, so pumping need not be done extremely quickly. Once this is known, the pump and pump line diameter can be chosen to match the desired flow rate. It is important to factor in the head (elevation) and distance (line friction) involved in determining these, as the pump can move less liquid at higher heads and smaller pipe diameters. In addition, it should be recognized that to prevent liquid freezing in the line there should not be any sags or a check valve in the line, so when pumping is done, some amount sap will flow back down the pipe into the storage tank (be sure sap cannot siphon back out of the storage tank at the top by keeping the end of the pipe well above the maximum tank level). Therefore, oversizing the pipe can lead to problems of sap storage. Factoring the amount of sap that will flow back to the tank when determining sap storage needs is prudent.

Despite the challenges in setting up a sap pumping system, the benefits are significant savings in time and energy transporting sap, and the ability to collect from trees that would otherwise remain untapped.

Leak Checking

With any type of tubing system, but particularly with vacuum tubing systems, leak checking is critical. Leaks can range from major breaks in the mainline releasing large quantities of sap in a short time, to the very tiny microleaks that can occur at fittings. Leaks in gravity systems, for the most part, are obvious—sap runs or drips out from the tubing system. Repairs are dictated by the type and extent of the leak and are generally fairly simple. With vacuum systems, and especially as the vacuum level increases, leaks can become far more subtle and difficult to find and correct. Unfortunately describing how to find leaks is a bit of a problem.[27] While we can describe leaks and how to fix them, there is nothing that will substitute for getting out in the woods, looking and listening for leaks, and figuring out their cause and the best way to correct the problem. So, the most helpful thing we can do at this point is to give you some hints to get you started and then send you off to learn by trial and error—and hopefully succeed.

The unfortunate reality is that most leaks don't make any audible noise. Furthermore, the woods are frequently not a quiet place. Given those facts, your ears, while sometimes useful, can't be relied upon to find most leaks. Leaks in tubing systems under vacuum are usually indicated by either the lack of sap movement (when the temperature is appropriate for the sap to be running), the presence of only a small trickle of sap in the line, air bubbles moving quickly in the line, a high-pitched sound (whistle), or frost on a section of mainline. Producers heading into the woods should bring a repair kit with a wide selection of the fittings, spouts, and tubing they use, along with electrical or silicone tape, a drill and bit, a tapping hammer, a small pair of needle-nose vise grips (with tubing over the pinching ends to prevent damage to tubing), clippers and a small folding pruning saw, a tubing tool, and a roll of flagging tape to mark locations you need to return to with other tools or parts for more extensive repairs.

Starting at the tree, look for sap weeping on the outside of the spout. This may occur for a short time (a few days) after tapping but is normal and likely not a leak. Some sap will appear on the outside of the wound that has been made by the drill that can't

[27] Several excellent resources on leak-checking are online, including https://mapleresearch.org/search/?_sf_s=leaks

make its way into the spout, but because of the high internal stem pressure, it flows to the outside of the spout and surfaces on the bark. If you observe a spot there—do nothing. The spot will eventually dry out in a day or two.

If a wet spot persists on the outside of the bark for more than a few days, or if bubbles are observed moving quickly through the spout (tiny bubbles that grow in size or small bubbles moving slowly are fine), then gently tap the spout once or twice to ensure it is seated properly. Resist the urge to hit the spout hard or to keep reseating it throughout the season; doing so will only serve to make the spout leak. If fast moving bubbles persist, inspect the spout closely for cracks and replace it if needed. If this doesn't work, either leave the spout in place with the leak (if the leak is not large) or pull the spout and cap it off.

As you walk along the lateral line, inspect it visually and listen for leaks. Some producers run their hand along the line as they are walking to feel the tubing for animal chews. Unfortunately, whether from curiosity, boredom, or in the hope it could be food, many different types of animals will chew on tubing and fittings. If damage is found, cut out the bad area and put in a union or replace the affected fittings. Alternatively, electrical or silicone tape can be used as a *temporary* repair.

If bubbles are observed at a tee, put the vise grips on the lateral line side to see if the leak stops (rigid tubing can be very hard to pinch off completely). If not, try the dropline side. Whichever side that is pinched off when the leak stops is the source of the leak. Look closely at the drop to determine where the leak might be and try to fix it. Replace the entire drop if necessary. If the leak on the upper leg of a drop cannot be fixed, this most likely indicates a leaking taphole; cut the spout and plug the line.

At the mainline, depress the loop between the saddle and mainline hook connector, and observe the sap flow. If sap and bubbles are moving slowly, great. If bubbles move quickly through the loop, there is a leak somewhere on the lateral line. If sap is not moving at all, but is moving on other lateral lines, inspect the hook connector and saddle closely and listen for leaks. Tighten the rachet straps, screw, or bolt and wire ties on the saddle to see if the situation can be corrected. If none of this helps, remove the saddle to inspect the gasket and replace the gasket, saddle, or union as needed. It is often better to flag the malfunctioning saddle and go back to replace it when the system is frozen or when the pump is off. Replacing a saddle introduces a lot of air into the mainline and will result in a significant amount of sap backflow.

Occasionally, saddle or mainline fitting leaks are indicated by a layer of frost buildup on the outside of the line or fitting. These areas should be inspected carefully, and the leak found and corrected. At the very least, tighten up all screws, bolts, and clamps in that area and make a note to check it again later.

Continue walking up and down each lateral and section of mainline to check for leaks. At the same time, look for dips or sags in the mainline, or areas where the mainline is under the snow. Either pull the mainline out of the snow, trample down, or dig out the snow along that section, and retension or prop it up on a post, or side-tie the mainline to trees/saplings in the vicinity to prevent it from falling below the snow level. Such areas will stay frozen and block the passage of sap or vacuum (air). Similarly, look for branches or trees that have fallen on lines and either cut them off or mark them with flagging tape to return to.

At mainline junctions or where single mainlines are joined to dual conductor lines, observe and/or listen for sap and air movement. Sap should be flowing down only into the wet line (although sap might be observed at times to flow briefly in the dry line). Look closely for frosted over line or fittings and tighten as necessary. If mainlines are equipped with valves and vacuum gauges, close the valve on the single conductor line and observe the gauge. If it holds or only drops very slowly the entire mainline is likely good. If it drops rapidly, there is a problem and further investigation of that line is warranted. Experienced producers may not need vacuum gauges—they can judge from the sound of air in the lines.

At the releaser, if sap and air are observed spraying in from a particular mainline, and it is not because the line is just starting to thaw out, there is likely to be a leak on that line. The use of valves on lines coming into the releaser can often help to isolate which lines might be affected.

As your experience with leak detection and correction grows, you can expect your vacuum level to improve, which in turn, will yield benefits in higher sap returns.

Monitoring Systems

Over the last few years, several companies have introduced electronic monitoring systems that measure flow, vacuum, and tank level to the maple industry. Generally, these systems are wireless, often operating in a mesh-network configuration that sends signals from sensor to sensor before eventually arriving at a point where incoming sensor data are aggregated, then sent to a web server where it can be displayed on a computer, tablet, or smartphone. With some systems cellular or satellite connection is used, eliminating the need for a internet connection. The number, placement, and configuration of sensors is widely adaptable, and repeaters may be used in some instances to carry the signal across long distances.

The primary advantage of these systems is their delivery of continuous or frequently updated information about the status of the vacuum level in the tubing system and level of sap in the tanks (along with other measurements if desired). The systems can be set up to notify the producer at any time of day or night through email, text, or voice alarms that vacuum levels are low or that sap levels are getting high. The task of deciding which section of the woods a leak is in or which mainline needs attention is greatly simplified. Producers are thus free to do other things while the monitoring system "watches" the operation. Given the fact that any one maple production season comprises only a small number of good sap runs, knowing quickly when and where a problem occurs is quite valuable. The primary disadvantages are cost and the need to have some (modest) level of understanding of how to operate the system. Some systems, with appropriate accessories, are also capable of turning pieces of equipment (pumps, heaters, valves) on or off remotely.

Sap Storage

Sap storage is an important step in the production of quality maple products. Adequate sap storage is necessary not only to hold sap until it is processed, but also to supply a constant flow of sap to the evaporator or other sap processing equipment. Proper sap storage involves correct sizing of storage facilities, maintaining cleanliness, and managing temperature and light levels. Sap storage capacity is a function of the number of taps, how quickly boiling can occur, the capacity of a reverse osmosis unit if used, and the size of the evaporator. There are few things more heartbreaking to maple producers than to walk into the sap shed and find the tanks flowing over with sap spilling on the ground.

Producers using buckets or bags should have a minimum of 1 gallon (3.8 liters) of sap storage per tap for each day of sap flow between processing. If most of the trees are quite large, this should be increased. With tubing, storage of 1½ gallons (5.7 liters) per tap is recommended for gravity systems. With vacuum tubing systems (either pumped or natural vacuum), 2 gallons (7.6 liters) or more (depending upon vacuum level reached) per tap would be a minimum.

To avoid losing sap during heavy runs, it is suggested that a sap storage capacity equivalent to two good days of sap flow be available. On the average this amounts to 2–3 gallons (7.6–11.3 liters) or more in some cases of sap storage per tap. In locations where back-to-back large flows are common, or good vacuum levels are achieved, some producers choose to have as much as 4 gallons (15 liters) of sap storage capacity per tap. However, this large storage capacity is the exception rather than the rule, and certainly is influenced by many factors, including how quickly sap can be processed.

Estimates of total storage capacity should include the storage tanks at the sugarhouse plus any secondary storage tanks (transfer or dump tanks) in the woods. Producers collecting with buckets/bags should also recognize that buckets/bags provide additional storage. While bucket/bag storage does not replace adequate tank storage at the sugarhouse, it is important in estimating storage needs to handle periods of peak sap flow. In most maple operations, sap is stored in tanks located at or adjacent to the sugarhouse. It is desirable, even for small operations, to have more than one storage tank at the sugarhouse. This allows empty tanks to be cleaned to receive fresh sap rather than dumping freshly collected sap into a tank partially filled with older sap.

Tanks must be constructed of food-grade materials that will not contribute to contamination of the sap. For ease of cleaning, surfaces should be nonabsorbent, smooth, corrosion resistant, and able to withstand repeated cleaning and sanitation. Stainless steel, food-grade plastic, fiberglass, and glass meet these standards (**Figure 6.43**). Porous tanks, such as unsealed concrete, are not suitable as sap storage tanks. Galvanized tanks and tanks with lead solder or rust should not be used. It must be remembered that the evaporation process concentrates

Figure 6.43. Transfer and storage tanks for sap come in a wide variety of sizes and configurations and should be food-grade, clean, and suitable for intended use.

contaminants. Commercial sap storage tanks are available from maple equipment vendors. Glass-lined or stainless steel-lined tanks from the dairy, brewery, or food processing industries are often available used. Both new and used tanks from a wide variety of sources are available. Cage totes are frequently available at a low cost, but the previous contents should be known and appropriate for food. If used tanks are selected for sap storage, only tanks that meet requirements for storing food grade materials should be purchased. Plastic or galvanized stock tanks are not acceptable for sap storage.

Sap storage tank location requires planning. Wherever possible, tanks should be located to allow gravity filling and emptying. When this is impractical, electric or gasoline-powered pumps can be used. Use strong supports and platforms when it is necessary to elevate tanks. Storage tanks filled with sap are heavy and require substantial support (one U.S. gallon of sap weighs slightly more than 8⅓ pounds; 1 liter of sap weighs essentially 1 kilogram).

Storage tanks should be placed in cool locations, not inside the sugarhouse near the evaporator. Some options for accomplishing this include underground tanks; placing the tanks on the cooler, shaded side of the sugarhouse (usually on the north side); placing tanks in a separate room of the sugarhouse; or building a tank shelter adjacent to the sugarhouse. Tanks located outside and in an aboveground location should be reflective white or silver in color. All tanks with open tops should be under cover to prevent contamination from foreign materials such as dust and rain or from animals. Tank covers should be appropriately colored and designed to allow air circulation to avoid heat buildup.

Vertical silo style tanks are fairly new in the maple industry. They have the advantage of requiring a much smaller footprint than normal open-top tanks, can be located outside the sugarhouse, can be built very tall for large storage capacity, and are often equipped with automatic washing units. The primary disadvantages are cost, the need for a cement pad, and the inability to move them (easily).

Sap storage tank design and location should also facilitate cleaning and maintenance. Closed tanks should have easy access. The insides of the tanks should be relatively smooth to avoid areas that are difficult to clean and where residue can collect. Producers using enclosed tanks need to follow safety precautions when cleaning in confined spaces. Each time a tank is emptied it should be thoroughly brushed and rinsed, preferably with hot water. At the end of the season, storage tanks should be thoroughly scrubbed with a nylon brush and 200 ppm bleach solution, and triple rinsed with potable water to remove any residue. As with other sap processing equipment, this cleaning should not be postponed since any residue will dry and will form a film layer that is difficult to remove. Use caution when cleaning tanks with chlorine solutions, particularly with enclosed tanks (workers should wear respirators to avoid breathing fumes when cleaning with chlorine solutions). Prior to being used at the beginning of the season, storage tanks should be cleaned and rinsed with chlorine solution and triple rinsed with potable water.

Sap storage tanks must be well maintained. Leaks should be repaired using only food-grade materials. Under no condition should solder containing lead be used. Although corroded tanks used to be repaired by painting, this is no longer a recommended practice. Many paints that are purportedly for "food use" are actually for incidental food contact and are therefore not meant to be used for extended food contact such as buckets or tanks. Only a two-part, food-grade, epoxy resin paint should be used to coat the interior of the tank, and only professionals should attempt surface preparation and painting.

Other considerations associated with sap storage tanks include the use of sight tubes with closed or elevated tanks for easier determination of sap supply, and the proper grading of transfer pipes between the tanks and the evaporator to reduce freezing and to provide effective tank drainage. In addition, some large producers use dump or transfer tanks in the sugarbush. For example, a 500- or 1,000-gallon (1,900- or 3,800 liters) tank might be permanently located in the sugarbush as a dump tank. Sap dumped into this tank is transferred by gravity or pump to the storage tanks at the sugarhouse. Such systems must use float valves to prevent accidental overflow and sap loss at the sugarhouse. All the desirable characteristics identified for sap storage tanks at the sugarhouse apply equally to dump or transfer tanks (e.g., they must be kept cool, and they must be clean and periodically recleaned).

Ultraviolet Lights and Sap Filters

The importance of minimizing microorganism contamination to optimizing the quality maple products has been repeatedly emphasized. Two pieces of equipment that are used by some maple producers to minimize microorganism contamination of sap are ultraviolet lights (UV) and small-pore filters.

Passing sap through an in-line UV unit when the sap is transferred from the collecting tank to the sap storage tank has been demonstrated to reduce the population of microorganisms (particularly bacteria) in stored sap (**Figure 6.44**). In many instances, UV treatment has resulted in longer sap storage times without a reduction in the grade of syrup produced, and in the production of higher-quality syrup, particularly late in the season when microorganism contamination is usually highest.

Commercial in-line UV units for use in treating maple sap are available through maple equipment

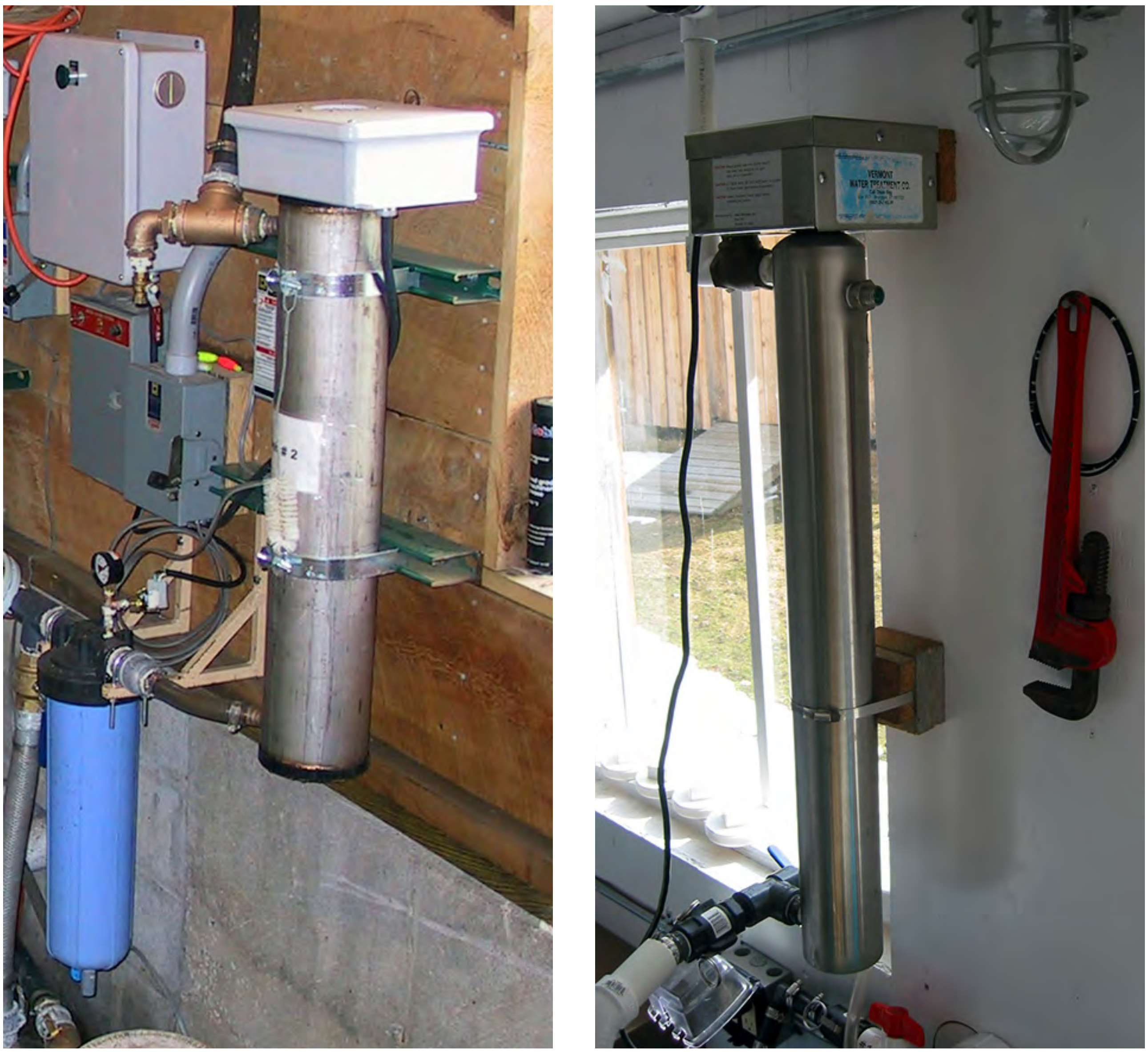


Figure 6.44. Two models of in-line ultraviolet filters (UV filters). The blue filter in the left picture is a small pore, cartridge filter.

dealers. However, only UV units designed specifically for maple sap have been verified as effective. Commercial units designed for water systems are less effective. All UV units must be properly maintained and operated within the flow limits for which they were designed. Caution is necessary when using ultraviolet light as it can cause serious eye damage. Ultraviolet lights suspended over sap storage tanks are dangerous to the naked eye. Ozone-based sterilization units have been introduced to the maple industry, although their efficacy has not been well established, and some research seems to indicate that sap sugar interferes with ozone action.

Passing sap through a small-pore filtering system as the sap is transferred to the storage tank can also markedly reduce the microorganism content of the sap. Microorganisms in sap range in size from hundreds of microns to less than a micron. They have the potential to rapidly increase in number, especially if sap temperatures are high. Commercial sap filters, as well as other types of liquid food filters, can be used to filter microorganisms from sap, potentially extending its storage life and improving the quality of syrup produced. These filters range from cartridge filters that remove fine debris and microorganisms down to the specifications of the filter (e.g., 5 microns), to food-grade diatomaceous earth (D.E.) filters that remove microorganisms down to the specifications of the D.E. In general, the finer the filter, the more effective will be the filtering process. Usually when very fine filtration is desired, a series of filters are used to perform the filtering process in stages in order to avoid rapidly plugging the fine filter. Research and experience have demonstrated that effective filtration with a relatively fine filter can often markedly improve the color of syrup produced from late-season sap. Coarse bag sap filters are intended to remove large debris and do not remove microorganisms to any substantial degree.

A more recent innovation in maple sap processing is ultrafiltration (UF) of sap, removing materials larger than about 0.2 microns, thus eliminating nearly all microbes. Sap and permeate treated in this manner are highly clarified and can be stored longer before processing. Generally, UF is used by those producers who process (or sell) sap or permeate for bottling.

Aeration of Sap to Reduce Off-Flavors

A limited amount of research has been done evaluating the manipulation of sap storage conditions through aeration in an attempt to aerate the sap and volatize the precursors that cause various off-flavors (buddy, sour sap, metabolism), or enhance the growth of microorganisms that might positively impact flavor development through their effects on the invert sugar composition of sap. Various methods to spray or recirculate sap through spray heads have been employed (**Figure 6.45**), but more research remains to be done to understand flavor development in maple and the causes of these

Figure 6.45. Sap aeration can be useful to retard anaerobic spoilage microorganisms.

off-flavors before recommendations can be made with confidence.

Cleaning Tubing Systems

While sanitation of spouts and droplines and, to a lesser extent, lateral lines is crucial in reducing microbial-induced taphole drying and enhancing sap yields, decontamination of mainlines is associated with higher-quality sap. Sanitation of mainlines has little or no impact on sap yield. Many producers choose to clean mainline systems annually, typically at the end of each season during or after pulling spouts. Often mainlines and lateral lines are cleaned at the same time, although for spout/dropline sanitation, cleaning in the fall just prior to freezing temperatures is likely to be more advantageous since any regrowth of microbes in the tubing network will be slowed by the cold temperatures. Cleaning can remove some accumulations of microbial growth. Sanitizing solutions may reduce the populations of microbes to fairly low levels. However, once the sap starts to run and the temperature begins to warm up, microbial growth will start immediately. Studies have shown that the timing of pre-season (or even within-season) cleaning can reduce the level of microbes, but regrowth is often astonishingly rapid. Whatever the method and materials used to clean tubing, it is important to remember that as tubing ages, natural deterioration of the inner tubing surface over time makes removal of microbial growth increasingly difficult. Current recommendations are for a 10–15-year replacement cycle for all tubing. Often lateral line tubing is marketed with a guarantee specifying the length of time it is guaranteed to last based upon the type and amount of stabilizer used in the formulation.

The choice of how cleaning is performed, when it is performed, and what (if any) sanitizer is used is all important. If water is used at any point to clean or rinse mainlines, it should be clean water (well water, city water, high-quality permeate). Untreated pond or stream water contains microbes that will multiply and spread inside the tubing. Many producers maintain modern tubing systems using water alone. This used to be the preferred method, since no chemicals are introduced into the tubing system or sprayed into the environment; however it is now recognized that this approach does not produce good sap yields, is clearly ineffective at sanitizing the system, and allows rapid microbial regrowth.

Cleaning methods fall into two broad categories: those methods using a chemical sanitizer and those that do not. These are described separately below.

Some maple syrup producers use chemical cleaners and sanitizers. If sanitizers are used it is important that all products used are approved, as appropriate, by either the Canadian Food Inspection Agency (CFIA) in Canada or the Environmental Protection Agency (EPA) in the United States. In Canada, all sanitizers must be registered by the Canadian Pest Management Regulatory Agency. In the U.S., food contact surface treatments also need to be listed in the FDA's Title 21 to be legally used on maple tubing.

The pros and cons of sanitizing, disinfecting, and cleaning chemicals currently in use in the maple industry are discussed below:

- **Sodium hypochlorite** (the active ingredient in bleach) solution was once a commonly used sanitizing agent in the maple industry and is still used by some to sanitize tubing. While sodium hypochlorite is an accepted sanitizing agent in the food industry, its use in maple tubing presents some challenges. It is effective but difficult to rinse completely from the tubing, and if not completely removed, it has the potential to contribute to the production of off-flavored syrup. Animals, particularly squirrels, are attracted to the sodium hypochlorite residue, and will frequently chew tubing and fittings that have been washed with a bleach solution. It has been observed that a significant decrease in squirrel damage often occurs after the use of washing solutions containing bleach has been discontinued. If a decision is made to use a bleach washing solution it is suggested that it be used at a concentration of 200 ppm. If household bleach is used as the source of sodium hypochlorite, 200 ppm is obtained by mixing 0.55 ounces of 5 percent household bleach per 1 gallon water. Note that these ratios change if a sodium hypochlorite source other than 5 percent household bleach is used.

For satisfactory results the sodium hypochlorite solution may require anywhere from 5 minutes to several hours of contact time. Traditionally, many producers have allowed the solution to remain in the tubing overnight, followed by a thorough rinsing the following day. If tubing is not rinsed, the first flow of sap the next spring should be allowed to run onto the ground. Because all traces of sodium hypochlorite are difficult to remove by rinsing, the use of bleach solutions to clean tubing is not as widely used as it once was. In addition, some formulations of bleach have additives to boost cleaning or to add scent. These should be avoided, especially by certified organic producers (the additives are not allowed).

- **Calcium hypochlorite** has been tried by some producers with success—it is thought to be as effective as sodium hypochlorite, but less attractive to animals that might gnaw on tubing. A source of calcium hypochlorite suitable for food-grade purposes should be used (not simply pool-grade bleach). Contact time requirements are similar to those for sodium hypochlorite, and rinsing is required.
- Food-grade **hydrogen peroxide** is also a good disinfectant. The current recommended concentration for a hydrogen peroxide wash solution is 1,000 ppm (2 parts hydrogen peroxide with a 5 percent active ingredient in 98 parts water). Hydrogen peroxide is more expensive than bleach, but it purportedly breaks down without leaving any residue (although rinsing is still not a bad idea) and does not attract squirrels or other rodents. Peroxyacetic acid is a common additive in peroxide-based sanitizers: if present, it would necessitate a subsequent rinse. A 5-minute minimum contact time is typical, but producers should check the product label for instructions specific to the sanitizer used.
- **Acid cleaners,** such as phosphoric acid, are sold under a variety of brand names as cleaners to be used in the maple industry for the removal of sugar and salt deposits from evaporators and other similar equipment. While some producers are using these cleaners to clean tubing (at a greater dilution rate than that used for evaporators) this practice is not recommended.
- Producers in Canada are permitted to use **isopropyl alcohol** (IPA). After cleaning lateral lines (and allowing some amount of IPA to remain in the lines), IPA is introduced into the end of mainlines to kill any microbes located there. Care should be taken with this practice to prevent IPA from contacting surfaces that could be damaged by the solution. Detailed instructions on the proper use of IPA are available and should be followed carefully. IPA is not permitted for use as a maple sanitizer in the U.S.A.
- The vinegar or **"Sour Sap"** method involves introducing vinegar (a mild acid) into sap lines, or more commonly, pulling and capping spouts with sap remaining in the lines. The theory behind this method is that the spoilage of sap produces acetic acid, which should kill the microbes in the tubing system. This approach, which was common several decades ago, has never been demonstrated to be effective. Acids are typically considered to be good cleaners, but are relatively ineffective as sanitizers. Problems with this method include foul odor, possible sour taste in sap, and the potential of the microbial residue it can leave behind to plug tubing, particularly in 3⁄16-inch tubing systems.

Note that mention or exclusion of any approach does not constitute an endorsement or specific recommendation of any product or imply that these approaches or substances are legal to use in any particular area. It is incumbent upon the user to comply with all federal, state, provincial, and local regulations and practices regarding the use of sanitizing chemicals in their area.

Household and industrial soaps and cleaners and any other sanitizer not appropriately labeled for use in maple tubing should not be used to clean tubing. Any type of scented sanitizer should be avoided (nobody wants lemon-flavored syrup).

Some sugarmakers with small tubing operations choose to take down all lateral lines at the end of the season. Removed tubing is often washed by flushing each line with hot water accessed by connecting the line to a household hot water system, or by some other means that forces a large quantity of clean, potable water or a sanitizing solution through each line and spout. If a sanitizing solution is used, tubing should be rinsed with potable water. When this is done, tubing should be forcibly blown dry with air from an oil-free compressor to reduce the chances of microbial regrowth.

Producers with larger tubing operations, or even those with small operations who have access to the right equipment, sometimes choose to wash their tubing while it's still in place in the sugarbush. There are several approaches to doing this. Until recently, many producers used a pressure washing system that pumped an air/water mix into tubing. Producers would pull spouts sequentially, allowing some air/water to blow out through the spout before capping it off. This approach has largely fallen into disfavor over the past decade, although some producers continue the practice, but add sanitizer (bleach or some other sanitizing solution) to the air/water mix. This process is followed by rinsing with potable water or, alternatively, allowing the first run of sap the next spring to flow on the ground.

A more common method, particularly among moderate to large maple operations in the U.S., is a practice termed "dry cleaning." In this approach spouts are pulled with the vacuum on before being capped or plugged. This practice pulls out most of the debris in the tubing but does not kill any of the microbes adhered to the tubing walls. Some will go back and leave spouts hanging uncapped and unplugged to dry out over the summer. Again, there is little chance of killing microbes with this approach.

More recently, producers use a backpack or handheld sprayer of some sort to inject a cleaning solution into the spout with the vacuum OFF. The advantage of this approach is that it allows a reasonable amount of contact time between the sanitizer and surface being cleaned. The solution is allowed to sit in the tubing for a given length of time, then removed with vacuum or by allowing the spouts to dangle uncapped. The efficacy of this approach depends on how well the residual sap has been removed from the tubing system before the sanitizer is applied, reducing dilution of the sanitizer and improving contact between the sanitizer and tubing walls. Again, rinsing or allowing some sap to flow on the ground the next spring is required.

For use in cleaning mainlines, a valve at the end is used to introduce the sanitizing solution (typically a gallon or more). Sometimes a cleaning sponge is inserted first under vacuum and the solution added to help pull the sponge through the system. This method is used less frequently than it was a decade ago. A thorough rinse with potable water should follow.

It is important to maintain records of the cleaning and sanitizing treatments that are used to clean tubing and related sap collection equipment. Traceability in food production is becoming increasingly important, and if a problem such as off-flavor develops, it is important to be able to trace it back to a possible cause. When chemicals have been used to clean tubing collection systems, some producers choose to discard the first collected sap until the lines have been thoroughly filled and rinsed with sap.

CHAPTER 7
Maple Syrup Production

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INTRODUCTION

The production of maple syrup is fundamentally the concentration of sap solids, primarily sugar, through the removal of water. Presently there are two main methods for achieving this: evaporation through boiling alone or concentration via reverse osmosis followed by boiling. Although both methods achieve the same result, a wide variety of equipment and practices are employed to achieve it. As simple as these processes are, they result in many complex physical and chemical reactions and transformations that affect the density, color, and flavor of syrup. Despite all the complexities involved in the production process, the primary goal is simple—to create a pure, natural, high-quality food product.

EVAPORATION

The process of transforming maple sap into maple syrup through evaporation has undergone tremendous change over the past two hundred years (see **Chapter 2**). This change has been driven by several factors, including changes in manufacturing practices and the desire to decrease the amount of time required for evaporation, increase fuel efficiency, produce a safe, high-quality food product, and reduce production costs. Many of these goals have been realized through improvements and changes in equipment design and manufacturing materials, technology, and techniques.

In addition to incorporating many performance enhancements, today's maple syrup processing systems differ from those used in the past in another, more fundamental way. While the first evaporators performed batch or semi-continuous processing, current evaporators are designed to maintain continuous or nearly continuous flow. Sap is introduced into one portion of the evaporator, and the sugar concentration increases as the liquid moves through the system until it is drawn off as syrup. Flow is controlled by mechanical floats or electric valves to keep the liquid at a constant depth, and relatively little operator intervention is required once the evaporator is running.

Whether small, large, or something in between, most evaporators comprise a minimum of four distinct parts (**Figure 7.1**): the arch (or firebox), the

FIGURE 7.1. Basic components of a maple evaporator. The arch sits on the floor and contains the heat source (wood in this case). Pans sit upon the top of the arch and hold the boiling liquid. The stack (rearmost in photo) exhausts the excess heat and combustion gases safely out of the vicinity.

heat source itself, one or more pans, and the smokestack (chimney). The pans rest on top of the arch and are piped together but can usually be separated with valves or plugs to facilitate removal from the arch. As pans increase in size, partitions are added to form channels directing the flow of sap through the evaporator so that the liquid follows a winding path from the inlet to the outlet. This design prevents fresh sap from mixing with partially processed sap and allows a sugar concentration gradient to be established along the length of the evaporator pathway, reducing the size of batches and facilitating a more continuous exit of syrup from the evaporator.

The Gradient

The continual flow of sap through the evaporator along an ever-increasing sugar concentration gradient reflects the process of transforming maple sap into maple syrup but can be a source of mystery to producers (**Figure 7.2**). What causes the gradient to develop and be maintained? When starting the evaporator for the first time or after a period of inactivity, there is no gradient (except between sections that have been plugged or valved off), and all the liquid in the pans has roughly the same sugar concentration. However, shortly after boiling commences and a constant influx of sap is achieved, a density gradient is established. As water evaporates from the sap, the sugar concentration, and thus density, of the remaining liquid increases. Fresh sap is constantly entering the evaporator as the regulator valve opens to maintain the proper liquid level. The liquid farthest away from the sap entry point is "pushed" toward the farthest end of the pathway, where the syrup draw-off is located. As boiling continues and sap continues to enter the evaporator, the sap that has been in the pan for the longest time is located in the far portions of the syrup pan. In physical terms, the more concentrated sections of near-syrup will "pull" liquid from the less concentrated solutions to balance out the solution. In theory, since the liquid that is further into the process has been in the pan for the longest time, it is typically only in the last partition where the liquid will reach the finished density for syrup. For theory to become reality, the flow must be unobstructed at all points in the evaporator, there should be little or no mixing between segments of the partitions, the pans must be level, and the heat source constant.

Basic Evaporator Components

FLUE PANS The flue (also called "sap" or "back") pan sits on the arch behind the syrup pans. It is so named because of the construction of the pan bottom; deep channels (flues) are built into the pan (**Figure 7.3**), greatly increasing the surface area and thus the heat exchange capacity when compared to a flat-bottomed pan. The flow of sap into the flue pan is controlled by a float or electric valve fitted into a regulator (or float) box. The float or valve is adjusted to maintain the desired depth of sap in the pan. From this entry point, sap flows via a distribution pipe into the flue pan. One or more partitions guide sap from the entry point to the pan exit point.

There are three basic types of flue pans: drop, raised, and tube. Drop flue pans are built with the flues running lengthwise below the level of the top of the arch. Heat from the burning fuel passes directly between the flues on its way toward the rear of the arch and up the smokestack. A single regulator box controls the level of sap in both the flue and syrup pans. Raised flue pans are designed so the flues rise several inches above the top of the arch, with the sap level being several inches higher than that the syrup pan. With raised flue pans, a second regulator box controls the flow of liquid from the

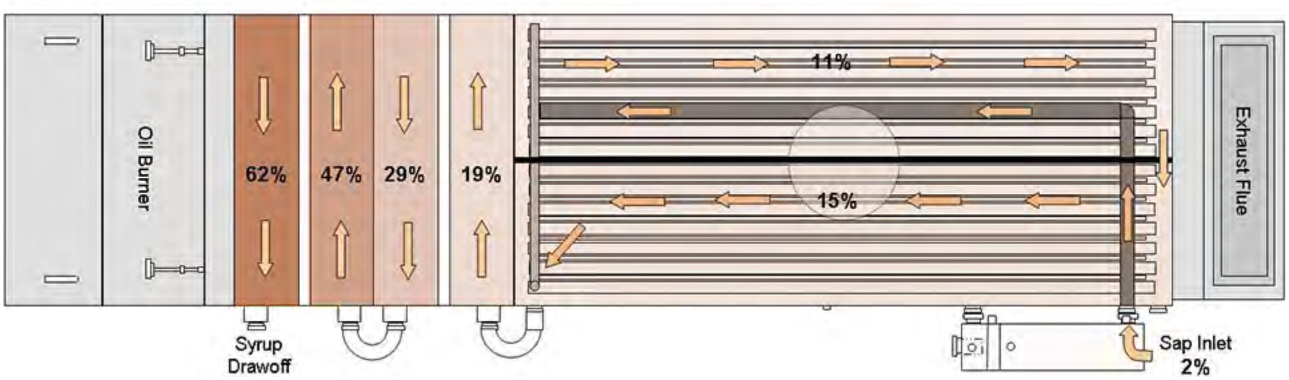


Figure 7.2. Density gradient in a maple evaporator. The development of the sap to syrup gradient in an evaporator is the result of the repeated addition of fresh sap into the sap pan along with the continual evaporation of water from both the sap and syrup pans. In this diagram, 2°Brix sap was introduced through the sap inlet pipe into the front of the upper sap channel. Arrows indicate the direction of flow. The values represent the average Brix concentration for that channel and are for the purpose of illustrating the sap to syrup gradient. The measurements will vary for each evaporator and sap concentration used.

(a) (b)

Figure 7.3. Evaporator with a raised flue sap pan and two cross flow syrup pans (a) and an evaporator with a drop flue sap pan and a reverse flow syrup pan (b). Note that the top of the raised flue sap pan sits higher in relation to the syrup pan than the drop flue sap pan. This particular reverse flow pan has four parallel front-to-back channels and a fifth channel (nearest the sap pan) at a right angle. This configuration allows the flow to be reversed without changing the draw-off side. Many reverse flow pans have only the parallel channels so the draw-off side must be switched when the flow is reversed.

flue pan to the syrup pan, and thus the level of sap in the flue and syrup pans can be regulated independently. Tube-style flue pans incorporate heat exchange pipes submerged within the liquid in the pan.

SYRUP PANS Syrup (or "front") pans have flat bottoms and internal partitions to channel the boiling sap toward the syrup draw-off as it increases in density. Reverse Flow pans (**Figure 7.3**, right) are designed to enable the path of the liquid from its entry into the pan to where it is drawn off to be reversed, so that the locations of the syrup draw-off and sap entry points can be alternated from one to the other. This design is primarily to facilitate the management of niter. In Cross Flow evaporators (**Figure 7.3**, left), syrup pans are divided into multiple individual pans, so that clean pans can be substituted as niter accumulates on pans during the boiling process. These pans are often divided into two or more sections. Individual pans are typically connected to form a larger syrup pan. Increasingly evaporators are constructed with a hybrid approach allowing flow reversal to be conducted easily from a single drawoff location.

The flue and syrup pans rest on an arch that contains the heat source. A flat or woven ceramic gasket is sandwiched between the pan and arch to prevent cold air from entering the arch and increasing combustion efficiency. This also eliminates the problem of combustion gases exiting through the space. Other evaporator components include floats or regulators to maintain liquid in the pans at a constant level, liquid level indicators, thermometers for monitoring pan and stack temperatures, pressure gauges, and drains (**Figure 7.4**). These and other

Lead in Maple Equipment

All equipment that contacts maple sap or syrup should be lead-free. The accumulation of lead in the human body can have significant health and developmental consequences, particularly in children. There is no “safe” level of lead.

Equipment fabricated from materials that contain lead should not be used to collect sap or process maple products. Older galvanized buckets and storage tanks and most evaporators manufactured prior to 1995 were constructed using some lead-containing materials. Primary among these materials was 50:50 solder (50 percent tin and 50 percent lead). Galvanizing used in maple equipment contains lead, as do evaporators constructed of terneplate, a lead-containing alloy. In addition, most bronze or brass fittings contain some lead, and parts or materials labeled as “lead-free” often contain small amounts of lead.

It is recommended that before purchasing any new or used equipment producers ask the manufacturer or seller for certification that it is manufactured from lead-free materials. Maple producers should consult with the equipment manufacturer to determine whether their existing evaporator or any other equipment (tanks, valves, fittings, pumps) currently in use in their operating environment contains lead. Low-cost lead testing kits are also available from most maple equipment dealers and hardware stores. When in doubt, producers should seriously consider replacing suspect equipment with stainless steel or food-grade plastic. The best approach is to replace maple equipment that contains lead as soon as possible.

For certain certification programs, such as those for organic maple production, and for the sale of syrup to many syrup packers, producers must confirm that their operation is free of lead-containing equipment.

(a)

(b)

(c)

(d)

(e)

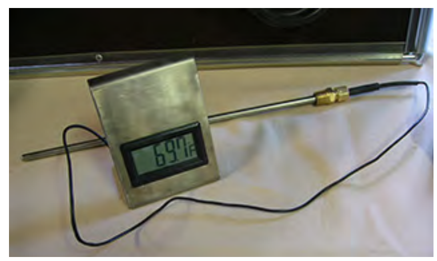
(f)

(g)

(h)

(i)

(j)



(k)

(l)

(m)

(n)

Figure 7.4. Several different devices and components can be found on evaporators depending upon its size and configuration, including: stack thermometer (a), operating controls (b), on/off control, draft indicator and oil pressure gauge (c), floatboxes (d) and (e), connections between pans (f, g), liquid sight level gauges (h), automatic low level shut-off (i), auto shut-off (j), simple thermometer and probe (k), boiling point elevation (temperature above the boiling point of water) indicator for draw-off partition (l), simple solenoid auto-draw systems (m), and modulating auto-draw system (n).

components are each discussed in more detail in the "Evaporator Operation" section.

Overall, although the basic concepts of the process are the same, evaporators can range from being very simple (**Figure 7.1**) to very complex (**Figure 7.5**).

TYPES OF EVAPORATORS

There are many types and styles of evaporators, differentiated principally by fuel type and the addition of features to increase performance and efficiency and/or match the operator's needs and desired processing conditions.

Wood Evaporators

BASIC WOOD EVAPORATORS The most basic wood evaporators consist of pans resting on an arch lined with firebrick, a firebox in front with open grilles for air to enter passively for combustion (without fans to increase the flow of air), and a stack in the rear through which smoke exits. Wood burns with a luminous flame, and most of the heat (about 80 percent) transferred from the fire to the evaporator is radiant. Under the flue pan, much of the heat results from burning gases released from the wood and moving in the draft toward the stack. Thus, in a basic wood evaporator, designs to encourage the movement of heat and flame along the bottom of the pans are advantageous. These include features such as vertical sidewalls and a relatively shallow depth to the arch floor beyond the firewall (**Figure 7.6**).

Figure 7.5. A modern maple evaporator designed for boiling high Brix concentrate, with cross flow pans and a reverse flow option to allow drawing off from one fixed position.

A spark arrestor is a highly recommended safety feature for all wood evaporators (**Figure 7.7**).

HIGHER-PERFORMANCE WOOD EVAPORATORS
Wood-fired evaporators are available with numerous design feature that increase the efficiency and performance over those of basic models, including:

- **Enhanced Insulation.** Various improvements to insulation retain heat

Figure 7.6. A basic wood evaporator includes vertical sidewalls and a relatively shallow depth to the arch floor beyond the firewall. This maintains the heat close to the bottom of the flues.

Figure 7.7. A spark arrester is useful in preventing release of these potential fire starters.

in the combustion chamber for increased combustion efficiency. These include high-density arch board to line the sidewalls and deck between the firebrick and sheet metal, insulated airtight doors, and double-walled arches with insulation in between the walls.

- **Forced Draft and Gasification.** Forced draft systems provide supplemental air for combustion using a blower and system to ensure the correct amount of air enters the combustion chamber. This increases the rate and completeness of combustion of both wood and combustible wood gases, which increases efficiency by increasing the heat yield per unit of wood and enabling more efficient combustion of lower-quality wood. Preheating the incoming air (using heat from combustion) can further increase the efficiency of combustion.
- **Double-pass designs.** Evaporators with this design use tube-style flue pans (**Figure 7.8**), which incorporate heat exchange pipes that contact the liquid in the pan. The combustion gases pass first under the pans and then through the heat exchange pipes before exiting through the stack. The heat from wood combustion is thus used twice for evaporation in the flue pan, substantially increasing heat exchange and overall efficiency.
- **Automation.** Wood-fired evaporators are available with automated control of airflow and temperature based on desired stack and/or arch temperatures, which facilitates a more constant temperature in the arch. This feature can further improve combustion efficiency and allow for the use of lower-quality wood. As with any type of automation, the gains in efficiency are ultimately dependent on the settings input by the user, and it is important to be able to bypass the feature in case of malfunction or changes in the desired processing conditions.

Figure 7.8. A schematic of a tube-style evaporator flue pan. Hot combustion gases flow through the tubes located near the bottom of the pan from the bottom right to the left. (CDL MAPLE EQUIPMENT)

With these features, it is possible to achieve substantial gains in efficiency and performance, including reductions in fuel consumption and firing interval, increased efficiency even with wood of lower quality or that is not perfectly dry, increased evaporation rate, and reduced emission of pollutants. For example, the firing interval of a basic evaporator ranges from about 10 to 20 minutes; however in an evaporator with higher-performance features the interval can be as long as between 30 and 60 minutes, depending on the quality of the wood.

High-performance wood evaporator models are available to process standard firewood, wood pellets, or chips. Hybrid models capable of using multiple wood types (e.g., wood pellets and standard firewood) are also available. Wood pellets and chips have the advantage of allowing for automated loading and firing; however, they are generally more expensive than standard wood evaporators. Care must also be taken to obtain high-quality pellets and chips that are well adapted to the evaporator burner. Appropriate storage measure to manage the moisture content and heat of chips and pellets are required to prevent quality degradation and reduce the risk of fire.

Oil Evaporators

BASIC OIL EVAPORATORS Like wood evaporators, basic oil evaporators consist of pans resting on an arch with a fuel source. Their arch design differs from that of wood evaporators, reflecting the fact that fuel oil burns in a compact ball. The firewall is sloped upward from front to rear to help transfer the radiant heat from the oil fireball to the bottom surfaces of the pans along the entire evaporator length. The most basic oil evaporators are equipped with a single-stage burner. While most oil evaporators run on fuel oil, some models can be equipped to use kerosene, propane, or natural gas. Arches are typically lined with ceramic blanket.

HIGHER-PERFORMANCE OIL EVAPORATORS

Oil-fueled evaporators are also available with numerous design features that offer substantially greater efficiency, performance, and control over basic oil evaporators.

- **Preheating** the air for combustion and the oil by running the oil line in the space between a double-walled arch increases BTU extraction from the fuel.
- **Draft control** with a barometric damper regulates the draft at a set level with changes in wind, temperature, and barometric pressure. This improves efficiency by ensuring the draft is regulated at the appropriate level, and thus the appropriate amount of heat from combustion is transferred to the pans rather than directed out the stack.
- **Dual stage and modulated burners.** Dual stage burners have both a "low" and "high" fire setting and facilitate starting in colder temperatures, as well as preheating the arch gradually on low fire at start-up and adjusting to low fire during processing if conditions warrant. With single or dual stage burners, the airflow and fuel delivery rate, and thus the amount of heat, are adjusted at a set level for each stage by the technician at the time of the burner adjustment. Modulated burners allow the amount of heat to be varied, with the fuel delivery and airflow automatically adjusted to optimum levels. This flexible design enables users to adjust the amount of heat to optimal levels for desired processing conditions without loss of combustion efficiency and to adapt to changing conditions in sap concentration or quality.
- **Double-pass designs.** Oil-fueled evaporators with this design have burners mounted in the rear. As in wood evaporators incorporating this design, heat from combustion travels first under the tube-style flue pan toward the front of the evaporator, then returns back toward the rear of the evaporator through heat-transfer tubes immersed in the liquid in the flue pan before exiting through the stack. The heat from combustion is thus used twice for evaporation in the flue pan, increasing heat exchange and overall efficiency.

Steam Evaporators

Evaporators that use steam as a heat source to drive evaporation incorporate heat exchange pipes within the evaporator pans. When water vaporizes into steam it requires energy (970 BTUs per pound); as the steam condenses, it releases this heat energy. In steam evaporators, steam is formed in a boiler and transferred under pressure to the evaporator, where it condenses in the heat exchange pipes. The energy that is released when the steam condenses boils the sap. This type of heat transfer differs from that in standard wood or oil evaporators, where flame or burning gases are in direct contact with the pan surfaces. The higher the pressure, the higher the temperature of the steam and the more heat energy is released when the steam condenses. The use of steam requires not only all the safety considerations that apply to any evaporator, but also additional precautions specifically related to steam. Furthermore, specific regulations required for the use of steam boilers vary considerably between states and provinces. Consequently, maple producers must ensure the proper installation, operation, maintenance, and inspection of their steam system by licensed technicians and understand and adhere to the regulations governing its use in their own geographic area.

Electric Evaporators

Evaporators are available for maple production that use electricity as a source of fuel (**Figure 7.9**), although

Figure 7.9. An electric-powered maple evaporator. Note the complete absence of steam, which is condensed within unit and heat energy extracted and recycled.

they tend to be relatively uncommon, especially in the U.S. where electric rates tend to be higher. In these evaporators, electric elements are used to initially heat the incoming sap. Steam from the heated sap is captured and directed through heat exchange tubes in the evaporator pan, where it is used to heat the sap and drive the evaporation process in the pans. The steam from the evaporating sap is captured and reused, and thus the electric elements are used only periodically after initial start-up. The evaporator operates as a closed system under slightly elevated pressure, with no steam or exhaust chimneys.

Additional Evaporator Accessories

Several ancillary devices are often employed along with evaporators to increase evaporation rate, enhance their efficiency, or to alter the characteristics of the syrup produced. These include:

- **Steam hoods** facilitate the movement of water vapor away from the evaporator and out of the sugarhouse. While they improve the working environment in the sugarhouse, they do not appreciably increase the efficiency of evaporation. Care must be taken to ensure that the gutter inside the hood is functioning properly to direct condensation out of the hood, preventing it from reentering pans where it would have to be boiled again.
- **Preheaters** use the heat in the evaporated water vapor or stack to increase the temperature of the incoming sap, thereby reducing the amount of fuel required to heat the sap in the evaporator and increasing overall evaporation efficiency by between 5 and 15 percent. Most preheaters consist of a series of parallel tubes with a drip tray below to collect and direct away the condensate that forms on the outside of the tubes. Note that the temperature of the sap should remain below the boiling point to prevent steam formation, which can impede flow, building pressure resulting in unsafe conditions. The inlet for cold sap should be at the bottom of the unit, and the outlet for hot sap on the top, to reduce the risk of circulation problems in the event of steam formation. At a minimum, preheaters must be cleaned after each boil with permeate (or potable water) to avoid microbial contamination and fouling and their negative impact on system performance and syrup quality.
- **Steam pans** (such as a "piggyback" or Steam-Away®) are enclosed units that sit tightly over the flue pan and use the heat energy from the steam of the evaporator to heat and remove water from sap before it enters the flue pan. These units use an energy recovery steam hood system, along with an air injection system, to capture heat from the steam that would normally be lost. Sap enters the flue pan both hot and at a slightly higher sugar concentration, thereby decreasing boiling time and increasing overall evaporator efficiency. For example, incoming sap at 2°Brix[1] will be concentrated to between 3° and 3.5°Brix before it enters the flue pan. With concentrate the increase in concentration will generally range from 4° to 7°Brix

[1] In this chapter, °Brix is used to express the total percent sugar concentration of a liquid (e.g., sap at 2°Brix has 2 percent sugar concentration), rather than the formal definition of °Brix, which refers only to the concentration of sucrose in a liquid.

depending on the starting concentration. Air intakes for steam pans must be carefully located to ensure that the incoming air is clean and not contaminated with exhaust vapors or other fumes that can introduce off-flavors and render syrup unsuitable for consumption. Like preheaters, steam pans must be thoroughly cleaned after each use.

- **Air injection** devices force air through a series of small holes in stainless-steel tubes lowered into the pans (either the flue pan or both flue and syrup pans). Although they do not increase the efficiency of evaporation, research has demonstrated that the use of air injection tends to result in the production of lighter-colored syrup with flavor consistent with that of lighter-colored syrup. There are anecdotal accounts that air injection units can aid in foam control and the prevention of niter deposition on pans, but these effects have not been experimentally observed. As with steam pans, air intakes for air injection units must be carefully located to ensure that the air source is clean and not contaminated. Filters on air injection units should be changed regularly.
- **Pan ratio options.** Traditional evaporators have syrup pans about one quarter to one third the length of the full unit. Current evaporators are available with a range of ratios of flue to syrup pans. Variations in this ratio are intended to optimize the management of heat, niter formation, foaming, flavor development, and other processing conditions as dictated by the concentration level of incoming sap to be processed. As sap sugar concentration increases, the need for high heat transfer and rapid boiling in the flue pan is decreased, while the formation of niter throughout the evaporator is increased. With increases in the concentration of sap to be processed, the ratio of flue to syrup pan can be adjusted to ensure that the concentration of material as it exits the flue pan remains lower than 35° to 40°Brix. Doing so not only helps prevent excessive niter accumulation in the flue pan but also optimizes efficiency. For example, the optimal flue pan percentage for sap between 16° and 20°Brix could be about 60 percent of the total length, and about 50 percent for sap concentrated to 25°Brix. Evaporators designed for use with very high Brix concentrate, 35°–40°Brix, typically have less than 35 percent flue pan, or no flue pan at all.

It should be noted that in many cases, the condensation from steam hoods, preheaters, and steam pans is not completely "clean" or sanitary. It can contain sugar and residues from defoamer and microbes. And in some cases, components may not be made entirely of stainless steel. These factors must be considered when planning uses for this material.

EVAPORATOR OPERATION

General Best Practices

There are several steps to take before firing the evaporator—either before the season or before each boil—to ensure optimal performance and efficiency.

- **Check the pans and insulation.** Pans should be thoroughly cleaned, inside and out, before the start of the season. Pan interiors should be free of any niter, cleaner residues, pest droppings, and dust and debris. Pan bottoms should be free of any soot to ensure unimpeded heat transfer. Test filling the pans with water can help uncover any leaks in the pans or junctions before the pans are filled with sap and reveal whether the pan is level. Before the first firing of the evaporator, check to ensure the insulation is intact and in good condition and is in the appropriate position. When the system is in operation, flames should not be visible between the pans, or between the pans and the arch. Ensuring these conditions are in place will facilitate the control of air intake and appropriate distribution of gases under the pans.

- **Burner adjustment.** For oil evaporators, a burner adjustment by a qualified service technician is essential. The technician will optimize the settings for fuel usage rate, draft, and combustion. To ensure the evaporator continues to perform at peak efficiency, this service should be repeated at least every two years. Fuel filters should be changed as needed.
- **Level the evaporator.** It is essential to ensure the evaporator and each pan are level to avoid uneven flow and the problems and issues with efficiency or even scorched pans that it can lead to. Optimally this should be checked before each firing, as in many sugarhouses the level of the floor may change during the season.
- **Sap supply to evaporator.** A properly functioning sap supply line is critical to evaporator function. The pipeline between the feed tank and the evaporator must be large enough to deliver a constant supply of liquid to the evaporator in sufficient quantity to maintain the set sap level under full boil. A sufficient height difference between the tank and evaporator to generate adequate head pressure facilitates optimal evaporator function. If the supply line is connected to an outside storage tank, it should be insulated to prevent freezing or drained when not in use. It can be helpful to use an alarm or signaling device to indicate when sap movement is interrupted, or if the liquid level becomes low in the tank or pans (**Figure 7.10**). The sap supply line should be equipped with a valve that can be used to adjust flow rate and also to cut off the flow when the evaporator is shut down. It is advisable to have a back-up method of quickly supplying sap or permeate to the evaporator in case there is an interruption to the primary sap feed line to prevent burning of the pans. A secondary sap or permeate line or simply a bucket of fresh sap or permeate kept close to the evaporator while boiling can serve this purpose.

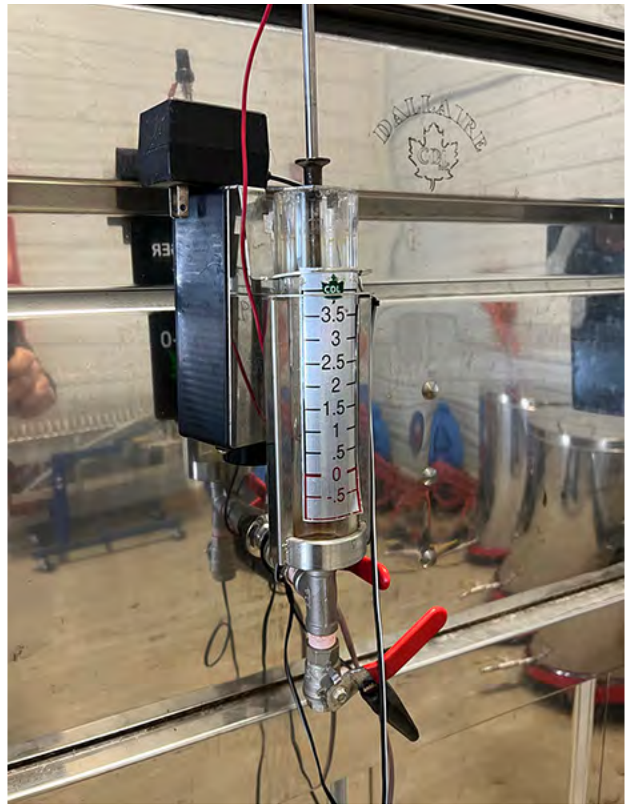


Figure 7.10. Alarm devices are useful for sounding an alert when liquid level gets low in tanks or pans.

- **Sugarhouse Records.** Keeping detailed records of sugarhouse activities can be an invaluable tool for developing and maintaining a successful operation. Accurate descriptive information can help producers optimize efficiency, troubleshoot problems, and effectively plan for future equipment changes and updates. The information recorded can range from basic information on sap production, boiling, and syrup production to more extensive data on evaporator settings and fuel use, tapping, sap and syrup flavor and quality, the quantity of defoamer used per unit, and weather. Developing a datasheet can help make recordkeeping convenient and simple.

Guidelines for Operation

Although each evaporator will have its own specific guidelines for operation, the following are general best practices and guidelines for operation that apply to most standard evaporators.

STARTING UP Before starting the evaporator each day, ensure that a steady supply of sap is available, and adjust the level in each pan to the desired set point. Confirm that the stack and steam covers are open and that fuel supply to the evaporator is available. Also, verify that floats or electric valves are operating properly, that defoamer is in place, that the draw-off probe temperature is set (confirm the boiling point of water to assist with this), and that the draw-off bucket or tank is ready to accept syrup.

For oil evaporators, start on low fire for 5–10 minutes to warm the arch before switching to high fire. This gradual warming can prevent deformation of the pans and production of smoke within the sugarhouse. For wood evaporators, prepare enough wood (inside the sugarhouse) for about an hour of boiling, and be sure to have a good mix of hard and soft wood of large and small sizes. Wood quarters should not be greater than 8 inches nor less than 2 inches wide. Start a small fire to warm the chimney, then ensure that the chimney is open before adding more wood. For wood-fired evaporators with drop flue pans, care must be exercised during firing to avoid damaging the front end of the flues as wood is pushed back into the arch. Wood should be cut shorter than the length of the firebox to help prevent this from happening.

After starting the evaporator, valves or plugs that were placed between pan sections at the end of the previous boil can be opened or removed as each section begins to boil. Start with the plug or valve at the cold float box, proceed to open the plugs in succession going toward the front of the evaporator and ending with the last one at the draw-off. This procedure helps ensure that the gradient is maintained or reestablished as rapidly as possible. If there is no plug in the final section of syrup pan (as in some cross flow pans), reducing the liquid level in the syrup pan at start-up can help facilitate the reestablishment of the gradient and help to prevent a very large first draw off. Once the first draw-off has occurred, the depth can be adjusted to the desired level.

CONTROLLING THE LIQUID LEVEL Maintaining the liquid at the desired level in the evaporator is essential for smooth operation and optimal efficiency, to ensure pans are not scorched, and to achieve desired flavor properties. It is a critical starting point that affects many other evaporator operating parameters.

To ensure liquid level in the pans is even all around, the arch and evaporator pans must be level. This can be difficult on unfinished floors, but even concrete floors can shift during the season or over several seasons, so checking arch and pan level before starting is important. Pans can also sometimes have low or damaged spots due to manufacturing or after scorching, which means running deeper liquid levels and being extra cautious. Checking evaporator level frequently is a good practice.

All evaporators should be equipped with liquid sight level indicators in both the syrup and flue pans (**Figure 7.11**). Although many indicators come pre-labeled with level measurements, these should be verified manually, as readings can vary substantially from the actual depth of liquid in the pans. It's also important to periodically purge the liquid in the sight levels during boiling and allow them to refill to ensure they are showing an accurate depth measurement, as they can sometimes become layered or blocked with niter and give inaccurate readings.

The liquid level in the evaporator pans is controlled by mechanical floats or electric valves fitted into a regulator box. With mechanical floats, the liquid level is adjusted manually by setting the height of the float in the regulator box. With electric valves, sensors control the opening or closing to precisely regulate the level of liquid in the pan. With all types of liquid regulation, it is important to verify that regulator boxes are level and parallel to the side of the evaporator to ensure good function. The importance of high-quality floats or valves cannot be overstated. They should be able to keep the liquid in the pan at the right level at all times and react rapidly to changing conditions (such as large draw-offs) without necessitating frequent user intervention or adjustment. All other facets of evaporator operation will be affected by how well the level is controlled.

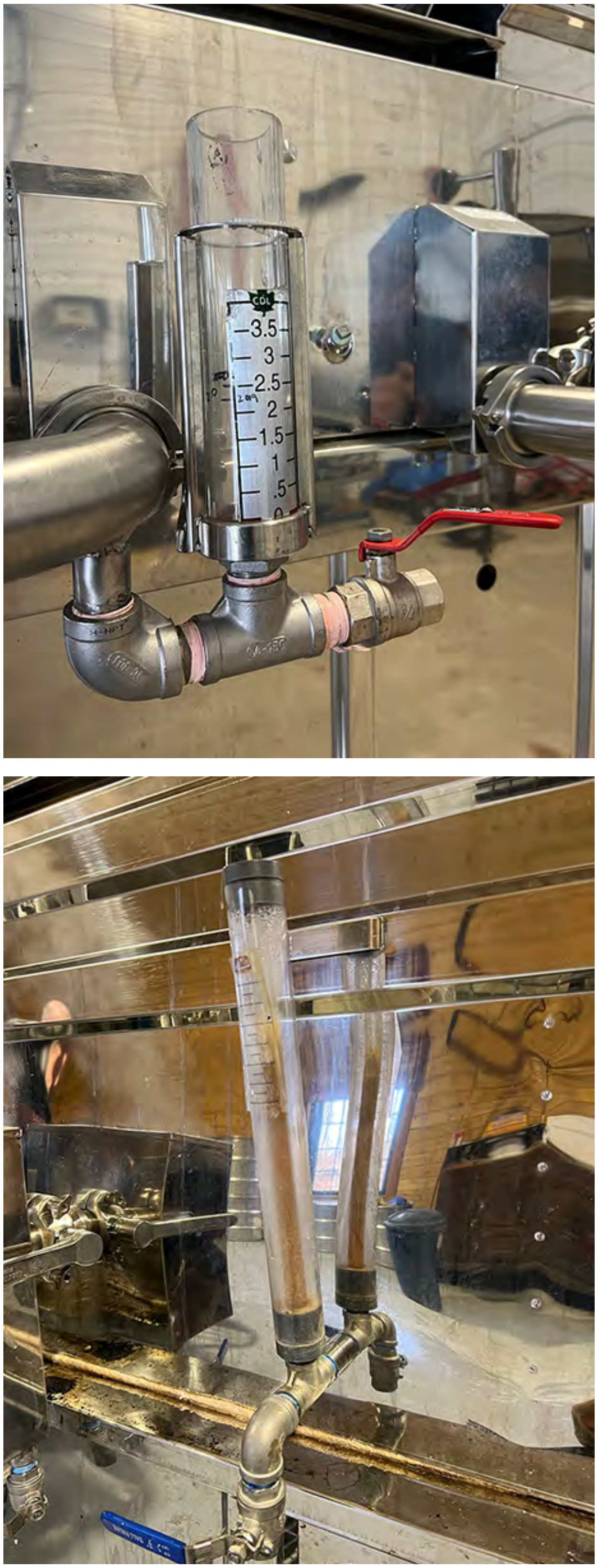


FIGURE 7.11. Liquid sight level indicators placed in both the front and back pans allow the operator to tell at a glance if there is a problem with sap/syrup depth.

The optimal depth of liquid used is influenced by a combination of factors, including the sap concentration and the preferences and experience level of the operator, and generally reflects a balance between evaporation rate, efficiency, and the risks associated with lower liquid levels. Shallow levels generally result in a higher evaporation rate but provide a smaller margin of error and higher risk of scorching pans. Sap quality and the desire to produce syrup with particular flavor properties can also influence the choice of liquid depth. It can be helpful to use deeper levels at the beginning of the season to provide additional response time if problems occur. The reliability of the floats or valves will also be a factor—floats or valves that are unable to respond rapidly necessitate maintaining a higher level of sap in the pan.

The division of sugarhouse responsibilities can also affect the decision on liquid depth. A sole operator with many tasks to accomplish may wish to run the sap level in the pans deeper than someone whose sole task is boiling. Stepping away from an evaporator for a moment while running a low level of liquid is a recipe for disaster—catastrophes can happen very quickly when the depth of the liquid you're boiling is too shallow.

Producers should experiment with pan depths and determine what works best for them; seeking advice from the evaporator manufacturer is also recommended. In general, for standard evaporators, liquid levels in the flue pan of between ½ and 2 inches above the flues are recommended for all sap concentrations, with only experienced and attentive operators running the evaporator at the low end of the depth range. In the syrup pan, it is important that levels are not too shallow as this can more easily result in scorching. The following are general guidelines for syrup pan levels:

2°–8°Brix=2 inches (5.1 centimeters)
8°–12°Brix=2.5 inches (6.4 centimeters)
12°–22+°Brix=3 inches (7.6 centimeters)

Evaporation rates are slightly faster with shallower depths, but the risk of catastrophe increases with shallower boiling.

Numerous factors beyond sap concentration will influence the optimum choice of liquid level. These include: the type and style of evaporator, the amount of heat in the pans, the ratio of syrup to flue pan, the foam and niter development rate and character, and the addition of evaporator accessories such as air injection and steam pans. For drop flue pans, it is important to keep the level of liquid above the transfer holes to ensure adequate flow between the flue and syrup pans.

FOAM MANAGEMENT The development of foam is an inevitable part of the syrup production process; however, best practices can help minimize its development, ease its control, and prevent the issues it can cause, including defoamer off-flavors, overflows, and pan or syrup scorching. The amount of foam generated typically increases with the level of heat, as well as when niter accumulates on pans or the sap quality declines. Any practices that help keep these contributing factors in check will help minimize foam development and the need to use defoaming agents.

When considering defoaming agents, it is important to remember the definition of pure maple syrup—100 percent maple sap, with nothing added or removed (except water). Only commercial, food-grade, non-allergenic defoaming agents can be used in maple production. Any defoamer that contains dairy or other animal products or allergens of any kind is unacceptable. When defoamer is used, it should be used sparingly. With most conventional commercial defoamers, only tiny quantities are needed to control or eliminate foam. Heavy use of defoamer can impart an off-flavor or unpleasant texture to syrup or result in a product that leaves a greasy film on the tongue, lips, or palate.

The use of defoamers in organic maple production is limited to certified organic products and typically involves certified organic cooking oils refined for high heat (canola, safflower, or deodorized sunflower oils). Because these oils are not engineered as anti-foaming agents, their effectiveness is extremely low, and relying on them can make managing foam challenging. Their low efficacy can also necessitate the use of large quantities, which increases the risk of off-flavors.

Proper care and storage of all defoamers is essential to ensuring their efficacy and preventing off-flavors such as those from rancid defoamer. Defoamers should be stored away from heat and light and kept in tightly closed containers (exposure to oxygen promotes rancidity). Fresh defoamer should be used every boiling session, and new defoamer purchased each year.

A variety of devices are available to dispense defoamer at a constant rate, or as needed when foam reaches a certain level (**Figure 7.12**). It is important to note that any of these devices can add more defoamer than necessary if not monitored carefully. Care should be taken with each type to ensure that as little defoamer as possible is added to the pan. For example, cups can be placed at a level above the liquid in the pans so that defoamer is added rarely, and only when foam is truly excessive. Peristaltic pump-type automatic defoamers add defoamer at a constant rate, with supplemental defoamer supplied as needed when the level of foam reaches the unit's sensor. These devices have been demonstrated to reduce excessive defoamer additions if used properly and work well with defoamers that are liquid at room temperature, particularly the oils currently approved for use in organic maple production. For manual addition of defoamer, dispensers that allow for the addition of a few drops at a time (**Figure 7.12**) to a specific problem area are preferable to spray bottles, which can easily add more than the intended or required amount and disperse defoamer across a wide area where it may not be needed.

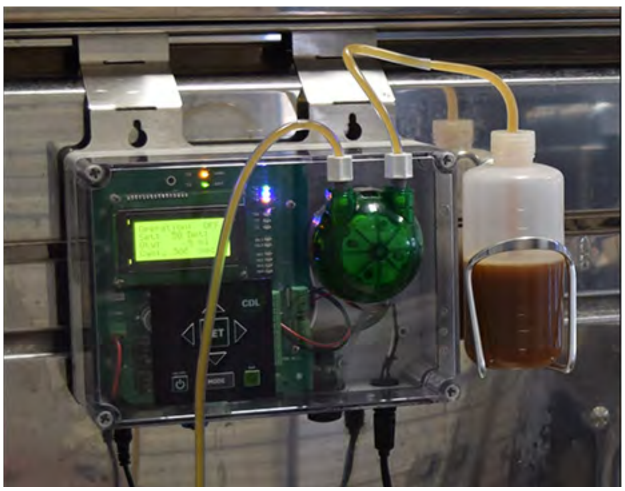
Adding defoamer close to the draw-off should be avoided whenever possible. Although this practice has sometimes been recommended to prevent excessive foaming in the syrup pan from disrupting the gradient, any defoamer added at this location tends to exit the pans almost immediately into the finished syrup and impart off-flavors, particularly if a constant trickle of syrup is being drawn off. Defoamer added near the draw-off has so little time in the evaporator that it is not very effective in reducing foam levels. This leads to excessive amounts of defoamer being used (**Figure 7.13**).

NITER MANAGEMENT As sap becomes more concentrated during evaporation, the mineral

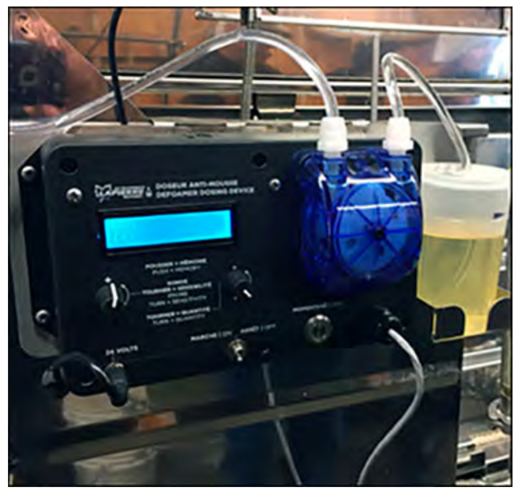
(a)

(b)

(c)



(d)



(e)

Figure 7.12. Several types of methods are available to disperse foam, from manual droppers (a), to passive cups filled with defoamer that hang over the pan edge in the evaporator (b), to liquid droppers (c), or fully-automated systems (d and e) that dispense defoamer both on a timed and as needed based upon a foam detecting probe.

concentration of the solution becomes saturated. This causes minerals to precipitate out of the solution. These minerals (mostly calcium malate) can deposit on pan surfaces as "niter" or scale (**Figure 7.14**), which can include trapped sugar, and occur more frequently where sugar concentration is the highest, particularly near the syrup draw-off. Accumulations of niter on pan surfaces cause excessive foaming and can create "hot spots" where burning or scorching may occur, giving the syrup an unpleasant, strong caramel, or bitter, burnt-niter taste. In addition, the pan can become warped due to the additional heat that occurs in the area of the deposit. The propensity for niter formation can vary widely not just between operations, but across the season and between years. For this reason, it is important to stay alert to niter management to be able to adjust to changing conditions. There are strategies and practices that can help minimize the effects of niter, make it easier to manage, and reduce the difficulty of cleaning evaporator pans and the need to use chemical cleaning agents.

Optimal management of niter requires close attention to the three main factors that determine

Figure 7.13. Excessive defoamer use indicated by the oily appearance (rainbow sheen) on top of the syrup in this finishing pan.

Figure 7.14. Niter (nitre) in evaporator pans. Niter that is attached is termed "scale" while niter that has flaked off and broken into small pieces and carried along in syrup is called "sugar sand." Dime for scale.

the severity, frequency, and distribution of the buildup: the quantity of heat, the concentration of the sap, and the ratio of syrup to flue pans. The hardness of niter deposits will increase with increasing levels of heat. Maintaining heat at optimal distribution throughout the evaporator and at the lowest levels possible that balance desired processing rates can help keep niter softer and easier to manage and remove. The effects of heat on niter increase with increasing sap concentration. Likewise, the amount and rate of niter deposition increases with increasing sap concentration—as sap concentration increases, the amount of niter deposited on pans throughout the evaporator will increase, with the largest amounts occurring where concentration is the highest. Thus, an increase in the concentration of sap by RO can necessitate reductions in the level of heat used and changes to its distribution, to ensure niter remains distributed optimally (i.e., minimized in the flue pan) and easier to manage. If these adjustments fail to resolve the issue you may need to consider changing the ratio of syrup pans to the flue pan.

Reversing the flow of liquid in syrup pans is a primary strategy for managing niter. Less concentrated sap is not fully saturated with minerals. When the direction of flow in pans is reversed, some of the niter on pan surfaces is dissolved and lifted off pan surfaces as the less saturated sap passes over it. This helps to keep the niter soft, less tightly adhered to the pan surface, and ultimately, easier to remove. For optimal management of niter, it is recommended to reverse the direction of flow after every barrel or every hour, depending on the characteristics of the operation. In evaporators with cross flow pans, switching pans on the same schedule will help achieve similar results to those obtained by reversing flow. A wooden spoon or similar tool can be used to help assess the accumulation of niter; when the feeling of the spoon against the pan surface becomes rough instead of smooth, it is probably time to change pans or reverse flow. Although most common for syrup pans, flow reversers for flue pans are also available. This device facilitates niter removal and reduces the need for frequent cleaning with acid, making it a particularly helpful option for larger operations or those where niter buildup is a persistent problem.

For both syrup and flue pans, another strategy for managing niter is to periodically empty the pan and rinse it with pressurized water or an automatic wash system. Automatic systems can then be run for a time, while evaporators without a wash system can be filled with permeate, brought to a boil for a few minutes, and then left to soak overnight. The optimal frequency will depend on the operation (amount of syrup processed, concentration of the sap, conditions in the evaporator, etc.) and will be determined by the producer—at larger operations it can be done after each boil, at smaller operations it can be done less frequently. This practice can help keep the niter in the pans softer and easy to remove, and reduce the need to clean with acid.

HEAT MANAGEMENT In addition to mitigating foaming and niter buildup, proper heat management is essential to ensuring optimal processing efficiency and syrup quality and flavor. Tools for this purpose include a stack thermometer, a thermometer in each section of syrup pan, a gauge to measure pressure in the arch, a manual stack damper, and a barometric damper (**Figure 7.15**).

Figure 7.15. A damper is used to regulate draft. These come in mechanical or automatic styles.

Stack temperature is a measure of how efficiently the heat is being used by the evaporator. Too high of a temperature indicates that heat is being lost up the chimney instead of being used for evaporation. A stack temperature that is too low (particularly in wood-fired evaporators), indicates the heat in the front pans may be too low to finish syrup. Although it will vary depending on evaporator type and features, stack temperature for wood evaporators should generally be between 600° and 800°F (315° and 425°C) and between 400° and 600°F (200° and 315°C) for oil evaporators. The higher stack temperatures in wood evaporators necessitate a thicker gauge of metal for stacks, and double walls can be used to further reduce the risk of fire. Features such as stack preheaters and double-pass flue pans will result in lower stack temperatures. In oil evaporators, stack temperature is used by the technician during the burner adjustment to determine whether the evaporator settings (quantity of fuel and air, distribution of heat, etc.) are aligned with optimal evaporator performance and efficiency. With wood-fired evaporators, stack temperature is used more actively by the producer during operation as a tool to optimize efficiency and performance. Monitoring stack temperature during a boil helps to determine the appropriate time to reload wood, and thus helps optimize firing intervals to maintain a constant, desired level of heat. Stack temperature can also indicate issues with the quality and mix (types) of wood being used. Sensors that measure the temperature in the arch in addition to that in the stack also provide insight into optimal firing intervals and the best settings for air temperature and flow. For wood evaporators without stack or arch temperature sensors, a more constant level of heat can be maintained by using regular firing intervals (a timer is helpful) and minimizing the length of time arch doors are open during loading.

The draft determines the distribution of heat under the evaporator pans, and thus it is essential to determine, set, and maintain it at an optimum setting, throughout each boil and across the season, to ensure optimal performance and syrup quality. An optimal draft setting is the point at which there is a good distribution of heat throughout the evaporator, no hot spots, and a nearly continuous stream of syrup exiting the draw-off. The adjustment and control of the draft is achieved through various mechanisms, depending on the type and style of the evaporator. In oil evaporators, a pressure gauge provides a measurement of the draft. The service technician will set the draft to a generally good level during the burner adjustment, but the producer will subsequently determine the pressure value at which the draft is optimized during operation. Once that value is determined, it can be maintained by adjusting the manual damper in the stack. A barometric damper automatically mitigates the effects of outside conditions (wind, temperature, barometric pressure) on the draft to help maintain it at the desired level. Automatic barometric dampers are typically set by the technician, and generally need not be adjusted afterwards by the producer. In basic wood evaporators, the draft is regulated by adjusting the air intake through the evaporator grates. In evaporators with forced draft, the speed of the fans and the stack damper (if present) are adjusted to regulate the draft. Draft is automatically maintained in models with automation. Although less common, pressure gauges can also be used in wood evaporators to help determine the optimal setting for the draft and to maintain it at that level. Without a gauge, the producer will determine the optimal draft and distribution of heat through observation of evaporator performance (e.g., checking for constant draw-off, steady boiling in front and back pans).

By monitoring the temperature of the liquid in the pans, the producer gains information that's useful for establishing the gradient, detecting, and correcting problems, and maintaining the conditions required for optimal syrup quality. When starting the evaporator for the first time in a season (or without sweet in the pans), there is no gradient within the evaporator, and care must be taken to ensure that the gradient is established and syrup is made in the appropriate location first, near the draw-off. Monitoring pan temperatures during this process can help producers determine whether the proper settings for establishing a gradient are in place of if there is a need to adjust them. During operation, monitoring pan temperatures confirms that the gradient in density in progression to the draw-off is maintained. This allows a disruption to the gradient (such as syrup being made in a location far from the draw-off) to be detected rapidly and corrected before syrup is burned. During start-up, careful monitoring of temperature can also help foresee and take measures to prevent the production of large batches of syrup (reducing heat, adding sap or water to certain partitions, raising liquid level). For similar reasons, monitoring pan temperatures is also essential to manage the reversal of flow.

Maintaining processing temperatures at lower levels can help ease the management of many operational parameters—foam, niter (and cleaning), and syrup quality. Using a fuel delivery amount and rate (whether for oil, wood, or other type of fuel) that is at the lowest level possible to balance desired processing rates and syrup flavor properties can help improve workflow and overall efficiency. If the desire is to complete boiling of the day's sap or concentrate as fast as possible, consider increasing the level of concentration with RO, rather than nozzle size or the amount of wood. This can help reduce the processing challenges caused by high levels of heat in the evaporator, while achieving desired processing rates.

DENSITY Boiling point is the standard approach used by most producers to monitor the concentration (density) of actively boiling sap during processing and determining when it has reached the correct density for syrup. As the sugar concentration of a sugar-water solution such as maple sap or syrup increases, the temperature at which the solution boils increases; thus, temperature can be used as an indicator of concentration. Most often we think of it as how much the temperature is elevated above the point of pure water, or the Boiling Point Elevation (BPE). **Table 7.1** presents the BPE above pure water for pure sucrose solutions of different concentrations at a given elevation and air pressure. Because maple syrup is not a pure sucrose solution, its BPE

The "Jones Rule of 86"—Original and Revised

The "Maple Rule of 86" was devised by C.H. Jones, a maple researcher at the University of Vermont, in the 1940s. Known afterwards as the "Jones Rule of 86", it was devised as a quick and easy way to estimate the amount of syrup made from sap of a known sugar content. Very simply:

86 ÷ Sap Sugar Content = Estimated Gal Sap to Produce 1 Gal Syrup

By subtracting 1 gallon from the result, you could derive the number of gallons of water to be boiled off to produce that 1 gallon of syrup. It should be noted, that this formula is not exact, but merely provides an estimate that was useful at a time when syrup was finished to 65.5°Brix.

Go forward a handful of decades and things have changed. Syrup is typically finished to a higher density between 66.0 and 66.9°Brix. Reverse osmosis is frequently used to concentrate syrup before boiling. The reliable "Jones Rule of 86" just isn't as reliable under those conditions.

Fortunately, with a little updating the "Revised Jones Rule"[1] is still useful but takes a little more mental work (or calculator or smartphone).

For syrup finished to 66.0°Brix.

87 ÷ Sap Sugar Content – 0.32 = Estimated Gal Sap to Produce 1 Gal Syrup

For syrup finished to 66.9°Brix.

88.1 ÷ Sap Sugar Content – 0.32 = Estimated Gal Sap to Produce 1 Gal Syrup

While the "Revised" rule isn't quite as simply or catchy, it is considerably more accurate estimate of the actual results you'll see upon boiling.

[1] Perkins, T.D. and M.L. Isselhardt. 2013. The "Jones Rule of 86" revisited. *Maple Syrup Digest*. Oct. pp. 26–28. https://mapleresearch.org/pub/m1013jonesruleof86/

will never perfectly match the values in the table, but it is a reasonably close approximation. At low sugar concentrations, changes in density produce relatively small changes in the boiling temperature (e.g., an increase in the sucrose concentration from 7.5° to 13.8°Brix increases the boiling temperature by only 0.2°F or 0.1°C). As the solution nears the density of syrup, comparatively small changes in concentration result in relatively large changes in boiling temperature (an increase in the sugar concentration from 64.5° to 67.0°Brix raises the boiling temperatures 1°F or 0.56°C).

THERMOMETER CALIBRATION It is extremely important to remember that BPE refers to the temperature elevation relative to that of pure water at the time and place syrup is being made. Pure water boils at 212°F (100°C) only when barometric pressure is 29.92 inches of mercury (760 millimeters; 101.32 kilopascals); normally this is referred to as the temperature at which water boils at sea level. Since the barometric pressure is seldom 29.92 inches when syrup is being made, and because it decreases with elevation above sea level, it is best not to associate 212°F with the temperature of pure boiling water. To use the BPE method, you must determine the temperature at which water boils at the time and location syrup is being made. Simply heating pure water to the point of boiling and measuring the temperature after the thermometer has been immersed for at least 3 minutes can accomplish this. The boiling temperature of 66.0°Brix syrup is determined by adding 7.1°F (3.5°C) to the temperature of the boiling water (**Table 7.1**). If syrup with a higher density is desired, the appropriate degree adjustment is added to the boiling point of water (e.g., for 66.5°Brix syrup add 7.3°F or 4.1°C to the boiling point of water). The finished density of syrup should always be verified with a hydrometer or other tool when the syrup has reached room temperature (see **Chapter 8**).

Maple equipment suppliers stock a variety of thermometers that are appropriate for use with the BPE method, including standard, dial, and digital thermometers. Dial thermometers with demarcations relative to BPE are also commonly used. With these thermometers, the zero point is set while the thermometer is immersed in boiling water. When multiple thermometers are used, the zero point of all must be set simultaneously to ensure they match. For all types, accuracy and reliability increase with instrument quality. Mercury thermometers are prohibited for use in maple production due to the risk of contamination of syrup and equipment if they break. Just because a digital thermometer will display to the hundredths of a degree does not mean it is accurate or precise to that level. Thermistor-style digital thermometers tend to be more accurate and precise than thermocouple-style thermometers.

CONTROLLING SYRUP DRAW-OFF A variety of automatic devices are available that continually monitor temperature and automatically open and close to draw off syrup when the appropriate temperature is reached. In their simplest form, these devices consist of a temperature probe that is placed in the liquid near the draw-off valve, a thermo-regulator adjusted to open and close when the probe senses a specific temperature, a solenoid or motor-controlled valve that is located in the draw-off line, and a power source to activate the valve when the thermoregulator closes. These devices can be simple models with valves that open completely when the set temperature is reached and close when a specific temperature above a user-defined set point is reached. More sophisticated models have modulating valves with outlet ports that open and close to varying degrees depending on how far the measured syrup temperature is from the set point temperatures. Units that adjust the set temperature automatically to compensate for changes in barometric pressure are also available. It is important to note that the programming of each unit is unique and will determine the actual temperatures sensed around the set points that trigger the opening and closing of the valve, or the speed and amount the valve opens and closes in the case of modulating valves. Thus, each device must be carefully adjusted for the specific conditions in which they are used to ensure that the valve is not opening too early or too late, or too slow or too fast; the probe location, liquid depth in the pans, and processing rate of the evaporator will

TABLE 7.1 Boiling point elevation in pure sucrose solutions at different solution densities. To determine the proper temperature at which the liquid is approximately the correct density, add the boiling point elevation temperature for the desired density to the boiling point of water (determined at the sugarhouse elevation each day). For example, if the desired syrup density is 66.5°Brix, you would add 7.3°F (4.1°C) to boiling point of water.

Boiling Point Elevation (°F)	Boiling Point Elevation (°C)	Solution Density (°Brix)
0.0	0.0	0.0
0.2	0.1	7.5
0.4	0.2	13.8
0.6	0.3	19.0
0.8	0.4	23.4
1.0	0.6	27.1
1.2	0.7	30.3
1.4	0.8	33.4
1.6	0.9	36.0
1.8	1.0	38.4
2.0	1.1	40.5
2.2	1.2	42.5
2.4	1.3	44.3
2.6	1.4	46.0
2.8	1.6	47.7
3.0	1.7	49.0
3.2	1.8	50.4
3.4	1.9	51.6
3.6	2.0	52.8
3.8	2.1	53.9
4.0	2.2	54.9
4.2	2.3	55.9
4.4	3.4	56.9
4.6	2.6	57.8
4.8	2.7	58.8
5.0	2.8	59.7
5.2	2.9	60.4
5.5	3.1	61.5
5.6	3.1	62.0
5.8	3.2	62.5
5.9	3.3	62.9
6.1	3.4	63.4
6.4	3.6	64.4
6.6	3.7	64.9
6.9	3.8	65.5
7.1	3.9	66.0
7.3	4.1	66.5
7.5	4.2	67.0
8.0	4.4	68.0
8.2	4.6	68.5
8.5	4.7	69.0
8.8	4.9	69.5
9.1	5.1	70.0
9.5	5.2	70.5
9.9	5.5	71.0
10.4	5.8	71.6
10.7	5.9	72.1
11.1	6.2	72.5
11.5	6.4	73.0
12.0	6.7	73.5

all affect the settings and programming needed for optimal function. In general, a variation of less than 0.5°F (0.28°C) between the opening and closing of the valve is a good target to aim for.

Maintaining the draw-off of syrup from the evaporator at a steady rate rather than drawing off in periodic batches can be advantageous. This practice can help to more precisely regulate the density of finished syrup as well as to reduce niter accumulation near the draw-off in the syrup pan. In addition, drawing off syrup at a constant, controlled rate (not too fast), can help ensure that floats and electric valves can keep up with the flow and maintain a constant liquid level in the pans. As a result, temperature fluctuations are reduced, which prevents large amounts of syrup being drawn off at once (batching) and its associated issues. With manual draw-off valves, adjustments are made to the aperture to maintain a steady flow of syrup that is at the constant temperature appropriate for finished syrup. To accomplish this with simple open-close

Figure 7.16. A partially-closed valve positioned between the pan and the draw-off valve can be used to help regulate the flow of syrup at the draw-off and to prevent the liquid level from dropping too low in the syrup pan.

automatic draw-off devices, a valve is installed between the unit and the pan (**Figure 7.16**) and adjusted as needed to maintain a constant flow at the set temperature of the unit. Modulating automatic draw-off valves can be programmed to achieve the desired conditions. Note that the function of all types of automatic devices may be affected by excessive foaming and the accumulation of niter on the unit's probe.

TOOLS FOR MEASURING DENSITY DURING PROCESSING Instruments for measuring syrup density are typically referenced to room temperature, but frequently density is measured hot off the evaporator. Because the mathematical relationship between density and temperature changes rapidly at near-syrup temperatures, small changes in temperature can result in large changes in syrup density. Thus, the density of syrup should always be verified at room temperature, where the tools to measure density are more accurate and the temperature is not changing quickly. Note also that all tools and methods (boiling point elevation, hydrometers, refractometers) used to measure syrup density assume a pure solution of sucrose. However, because syrup contains small, but varying amounts of dissolved solids other than sucrose, there is some amount of error inherent in each of these methods (see **Chapter 8**), but these typically have no real-world consequences for producers or consumers of maple syrup.

The density of syrup drawn off the evaporator based on temperature elevation should be verified frequently during processing to ensure that the appropriate density is achieved and maintained. The primary tools to confirm density during processing are the hydrometer and the hydrotherm (**Figure 7.17**). Refractometers are not recommended for use during processing or with hot syrup. Detailed instructions for using these tools are presented in **Chapter 8**. Hydrometers are well suited to making rapid measurements of the density of hot syrup, and measurements can be made of a sample taken directly from the draw-off valve or of the batch from a sample taken from the syrup tank. A hydrometer cup should always be used to prevent possible contamination with broken glass. The temperature of syrup drops rapidly after it exits the evaporator and because hydrometer readings are temperature sensitive, the temperature of the liquid must be measured at the time the hydrometer reading is made to correct the measurement. The correction is available on a separate chart and is applied to the direct hydrometer reading to get the corrected value. Some hydrometer cups incorporate a thermometer—others in incorporate a scale that applies the temperature correction factor and indicate the hydrometer reading corresponding to a density of 66.9°Brix at that temperature. Hydrotherms incorporate a thermometer directly into a hydrometer and allow the temperature correction factor to be read directly from the hydrometer stem.

Figure 7.17. Hydrotherm (left) and hydrometer (right).

While this feature contributes to more accurate readings, hydrotherms require additional time (about 2 minutes) to equilibrate to the temperature of the syrup, and thus do not allow measurements to be made as rapidly as with hydrometers.

FINISHING PANS As an alternative to drawing off syrup from the evaporator at finished density, syrup can be drawn off at lower density and finished in a separate finishing pan. This practice can be helpful to provide more precise control of heat to achieve the correct density. In smaller operations the use of a finishing pan can enable the accumulation of syrup until there is enough to filter at the appropriate temperature and/or fill a drum of a predetermined size or the desired number of bottles. It can be used in larger operations with evaporators where heat/temperature control is difficult, or as a strategy to facilitate processing efficiency and niter management by using an evaporator with only flue pans and a second large finisher; the greatest accumulation of niter will occur in the flat pans of the latter, which are easier to clean.

BRIX EQUALIZER TANKS A recent introduction into the maple industry is a Brix equalizer tank. These are mostly used in moderate to large operations with a high volume of syrup production. Syrup is drawn off the evaporator slightly high in density into the tank. A stirring mechanism homogenizes the syrup while a built-in refractometer tracks the syrup density and temperature. If needed, permeate is added to bring the syrup to the desired density. After thorough mixing, the syrup is filtered and put in drums. The advantage of this system is that high volumes of syrup can be prepared to a tight density specification, eliminating the problem of under-density or over-density syrup. Because packers penalize bulk producers for low-density syrup, but generally do not increase the amount they pay for over-dense syrup, producers will often err on the side of producing syrup that is slightly too dense. When dealing with high volumes of syrup, even slightly over-dense syrup can cost producers a significant amount of lost revenue. Mixing tanks help to eliminate this problem by producing syrup within a tight density specification, therefore resulting in slightly higher production overall.

SHUTTING DOWN When it is time to shut down the evaporator, care must be taken to avoid damaging the pans, and ensure the quality of the remaining sweet is maintained until the next boil. Residual heat will be maintained in the arch for a time after shutdown even though fuel is no longer being supplied. This can cause damage to the pans if the sap level is low and the liquid continues to evaporate to the point where the syrup in the evaporator scorches, sometimes resulting in irreparable damage. Pans should be filled with enough liquid at shutdown to prevent them from running dry and becoming damaged. The required amount varies by evaporator and fuel type, and ultimately will be determined through experience. It is prudent to be cautious and flood the pans deeper until the appropriate level can be determined through experience. If additional liquid is needed, permeate or potable water, rather than unprocessed sap (which can introduce live spoilage microbes), should be used. When the material in the evaporator has cooled sufficiently, connections between partitions can be plugged to help maintain the concentration gradient in the evaporator.

Microorganisms present in unprocessed sap can impact the material that remains in the evaporator between boils, resulting in spoilage or the development of “ropy”-textured syrup (see **Chapter 8**). To help prevent this it is recommended that boiling continue for 15 minutes after the last fresh sap has entered the evaporator to kill off any microbes that recently entered the pans. This will help reduce the chances that ropiness or other spoilage issues will develop. This is particularly important in the later part of the sugaring season when temperatures in the sugarhouse are warmer, and in warmer climates. To facilitate this procedure without damaging pans, manually raise the liquid level in the pans (by pressing on the float, etc.) to a sufficient depth to allow 15 minutes of boiling after the last fresh sap has entered the pans. Permeate can also be used. Afterwards, all sight levels, the cold float box, and the supply pipe should be drained and washed. These actions will reduce the chances that living microorganisms are present to contaminate and initiate the development of ropiness in the remaining liquid in the pans. In addition, all sap and concentrate tanks and supply pipes should be cleaned regularly.

Cleaning the Evaporator

The accumulation of niter on pan surfaces reduces the efficiency of heat transfer and increases the development of foam and the risk of off-flavors. Thus, maintaining a clean evaporator is an essential component of maple production. The undersides of pans should also be kept clean to maximize heat transfer (soot acts as an insulator). Particular attention should be given to removing soot accumulations from the flues of the back pan with a stiff nylon brush, especially in wood-fired evaporators. There are several operational and daily maintenance practices that can help make niter removal and cleaning the evaporator easier and thus reduce the need to use chemicals.

The preventative strategies outlined previously for managing niter are essential steps to facilitating evaporator cleaning. Reversing flow or changing pans frequently and maintaining heat at optimum levels will help keep niter accumulations minimal, soften them, and ease their removal. Draining the pans after boiling and rinsing them with pressurized water or via an automated spray wash system, then allowing the wash system to run is an another approach to keeping equipment clean, as is boiling permeate and allowing the pans to soak overnight in hot permeate. The required frequency of these procedures will depend on the operation, generally increasing with the amount of syrup processed, but can change somewhat over a season or from one season to the next.

Periodically, or at the end of the season, niter will need to be removed using chemical cleaners. In general, the procedure involves first removing a much loose scale as possible with a soft brush or pressurized water, filling the pans with permeate (or soft water), adding a commercial pan acid cleaner, heating the solution and allowing it to soak, then brushing the pan sides and bottoms with a nylon brush. These procedures are followed by neutralizing the solution and then draining and rinsing the pans completely. Detailed instructions should be obtained from the evaporator manufacturer and supplier of the cleaner. Only commercial cleaners from maple equipment manufacturers should be used, and the directions on the package followed. Always use the necessary safety practices and personal protective equipment (see "Chemical Safety"). When using chemical cleaners, it is absolutely critical to remove all niter completely, from both the sides and the bottoms of the pans. Any residual niter will retain acid residues and contaminate the next syrup processed. If there is residual niter on the pan bottoms or sides after cleaning, it is necessary to boil with water for an hour, neutralize, and then drain and rinse the pans again to ensure no acid residues remain to contaminate syrup during subsequent processing.

An alternative to commercial pan-cleaning acids sometimes used at the end of the season is the historical method of allowing sap to turn to acetic acid (vinegar). Sap collected at the very end of the season (even if buddy) is not boiled but rather is used to flood the pan nearly to the top. Over several months the sap will ferment, producing a mild acid. Eventually the pans are drained and rinsed. Drawbacks of this approach are that it takes several months, is horribly smelly, and is very unsightly. For producers who host events or visitors to their sugarhouse in the off-season, this method may not be workable unless a pan cover is employed and very good ventilation is available.

Automated pan washing systems are available for syrup and flue pans to assist with cleaning with permeate and/or acid cleaners. Systems and their operation vary, but for all it is recommended to take steps to ensure that the flow rate of the water from the system is well matched with the rate that it drains to ensure that the water sprayed from the wash system is directly hitting the pan surface rather than the liquid within the pans. Recommended steps include oversizing the drain, maintaining a slope when possible, and, if necessary, reducing the flow rate or varying the location of the wash spray to facilitate evacuation of the liquid.

Chlorine-based cleaners or sanitizers, or other strong oxidizing solutions should NOT be used to clean evaporator pans. These can cause permanent pitting or dulling of pan finishes. If chlorine must be used to sanitize after ropey sap/syrup, the cleaner should not be left in the pan for long and should be rinsed copiously from the evaporator after use. Scrubbing with abrasive cleaners, sandpaper, or steel wool should be avoided as these will result in scratches where niter will build up more rapidly. If a pan is slightly scorched, the burnt material can be removed with a hard-plastic spatula or similar device. For heavily scorched pans, a piece of copper pipe with one end flattened and filed to a chisel point can be used to scrape off the burnt material before regular cleaning.

REVERSE OSMOSIS

The removal of some of the water from sap prior to boiling in an evaporator can be achieved using reverse osmosis (RO). Reverse osmosis is a process in which some of the water in maple sap is removed by forcing sap, under pressure, through a semi-permeable membrane (**Figure 7.18**). The pores in the membrane are large enough to permit water molecules to pass through, but too small to allow the passage of sugar and other large molecules. As some of the water in the sap is pushed through these membranes, the sap becomes more concentrated. The term *reverse osmosis* as used generically in the maple industry refers to the variety of types of membrane separation and membranes used in maple syrup production, including reverse osmosis and nanofiltration systems.

Current RO systems used in the maple industry (**Figure 7.19**) are capable of concentrating sap to between approximately 4° and 40°Brix, with a concentration between 8°and 20°Brix being most common. RO can thus be used to remove more than 90 percent of the water from sap prior to evaporation (**Figure 7.20**), resulting in a substantial reduction in both the amount of time and fuel required to complete the remaining concentration to syrup density through boiling (**Figure 7.21** and **Figure 7.22**). This significantly reduces the costs and increases the overall efficiency and profitability of syrup production. For example, sap with a 2°Brix sugar concentration requires the evaporation of 42 gallons of water for each gallon of finished syrup, while sap concentrate at 8°Brix requires the evaporation of less than 11 gallons of water for each gallon of finished syrup. Because the volume of water that needs to be boiled

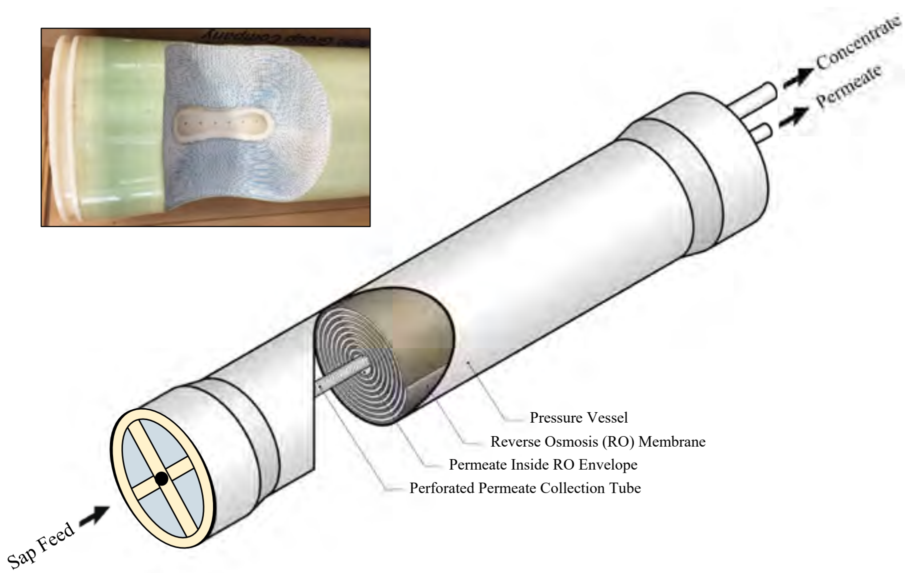


Figure 7.18. Cutaway diagram of an RO membrane. Sap feeds into the membrane vessel from the lower left. Water passes into the membrane spiral and passes through the membrane before entering the perforated permeate collection tube in the center. Permeate and concentrate exit at the upper right through separate tubes. Inset photo shows an actual maple RO membrane cut to show the inner components.

FIGURE 7.19. A variety of RO systems for maple sap concentration.

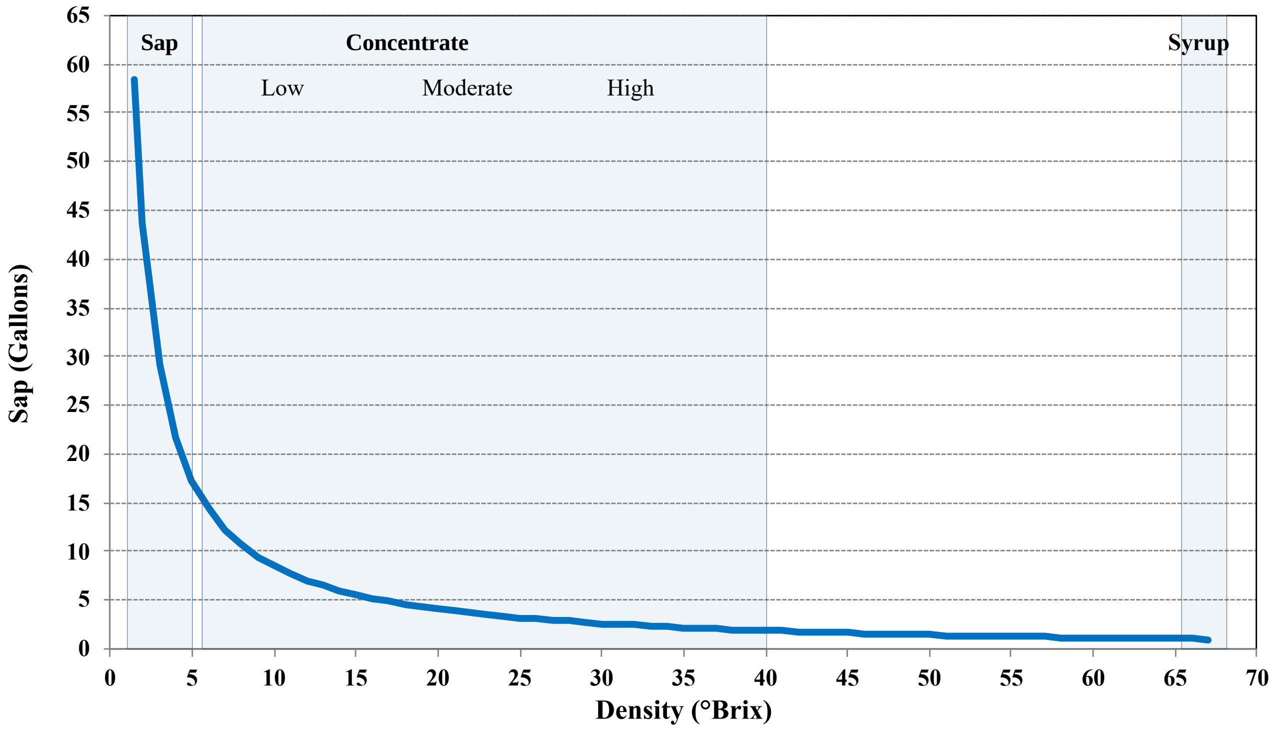


Figure 7.20. Relationship between the starting sugar concentration of sap and the number of gallons of sap required to produce 1 gallon of maple syrup. The typical Brix ranges of sap, concentrate, and syrup are indicated. Adapted from: van den Berg, A.K., T.D. Perkins, M.L. Isselhardt, M.A. Godshall, and S.W. Lloyd. 2011. Effects of producing maple syrup from concentrated and reconstituted sap of different sugar concentrations. *Int. Sugar J.* **113:** 35–44.

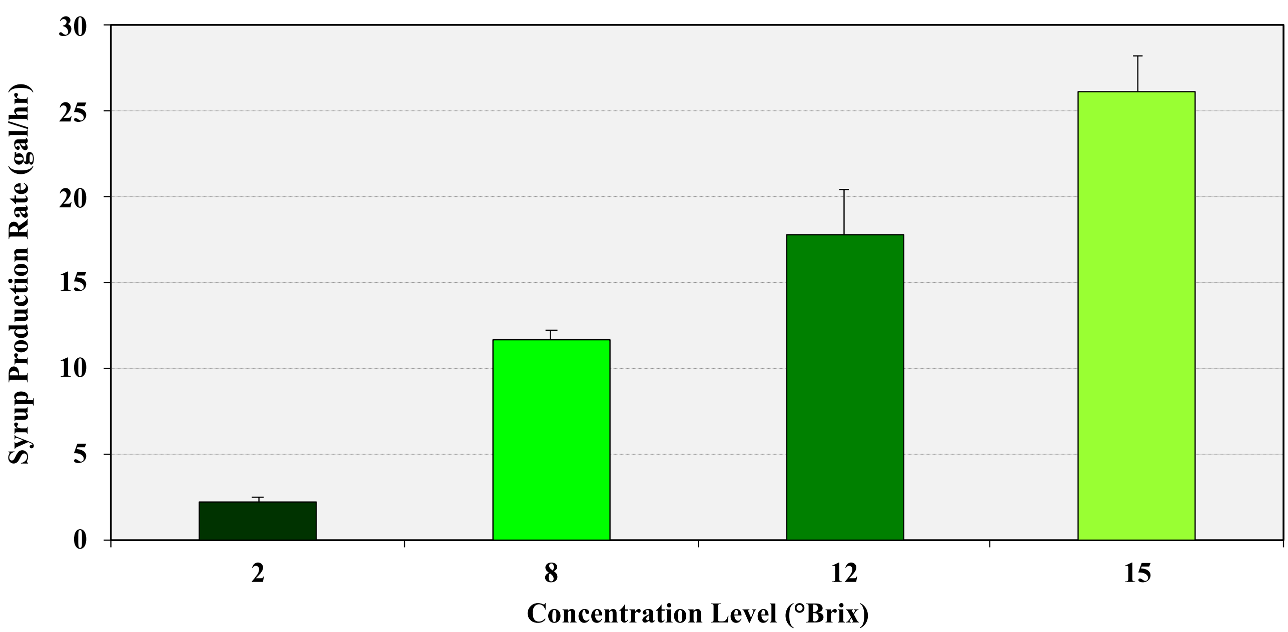


Figure 7.21. Average syrup production rate (gallons of syrup per hour) in four 3-foot by 10-foot standard evaporators processing sap concentrated to four different levels. Adapted from: van den Berg, A.K., T.D. Perkins, M.L. Isselhardt, M.A. Godshall, and S.W. Lloyd. 2011. Effects of producing maple syrup from concentrated and reconstituted sap of different sugar concentrations. *Int. Sugar J.* **113:** 35–44.

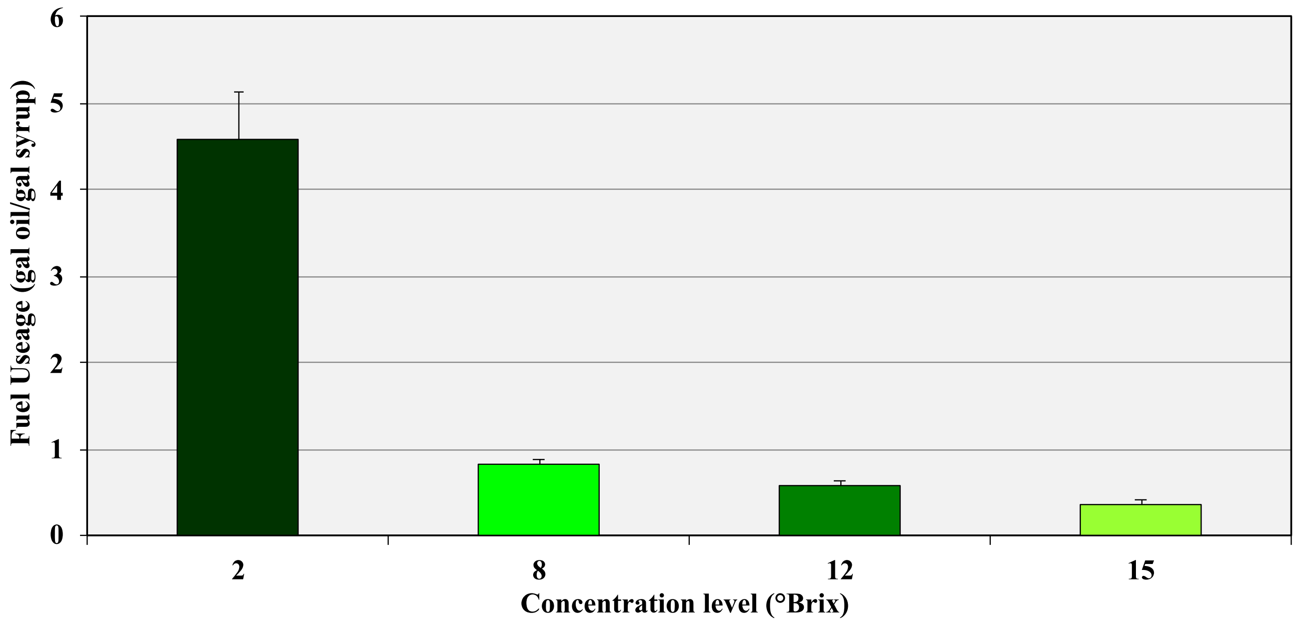


Figure 7.22. Average amount of oil required to produce a gallon of syrup in four 3-foot by 10-foot standard evaporators processing sap concentrated to four different levels. From: van den Berg, A.K., T.D. Perkins, M.L. Isselhardt, M.A. Godshall, and S.W. Lloyd. 2011. Effects of producing maple syrup from concentrated and reconstituted sap of different sugar concentrations. *Int. Sugar J.* **113:** 35–44.

off after sap is processed with an RO is greatly reduced, a much smaller evaporator is required to process the sap from a given number of taps.

Because the majority of the reactions responsible for the development of the characteristic color and flavor of maple syrup require heat and occur while sap is being processed in the evaporator, it has been speculated that changes in processing conditions that result from the use of RO, such as the reduced length of boiling, the shorter time the liquid is maintained at elevated temperatures in evaporator pans, and the high concentration of the material being processed, might in some way affect how these reactions occur and therefore have some impact on the properties and characteristics of the syrup produced. However, controlled experiments with maple processing equipment at the University of Vermont[2] have demonstrated that while the concentration of sap with RO up to 22°Brix generally results in the production of lighter-colored syrup, it does not substantially impact the composition or flavor of syrup produced, particularly when adjustments to processing conditions (such as the depth of liquid in pans and the ratio of flue to syrup pans) are made to accommodate higher RO concentration levels. Controlled experiments have not been done with concentration levels higher than 22°Brix; however observational studies suggest that the use of sap with higher concentration levels and associated evaporation equipment results in flavor much like that of syrup of the same color produced with less concentrated sap.

Reverse Osmosis Systems

Commercial RO systems for maple sap processing generally consists of prefilters, feed, recirculation, and pressure pumps, and one or more membranes (**Figure 7.23**). Membranes are specialized filters that allow water to pass through but not sugars, are generally 4, 8, or 16 inches (200, 400, 800 millimeters) in diameter and 40 inches (1,016 millimeters) long and are housed in stainless steel or PVC pressure columns. A membrane and housing (and pump if integrated into the system) are collectively referred to as a "post." RO systems can consist of single or

[2] https://mapleresearch.org/search/?_sf_s=RO&_sft_keys=reverse-osmosis&_sft_authors=van-den-berg-abby-k.

Maple Syrup Flavor

Maple sap is a dilute solution of mainly water and sugar (1°–5°Brix), along with trace amounts of other substances, including organic acids, free amino acids, protein, minerals, and phenolic compounds. It is slightly sweet, with relatively little or no flavor. The predominant sugar in maple sap within the tree is sucrose—a molecule composed of two other sugars, glucose and fructose (commonly called "invert sugars"), that are bonded together. After sap exits the tree, a portion of the sucrose may be converted to invert sugars by microbial activity, heat, and changes in pH.

If sap is concentrated to maple syrup density using only a method like RO or freeze-drying, the result is a nearly colorless, tasteless sugar syrup. This is because the majority of the reactions ("nonenzymatic browning") responsible for the development of color and flavor in maple syrup occur as sap is processed with heat. These include Maillard reactions, a complex series of chemical reactions that begin with reactions between certain sugars and amino acids, and are responsible for a variety of colors, aromas, flavors, and off-flavors in foods. Sucrose does not react directly in Maillard reactions, but the invert sugars it can be broken down to, glucose and fructose, do.

In maple sap, the amount of and rate at which these reactions occur, and how many and which types of flavor compounds they produce, are affected by two main factors: sap composition and processing conditions. Processing conditions include principally the temperature and length of heating. Sap composition includes the concentration and types of reactants present, such as how much invert sugar and which specific amino acids, as well as the pH and water content. Thus, any factor that influences sap composition or processing conditions can influence syrup flavor and color development. Because sap composition, including pH and the relative quantity of invert sugar, is strongly influenced by microbial activity, any factors that affect microbial population levels, growth, and activity can also ultimately influence flavor development. Thus, there are factors that affect maple syrup flavor that can be influenced, including aspects of sap quality and the amount of heat and length of processing in the evaporator, as well as those that cannot, such as the amino acid composition of sap, or the presence of other compounds that might contribute to flavor, such as phenolics and organic acids. This complexity is why there is such a wide diversity in the flavor of pure maple syrup, including across and between seasons in the same operation, and why it is impossible to synthetically recreate the range and complexity of pure maple syrup flavor.

multiple posts. Additional features often include a wash tank to facilitate cleaning of the membrane, gauges to indicate temperature and pressure, and flow rate meters and valves for measurement and control of concentrate and permeate.

In general, sap is introduced into the RO through the prefilter, and one or more pumps are used to create sap flow and build pressure in the system. This pressure forces some of the water (termed "permeate") in sap to be pushed through a semi-permeable membrane wrapped around a central permeate collection tube. Some of the permeate is typically stored for subsequent use in cleaning and rinsing the RO unit and other equipment. Most of the permeate is allowed to drain onto the ground. The concentrated sap (termed "concentrate") is drawn off to be further processed in the evaporator. During the process a portion of the sap is generally recirculated within the RO to help maintain high flow rates, which serves to slow the clogging of membrane pores.

Each individual membrane has a maximum rate of rejection (the amount of water that is removed from sap), typically 80 percent (theoretically, the maximum concentration is generally about 4.7 times the sugar content of the feed sap). Exceeding this level by restricting the concentrate flow too tightly is problematic as it can result in very low flow rates, resulting in rapid, and perhaps irreversible, plugging of the membrane if sustained.

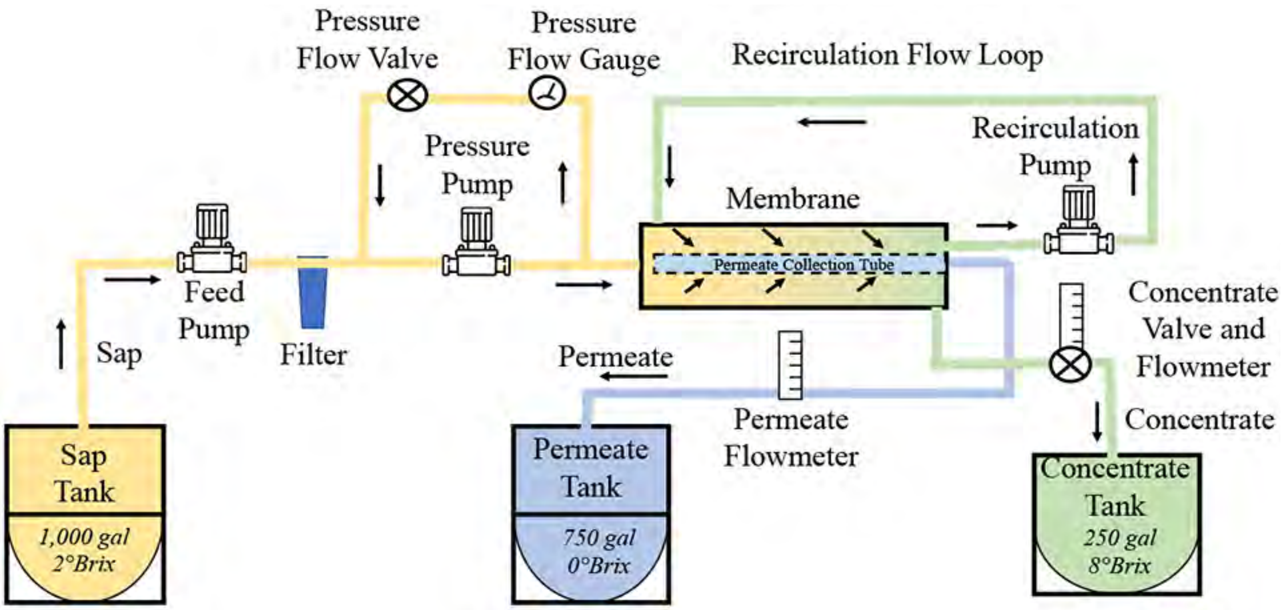


Figure 7.23. Generalized flow diagram of a typical maple RO system during the concentration process. Sap is drawn from a tank by a feed pump before passing through a 5-micron filter (in some operations the filter comes before the feed pump). A pressure pump feeds sap into a pressure vessel containing a membrane. A pressure loop is used to regulate the pressure within the vessel. Permeate (water) moves through the spiral winding of the membrane until it passes into the central permeate collection tube and exits the vessel into a permeate tank. Concentrate flows into the storage tank as regulated by a flow valve and into a recirculation loop to maintain adequate flow across the membrane to reduce fouling. Example quantities of liquid and the sugar concentration for each component (sap, permeate, concentrate) are indicated. Rinse, wash, and purge flows are not shown in this diagram, nor are ancillary devices such as temperature or pressure cutoff switches. Membrane vessels may be plumbed in different combinations (with added pumps) to generate higher processing rates and/or higher concentration levels.

Thus, when using a single membrane, the maximum concentration level should be limited to about 8°Brix when starting with 2°Brix sap. If a higher level of concentration or faster flow rate is needed, additional membranes can be added to a system in various configurations. The size and number of feed, pressure, and recirculation pumps must also be adjusted to compensate for the number of membranes and the desired concentration level and flow rate. The addition of membranes in series, where sap is concentrated successively by each membrane, can increase total rejection rates to 90 percent—facilitating the concentration of sap to higher sugar levels. The examples in **Figure 7.24** illustrate how rejection rates are calculated, and how this measure relates to potential maximum concentration levels. Membranes can also be added to a system in a parallel configuration, which results in boosting sap processing and flow rates. Parallel and serial configurations and combinations of membranes can be used to achieve the desired concentration level and flow rates to the needs of the specific operation. Ultimately, an optimal configuration can be determined to achieve the desired concentration and flow rate. Often this is dictated by the design of the evaporator being used and its processing (evaporation + draw-off) rate. When purchasing an RO system, the ability to expand or reconfigure to accommodate future growth should be factored in. Some machines are designed with expansion in mind—others are not.

Passing sap through the RO twice or recirculating back to a feed tank is another way to obtain higher sugar concentrations. However, this is often not an optimal strategy, as it results in higher concentrate temperatures and longer holding times for concentrate prior to evaporation, which increases the risk of loss of syrup quality and the possible occurrence of ropy syrup.

The permeate generated during RO

The flow rates of an RO must be maintained at levels lower than the maximum rejection rate (the percentage of water removed from the sap) of the membrane. For units with only one membrane, this rate is typically 80%. The rejection rate is calculated by dividing the permeate flow rate by the total flow rate and multiplying by 100:

$$\frac{\text{Permeate flow rate}}{\text{Total flow rate}} \times 100 = \%\ \text{Rejection}$$

So, for an RO with one 8-inch membrane, if the permeate flow rate is 7 gallons per minute (gpm) and the concentrate flow rate is 2 gpm, the rejection rate would be calculated as follows:

$$\frac{7}{(2+7)} \times 100 = 77.8\%$$

In this example, 77.8% of the water is being removed from the sap; flow rates are respecting the maximum limits of the membrane and are acceptable. The concentration of sugar in the concentrate will vary depending on the concentration of the incoming sap, because the rejection rate also determines the maximum concentration achievable. This can be calculated as follows:

$$\frac{\text{Rejection rate}}{(100-\ \text{Rejection rate})} \times \%\ \text{sap sugar concentration} = \%\ \text{sugar in concentrate}$$

So, with sap starting at 2% sugar, the concentration of the concentrate in the example would be about 7%:

$$\frac{77.8}{(100-77.8)} \times 2 = 7\%$$

Adding additional membranes in series can increase the maximum rejection rate of the unit to up to 90% and facilitates higher concentrations. For example, in an RO with four 8-inch membranes in series, if the permeate and concentrate flow rates are 34 and 4 gpm, respectively, the rejection rate would be calculated as follows:

$$\frac{34}{(4+34)} = 89.5\%$$

And with an incoming sap concentration of 2%, the sugar concentration in the concentrate would be about 17%:

$$\frac{89.5}{(100-89.5)} \times 2 = 17\%$$

Figure 7.24. Calculating rejection rates.

concentration is used for a variety of tasks in the sugarhouse. However, it is important note that the quality of permeate is only as good as the operational condition of the machine and its membranes. Permeate can contain sugar, substantial quantities of minerals, and residues from microbial biofilms or cleaning chemicals when the unit is not operated or maintained properly, and these factors must be considered when planning uses for permeate.

Reverse Osmosis Operation

RO is an acceptable technology to use in maple production because the integrity of the syrup product is maintained—RO is a concentration process, and nearly all constituents present in sap carry through (in the same ratios) to the concentrate. The use of membranes appropriate for maple sap helps to ensure this, as does proper operation and maintenance of membranes and RO systems and adherence to design specifications and operational parameters (rejection rates, pressures, temperatures, seal of gaskets, etc.).

All RO machines work according to the same general principles, but each system and each type of membrane entails unique and specific procedures for appropriate and safe operation. It is critical that specific manufacturer's instructions for operation, cleaning, maintenance, and off-season storage of both the machine and its membranes are followed. Because the specific instructions can vary across different manufacturers, detailed procedures will not be included here. However, the following are a few basic guidelines that apply universally:

- In essence, the operation of an RO unit involves the adjustment of valves to control the flow rate and concentration of sap as it moves through the unit. It is critical to maintain appropriate pressures and flow rates at all times. (These values are specified by the unit's manufacturer.) The relationship between the amount of liquid flowing across the membrane, the amount of water being removed, and the amount of concentrate being drawn off are essential to the proper operation of an RO.
- For all RO operations (concentrating, cleaning, etc.) there is an appropriate sequence to follow to ensure that the membranes are not blocked or damaged.
- Each type of membrane has its own manufacturing characteristics and operating parameters. It is important to know what type of membranes an RO is equipped with and to obtain the technical datasheets and instructions that detail proper operation.
- Design and build the plumbing around the RO so that it is easy to know which liquid is going into and out of the device (sap, cold permeate, hot permeate, concentrate, cleaning solution). Also, it must be easy to see and know where the concentrate and the permeate passing through the outlet of the device are going (concentrate tank, sap tank, cold permeate tank, hot permeate tank, wash tank, drain). All hoses and valves should be clearly and prominently identified to avoid mistakes.
- Some operations must be done at low pressure (rinsing to remove the membrane storage solution, sugar purging, washing with hot permeate or with chemicals, rinsing after washing), while others require high pressure (concentration, membrane performance tests, and benchmarking).
- Make sure there is sufficient elevation between the feed tank and inlet to allow the pipe to easily move the sap to the RO. A minimum of 1–2 feet (0.3–0.6 meters) of head is suggested. More is helpful. Little or no head, sags in lines, or small leaks can trap air, leading to cavitation of and possible damage to the feed pumps.
- When starting to concentrate sap, ramp up membrane pressure slowly to give yourself enough time to check if everything is operating well.
- There is a time lag in changes in the °Brix of the concentrate after adjustments are made to membrane pressure. Wait a few minutes after changing pressure (via valves) before checking readings to allow

enough time for the adjustment to take effect.

- Check the temperature and pH regularly during wash cycles, as these may change. Adjust as necessary to maintain the appropriate and effective parameters (as specified by the manufacturer) throughout the cycle. Exceeding wash parameters can result in permanent membrane damage.
- Sap must be filtered before it enters the RO. Disposable cartridge prefilters are standard for this purpose. A minimum of one cartridge per membrane is recommended, and the final pore size of filtration must be 5 microns. Additional filters will increase the filtering surface area and help to maintain an adequate sap feed flow rate. Other methods of filtering, such as cloth filters, may be added ahead of the cartridge filters; however, it can be difficult to maintain the filtration integrity and sanitation of these other methods over time.
- In general, smaller pipes or fittings or excess changes in direction anywhere within the liquid pathways will create turbulence and restrict flows. It is particularly important to ensure sap feed pipes and permeate exit lines are adequately sized to prevent flow restrictions. General guidelines are a minimum of 1½ –2 inches for sap feed and 1¼ inch for permeate lines; however, the required sizes will increase with larger RO units, and in certain circumstances such as the location of sap tanks far away from or at a lower level than the RO. Those types of situations may necessitate an additional feed (prime) pump.
- ROs are available with various levels of automation that can initiate and terminate concentration, rinse, and wash processes without user intervention or allow for remote control of the system with a smartphone or computer. However, even with automated units, it is essential to know the appropriate procedures and settings to run the system manually.

Daily RO operation, including rinsing, washing, and benchmarking, is critical to ensure continued optimum performance.

Membrane Performance

BENCHMARKING AND PERFORMANC TESTING

Benchmarking, recording, and tracking membrane performance throughout the season and from one season to the next are essential to optimizing the functioning and efficiency of membranes and maximizing their life span. During the concentration cycle, membrane performance will decline, and flow rates decrease as the membrane becomes "fouled"—pores of the membrane become blocked with sugars, microorganisms and their metabolites (biofilm), minerals, and other contaminants. Keeping track of basic performance parameters (**Table 7.2**) will help ensure the RO is operating at peak levels (maximum rate of rejection) by enabling the operator to identify declines in membrane performance and troubleshoot issues. For example, monitoring the flow rates of individual membranes can help the system operator detect if a membrane is plugged or if there is insufficient flow in the last membrane of a series. Timely identification of problems helps ensure their resolution before membranes suffer a permanent loss in performance—a major (and costly) issue if it occurs in the middle of a large sap run.

Membrane performance tests and benchmarking provide further information for tracking RO performance and guiding decisions about cleaning and maintenance procedures. Precise procedures will vary by manufacturer, but the benchmarking process essentially involves recording the rate of permeate flow under controlled conditions at a standard pressure level and concentrate flow rate (**Table 7.3**). The recorded permeate flow rate is then multiplied by a temperature correction factor (**Table 7.4**) to adjust for differences in the rate of flow caused by differences in temperature (membrane performance is highly affected by sap temperature). The initial procedure should be performed at the beginning of each production season to establish the "benchmark"

TABLE 7.2 Basic RO benchmarking parameters to monitor membrane performance with an example.

			Permeate flow (gpm)					
Date	°Brix of sap	°Brix of concentrate	Membrane 1	Membrane 2	Membrane 3	Membrane 4	Total Permeate flow (gpm)	Total Concentrate flow (gpm)
4/12	2.5	11.5	5	5	5	3.25	18.25	6.25

Date	Total Flow (gph) Permeate Flow + Concentrate Flow) x 60	Percent Concentration (Permeate Flow + Concentrate Flow) x 100	Operation Temperature (F)	Operation Pressure (psi)	Duration of Concentration (hrs)	Total sap (gal)	Total Concentrate (gal)	Wash details/ Notes
4/12	1470	74.5%	37.6	250	4	5880	1500	

Table has been broken into two lines to fit on the page.

TABLE 7.3 Example of a RO benchmarking worksheet to monitor daily and seasonal changes in membrane performance Indicating the need to wash the membrane. By monitoring membrane efficiency, producers can determine when a rise or soap wash is required to restore flows to higher levels. Benchmarking should always be conducted at the same standard pump pressure level and concentrate flow rate and corrected for temperature (See Table 7.4).

Date	Operation	Time of Operation (hours)	Permeate flow rate (gal/min)	Permeate Temperature (°F)	Permeate Temperature (°C)	Correction Factor	Temperature Corrected Flow Rate (gal/min)	Efficiency (%)
3/13	6h Concentration 1h Hot water wash	6	18	46	8	1.155	20.8	100
3/14	8h Concentration 1h Hot water wash	8	15	41	5	1.266	19.0	91
3/15	9h concentration 1h Hot water wash	9	17	59	15	0.948	16.1	78
3/15	Soap Wash Rinse							
3/15	Performance Test		17	45	7	1.188	20.2	97
3/16	5h Concentration 1h Hot water wash	5	18	52	11	1.057	19.0	92

TABLE 7.4 RO membranes are very sensitive to changes in temperature. A permeate flow correction factor is used to correct flow rates for various temperatures.

Permeate Temperature (°F)	Permeate Temperature (°C)	Correction Factor
32	0	1.488
34	1	1.439
36	2	1.391
37	3	1.348
39	4	1.305
41	5	1.266
43	6	1.226
45	7	1.188
46	8	1.155
48	9	1.120
50	10	1.088
52	11	1.057
54	12	1.028
55	13	1.000
57	14	0.973
59	15	0.948
61	16	0.923
63	17	0.899
64	18	0.876
66	19	0.855
68	20	0.833
70	21	0.814
72	22	0.794
73	23	0.776
75	24	0.758
77	25	0.741

performance of the membranes—that is, (hopefully) the best level of performance that the membranes can achieve. This step should then be repeated after each concentration cycle (or more frequently depending on operating conditions and manufacturer's specifications) to continuously track and assess membrane performance. Comparing the result obtained at any point during the season to the established benchmark indicates how much membrane performance has decreased. This procedure can help determine when and what type of washing procedures are required and identify problems with membrane performance. **Table 7.3** illustrates an example benchmarking datasheet and calculations.[3]

MEMBRANE CLEANING Appropriate cleaning regimes are necessary to maintain maximum membrane performance and longevity by limiting biofilm formation, removing contaminants and fouling agents from the membrane's pores and surface, and ensuring membrane fibers are in optimal condition. An effective approach generally requires a combination of rinsing and washing with permeate after each concentration, as well as less frequent, but more intensive, wash cycles with chemicals. A general flowchart of the order of operations for rinsing and wash cycles using the results of benchmarking to guide decision-making is included in **Figure 7.25**. However, the specific cleaning strategy, including the recommended frequency of cleaning, the type and concentration of cleaning agent used, and the optimal temperature and pH for the wash, and the amount of permeate for the rinse, is highly specific to the manufacturer of the RO unit and the membranes being used (datasheets for membranes are available from the manufacturer). Always follow the cleaning procedures and chemical usage (type and amount) specified by the manufacturer for both the RO unit and the membranes being used. Improper use of cleaning chemicals can damage membranes and contaminate syrup.

Although specific procedures vary for each unit, there are some general guidelines for cleaning that apply to all ROs and membranes. Once the concentration cycle has been completed, the RO must be rinsed with permeate to purge sugar from the membranes for about 20 minutes until a reading of near 0°Brix to prevent biofilm formation and membrane clogging. Wash cycles with hot permeate or chemicals should be performed at a minimum of 86°F (30°C) for 30 minutes, with 15 gallons

[3] RO worksheets in this chapter are available at: www.mapleresearch.org.

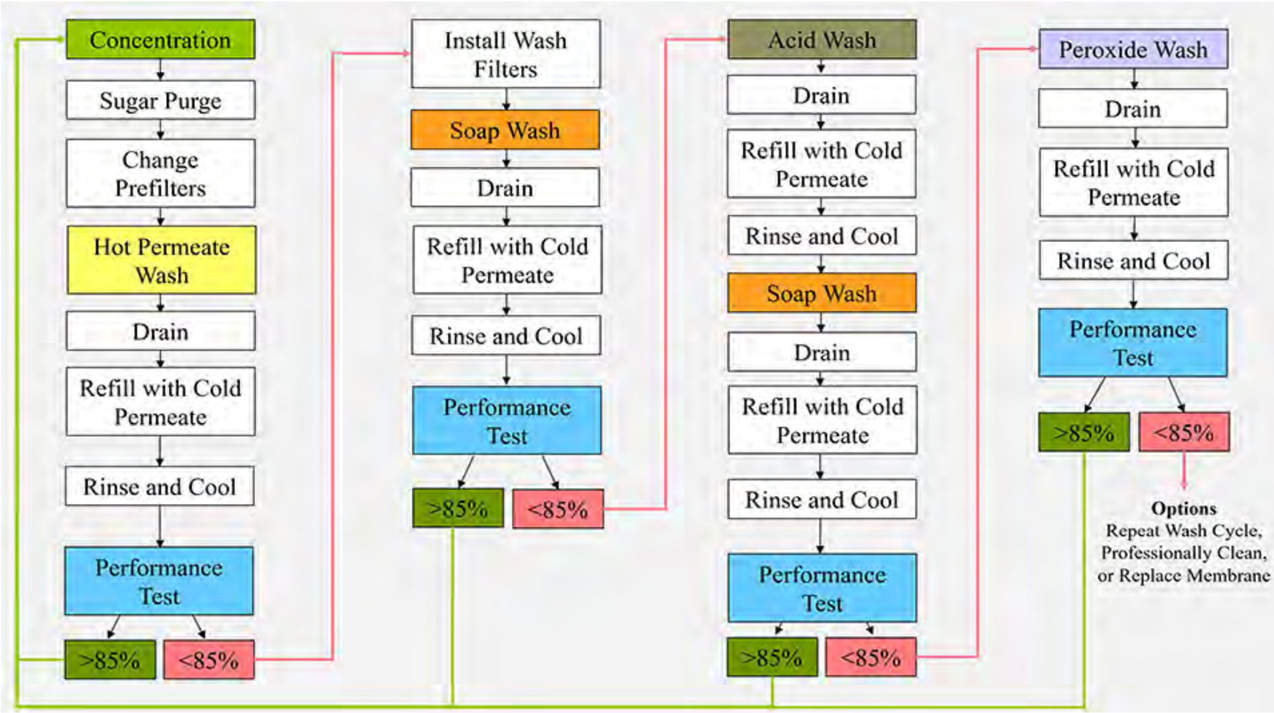


Figure 7.25. Decision-making flow chart for membrane washing.

(57 liters) of solution for each 8-inch membrane during recirculation of the wash. Maximum temperatures for hot permeate or chemical wash cycles are specific to the membrane and RO unit and must be strictly observed to avoid damage.

Adequate rinsing of the RO unit with cold permeate after hot permeate or chemical wash cycles is critical to ensuring that wash water and chemical residues do not contaminate syrup and to enabling the membranes to cool and tighten. In general, the RO unit must be rinsed with 30 to 40 times the volume of liquid that the unit holds internally to ensure that the wash water and cleaning chemical are completely removed from the pressure vessels, pumps, plumbing, and membranes. For example, an RO with three 8-inch posts would hold a total of approximately 28 gallons (106 liters) of liquid. Therefore, 1,120 gallons (28 gallons × 40) or 4,200 liters of permeate would be required for a complete rinse following a wash cycle. Draining the wash solution from membrane posts before rinsing can substantially reduce the amount of rinse water required, since it reduces the amount of wash solution that must be removed through dilution. Each 8-inch membrane post holds about 6 gallons (23 liters) of liquid—thus, in the same three-membrane RO, draining the posts before rinsing would reduce the amount of rinse water needed to 400 gallons ([28 – (3 × 6)] × 40) or 1,500 liters. This procedure requires an air inlet on the membrane post, and one or more exit valves to permit liquid drainage. Some RO units include systems that use compressed air to improve draining of wash water during this process.

Most chemicals used in RO cleaning are concentrated and hazardous, typically either very strong bases ("soaps") or acids. RO soap, a strong caustic material, is used to remove biological materials (biofilm); acids are used to remove minerals. Specific procedures are required for each type of wash. Appropriate procedures must be used when handling, storing, and disposing of not only the chemicals themselves, but also the wash and rinse water. More detailed guidelines can be found in the "Chemical Safety" section.

It is important that water used to wash or rinse RO systems be free of chlorine. Membranes are fairly sensitive to chlorine, so chlorinated municipal water or bleach solutions should not be used.

Membrane Evaluation Monitoring permeate properties provides information on membrane performance that can help operators identify and troubleshoot issues. The electrical conductivity of permeate provides a measurement of the mineral ions present. Monitoring for elevated levels of conductivity can help indicate increased passage of mineral ions and identify a loss of membrane function and provide an indirect indication of a passage of sugar. For example, a reading of permeate conductivity that exceeds 10 µS typically indicates there may be a significant quantity of sugar being lost. When elevated values are observed, the total amount of sugar being lost can be assessed by boiling a small volume of permeate and measuring the sugar content of the concentrated material with a handheld refractometer. Most refractometers are not sensitive enough to use to detect sugar losses directly in unconcentrated permeate, as significant losses can be occurring at concentrations too low to register on the instrument.

To help troubleshoot the cause of problems that might occur later in the season, it is advantageous to measure the conductivity of the permeate from each membrane, as well as that of the permeate in the tank, at the beginning of the season. Frequently valves are installed on the flowmeter associated with each membrane to allow sampling of permeate. If performance issues arise later in the season, these initial readings can be compared to subsequent readings to help identify which membrane is malfunctioning (**Table 7.5**).

TABLE 7.5 Example of data of permeate conductivity used to track individual membrane performance. Initial readings are taken at the beginning of the season to serve as a baseline. If conductivity values in the tank rise, remeasure the conductivity from each membrane. In this example Membrane #1 is unchanged. Membrane #3 has risen only slightly. The conductivity of Membrane #2 has risen by a factor of 3, indicating the issue is likely here.

	Conductivity (µS/cm)			
	Membrane #			Permeate Tank
Date	1	2	3	
3/20	2	8	15	2
3/21				3
3/23				5
3/24				5
⋮				
4/13				17
4/13	2	25	18	17

Membrane Storage

Membranes must be stored according to manufacturer specifications during the off-season. Generally, they are placed in a preservative solution, such as sodium metabisulfite, after an intensive cleaning. Many manufacturers offer a service that includes this level of cleaning as well as storage of membranes at the end of the season and information from testing to help evaluate membrane function.

Membranes must be thoroughly rinsed at the beginning of each season to remove the storage solution. The rinse cycle is used for this process, as too much pressure can clog membranes by forcing minerals from the preservative into membrane pores. This generally requires between ½ and 1 gallon of water for each rated gallon capacity of the membrane. The rinse water used must be pure—permeate obtained from a neighbor is an ideal. If not available, well water can be used if it is tested and contains less than 100 ppm (200 µS) total hardness, 0.5 ppm of iron, 1,000 CFU/milliliter total bacteria, and 100 CFU/milliliter coliform bacteria. Alternatively, an old membrane can be used to generate permeate from well or spring water for the process of rinsing the good membranes. If none of these options are available, the first good-quality sap can be used—the solution generated contains chemicals and other residues and *must* be discarded.

Planning and Selecting Sap Processing Equipment

The first step in selecting sap processing equipment is to consider the time and labor available, including how many people will be available during the season for sugarhouse activities (operating the RO, boiling, etc.), their skill level (are they able to operate the evaporator, the RO, etc.), and timing of their availability (is labor available anytime, days or evenings only, etc.). Also, it is important to consider whether individuals might be tasked with other activities outside the sugarhouse that need to be performed during sap processing, such as checking for leaks or transporting sap. The labor available and needed outside of the production season is also important to consider, as this will help inform decisions like the choice of evaporator fuel, such as whether labor is needed to cut and prepare wood. The final labor factor to determine is the number of hours a day that are available or desired to devote to sugarhouse activities, including setup, boiling, filtering, and cleanup.

The next set of factors to determine and consider are the specific parameters of the operation. At a minimum, the number of taps and the average daily sap yields per tap need be calculated. Estimates of maximum flow rates per hour and sap sugar content can also be helpful information for choosing the right size of equipment. The potential for future expansion should also be kept in mind.

With this information, it is possible to determine a variety of equipment types, sizes, and configurations that will meet an operation's needs and achieve the desired workflow. There usually isn't a single optimal configuration for a particular operation, but rather a variety of possible strategies to achieve its needs and desired goals. In general, concentrating with RO will greatly reduce the amount of liquid to process in the evaporator, and thus the chosen concentration level will help determine the optimal evaporator choices, with higher concentration levels generally allowing for smaller evaporators and shorter boiling times. In addition, the concentration level will influence the choice of flue to syrup pan ratio—as concentration increases above about 22°Brix, the optimal amount of syrup pan increases to ensure that the concentration of the sap exiting the flue pan is less than 40°Brix (see "Managing Niter"). Further, each evaporator, whether it is a traditional-style, steam, electric, or other type, has a specific evaporation capacity in gallons of water per square foot per hour. This rate varies by evaporator design and type and is influenced by the type of fuel, the ratio of flue to syrup pan, and the addition of high-performance features such as insulation, forced air for wood evaporators, preheaters, double-pass designs, and steam pans. These rates serve as general guidelines for making assessments of the optimal equipment type and configuration for a particular operation. All these parameters—the sap concentration and evaporator type, features, size, and, ultimately, its processing capacity—are considered together with an operation's parameters—the number of hours per day for boiling and sugarhouse activities, labor availability, and so forth—to determine an optimal configuration for the operation's specific needs.

For example, a 10,000-tap operation with an average sap yield of 1 gallon per tap per day will generally need equipment capable of processing 10,000 gallons of sap per day. One possible configuration would be to concentrate the sap to 8°Brix. This would result in about 2,500 gallons of liquid to process in the evaporator, which could be accomplished in about 8 hours with a 5 × 16[4] high-performance wood evaporator, or a 4 × 16 basic oil evaporator. An alternative approach would be to concentrate the sap to 16°Brix, which would result in 1,250 gallons of liquid to process in the evaporator. Subsequent boiling could be achieved in 6 hours with a 3½ × 12 basic oil evaporator, or in 5 hours with a 3½ × 12 oil evaporator with some higher-performance features. Adding a steam pan to that configuration would effectively raise the concentration by about 5°Brix and reduce boiling time by about an hour per day. That same reduction could also be accomplished without the addition of a steam pan by increasing the concentration with RO to 21°Brix. Alternatively, a concentration of 22°Brix would produce about 900 gallons per day to process in the evaporator. This could be accomplished in about 4 hours in a 4 × 10 standard oil evaporator, or 3.5 hours in a higher-performance model of the same size. Higher concentrations (>22°Brix) result in even smaller amounts of concentrate to boil, potentially facilitating shorter boiling times and

[4] Evaporators are sized in feet. Thus, a 5 × 16 evaporator is 5 feet wide by 16 feet long.

smaller evaporators. (However, it should be noted that reductions in evaporator processing rates as relative syrup pan length is increased to adjust for higher concentrations result in less dramatic reductions in evaporator size and boiling time than might be expected). Clearly, many different configurations are possible. Often the decision comes down to a few limiting factors or personal choice. It is recommended that producers discuss their needs and operational parameters with equipment dealers and consider their input as they evaluate the variety of potential strategies and configurations that might be suitable.

Although the basic calculations for sizing equipment are often based on the number of hours available or desired to boil, another important factor to consider is the overall time and amount of labor required for each configuration. Each boiling session requires time for setup, the boiling itself, and cleanup, and each different piece of equipment has its own specific cleaning and maintenance requirements. There is generally a minimum efficient amount of time to boil each session (about 3 hours is a general rule of thumb), and this needs to be considered when choosing equipment sizes and configurations. In addition, some gains in efficiency in one aspect of an operation can result in losses in other areas and reduce overall efficiency. For example, a steam pan can achieve a 4°–7°Brix increase in concentration but may require additional time and infrastructure for cleaning and maintenance. In some circumstances, overall time efficiency can be optimized by using a refrigerated bulk tank to temporarily store concentrate, which allows for less frequent but longer boils (and fewer cleanup cycles). This option can help ease scheduling challenges by enabling the producer to delay boiling slightly until labor is available.

Although there are myriad configurations possible that vary according to an operation's parameters and requirements, there are a few basic guidelines for choosing equipment that apply as a general rule.

- Do not undersize equipment. Choosing equipment that is just barely capable of meeting an operation's needs to reduce equipment costs can seem prudent. However, it is essential to choose equipment sized and configured such that it is not necessary to constantly operate it at maximum capacity. For evaporators this can result in challenges with foaming, niter accumulation, and cleaning and may reduce overall efficiency significantly. Undersizing of the RO unit can lead to frequent clogging, resulting in challenges with maintaining the flow rates required to feed the evaporator or meet the operation's needs. On the other hand, it is possible in some circumstances to choose smaller equipment, with the understanding that two consecutive shifts of workers will be required on days with very high sap flow.
- A general rule of thumb is to size the RO to be able to keep up with (or slightly gain on) the evaporator evaporation rate. The typical workflow or setup of some operations may not require this capacity. Thoughtful consideration of the likely or desired workflow in an operation will help determine the optimal configuration.
- Some equipment options, like refrigerated bulk tanks or very high RO concentrations, will significantly change the workflow possibilities and considerations for selecting and sizing all equipment. For example, refrigerated bulk tanks allow concentrate to be stored for several days before boiling without a loss of quality. Because concentrate need not be boiled every day, sap can be concentrated to higher levels, and a slower RO processing rate can be acceptable. A larger evaporator with higher processing rates, capable of processing several days' worth of concentrate in a single boiling session of a reasonable length could be used.
- All storage capacity choices will be influenced by an operation's yields and equipment configurations. In general, it is recommended to have at least 1½ gallons per tap of sap storage capacity each day, or even up to 2 gallons per tap if using high

vacuum. In operations with an RO system, a minimum of 40 times the total volume of liquid that the RO holds is needed for permeate storage; however, twice that amount of capacity is generally recommended to accommodate other needs for permeate, including general cleaning, evaporator pan washing, filtering and filter press cleaning, or for the rare occasions when two wash cycles are necessary to restore function.
- The availability of full-time, year-round positions in an operation can sometimes improve efficiency and reduce overall costs in the long term, by increasing retention of skilled and well-trained individuals, and thus reducing the number of new seasonal employees that need to be hired and trained each year.

Chemical Safety

Most chemicals used in evaporator and RO cleaning are concentrated and hazardous, typically either very strong bases or acids (corrosives, very low or high pH values). Appropriate procedures must be used when handling, storing, and disposing of the chemicals themselves and the wash and rinse water used with them. The publications *Chemical Safety in Maple Sugaring Operations*[5] and *Procedures for Neutralizing Maple Wash Water*,[6] give more detailed information and guidance on how to safely store, use, neutralize, and dispose of the chemicals used in maple operations. Producers should refer to these publications, as well as the safety instructions provided by the equipment manufacturer or dealer and the Safety Data Sheet (SDS) for each chemical used for detailed and specific safety information in addition to any applicable guidance or regulations for their state or province. The following general guidelines for chemical use in maple operations should be followed in all circumstances:

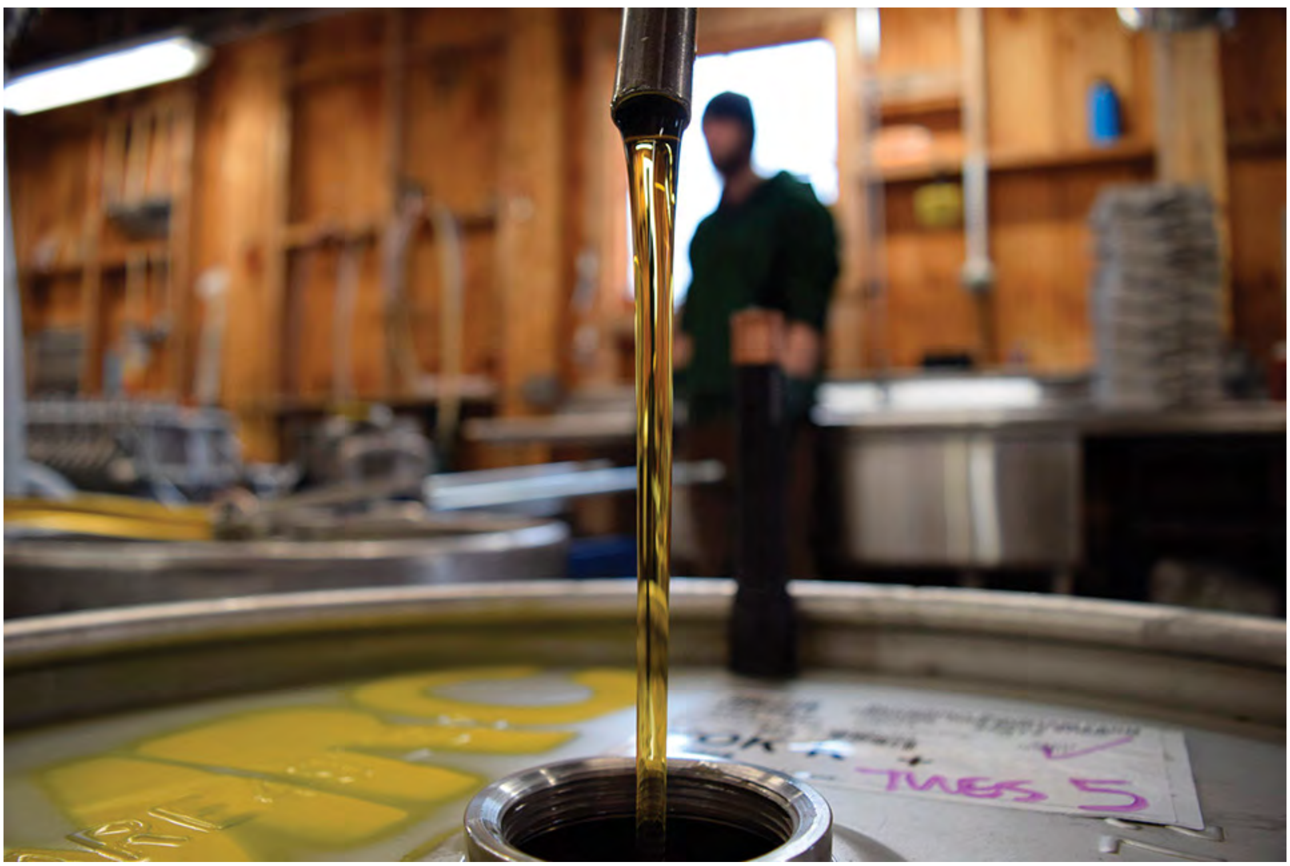
- Obtain the SDS and the specific instructions for use for each chemical at the time of purchase from the equipment dealer and keep them where they can be easily referenced before and during use. SDSs contain specific information for each chemical about its hazards, and how to safely use, store, and dispose of it.
- Always wear appropriate personal protective equipment specific for the chemical being used. This information is specified on the SDS and can include thick butyl rubber gloves, chemical-resistant goggles and face shields, chemical-resistant aprons, and disposable respirators.
- Appropriate safety equipment must be in place, kept up to date and in useable condition, and all personnel instructed in its proper use. This can include a spill control kit, an emergency eye wash station, and a shower or drench hose.
- Always maintain adequate ventilation and wear respiratory protection when appropriate. The dust and vapors from the corrosive chemicals used in evaporator and RO cleaning are hazardous and can damage lung, mouth, and throat tissues, as well as exposed skin.
- The spent wash water from evaporator and RO cleaning may be too corrosive for direct discharge into sewer drains, onto the ground, or into septic systems. The water generally must be neutralized to a safe pH range prior to disposal to comply with environmental regulations. Note that in many jurisdictions if a cleaner that contains phosphoric acid is used, additional steps to mitigate the impact of releasing this material into the environment may be required. Contact your local maple Extension specialist or Department of Environmental Conservation (or equivalent) for more details.

[5] van den Berg, A.K., T.D. Perkins, and H.J. Marckres. 2005. Chemical safety in sugaring operations. Miscellaneous Publication. University of Vermont. 11pp. https://mapleresearch.org/pub/chemsafety/

[6] Wilmot, T.R. 2011. Procedures for neutralizing maple wash water. Miscellaneous Publication. University of Vermont. 3pp. https://mapleresearch.org/pub/vtwashwater/

- In all instances, applicable local, state, and federal regulations relative to using, storing, handling, and disposing of chemicals and wash water must be followed. The Department of Environmental Conservation (or equivalent) in each state and province can provide help with this information, and each typically has a toll-free phone number to call for assistance.

Producers should take note that the regulations pertaining to neutralization and disposal of RO wash water are being developed and revised as of the writing of this manual. Be sure to reference the current local, state, or provincial rules for updates to procedures to ensure compliance.



CHAPTER 8

Syrup Filtration, Grading, Packaging, and Storage

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CHAPTER CONTENTS

Perkins, T.D., R.B. Heiligmann, M.R. Koelling, and A.K. van den Berg (Editors). 2022. *North American Maple Syrup Producers Manual. Third Edition*. The University of Vermont and the North American Maple Syrup Council, Burlington, Vermont. www.mapleresearch.org/manual/

INTRODUCTION

Previous chapters focused on best practices for collecting maple sap and producing quality maple syrup. This chapter presents best practices for syrup filtration, syrup packaging, and syrup storage, along with detailed discussions of determining syrup density and syrup grading (the process of measuring/codifying the character of a batch of syrup based on density, color, clarity, and flavor). Effective filtration and proper packaging and storage are essential to producing high-quality maple syrup. Density measurement and grading are methods for evaluating and communicating the quality and character of an individual batch or container of syrup. By focusing on producing syrup of the highest quality and excellent flavor, producers will receive the best price for bulk syrup, serve wholesale and ingredient buyers well, and attract and maintain retail sale customers. While grading maple syrup is not always a legal requirement, it reflects the pride and care producers take in meeting quality standards and helps sustain the reputation and marketability of pure maple syrup with the public.

SYRUP GRADING

Maple syrup grading is the measurement and comparison of density, color, clarity, and flavor to achieve acceptable and desirable syrup quality. Natural variation in syrup color and flavor occurs as a result of many environmental and processing factors. These include the method of production, year of production, and time of season the syrup was produced. Grading standards can be used as tools to help communicate variation in maple syrup characteristics to customers to assist them in finding the type of syrup they desire and to provide assurance that bulk, wholesale, or retail consumers will obtain maple syrup with the desired characteristics.

Significant changes were made relatively recently to harmonize the grades of maple syrup of maple syrup across all maple syrup producing regions. Prior to this development, several states and provinces had their own grading standards and nomenclature for syrup produced or sold in that state or province. The move toward a single set of industry-defined standards and grades was undertaken to simplify the marketing of maple syrup and to provide consumers with consistent terminology.

In some states and/or provinces, grading and labeling of all syrup is mandatory; in others there is no legal requirement to grade maple syrup; however, if a grade determination is stated, the syrup must meet all pertinent standards. When producers are located within a jurisdiction with no legal requirement to grade maple syrup, the decision to grade or not is entirely their own—they may choose to grade all, part, or none of their product. Producers should acquaint themselves with the specific grading standard(s) and requirements appropriate to the area where the syrup will be sold.

Grading is a skill that is gained and honed through time and experience. The process is more difficult than it appears and depends on good equipment and proper technique, along with lots of practice. Producers who wish to learn more about grading or practice their grading skills and procedures might consider attending a grading school (**Figure 8.1**) or helping judge maple syrup contests.

Grading Standards

Pure maple syrup is by definition produced exclusively by the concentration and heating of maple sap or the solution/dilution of a maple product in potable water with a minimum of 66.0 percent[1] and maximum of 68.9 percent soluble solids.

Figure 8.1. Attending a maple grading school is an excellent way for maple producers to enhance their skills in making excellent maple syrup.

[1] Syrup must meet a minimum density of 66°Brix in all Canadian provinces and most U.S. states and 66.9°Brix in Vermont and New Hampshire.

U.S. and Canadian Grade A maple syrup must

- have a minimum of 66.0 percent and not more than 68.9 percent soluble solids by weight (Brix);
- be of uniform color;
- have good flavor and odor associated with the color class;
- be free of off-flavors or objectionable odors;
- not be cloudy or turbid or contain sediment or foreign material;
- have no defect that affects its flavor, odor, appearance, edibility, or quality.

The federal governments in Canada and the U.S.A. officially adopted (in 2014 and 2015 respectively) the grading standards and color and flavor classes for Grade A (retail) syrup shown in **Table 8.1**.

Additionally, maple syrup for retail sale must also be traceable to batch, and compliant with appropriate U.S. and Canadian federal standards, in addition to all state, provincial, and local regulations pertaining to production, labeling, containers, registration, and standards for food safety.

Many individual states and provinces adopted the same standards (sometimes with minor modifications) over the past few years to harmonize the standards across maple producing regions.[2] The new standards were adopted in part to avoid consumer confusion about Grade A syrup and to dispel the implication that syrup formerly labelled as Grade B was of lower quality. The new grading scheme also allows for flavor descriptors designed to provide consumers a better idea of syrup attributes and make it easier for them to choose to purchase syrup with the taste characteristics they prefer. In addition, to help align with shifting of consumer preference from lighter, delicate-flavored syrups toward darker, stronger-flavored syrups, a new "Very Dark" grade was established to allow good-flavored syrup that previously had a color designated as "Commercial" to be sold in retail-sized containers. Syrup with defects such that it cannot meet the standards for Grade A falls into either "Processing Grade" (may contain off-flavors or objectionable odors), not suitable for retail sale, or may be classified as "Substandard."

TABLE 8.1 Color and flavor classes and light transmittance ranges for Grade A maple syrup.

Color	Taste	Light Transmittance (% Tc)
Golden	Delicate	> 75.0
Amber	Rich	50.0–74.9
Dark	Robust	25.0–49.9
Very Dark	Strong	<25.0

Maple syrup is graded and classified based on four primary characteristics: clarity, density, color, and flavor. The following will detail best practices for optimizing these four grading characteristics in a way that maintains the highest quality of your product.

Syrup Clarity and Filtration

When maple syrup is drawn off the evaporator it contains suspended solids that impart a cloudy appearance. Most of the cloudiness found in unfiltered syrup is the result of a naturally occurring mineral precipitate known as "sugar sand" or "niter." Sugar sand is principally composed of calcium and magnesium salts of malic acid, one of the organic acids present in maple sap (and the same compound that contributes to "tartness" in apples). Sugar sand forms during evaporation as the solution becomes more concentrated. The sugar sand precipitates when its solubility threshold is exceeded. Some of this material remains suspended, and some adheres to pan surfaces as "scale." As evaporation continues, some of this deposited scale can flake off to form flakes and particles. Sugar sand can occur in various forms ranging from a soft, oily substance that is dark in color to a fine-grained, crystalline material that is light in color similar to beach sand

[2] http://www.internationalmaplesyrupinstitute.com/uploads/7/0/9/2/7092109/__7709649_orig.jpg

(hence the name "sugar sand").[3] Sugar sand causes syrup to appear cloudy or darker in color and can impart a gritty texture and an off-flavor. Consumers often confuse the settled sediment with mold or broken glass.

The amount of sugar sand produced when making maple syrup varies from year to year, within a season, and from one sugaring operation to the next. There is little empirical evidence to explain how and when sugar sand appears during the season. Soil and site factors likely contribute to its chemical composition, and changes in sap sugar content and pH across the season may also impact its volume and consistency. In general, producers experience less sugar sand early on, and increasing levels as the season progresses. Processing equipment (buckets, sap tanks, evaporators, etc.) can affect the chemical composition of sugar sand and, in turn, syrup chemistry. Sugar sand includes concentrated metals and minerals that, if not removed, can contaminate otherwise good quality syrup. This is why it is essential that only food-grade equipment is used to produce maple syrup. Galvanized and/or lead-containing equipment is not appropriate for sap and syrup processing to reduce the potential of leaching of harmful contaminants into sap, sugar sand, and syrup.

Clarity describes the clearness or lack of cloudiness of syrup. To meet the clarity standard for Grade A syrup, syrup must be "clean and clear"—free of any cloudiness, turbidity, or foreign material. For grading purposes, this is commonly determined visually. Check the clarity of your product right before packing in retail containers (**Figure 8.2**). If packed in glass, check for sediment again a few days after packing. Air bubbles can cause syrup to appear cloudy or dark, so samples being checked for clarity should not be agitated immediately beforehand. Note that the presence of suspended solids (lower clarity) can also influence the perceived color of syrup.

Meeting the clarity standard requires the removal of suspended material through filtration; the level of syrup clarity reflects the performance of the filtration system in removing suspended solids and sediment.

Figure 8.2. Maple syrup should be clear and free of sediment. Syrup before filtering (left) and after filtering (right).

Types of Filtration

Syrup may be filtered either with or without a pressure system. When done correctly, either process will result in effective filtration that meets the minimum standards for clarity. The main difference between the two systems is filtering speed and efficiency. The key to effective and efficient filtering, no matter the style, is syrup temperature. The hotter the syrup the easier it will filter. That said, producers must know that more sugar sand may form if syrup is allowed to overheat.

CLOTH FILTERS/CONE FILTERS Filtering with cloth is a time-honored method of removing suspended solids from syrup. Hot, finished syrup is passed through a type of fabric that traps and removes the suspended particles.

Historically, natural textiles (wool felt, linen, or flannel) were used as a filtration medium. However synthetic fabrics (polyester and acrylic) are more durable and shrink resistant and consequently are now more commonly used for this purpose than traditional materials. Cloth filters have limited capacity; the rate of filtering drops not only as the fabric

[3] Isselhardt, M., A. van den Berg, and T. Perkins. 2012. Chemical composition of scale in maple syrup evaporators. *Maple Syrup Digest*. Dec., pp. 23–28. https://mapleresearch.org/pub/m1212chemicalcomposition/

becomes clogged but also as the volume of syrup remaining to be filtered drops. The rate of syrup filtering also significantly slows as the syrup cools. The key to success is keeping the syrup and filters as hot as possible. By employing best practices, one can expect to filter 2–3 gallons of syrup before needing to change filters. Sometimes, however, the characteristics of the material being filtered changes (from coarse and gritty to fine or almost paste-like) and it will be difficult to filter much syrup at all.

A cone filter uses a cone-shaped wool or synthetic felt filter that is suspended over an appropriately sized and shaped container (**Figure 8.3**). Hot syrup is poured into the filter and flows to the collection container below. Since the filtration process is very slow, especially if large amounts of suspended particles are present, two or three filters may be suspended side by side over a single collection container. Syrup is placed in each filter as space is available. Producers sometimes will trickle syrup out of the draw-off into the filter to maintain a steady hot stream of syrup to enhance filtering rate. Filtering tanks are frequently fitted with valves so syrup can be directly packaged following filtering. When this is done, some provision must be made to keep filtered syrup hot (180°–185°F / 82°–85°C, see "Hot Packing") while it is being packaged.

Figure 8.3. Filtering syrup directly off the evaporator with cone (felt hat) filter and paper prefilter.

Flat filters consist of a wool or synthetic felt sheet placed over a food-grade hardware cloth or stainless steel supporting screen (**Figure 8.4**). Hot syrup is poured on the filter and allowed to pass through to the collection container below. Once in the collection tank, syrup may be packaged directly if it is at the appropriate temperature.

As hot syrup passes through a cloth filter, suspended sugar sand and other particles in the syrup accumulate on the filter. This material reduces the rate of syrup flow through the filter, eventually requiring that the filter be changed. Paper or nylon prefilters can be placed on top of the cloth filter to prolong the period of use between washings (**Figures 8.3** and **8.4**). When deposits of sugar sand build up, the prefilter is either replaced or removed, washed, and reinstalled. Regularly replacing or refreshing the prefilters may help extend the interval between filter changes. Some producers use two or three prefilters, removing the top prefilter when it starts to clog. Any remaining unfiltered syrup is then gently poured into the next prefilter. Prefilters should not be dry when unfiltered syrup is introduced.

Care must be taken when cleaning cloth filters. New filters and prefilters must be thoroughly

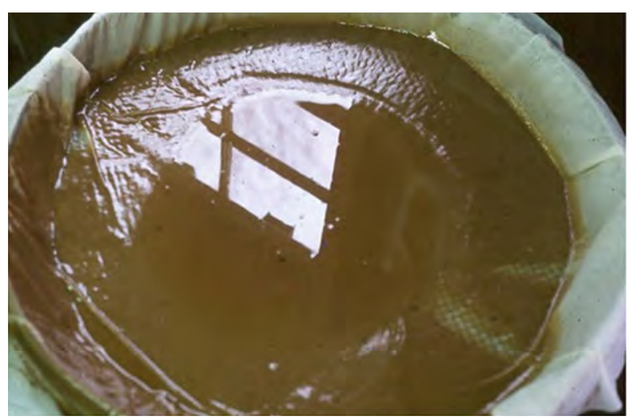


Figure 8.4. Flat gravity filter/bottling system showing filter sheet and paper prefilter (on top of "felt" filter) and supporting screen.

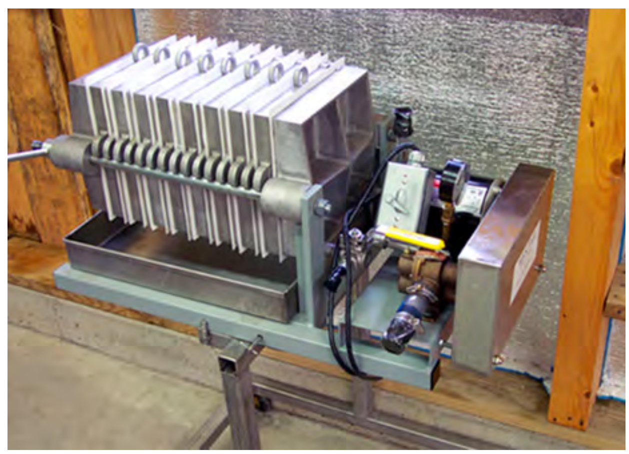
washed before they are put into use as they may contain manufacturing residues that must be removed. No soap, detergent, or chlorine solution should ever be used when washing filters as these might impart off-flavors to the syrup. Boil the filters for a short time in clean water followed by multiple water rinses and air drying before first use. Filters should never be wrung out or twisted since this will tear fibers and reduce the filter's effectiveness. Following rinsing the filters should be dried to avoid diluting the finished syrup.

While different techniques may be used to wash both nylon prefilters and cloth filters during the season, many producers use a system that attempts to keep the "syrup side" of the filter from coming in contact with sugar sand. Before washing, the filter is turned inside-out (inverted) and the niter is carefully scraped off what was originally the inside of the filter. Water is then forced through the filter from the "syrup side" to the "sugar sand side." When all the sugar sand has been removed, the inverted filter is returned to its original configuration, rinsed, and allowed to dry. Use only hot water to clean filters. When not in use, fully dried filters should be stored in a clean, dry place and protected from contamination. Filters should not be exposed to mothballs or other aromatic substances (e.g., scented soap, cleaning agents) as these odors will cause an off-flavor in the syrup. At the beginning of each season, filters should be inspected carefully for cuts, tears, or wear that might allow passage of sugar sand. Producers should also inspect carefully for signs of mold or mildew and smell the filters to see if there is any hint of unusual or objectionable odors.

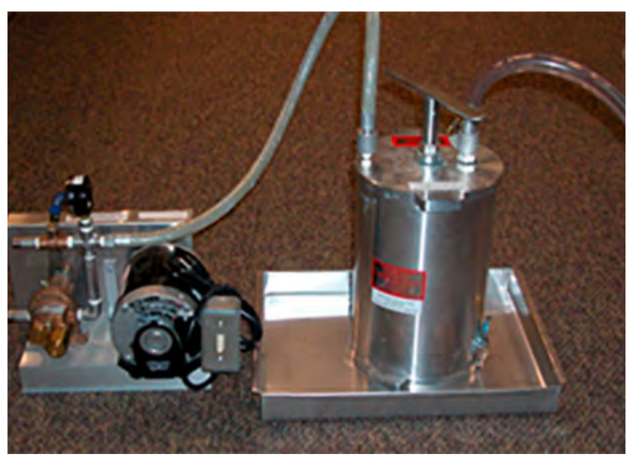
Keys to effective cone filtering:

- Make sure the syrup is the correct density and as hot as possible but avoid over-concentrating the syrup.
- Use several (three to five) prefilters stacked inside the cone filter and remove them sequentially as they clog.
- Optimize filtration performance by moistening filters and prefilters slightly before use, minimizing the amount of water used to dampen them to avoid diluting syrup density.
- Keep filter(s) and unfiltered syrup in a covered tank until needed so the syrup will stay warm longer and there will be more syrup ready for filtration.
- Have multiple filters/assemblies ready for use and switch or go back and forth from one to the other as needed.

PRESSURE FILTERS Pressure filters come in two general types, plate and canister (**Figure 8.5**). Both use pumps to force unfiltered syrup through a filtration medium. Pressure filters are the quickest, most efficient, and most effective method of filtering syrup. Both types use filter paper or cloth along with diatomaceous earth (commonly referred to as "D.E." or



(a)



(b)

FIGURE 8.5. Plate (a) and canister (b) pressure filters, both equipped with electric Oberdorfer gear pumps.

"filter aid") as the filtration medium. D.E. is made up of the fossilized remains of single-celled, hard-shelled microalgae (diatoms). This fine-grained, inert, whitish powder is predominantly composed of silica and is used widely as a filter aid by many food and beverage industries. At the microscopic level, individual D.E. particles are rigid enough to avoid compressing completely. The exceptional filtering capacity of D.E. is largely due to this rigidity and the secondary porosity of the individual diatom shells. Syrup filtered with this method is free of detectable particles and has a polished and sparkling appearance. It is essential that only food-grade D.E. of the proper particle size be used in filtering maple syrup. Pool-grade D.E. is NOT appropriate since it contains contaminants that should not be introduced into syrup.

D.E. should be stored covered in a clean and dry area to prevent mold growth and contamination that could affect filtered syrup. Improperly stored D.E. will often take on a musty odor, and so will any syrup filtered through it. D.E. should also be stored separately from pan cleaner and other cleaning chemicals. Like other silica-based products, D.E. can cause irritation and damage to the skin, eyes, mouth, throat, nose, and lungs. Read the "Material Safety Data Sheet" for D.E. and take appropriate safety measures. Avoid breathing the dust, and activities that increase the generation and circulation of dust from D.E., such as dry sweeping. A respirator, gloves, and eye protection are recommended when handling D.E. Many producers will store bags of D.E. in plastic bins that resemble trash receptacles. If you do this, clearly mark the bin as "NOT TRASH" so visitors do not toss inappropriate materials in with the D.E. Note also that new bins often have a strong plastic smell, which can impart odors to the bagged D.E. and affect syrup taste. Use of a food grade bin is recommended (**Figure 8.6**).

Assembly procedures and recommended methods of operation can vary considerably among different pressure filter units. The following discussion is provided as a generic introduction to pressure filters, not as a step-by-step guide to their use. Consult the instructions from the filter manufacturer for proper operating methods.

Figure 8.6. Filter aid should be stored in a food-grade container with a lid so it remains dry and clean for use.

PLATE FILTER PRESS The major components of most plate filter presses include the filter press frame, end plates, filter plates, a pump, some form of power for the pump, and appropriate connecting hardware, including a pressure gauge. Filter plates are of two types, frame, or cake, plates and backer, or waffle, plates. In addition to these, the press has two end plates. The frame, or cake, plates look somewhat like picture frames, with an open area in the center where the diatomaceous earth cake is formed. The backer, or waffle, plates are solid-appearing plates that have a waffle surface texture. In an assembled press, the backer plates alternate with the cake plates, dividing the press into a series of filtering compartments. End plates sandwich the entire stack.

Plate presses come in several different sizes, ranging from small 5-inch presses for hobby producers made to filter 2–10 gallons to huge industrial-size presses capable of handling several hundreds of gallons of syrup at a time. In addition, presses may be short-bank or long-bank, signifying the relative number of plates in the press. By selecting the appropriately sized press or varying the number of plates in an assembly to match the anticipated syrup production rate, producers can manage filtering more efficiently. Restriction (solid) plates can also be inserted into the stack of plates to vary the number of plates through which filtering occurs.

A variety of pumps are used with plate-type filter presses. Pressure filters typically use electric, air compressor, or hand-operated pumps to move the syrup through the apparatus.

The cake of D.E. (**Figure 8.7**) that is formed in the center of each of the cake plates and the filter paper placed between each plate in the "stack" accomplish the filtering process in a plate-type press. The filter paper acts primarily as a barrier against D.E. particles, which gradually build up there during the filtering process, forming the "cake." It is important to recognize that the initial layer of the cake often deposited as part of a press charging process continues to thicken as more syrup is filtered.

The plate-type filter press (**Figure 8.8**) operates as follows:

- Hot syrup containing D.E. is pumped into the press.
- Syrup flows into a D.E. cake through holes in the sides of the frame plates.
- Syrup then flows through the cakes of D.E. while suspended solids and D.E. are retained by the filter paper, gradually increasing the thickness of the filter cakes.

Figure 8.7. Cake of D.E., sugar sand, and syrup in a filter press after use. Inspection of the cake thickness in relation to the plate cavity will inform the producer of how much filtering capacity has been used in the filtering run.

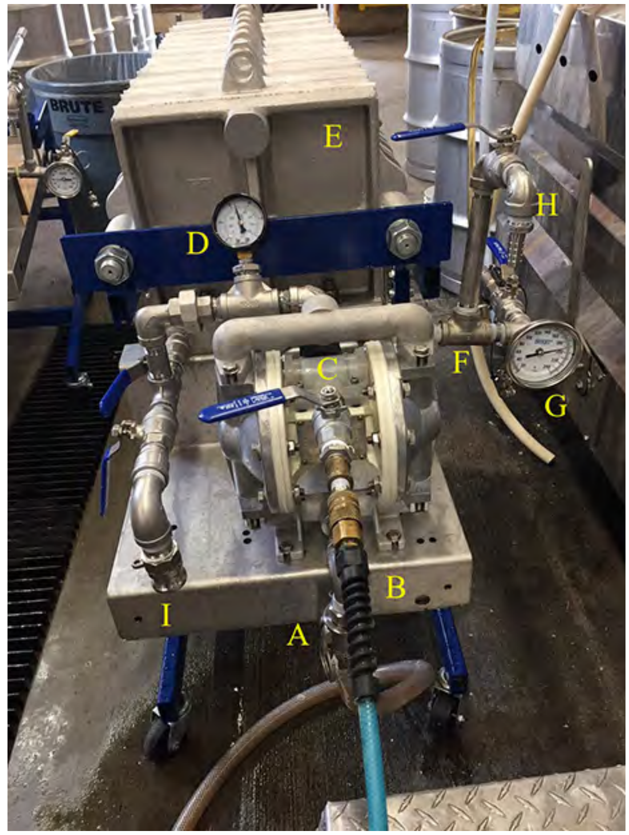


Figure 8.8. A plate filter press assembled and ready to filter syrup. This press is equipped with an air-powered diaphragm pump. Components include: unfiltered syrup inlet (a), air inlet (b), diaphragm pump (c), pressure gauge (d), plate press and papers (e), filtered syrup outlet (f), temperature gauge (g), filtered syrup sample port (h), and press bypass port (i).

- Syrup then flows along the waffled surfaces of the adjacent backer plates.
- Syrup exits the compartments and the press through holes in the side of the backer plates and flows into a storage container or is recirculated back into the original feed vessel.

Prior to filtering, hot syrup is typically mixed with D.E. before being pumped through the filter press. The amount of D.E. required depends on a variety of factors. These include the size of the filter press (number and size of plates), the amount of syrup to be filtered, and the quantity of solids to be removed. For example, 1 cup of D.E. for every 5 gallons (4.2 Imp. gal) of syrup to be filtered is a common recommendation for "average" quality syrup to be filtered in a standard 10-inch plate-type press. Fifty gallons (42 Imp. gal) of syrup would, therefore, require 10 cups of D.E.

While some recommendations suggest mixing the required amount of D.E. with the entire batch of syrup to be filtered, more commonly producers will "charge" the filter press with half the D.E. before actual filtering to produce superior results. To charge the filter press, mix half of the required D.E. with 3–5 gallons (2.5–4.2 Imp. Gal, 14–23 liters) of hot syrup in a stainless container. Hot water is sometimes used successfully to charge a filter press with D.E., but producers using this procedure must monitor the extent to which the water dilutes the filtered syrup to avoid ending up with a batch of syrup below legal density. Pump this mixture through the filter press and collect the output in a second stainless container. This process deposits an initial layer of D.E. on the filter paper within each compartment of the press, creating the initial filter aid cake. As the last of this syrup and D.E. charging mixture exits the filter press, check the output for clarity. If cloudy, the charging mixture should be circulated through the filter press repeatedly until it runs clear. When the syrup is clear of all suspended solids, the mixture of syrup and D.E. can be added to the remainder of syrup to be filtered. The remaining required amount of filter aid can then be added, and the entire batch filtered through the press.

As an alternative to filtering in batches, syrup can be filtered continuously during processing. With this method D.E. is mixed with the syrup in the draw-off tank, recirculated until the filter aid cake develops and the syrup runs clear; then the output is routed to the appropriate storage container. By altering the speed of the pumping, the speed at which syrup is drawn off can be matched to the filtering speed to keep the press hot. D.E. is periodically added to the draw-off tank as additional syrup is made to allow the cake to continue to form. After some time, the plate cavities will be completely filled with D.E. and niter, pressure will build, and the press will need to be broken down and cleaned. Hot potable water can be run through the press to reclaim any syrup before the unit is disassembled.

Figure 8.9. Inner and outer sleeves of a canister pressure filter showing filter cloth wrapped around inner canister. Lid and hoses are not shown.

Canister pressure filters The major components of a canister pressure filter include a stainless-steel outer canister, a smaller stainless-steel inner canister with perforated walls, a pump/motor, and the appropriate connecting hardware and pressure gauge (**Figures 8.5** bottom). When the canister filter is assembled, a reusable cloth filter is placed around the inner canister (**Figure 8.9**), which provides the support for the cloth filter and the diatomaceous earth cake. A prefilter is sometimes used to augment the filter cloth. As with the plate filter press, the canister press should be "charged" with about half of the required filter aid. Hot syrup containing filter aid is pumped into the outer canister. It then passes through the diatomaceous earth cake forming on the outer surface of the cloth filter, through the cloth filter and into the inner canister through the perforations in the wall, and out of the filter through an outlet in the top of the inner canister. While some producers filter small batches of syrup through a canister pressure filter without using filter aid, the success of this approach depends solely on the effectiveness of the filter cloth as a filtration medium.

Using Pressure Filters

- Obtain a complete set of instructions on the assembly and use of the specific model. All components should be food grade and rated for use with hot (>180°F, 82°C) liquids.

- Thoroughly clean all parts with hot water before use each season. Assemble, disassemble, and clean the filter and hoses according to manufacturer's recommendations. Be sure none of the plates are reversed (a common mistake that will result in passage of D.E. and niter).
- Filter the syrup hot—recommendations on the optimal temperature for the syrup range from 180°F (82°C) to 200°F (93°C). Keeping the filter press itself hot will also aid in filtering syrup. A thermometer placed in line will help to ensure syrup is packed at a high enough temperature to prevent spoilage.
- Have a bypass (pressure relief) line and valve located between the pump and the press that can be used to divert some of the syrup back to the feed tank before it enters the filter. If the pressure in the system is approaching the pressure limit with a small amount of syrup remaining to be filtered, some of the syrup coming from the pump can be diverted back to the tank of unfiltered syrup. This slows the filtering rate and reduces the pressure, thereby allowing a small amount of additional syrup to be filtered before shutdown is necessary. The bypass valve can also be used to slowly warm a press that has cooled.
- Operate the filter press only within the recommended pressure range for safety and efficiency. Most pressure filters begin filtering at pressures below 20 psi (depending on the pump), and filtering should be discontinued when the pressure approaches 50 psi (consult manufacturer's instructions). At higher pressures, filters become too clogged to function safely and effectively and should be cleaned and recharged. Be prepared to stop the pump quickly if a filter paper breaks to avoid passing D.E. and niter into filtered syrup.
- Use only food-grade diatomaceous earth filter aid as recommended by the manufacturer. Non–food-grade D.E., such as that used for swimming pools, contains contaminants that will render syrup unfit for consumption.
- Avoid carrying over large amounts of D.E. from year to year to reduce the risk of introducing mold contamination during filtering. Check any leftover D.E. carefully before use.

The quality of the syrup and amount of suspended sediment will determine the amount of syrup that can be filtered before it is necessary to clean the filter, and some batches of syrup will be more difficult to filter than other. Generally, the more suspended sediment in the syrup, the smaller the quantity that can be filtered per charge. Producers report filtering as much as 100 gallons of syrup low in suspended solids to as little as 10–15 gallons of syrup that is high in suspended solids. For a 7- or 10-inch plate filter press or 12-inch canister filter press, filtering 50–60 gallons (42–50 Imp. gal.) of syrup per charge is a reasonable expectation. Careful attention to the pressure gauge will help avoid dangerous situations.

One common misconception is that it is the diatomaceous earth that causes the pressure to build in a pressure filter system. Actually, it is the solids suspended in the syrup plugging the minute holes formed by the D.E. that cause the pressure buildup. As more filter aid is added, more pore space for filtering is created. Therefore, while the natural tendency is to reduce the amount of filter aid used when filtering gets difficult, the opposite approach (adding more D.E.) will usually do the most good. When filtering is hard, *increasing* the amount of filter aid typically yields improved results.

Toward the end of the season there may be syrup that becomes nearly impossible to filter. This syrup may begin to plug the filter almost immediately. Using additional D.E. and/or relieving pressure by diverting some of the syrup through a partially open bypass value can help filter this syrup. However, especially near season end, there may be batches of syrup that simply will not filter. This is particularly the case if syrup is ropy. Producers should use this development as a signal that the season has come to an end.

A brochure and video outlining good practices in using a plate pressure filter press, are available online.[4]

Canister Vacuum Filters

Vacuum filters are another filtering tool available to maple syrup producers (**Figure 8.10**). The systems work by pulling (rather than pushing) unfiltered syrup through a filtration medium. Parts are relatively simple and quick to assemble and clean, and the devices are suitable for filtering moderately small quantities of syrup. Some potential drawbacks of these systems include reduced filtering capacity compared to plate filter presses and the additional requirement of a vacuum pump capable of providing adequate suction without exposing syrup to poor-quality air. These systems are relatively new to the maple industry, so information on their use and capabilities and their application to various syrup types is currently limited.

Figure 8.10. A canister vacuum filter. A filter and prefilter are placed on the screen in the top section, unfiltered syrup is added, and a vacuum applied to the lower section, drawing syrup through the filter.

Sedimentation

This process is a relatively simple way of removing suspended solids from syrup but has several disadvantages and has largely been consigned to the past, although it is still a valid approach for small operations. The process involves allowing a batch of unfiltered syrup to sit, providing time for the suspended particles to sink by gravity. The syrup must then be decanted without disturbing the sediment collected on the bottom. Some producers have created special containers with a valve positioned a few inches above the bottom for this purpose. One major disadvantage of this approach to filtration is that to be effective, it needs to extend across several days to a week or more. This requirement makes filtering during the season difficult as more syrup may be produced before the last batch is ready for canning. The increased contact time between syrup and sugar sand has the potential to impart undesired flavors. This method of removing solids will also likely result in elevated levels of lead in the syrup if there is any lead-containing equipment used in sap collection, storage, or processing. Additionally, some fine particles may remain suspended, which could detract from the syrup's perceived quality.

Centrifugation

Experimental use of centrifuges to remove sediment from syrup has met with some success, but commercial systems for maple are not yet available. In essence, syrup is spun rapidly in a filter device to provide additional force to pull syrup through the filter. Very large devices of this kind are used in the cane and beet sugar industries to separate sugar crystals from the liquid they're suspended in.

[4] Isselhardt, M., S. Williams, B. Stowe, and T. Perkins. 2005. Proper Plate Filter Press Operation. University of Vermont Misc. Brochure 5 pp. https://mapleresearch.org/pub/filterpressop/
Isselhardt, M. 2020. Filtering Maple Syrup. Syrup Production Video. https://mapleresearch.org/pub/4221fil1/

Post-filtration Contamination

Foreign objects in syrup can negatively affect syrup clarity and purity. Special precautions should be taken to keep barrels and other packing containers clean and free of contaminants, both before and after syrup is packaged. Hair, broken glass, insects, paper particles, mold, rodent droppings, and animal nests are all potential contaminants of syrup after filtration. To avoid these contaminants, attention must be paid to proper sealing and storage of packing containers and to their inspection prior to use. The risks that contaminated syrup pose to consumers range from an extremely unappetizing product experience to a serious health hazard. Given the possibility of these outcomes, selling contaminated syrup is detrimental to the reputation of both the individual maple producer's business and to the maple syrup industry as a whole.

SYRUP DENSITY

To maintain product quality during storage, it is absolutely essential that maple syrup meet the legal density standards. Syrup with a density of less than 66.0°Brix is at an increased risk of microbial growth and spoilage (**Figure 8.11**). Syrup with a density greater than 68.9°Brix will likely form sugar crystals (**Figure 8.12**) when stored at room temperature for extended periods.

The character and quality of maple syrup are also strongly affected by its density. Viscosity (the measure of a fluid's resistance to flow, its apparent thickness) is an important characteristic of pure maple syrup. Below 30°Brix, sap sugar content has relatively little effect on viscosity. As the sugar concentration increases toward standard density syrup, the increase in viscosity, and the effects of sugar content on viscosity, become pronounced. Maple syrup with a density of only 0.5°–1.0°Brix below standard density syrup feels and tastes "thin" or "watery." Conversely, an increase of only 1.0°Brix above standard density causes the syrup to acquire a thicker or richer feel on the tongue and a noticeable perception of increased sweetness. For this reason, some producers will finish their syrup at a density slightly above the minimum required. Customers can tell the difference between 66° and 67°Brix (but may not know why) and generally will prefer the taste and mouthfeel of the heavier syrup.

Contrary to the relatively common consumer belief that darker syrups are "thicker," syrup color does not affect density.

Figure 8.11. Mold floating on the top of maple syrup. Syrup with mold should be discarded.

Figure 8.12. Sucrose crystals that have formed in overdense maple syrup.

Syrup Density Scales—Brix and Baume

The Brix scale is the most commonly used measure of density in the maple industry. It is a measure of the percentage of sucrose by weight in relation to a pure sucrose solution. Since maple sap and syrup do contain trace amounts of minerals and other (non-sucrose) sugars, there is always a small degree of error inherent in these measurements, but it is generally negligible and is therefore discounted. For practical purposes, the Brix scale works well to express the percentage of sugar in maple syrup. When using the Brix scale, density is expressed as "degrees Brix" and is most often written as "°Brix."

The Baume scale is less widely known and employed than the Brix scale, but it is firmly entrencheO in some geographic areas and some maple producers use it exclusively. The Baume scale relates the density of a liquid to that of a pure salt solution. It does not directly express the solids content of maple syrup and therefore does not have the same utility for determining syrup sugar concentrations. Comparisons between the Brix and Baume scales are presented in **Table 8.2**. This table may be used to convert between the two scales. As an example, 66.0°Brix is equivalent to 35.6°Baume.

TABLE 8.2 Density corrections commonly used for Brix and Baume readings for hydrometers calibrated for 60° F. Add values preceded by a "+", subtract values preceded by a "-".

Temperature at Which Density Is Measured	Brix Adjustment[1] (+ or –)	Baume Adjustment[2] (+ or –)
209+	+8.0	+4.00
202+	+7.5	+3.75
193+	+7.0	+3.50
185	+6.5	+3.25
176	+6.0	+3.00
167	+5.5	+2.75
158	+5.0	+2.50
149	+4.5	+2.25
140	+4.0	+2.00
130	+3.5	+1.75
120	+3.0	+1.50
110	+2.5	+1.25
100	+2.0	+1.0
90	+1.5	+0.75
80	+1.0	+0.5
70	+0.5	+0.25
60	0.0	0.0
50	–0.5	–0.25
40	–1.0	–0.5

[1] Brix adjustments calculated at 0.05°Brix for each 1°F.

[2] Baume adjustments calculated at 0.025°Baume for each 1°F. The Jones Rule of 86 indicates the actual adjustment should be 0.0265°Baume for each 1°F, but that level of precision exceeds that achievable with commonly used hydrometers.

Measuring Syrup Density

Syrup density is most commonly determined by using either a refractometer or a hydrometer. Hydrotherms, instruments that have elements of both thermometers and hydrometers, are also used by some producers.

USING A HYDROMETER For the majority of producers, the hydrometer (**Figure 8.13**) is the instrument of choice for determining syrup density. Hydrometers are specially constructed glass tubes that contain a weighted bottom and a calibrated scale (Brix or Baume) and are generally fairly inexpensive. Hydrometers are floated in syrup to measure density. The hydrometer is read at the level where syrup intersects the hydrometer's scale, not where the meniscus climbs the hydrometer stem. A hydrometer will float higher in dense syrup and lower in thin syrup.

Hydrometers are well adapted for use in the sugarhouse as they can be used to measure the density of syrup across a wide temperature range from near freezing to near boiling. However, the depth at which a hydrometer floats in syrup depends on the syrup's density and temperature, and hydrometers are calibrated for use in syrup at a specified temperature. Most hydrometers commonly used in the maple industry are calibrated at 60°F (15.6°C).

Figure 8.13. Maple syrup hydrometer floating in a hydrometer cup.

When the hydrometer is placed in syrup at the calibration temperature, the hydrometer reads the correct density. At all other temperatures the hydrometer reading must be corrected. For this reason, the temperature of the syrup must be measured immediately before reading the hydrometer. Most hydrometers used in the maple industry are marked with two prominent lines; one labeled "Cold Test 60°F" and one labeled "Hot Test 211°F." These two lines are placed on the scale paper to make it easier to identify the depth at which the hydrometer should float in syrup with a density of 66.9°Brix (36°Baume) when the syrup is at 60°F and near boiling at 211°F. **Table 8.2** presents the density corrections required for various temperatures for hydrometers calibrated for 60°F. For example, when using a hydrometer calibrated for 60°F, if the hydrometer scale reads 65.8°Brix and the syrup temperature is 80°F (26.7°C), you would apply a +1.0 adjustment to the measurement to determine the actual density of the syrup, 66.8°Brix.

Producers should note that most maple hydrometers are calibrated to produce syrup at 66.9°Brix. While this fits within the range of syrup density, going slightly dense can inadvertently push syrup beyond the regulatory limit of some jurisdictions. Furthermore, producing over-dense syrup means giving away valuable sugar during retail or bulk sales. A slight downward adjustment below the red line is more favorable to producers in that regard, as long as syrup remains within the density limits governing the sale of syrup in the given area.

Before using a hydrometer, closely examine it and identify the positions of each line. The gradations of the scale on most maple syrup hydrometers represents roughly 0.5°Brix (0.25°Baume). Be sure to measure from the same part of the red line consistently. If 66.9°Brix (36°Baume) is the desired finish point, the lines can provide a precise guide. However, if some other density is desired, the lines may be less useful. When this is the case, the density of the syrup is read and corrected for temperature, and the "Hot Test" density is determined by subtracting 8°Brix (4°Baume) from the desired density.

Hydrometers should be stored in a vertical position (standing up) to prevent the bottom weight from drifting to one side, which could result in inaccurate readings. If the hydrometer is stored in its original box, mark the position of the top of the scale paper on the inside bottom or side of the box to use as a reference. If the paper slips or is not aligned with this marking, discard that hydrometer.

Hydrometers can become inaccurate for a variety of reasons, including small chips in the glass, movement of the paper scale, and accumulation of niter on the instrument's surface. Occasionally they can be inaccurate from the time of manufacture. Vermont law requires all hydrometers used in the state for maple syrup be tested, approved, and so marked by the Vermont Agency of Agriculture, Food & Markets (VAAFM). Hydrometers that have undergone this testing are sold by many maple equipment dealers and can be identified by a temporary stamp on the outside that will disappear the first time the hydrometer is submerged in liquid. Purchasing a hydrometer tested by VAAFM is one way to increase the likelihood of hydrometer accuracy. Further, the accuracy of all hydrometers should be checked annually. This service is provided by many state/provincial Extension or Agency of Agriculture programs. In addition, having at least three hydrometers is recommended—this not only provides insurance in case of breakage, but allows the readings of each to be compared to detect if one has become inaccurate.

When using a hydrometer, consider the following suggestions:

- Make sure the hydrometer is clean and dry.
- Use a hydrometer cup nearly as long or longer than the hydrometer and at least one and a half times as wide.
- Fill and empty the hydrometer cup several times with syrup to warm the cup.
- Fill the cup to the top; then pour out a small amount of syrup to get rid of foam or bubbles that can interfere with the measurement.
- Lower the hydrometer slowly into syrup. Dropping the hydrometer into the cup can leave extra syrup clinging to the stem, thus causing the reading to be inaccurate. It can also result in a broken hydrometer if the syrup is very thin and the hydrometer hits the bottom of the cup.
- Do not pour syrup over the hydrometer into the hydrometer cup. Doing so can cause syrup to stick to the upper part of the stem, resulting in inaccurate readings.
- Read the density as soon as the hydrometer is stable.
- Determine the temperature of the syrup immediately before reading the hydrometer. The temperature of the syrup can most conveniently be read with a small digital or dial thermometer. Some hydrometer cups have a thermometer built into the base.
- If the syrup temperature is other than the calibration temperature, correct the density reading using **Table 8.2**.
- It should be noted that hydrometer readings of hot syrup, particularly above 180°F (82°C), are relatively inaccurate. The effects of temperature on hydrometer readings are much greater at higher temperatures, and above 180°F (82°C) the temperature of syrup is changing rapidly. In addition, temperature corrections for hydrometer readings 180°F (82°C) are extrapolated rather than experimentally determined. Because of this, it is optimal to confirm hydrometer density measurements made with hot syrup after the syrup has cooled to room temperature. The closer to the calibration temperature of the hydrometer, the more accurate readings will be.

Common sources of error when using a hydrometer include the following:

- Failing to correctly adjust for temperature.
- Using a damaged hydrometer. Any chip or crack in the glass will impact accuracy.
- Failure to clean a hydrometer after each use can result in a coating of niter on the hydrometer. This coating adds weight, which pulls the hydrometer down and results in the production of over-dense syrup. Clean the hydrometer with warm water after each use. If a hydrometer becomes coated with sugar sand, it must be cleaned. First try soaking in warm water (permeate works well). If needed, a mild acid such as vinegar could be used. Avoid scratching the glass—only mildly abrasive materials should be used. If the hydrometer cannot be cleaned, it should be discarded.
- Allowing the hydrometer stem to sink too far into syrup, picking up syrup on the surface of the stem. This coating of syrup will increase the weight of the hydrometer, producing inaccurate readings.
- Resting of the hydrometer on the side of the hydrometer cup or other container such that it does not float freely in the syrup.
- Reading the hydrometer scale at the wrong point (at the meniscus instead of the syrup level).

Invented and sold by Smokey Lake Maple Products (Wisconsin), the Murphy Cup™ and the Murphy Float™ (**Figure 8.14**) are two versions of a relatively new tool that assists with hydrometer use. The Murphy Cup essentially consists of a hydrometer cup with a specialized thermometer built into it. The scale on the thermometer dial is presented in Brix units and already incorporates the correction of

FIGURE 8.14. The Smokey Lake Maple Products Murphy Cup™ or Murphy Float™ has a built-in indication of the necessary correction of syrup density. These tools are used in conjunction with a hydrometer. In this example, the hydrometer should read 62.3°Brix for the syrup to be at the correct density.

Brix for temperature. The device doesn't actually read the sugar content, rather it indicates the Brix reading that the hydrometer floating in the cup should be at for syrup at that temperature (for 66.9°Brix syrup); essentially, it has a built-in calibration to tell the user the proper hydrometer reading at the temperature of the syrup. If the Brix reading of the Murphy Cup dial matches that of the hydrometer, the syrup is the correct density. If the hydrometer reading exceeds the value on the Murphy Cup thermometer, the syrup is too dense. If it reads lower, the syrup is too thin. There is no need to consult a calibration chart, and the device is suitable for syrup at any temperature. The Murphy Float is based on the same concept, but the device's calibrated thermometer is located inside a stainless housing that can be floated in syrup in a draw-off tank.

USING A REFRACTOMETER Refractometers (**Figure 8.15**) are instruments that measure the degree to which light is bent (refracted) by dissolved solids passing through a liquid. The amount of bending is proportional to the concentration of dissolved solids, in this case, sugar. The more sugar in the solution the greater light is bent. Maple producers can use refractometers to estimate density using the Brix scale since 98 percent or more of the dissolved solids in maple sap and syrup are sucrose.

(a)

(b)

FIGURE 8.15. Optical (a) and digital (b) refractometers can be used to measure sap, concentrate, permeate, or syrup sugar content. Some refractometers incorporate automatic temperature compensation (ATC), others do not.

Temperature affects the relationship between dissolved solids and light refraction, so as with hydrometers, refractometer readings must also be adjusted for temperature. Some optical and most digital refractometers have automatic temperature compensation. Note however that many older refractometers do not automatically compensate for temperature; thus readings must be corrected if the syrup's temperature differs from the instrument's calibrated temperature. Note that, as with hydrometers, the effects of temperature on refractometer readings are much greater at higher temperatures.

For this reason, refractometer readings are most accurate when the temperature of the syrup being measured is close to room temperature (68°F/20°C), and, ideally, measurements made with hot syrup should be confirmed after syrup has cooled.

Two distinct types of handheld refractometers are used in maple production, optical and digital. Optical refractometers require the user to place a sample of liquid on the flat glass plate of the device and read the Brix value of the solution through an eyepiece. The value is indicated by a dark shadow line appearing against a calibrated background scale. If the light source is poor, the shadow line will appear blurry, making precise measurements difficult. The second type of refractometer commonly used by maple producers is the digital refractometer. These devices work on the same principal but provide their own light source and sensor and have a digital display. A few drops of liquid are put in the sample well, the cover (if included) closed, and a button pressed to initiate the measurement. The result is displayed on a digital display. Handheld digital refractometers are reasonably precise instruments; accuracy and readability of those commonly used in the maple industry are approximately 0.2°Brix when used properly. They are easy to use, require only a few drops of sap or syrup to get a measurement, and results are very fast. They are moderately expensive, with cost depending on construction and features such as automatic temperature compensation and sample covers.

Refractometers must be calibrated to a zero point relatively frequently to ensure accurate readings (daily or more often depending on the model and usage conditions). This can be easily done with distilled water. (Permeate can be used but is less than optimal, as it can contain minute quantities of sugar). Calibration is accomplished electronically or via a small set screw depending upon on the device. The accuracy of syrup refractometers can be checked using a calibration fluid of a known density.

A primary limitation of refractometers is that the handheld instruments currently on the market are not capable of measuring the density of hot syrup (>180°F/82°C), for several reasons. First, liquids near the temperature of boiling syrup may permanently damage the glass of the sample well or plate. Second, temperature correction factors for the refractive index of sucrose do not exist for temperatures above 180°F (82°C), so refractometers do not correct readings above this temperature. Finally, because hot syrup cools rapidly and the effects of temperature on refractometer readings are very significant at higher temperatures, the accuracy of the measurement is greatly affected. Waiting 30 seconds to a minute will allow the syrup and instrument to become isothermal and a reading to be taken. However, evaporation of water from the hot syrup in the sample well will continue during the time you wait, meaning that you may have a measurement, but it no longer represents the density of the syrup as it came off the evaporator. A sample cover can mitigate, but doesn't eliminate, this problem. It is important to understand that significant changes to sample density can occur when hot syrup sample is left (covered or uncovered) on the surface of refractometer.

USING A HYDROTHERM A hydrotherm (**Figure 8.16**) is a special hydrometer that has a liquid thermometer built into it to automatically locate the point on the hydrometer (the top of the thermometer liquid column) for measuring standard-density syrup. They are used in conjunction with a hydrometer, with the advantage being that hydrotherm self-adjusts for the temperature of the syrup. However, there are a few disadvantages to using a hydrotherm. First, the top of the liquid column of many commonly available hydrotherms is calibrated

FIGURE 8.16. A hydrotherm (on left) and a hydrometer (on right)

to 65.8°Brix rather than 66.0° or 66.9°Brix. This means that the hydrotherm cannot be directly read and an adjustment must be made to avoid the risk of producing substandard syrup based on an over-estimation of its density. Also, hydrotherms require at least 2 minutes to equilibrate to the temperature of the syrup, making them slightly less suited than hydrometers to the rapid density measurements re-quired during syrup production. Finally, the hydrotherms marketed for maple production are not checked by a certified state agency and cannot be easily calibrated or checked for accuracy. If a hydrotherm is used, it is recommended to confirm density measurements with a hydrometer or refractometer.

Adjusting Syrup Density

Occasionally syrup is produced that is not within the desired density range. If the syrup density is too low, it can be reprocessed (boiled further) to a higher density or blended with another syrup with a higher Brix level to increase density. If the density is too high, syrup can be blended with potable water or lower-density syrup to reduce the density.[5] The challenge is to determine how much water to blend with the high-density syrup.

Guessing the amount of water to blend with syrup can be a frustrating experience and one that often ends in error. A general rule of thumb is to add about 0.5 fluid ounces of potable water per gallon for each 1°Brix the syrup is too thick. Be sure to mix thoroughly between each successive measurement and addition of water. Note that is far easier to add water slowly to allow the density to slowly creep down to the proper level than to have to boil off more water to increase syrup density. A more precise alternative is to calculate the proportions of syrup and water needed to achieve a desired density using the Pearson's Square technique. The mathematical formula and online calculators are available to make this process very simple.[6]

Producers desiring to lower the density of syrup with water may find **Table 8.3** useful. This table provides the quantity of water that should be added to a gallon of syrup to lower its density by a desired amount. For example, suppose a producer had 1 gallon of 68.5°Brix syrup and wished to lower its density by 1.5°Brix to 67.0°Brix using water. Using **Table 8.3**, locate the row labeled "water" in the left-hand column and follow that row across to 1.5°Brix, the desired reduction in density. According to the table, 3.8 fluid ounces of water are required to reduce 1 gallon of 68.5°Brix syrup to 67.0°Brix.

Whenever syrup is blended, the resulting blend should be thoroughly mixed and reheated to the appropriate temperature prior to packing. The blending process can take a surprisingly long time but is critical to prevent separation in storage. Reheating will reduce the viscosity of the syrup, making it easier to complete the blending process. Keep in mind that excessive or prolonged heating can result in additional production of sugar sand and raise the density as more water is evaporated, so always double-check the density and clarity of syrup before packing.

Several maple equipment manufacturing companies offer mixing tanks (homogenization tanks, Brix equalizer tanks, calibration tank) that automate the process of adjusting and blending syrup within a very narrow density range. Syrup is drawn off (typically slightly over-dense) into the tank and density is measured with an inline refractometer. Water can be added manually or automatically, and the syrup recirculates within the tank to homogenize it. When finished, syrup is homogenized at the

[5] If the syrup is not being boiled after blending, only potable water (water from a known clean and drinkable source or water that has been boiled) should be used for blending. Sap or concentrate contains live microorganisms, which when added to finished syrup (and not brought to a boil) can lead to accelerated spoilage. Hot (boiling) sap or concentrate can be safely used.

[6] Heiligmann, R. 2003. Blending off-density syrup with other syrup to adjust the density—determining how much I need. *Maple Syrup Digest.* June. pp. 20–22. https://mapleresearch.org/pub/m0603blendingsyruppart1/

Heiligmann, R. 2003. Blending heavy syrup with water or sap to lower its density—determining how much I need. *Maple Syrup Digest.* Oct.. pp. 12–15. https://mapleresearch.org/pub/m1003blendingsyruppart2/

Cornell University Maple Program. Cornell Maple Calculators—Calculators and Other Tools. https://mapleresearch.org/pub/4221cor/

TABLE 8.3 The volume of water that should be added to 1 gallon of syrup to lower its density a desired amount.

	Density Reduction of Syrup Desired (°Brix)							
	0.5°	1°	1.5°	2°	2.5°	3°	3.5°	4°
	Fluid Ounces of Water to Add per Gallon of Syrup to Reduce Density							
0° (Water)	1.26	2.52	3.80	5.08	6.38	7.68	8.99	10.32

preset density and temperature ready for canning or packing into barrels. This automated process can greatly reduce the amount of time and effort required in a busy, high-throughput sugarhouse to produce syrup of the correct density. It is used most frequently in high-volume production operations where maintaining tight control over syrup density has significant economic consequences and going back to reprocess syrup to the proper density is not feasible.

FLAVOR GRADING

Well-presented and packaged syrup may be pleasing to the eye, but it is the flavor of maple that is the most unique and important characteristic a sugarmaker has to sell. Although flavor is the least quantitative characteristic associated with maple grades, there is an expected range of flavors producers and consumers associate with specific maple syrup classes, with darker syrups generally having stronger flavor, and lighter syrups more delicate flavor. Current flavor-grading standards for Grade A syrup specify "good flavor and odor and intensity of flavor (maple taste) normally associated with the color class" and "free of off flavors and odors."

Maple Flavors

The characteristic tastes of the four classes are further described as follows:

- Delicate—mild maple taste
- Rich—a full-bodied maple taste of medium intensity
- Robust—stronger maple taste than that associated with the lighter colors
- Strong—maple taste that is stronger than robust

For grading purposes flavor is evaluated by taste and odor, but the sense of sight is also important to use in the process. Does the sample look clear? Is there any hint of mold or foam that could indicate musty or fermented syrup? Smelling before tasting is also important, as it ensures that the sweetness does not overpower the subtle flavors and aroma of the syrup. Is there anything different or strange to the smell of the sample? The smell of the sample can be a powerful indicator of quality. The final sense to use is taste. When tasting the sample, avoid swallowing it too quickly. Let the sample come in contact with as many taste buds as possible and note the aroma. Allowing syrup to coat the entire mouth will provide the most complete sensory experience. Tasting syrup is not just for analyzing flavor but is an opportunity to identify any mouthfeel defects: oily or waxy (defoamer), sizzle (niter), watering of the tongue (chlorine, salty), or unusual textures (ropy). Be aware of any aftertaste present. Bear in mind that every individual's perception of flavor is different. Some individuals are unable to detect certain off-flavors, and over time, producers can lose some objectivity when grading their own syrup. It can be helpful to get a second opinion when evaluating the flavor your own product. The senses of taste and smell also change with age—children often find almost all syrup tastes good (sweet), and the ability to taste and smell gradually decreases with age.

The sugarhouse is often not the best place to grade maple syrup flavor given that producers are often fatigued and saturated with maple smells. Good practice is to take two (or more) sample jars of syrup when packing each barrel and to taste each batch before selling or canning to avoid surprises. Off-flavors are sometimes not easily detected immediately but can deepen in intensity during storage.

Entering Syrup in a Maple Contest

Entering product in a maple contest is an easy way to get feedback on the quality of your product. Make sure to read the contest rules carefully to ensure your entries are submitted in the right size and correct class. One mistake many first-time contestants make is failing to grade the syrup themselves right before entering. It is typically not necessary to enter hot packed syrup; however, the syrup that is entered must meet the standards for the class in which the producer is competing. Entering syrup in the wrong class has often led to judges rejecting otherwise excellent syrup. Entering syrup in reused containers (especially poorly cleaned canning jars) is a frequent cause of off-flavor rejection.

Keep these syrup samples frozen or refrigerated to avoid spoilage.

Several tools, including the "Flavor Wheel for Maple Products,"[7] and the "Map of Maple,"[8] are available online to help producers learn more about tasting, evaluating, and describing the flavors of maple syrup.

Off-Flavors

From time to time, off-flavors can occur in maple syrup (**Table 8.4**). Off-flavored syrup that is allowed to reach consumers can injure the reputation of the maple syrup industry in general. It can also result in reduced value of your product from bulk buyers. Being able to identify the causes of off-flavors and addressing those causes to prevent or mitigate problems will improve the quality of your syrup.

Off-flavors can be divided into two broad categories: those that occur naturally (also known as "mother nature off-flavors") and those created through mistakes in production, either by materials the sap or syrup may come in contact with (non-food-grade plastics for example) or in how the sap/syrup was handled during processing or storage. This second group are termed "processing off-flavors." Quite frequently there can be combinations of multiple off-flavors that occur, making a positive diagnosis of the source more complicated. Off-flavors range greatly in intensity as well. Just as not every consumer can detect differences in syrup grades, not all producers are able to detect off-flavors equally. If an off-flavor is detected but isn't immediately identifiable, a producer should work backwards to narrow down the potential cause of the defect.

A good way to improve the ability to evaluate syrup flavor is to taste a variety of syrup from many producers. If a given batch of syrup is suspect in

[7] Centre Acer, Saint-Norbert-d'Arthabaska, Quebec https://agriculture.canada.ca/en/news-agriculture-and-agri-food-canada/scientific-achievements-agriculture/maple-syrup-flavour-research#b

[8] University of Vermont Department of Food & Nutrition and the Vermont Agency of Agriculture, Food & Markets https://www.uvm.edu/sites/default/files/Map-of-Maple.pdf

TABLE 8.4 Identifying and eliminating off-flavors in maple syrup.[1] Table grade maple syrup has a unique, subtle flavor which can easily be damaged or destroyed by a variety of undesirable or off-flavors. Some off-flavors, such as metabolism and buddy, are the result of natural processes over which a producer has little control. Most off-flavors, however, are the result of mistakes in collection, processing, or storage that can be avoided. The following table presents off-flavors commonly encountered in maple syrup, identifying characteristics of each off-flavor, common causes and solutions to eliminate each off-flavor. Regardless of the cause, syrup that fails to meet the standard for Grade A pure maple syrup does not belong in containers sold directly to consumers.

The descriptions listed in the second column, entitled "identifying characteristics", are at best, word descriptions of what the mouth and noise sense. Each person will sense these off-flavors somewhat differently, and words are often inaccurate in expressing how an individual perceives and senses a particular flavor. Producers should take every opportunity to taste syrups with known off-flavors in order to develop a sensory recognition of each off-flavor. Similarly, producers should taste "good" syrups from different sugarbushes and geographic regions to develop an appreciation for the range in flavor that exists for pure, high quality maple syrup.)

Undesirable Flavor	Identifying Characteristics	Cause	Solution
Buddy	Chocolaty (almost tootsie roll-like), to butterscotch, to strong bitter taste. Odor of chocolate sometimes present. More pronounced buddy off-flavor later in the season can exhibit cooked cabbage and sulfur notes. In Quebec, mild buddy off-flavor is typically referred to as "sève" ("sap"), while more pronounced buddy off-flavor is referred to as "bourgeon" ("buddy").	Common at the end of the season in sap from trees whose buds are swelling. May occur earlier if extended warm period experienced.	Once buddy off-flavor is detected, producers should evaluate the economic value of continuing to produce syrup. Buddy odor more readily detected in finished syrup or sap boiling in evaporator.
Burnt Niter	Bitter, strong caramel flavor, often biting and bordering on burned flavor. May produce fizzy effect on tongue.	Accumulation and burning of niter on bottom of the front pan, particularly in last partition.	Avoid niter accumulation in evaporator as discussed in Chapter 7.
Chemical	Flavor and smell of the chemical (e.g., soap, bleach) used. May have characteristics of chemical (e.g., bleach produces weeping sensation on the tongue).	Incomplete rinsing; improper chemical use. Improper placement of intake for air injection devices. Use of barrels or tanks for sap previously used for chemicals.	Effective rinsing; avoidance of improper chemicals.

[1] Adapted in part from Martel, B.A., H.J. Marckres, A. Dahlberg, M.L. Whalen, and M.F. Morselli. 1986. Maple quality control puts the accent on flavor. VT Dept. Agr., Montpelier, 2pp.

TABLE 8.4 (*cont'd.*)

Undesirable Flavor	Identifying Characteristics	Cause	Solution
Chlorine	Medicinal or bathroom cleaner smell, may be salty, cause weeping feeling on tongue. Degree of effect depends on chlorine concentration.	Usually caused by insufficient rinsing after using bleach sanitizer.	Effective rinsing.
Defoamer	Waxy or oily taste. If improper defoamer used (e.g., milk based or animal fat), may have rancid taste.	Use of excessive or improper defoamer.	Use as little defoamer as possible. Use defoamers designed for maple.
Detergent/Soap	Maple flavor often absent. Syrup tastes soapy or with perfume odor/flavor. Ingestion may cause nausea. Syrup may be sudsy if agitated.	Use of detergent/soap as a cleaning agent with incomplete rinsing (e.g., residual soap left in syrup bottles cleaned in a dishwasher).	Avoid use of detergents and soap whenever possible. When necessary, rinse appropriately.
Earthy	An earthy or rotten wood flavor.	Tapping into dark, stained, or decayed wood.	Avoid tapping into rotten wood.
Fermented	Sweet, fruity, and/or alcoholic flavor and odor. Syrup can have foamy appearance. Bulging container.	Conversion of sugars in syrup to alcohol by microorganisms, primarily yeasts.	Proper bottling/canning techniques, including cleaning/proper temperature. Prolonged storage in plastic drums, especially if opened for sampling or partial use.
Filters, New "Felt"	Slight chemical odor and/flavor.	Improper or no cleaning before use.	Boil filters in water and thoroughly dry.
Filters, Previously Used "Felt"	Detergent-like from improper cleaning, or moldy from improper handling/storage. Greasy or fatty.	Improper cleaning and/or storage. Excess defoamer use.	Clean with pure water and dry before storage. Do not store with moth balls.
Food	Syrup tastes like specific food.	Bottling in containers previously holding food; using unclean sap collecting container (plastic milk/juice bottles); storage of syrup in porous container near food material with strong odor.	Use new bottles/caps, adequately clean recycled bottles, adequately clean food-grade, non-maple sap collection or storage containers; proper storage of syrup.
Manure	Syrup smells or tastes of animals or manure.	Proximity to animal stalls. Improper air circulation or placement of intake of air injection devices.	Maintain separation of animal spaces from sap storage and syrup processing. Correct air injection intake placement.

TABLE 8.4 (*cont'd.*)

Undesirable Flavor	Identifying Characteristics	Cause	Solution
Metabolism	Sap and/or syrup may have disagreeable odor; syrup has an off-flavor ranging from slight (still palatable) to unacceptable. Metabolism odor/flavor is complex and has is described as woody or popcornish, sometimes peanut butter or cardboard, or with a chocolate odor.	A naturally occurring off-flavor that results from changes in the chemical composition of the sap, which develops under certain environmental conditions. Typically found in early-season, light-colored syrup.	Metabolism off-flavor may be reduced by dilution and reboiling. This helps to both lessen the compound causing the off-flavor and develop stronger flavors in the affected syrup.[2]
Metallic	Tinny flavor, sharp, tingly, often can feel on teeth. Flavor not detectable by everyone.	Prolonged storage in metal containers or storage in poor-quality containers.	Use high-quality storage containers.
Musty	Musty, light moldy, "dirty sock" odor and/or flavor.	Use of moldy filters or D.E.	Clean, store, and handle filters correctly. Keep D.E. stored in original packaging and in dry container.
Moldy	Stronger moldy odor and flavor.	Presence of mold resulting from bottling at low temperature, or improper storage after opening.	Follow proper bottling recommendations.
Paint	Syrup has an oily, fatty flavor and feel on the tongue, often similar to cod liver oil.	Use of paint on surface that sap comes into contact with, such as inside of sap buckets or holding tanks, to prolong their useable life.	Avoid using paint on surfaces of maple equipment that will come in contact with sap or syrup.
Plastic	Bittersweet flavor, or flavor resembling the way the plastic smells.	Use of nonfood grade plastic to collect, store, or transport sap or syrup; use of plastic not suitable for handling/storing hot syrup.	Use only food-grade plastic appropriate for specific application.
Ropy Syrup	Syrup appears viscous, pours with a stringy, wavy motion. When extreme, behaves like jelly or taffy, and may stretch out when pouring is stopped. Rubbery.	Results from sour sap being made into syrup. Due to bacterial action converting sugar in sap to polysaccharides.	Follow recommendations in Chapters 6 and 7 for quickly and collecting and processing sap in a sanitary manner.

[2] https://mapleresearch.org/pub/m1009metabolismoffflavorpart2/

TABLE 8.4 (*cont'd.*)

Undesirable Flavor	Identifying Characteristics	Cause	Solution
Sour	Sour flavor to syrup.	Results from acids in syrup formed by bacterial acting on sugars in syrup. Occurs at times in tubing systems during low flows at high temperatures or prolonged sap storage time.	Follow proper bottling to achieve temperatures necessary to kill microbes.
Soap	See Detergent/Soap.	See Detergent/Soap.	See Detergent/Soap.
Scorch	Burned flavor, strong bite.	Burning of syrup.	Raise liquid level in evaporator to prevent burning syrup. Ensure pans are level.

terms of flavor, consider asking several different people to taste and comment. Also, tasting syrup at the time it is produced is perhaps the least favorable time to detect off-flavors. Consider filtering and color grading syrup and applying an initial flavor grade but returning to the batch sometime after production has ended and when tasting can be more objective. Meetings with other producers and maple producer associations are great opportunities for tasting syrup and increasing your tasting and off-flavor detection skills. Off-flavor reference kits containing some examples of common off-flavors can also be purchased from maple equipment dealers and producer associations.

Avoiding Off-Flavor Syrup

- To ensure off-flavors don't go undetected, set aside two or more samples of each barrel and have a tasting session with more than one person after the season has finished to accurately compare between batches and plan how each batch will be marketed.
- Syrup is best graded for flavor at room temperature. Flavors, both good and bad, are more difficult to detect when syrup is hot or cold.
- New cloth filters have residue from the manufacturing process that can impart an off-flavor to syrup. Make sure to rinse new filters with lots of clean hot water.
- Use only the amount of defoamer needed to control foam while boiling. Using too much defoamer can result in an off-flavor or unpleasant mouthfeel. Buy new defoamer each season since old defoamer can impart a rancid off-flavor to syrup. Be judicious about how defoamer is added to the evaporator.
- Sap that has been stored for a prolonged time or in warm conditions or sap running slowly through mainlines in warm weather (as is often the case toward the end of the season) can produce "sour" off-flavor in syrup. Make sure to process sap as quickly as possible after gathering, and clean tanks and plumbing appropriately to avoid fermentation.
- Even the small amount of moisture that remains in the barrel from steam cleaning can grow mold over the summer and contaminate an entire batch of syrup with a musty off-flavor. Wash and inspect (look at and smell) barrels before filling.
- Plastic bung gaskets for barrels can provide an entry point for air and facilitate microbial growth when damaged. They can also harbor mold. Inspect these gaskets each time a barrel is opened or sealed and replace as needed.

- Some producers use cloth filter material to strain sap before processing. These filters are difficult to fully clean and can contaminate sap with microorganisms and other materials. If used, they should be thoroughly cleaned and replaced regularly to reduce negatively affecting syrup quality.
- If good-tasting syrup takes on a musty off-flavor after being run through the filter press, the problem could be with your diatomaceous earth (D.E.). If bags of D.E. are exposed to moisture while in storage they can become contaminated with mold. D.E. stored in damp conditions may not show any visual signs of damage but can impart a musty flavor to syrup when used with a filter press.
- Don't assume all debris (metal filings, tooling oil, grease) from manufacturing was removed from equipment before delivery. Wash and rinse *all* new pieces of equipment (evaporator, sap tanks, filter tanks, filter press, pumps, etc.) well before using.
- Follow cleaning instructions closely for pans, RO unit, and other evaporator components. Be sure to thoroughly rinse and completely remove all residues of cleaning products from all areas of the maple processing equipment that they may have contacted.
- Avoid using soaps or detergents as even tiny amounts of residue can impart an off-flavor to syrup.
- Do not "skim and reheat" moldy syrup. Fungi are made up of more than just the visible material floating on the surface. Moldy syrup should be discarded. Various microorganisms can sometimes grow in correct density maple syrup. Attention to keeping all items that contact syrup clean can limit contamination. Make sure customers know to refrigerate open syrup in order to slow or prevent the growth of mold.
- Syrup with a fermented off-flavor has been described as "sickeningly sweet" or "fruity" or having a "fizzy" mouthfeel. Fermentation may be the result of low-density syrup or syrup stored in pails or barrels that do not have an effective oxygen barrier. Porous or incompletely filled plastic barrels are sometimes associated with this defect.
- Don't attempt to grade syrup flavor when you are tired, have a cold, just had a meal with strong flavors, or have been boiling sap for hours. All these conditions will diminish your ability to detect off-flavors.
- The sugaring season is often long and exhausting, and the end of the season is when several off-flavors are more likely to appear. It can be difficult to distinguish very strong late-season syrup flavor from off-flavor.
- Beware of the phrase "it's not that bad." Presenting consumers with anything other than the best-tasting syrup can damage the market for pure maple products. Even slight off-flavors do not belong in retail containers. At the end of the season, and particularly in poor production seasons, producers sometimes tend to drift toward accepting syrup that they might otherwise reject.

Blending Syrup Flavors

When syrup with an off-flavor is produced, the temptation is to blend the off-flavored syrup with good syrup to lessen the undesirable flavor. While this may be successful in some situations, it very frequently yields a larger quantity of poor-tasting syrup. Even a small amount of moderately strong off-flavored syrup can overpower the flavor of many gallons of good syrup. For these reasons, the practice is not recommended. At best, this practice should be applied only to small quantities for testing and approached with a great deal of caution. It is not fair to the maple consumer to sell syrup that is judged to be "not bad" or is "good enough" as it provides a poor image of maple as a high-quality food product. Syrup that is "not bad" is not necessarily "good" and shouldn't be treated as such. Would you like to go in a store and buy a steak that is labeled "good enough"?

COLOR GRADING

Syrup must be graded by correctly placing the sample into one of four ranges of color (**Table 8.1**). In practice, the color class of syrup is determined by comparing a sample of syrup against a set of known color standards, either a temporary or permanent color comparator, or by measuring the percentage of light transmittance (%LT) through the syrup at a specific wavelength with an electronic device called a photometer or spectrophotometer.

Color Grading Tools

Color grading kits are available from maple equipment dealers. These kits are visual comparators; the color class of the syrup is determined by comparing the sample color to a set of colored glass or plastic plates or glycerin solutions (**Figure 8.17**). When using a comparator, a sample of syrup is placed in the sample syrup container supplied with the kit, and the color is compared with the color standards. It is important to use only the sample container provided with the kit—use of a different size or style container can result in incorrect interpretations. In all visual kits, the colors of the standards are the darkest that a sample can be and still be within that class. The color of the sample must be as light or lighter than the standard to be in that class. It is not which color class standard a sample is closest to. For example, if the sample falls between the "Amber" and the "Dark" standard, that sample falls into the "Dark" syrup color class. When using a visual comparator, it is important to have good, even light behind the kit. If clear daylight is unavailable, a florescent light that concentrates light behind the kit also works well. Trying to color grade syrup at night with a traditional light bulb is very difficult and frequently results in a syrup being misclassified.

Visual grading kits are of two types, permanent kits using colored glass or plastic plates as standards and temporary kits made of colored glycerin in bottles. The colors in the permanent kits are stable and do not fade over time unless stored in strong light for a long period of time, hence the designation permanent. Conversely, the coloring that is added to the glycerin solutions in temporary kits fades and become lighter over time, making them inaccurate, hence the temporary designation. Permanent kits are considerably more expensive than temporary kits but will last indefinitely as long as they are cared for. Temporary kits should be replaced annually. Because the colors of these kits can fade (**Figure 8.18**), a producer using an inaccurate kit may wind up unknowingly downgrading syrup to a lower class, resulting in a loss of product value much greater than the cost of a new temporary kit. It is recommended that producers store all visual kits covered and in a cool, dark location when not in use.

When used to evaluate the color of maple syrup, a spectrophotometer measures the amount of light of a specific wavelength (560 nanometers) that passes through a cell of a specific width within the unit. This reading, expressed as "percent light transmission," is compared to a clear glycerin standard calibrated to read 100 percent transmission. These values are found in the left-hand column of **Table 8.1**. Until

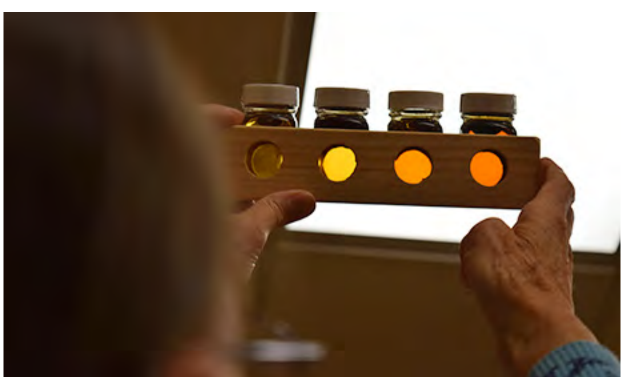


Figure 8.17. Using a temporary visual color grading kit to classify maple syrup.

Figure 8.18. Temporary grading kits will lighten with exposure over time, making any grade determination incorrect.

recently, the cost of these units was prohibitive for maple producers. Today, low-cost photometers are available specifically for the maple industry (**Figure 8.19**). Producers using these instruments should read and understand the instructions for use and follow them carefully. Small air bubbles, poorly filtered syrup, or fingerprints on the sample cuvette will result in measurement errors. In almost all cases, errors made while using a spectrophotometer will result in a reading that is darker than the actual grade. A variance of two percent in the readings (more with some samples) is not uncommon, due to the precision of the instrument and the condition of the cuvette (the provided syrup container). When the sample of syrup being evaluated is close to the boundary between two grades, two different spectrophotometers could produce different readings, thereby placing the syrup in different grades. In cases of a dispute, a certified analytical lab–grade spectrophotometer or permanent visual grading kit may be used.

Blending Syrup

For a variety of reasons, producers may contemplate blending two syrups to achieve a desired color grade in the blend. Certainly, syrups can be combined to produce a blended color, but achieving the desired results is as much of an art as it is a science. The best advice is to first blend small trial amounts to evaluate the results of mixing various proportions. Keep in mind before starting that it is generally easier to make syrup darker than to make it lighter. In general, it takes only a little dark syrup to darken light syrup, but more light syrup than you might expect to bring the color of dark syrup back up. Online calculators can be used to help in the process of blending.[9]

(a) (b)

Figure 8.19. Handheld Hannah "Checker" (a) and photometers (b) can also be used to color-grade of maple syrup.

[9] Cornell University Maple Program. 2020. Grade blending: a new calculator to get blended syrup in grade. *Maple Syrup Digest*, Sept., pp. 26–27. https://mapleresearch.org/pub/gradeblendingmd0920/ Cornell University Maple Program. Cornell Maple Calculators—Calculators and Other Tools. https://mapleresearch.org/pub/4221cor/

Whether choosing to blend syrups is a good decision depends on a producer's individual market demand and their supply of the different color grades. When finished, be sure to taste the blend to ensure that the flavor fits the final color class, as the delicate flavor of the lighter syrup is often overwhelmed by the stronger flavors that accompany darker syrup.

SYRUP PACKING, HANDLING, AND STORAGE

Once maple sap has been processed into maple syrup and is graded, it is ready for packing in some type of container. Whether the syrup is going into a drum, pail, or retail packing, some basic requirements and recommendations need to be considered.

Hot Packing

Maple syrup must be hot packed to prevent the development of yeasts, mold, or bacteria in packaged syrup. The commonly accepted minimum temperature for hot packing maple syrup is 180°F (82°C). It is important that the entire inside of the container, including the cap, be exposed to the hot temperature. This is commonly accomplished by inverting the container immediately after it is filled and sealed, but the specific recommended procedure depends upon the container and seal type.

Syrup may precipitate additional sugar sand when heated for packing, particularly if the syrup is heated over 200°F (93°C). Heating with a canner or double-boiler, or constant stirring of the syrup during heating will minimize hot spots in the pan and discourage the formation of niter. Consider packing a small portion of syrup in a glass sample jar at the end of each batch to use as a reference (**Figure 8.20**).

The method and equipment used to package maple syrup depends on a variety of factors including the size of the operation or volume of syrup to be packed. Hobbyists and smaller-volume producers may either simply reheat filtered syrup and

Figure 8.20. Jars of each batch of syrup should be retained as reference samples.

pour it directly into containers or run it through a commercial coffee maker dedicated exclusively to hot packing syrup. (Note that this appliance should not be used for making coffee either before or after using it to pack syrup.) For larger producers, a variety of bottling equipment systems are available in a broad range of sizes, along with air-powered cappers and metered syrup dispensers.

Labeling and Traceability

Maple producers must know and follow the laws and regulations that impact the sale of their product. These regulations define not only factors relating to syrup quality, but also what needs to appear on the label. Maple producers and packers must reduce any contamination hazards by implementing good food-production practices and have a plan in place to address any issues that do occur if poor quality syrup does find its way to retail. Mistakes can and will happen. Planning for those events by having effective ways to trace and recall a given batch of syrup will mitigate the risk that all syrup will be affected if there is the need to remove syrup from sale. A date or tracking code should be assigned to each barrel of syrup and carried over to all wholesale or retail containers to keep track of the age and quality of the product. Good recordkeeping is essential when circumstances require tracing a batch's origin date or recalling any product. If a problem arises, a well-organized documentation system will make it easy to check records to verify what was packed, and when. A thorough discussion of food safety issues can be found in **Chapter 14**.

Considerations for Retail Containers

Many different types, styles, and sizes of syrup retail containers are available. The choice largely depends on producer as well as customer preference. Each has advantages as well as disadvantages associated with its use. While the handling and filling are generally similar for each type, there are some important guidelines and considerations related to the use and storage characteristics of each. All retail containers must be new, food grade, clean, dry, and free of contamination before being filled. Non–food-grade containers and reused or repurposed food-grade containers can leach chemicals and contaminants into or impart off-flavors to otherwise high-quality syrup (pickle-flavored syrup is not popular). Consumers expect top-quality products regardless of the size of your operation.

PLASTIC CONTAINERS Plastic containers are very popular for packaging maple syrup. They are readily available from dealers in a variety of sizes and shapes, can be custom lithographed or wrapped with state or individual producer designs and information at a modest price, and are highly resistant to breakage. Syrup stored in plastic containers will darken over time, with the rate varying with the type of plastic[10] and with the syrup invert level. If the syrup being packed in plastic is on the dark end of a given grade, it may well darken to the next grade by the time the consumer (or an inspector) opens it. Consider grading this syrup to the next darker grade.

Color darkening and, to a much lesser extent, flavor loss, appear to be associated with exposure to oxygen (**Figure 8.21**). Plastic containers coated with an oxygen-impermeable barrier help protect syrup from darkening and flavor changes that can happen in packed syrup over time and so are better adapted to longer storage periods. Research has shown that syrup darkens on average 2.6 percent in light transmittance per month in uncoated plastic jugs compared to 0.8 percent in coated jugs. New compositions and styles of plastic containers have recently been introduced to the maple industry, but there has so far been insufficient experience with them to form a basis for recommendations.

FIGURE 8.21. Darkening of syrup at the top of the sample jar due to exposure to air in the headspace.

[10] https://mapleresearch.org/search/?_sf_s=darkening

A possibly related, but seemingly quite rare phenomenon is termed "layering." Syrup appears to stratify into distinctly different color zones in containers. Limited testing has shown that the top layer of syrup is darker than the bottom, the invert level is slightly higher, the syrup pH is slightly lower, and slightly less dense than the bottom layer. Whether this is simply due to oxidation or something completely different is unknown, but limited research has been conducted due to the infrequent and unpredictable nature of this issue.

GLASS CONTAINERS Glass containers are popular with consumers who like to see the natural color and beauty of the product they are buying. Glass also maintains product quality well (though long-term storage should be in the dark). However, packaging in glass requires some special considerations beyond the additional care needed to avoid breakage during handling and shipping. First, due to the high visibility of syrup packed in glass, special attention must be paid to syrup clarity, particularly when using cloth filters. There is a common semi-humorous expression among maple producers that they "... never had a problem with niter until I started packing in glass." Also, hot syrup used to fill glass containers cools rapidly, especially in small containers. When filling small glass containers, a higher packing temperature, or preheating of the glass in an oven or water bath, may be needed for the syrup and container to reach and maintain the temperature required to minimize spoilage (180°F/82°C). These steps must be balanced with the tendency of syrup to darken or develop more sugar sand when held at an elevated temperature for an extended period.

METAL CONTAINERS Metal cans are the traditional choice for maple syrup packaging. They are particularly well suited for packing in the 1-quart to 1-gallon size, although some unique, collectable cans, such as the traditional log cabin can, are available in smaller sizes. The 540-milliliter (18.25-ounce) round can remains common and popular in Quebec. While metal containers can be effective in maintaining syrup grade color over long periods, their effectiveness in retaining flavor is mixed. Off-flavors, often characterized as metallic or "tinny" (**Table 8.4**), have sometimes been observed in syrup packaged in metal containers. Metal containers with a food-grade plastic lining alleviate this issue; however, until recently the lining material contained bisphenol A (BPA), a substance that over the past decade has raised environmental and consumer concern. Newer linings are made of acrylic and polyester.

Only metal containers manufactured for food products should be used for maple syrup. Once metal containers are filled, securely install and seat the cap insert (if applicable), tightly screw on the cap, and place the container on its side to sterilize the cap and inner top of the container. After opening, syrup should not be stored in metal containers for any length of time as it might acquire a metallic off-flavor. Producers should avoid stockpiling metal containers since keeping them in storage for extended periods increases the risk of corrosion.

Avoiding Stack Burn

The color of pure maple syrup results partially from a browning reaction that occurs during evaporation. When syrup is packaged hot, this same browning reaction can continue in the container until the syrup has cooled. This may result in a continued grade change after packaging. For example, hot-packed Amber syrup may change to a Dark or even Very Dark grade as it cools. This darkening of color due to prolonged retention of heat in the containers is referred to as "stack burn."

To avoid stack burn, it is recommended that filled containers be allowed to cool in an area where air can freely circulate around them before they are boxed or packed close together. Once the syrup and its container have reached room temperature, all containers can be stacked more closely. Some producers have hastened the cooling process by using a fan to cool the syrup immediately after packing, or by packing syrup in a cool room. Larger syrup packers and processors may employ refrigerated cooling tunnels to rapidly reduce the temperature of syrup to storage room temperature.

Storage of Syrup in Retail Containers

Once containers filled with syrup have adequately cooled, they are ready for storage. Time, temperature, and exposure are important factors to consider when storing maple syrup. It is natural for some lots of syrup to lose flavor when stored for long periods of time. For this reason, it is recommended that syrup be kept in bulk and only packed in retail containers for a two- to three-month supply. Doing so will allow greater control over not only retail inventory, but also the quality of the product. Filled containers should be stored in a darkened, clean, relatively cool location where temperature fluctuations are minimized. To maintain constant temperatures and control humidity, it is recommended that syrup be stored in air-conditioned storage rooms in the summer months. Walk-in coolers represent ideal storage conditions and provide excellent conditions for maintaining syrup quality. Syrup in retail containers also can be stored at below-freezing temperatures (though it never freezes solid). If this is done, quality will be maintained indefinitely.

Maple syrup packed in metal containers has an expected shelf-life of approximately 6–12 months. Metal containers lined with food-grade lacquer can extend this time frame. Syrup packed in plastic has a shelf-life up to 2 years. Stored in glass, syrup retains its quality for up to about 4 years. Syrup should be stored refrigerated or in a freezer once the container has been opened.

Bulk Storage Considerations

Syrup can be packed directly into containers intended for retail sale or placed in larger cans or pails or drums or totes. These larger-sized containers (referred to as bulk storage) are used when selling to packers or in wholesale markets and are commonly used by producers as sources of syrup for filling retail containers later in the year. Most maple producers will find it advantageous to pack some syrup in retail containers during the producing season; however, it is recommended that at least part of the crop be packed in bulk containers for filling later orders. Bulk storage allows for filling individual orders on a customized basis while making certain that syrup quality at the time of filling is high.

Bulk storage containers should be checked carefully before filling for foreign objects, cleanliness, and odors. Typically, larger drums are rinsed shortly before use, drained, and then filled as the syrup comes off the filter press or mixing tank. Drum filling and overflow control devices that daisy chain multiple drums together with hose make this task simpler as there is less need to continuously check to ensure drums don't overfill. With overflow devices, once a drum is filled the syrup automatically flows to the next barrel. Drums should be filled while the syrup remains over 180°F (82°C). If a drum is only partially filled during a boil or over a couple of boils, additional syrup can be added later as long as all the contents of the drum reach packing temperature before being capped. Overflow devices are also useful in accomplishing this and in homogenizing syrup across more than one evaporation run. A barrel heating belt can assist in maintaining syrup at appropriate temperature during production. Drums should be capped while still hot and a label affixed indicating date of filling, lot or code number (for tracking purposes), density, color grade, flavor/off-flavor, and any other information the producer or packer wishes.

After hot packing, those conditions conducive to maintaining syrup quality in retail packages are also applicable to storage of bulk syrup. Control of temperature, minimal exposure to light, and storage in a clean location protected from airborne contaminants and animal or bird access are especially important. It is important to keep filled bulk containers sealed until ready for use. Opening them exposes syrup to bacteria, yeast, and mold. Once opened, syrup stored in a bulk container should be used or repackaged as quickly as possible. For this reason, choosing the proper size bulk container appropriate for each operation is an important consideration. For small- to medium-sized operations, storage in 5-gallon containers that can be hot-filled and sealed may be preferable storage in larger 40 or 50 gallon drums. This depends upon how frequently and how much syrup is packed into smaller containers. When large drums are opened repeatedly to remove syrup there are multiple opportunities for microbial contaminants to enter. Smaller containers are more likely to be packed into retail containers all at once, decreasing the chances of syrup spoilage and grade reduction from frequent exposure to airborne bacteria, yeast, and mold.

When syrup is removed from bulk containers for packaging in retail containers it must be reheated. If bacteria, mold, or yeast growth is present, that syrup should be discarded. Following heating to a minimum of 180°F (82° C), the syrup should be filtered and packaged. When reheating has been completed, the syrup density should be checked and necessary adjustments made to make certain the syrup is at the correct density when packaged. It is not uncommon for the density of syrup to increase slightly during the process of reheating and packaging. It is also advisable to taste each batch to verify acceptable flavor. Plastic bung gaskets designed to provide an airtight seal for barrels should be inspected every time a barrel is opened or sealed. Replace gaskets if they look damaged in any way.

After a bulk container is emptied, wash it thoroughly with hot water or steam and dry completely. Never use soaps or detergents in cleaning bulk storage containers. Drying individual drums can be difficult; however, if the drum is inverted and a towel placed in the bung opening, moisture can be wicked out with the towel. Store empty bulk containers in a dry area, free of any type of contamination. Don't assume that barrels of syrup sold to packers and returned "steam cleaned" are ready to fill with next year's crop. Even the small amount of moisture that remains in the barrel from steam cleaning can grow mold over the summer and contaminate an entire batch of syrup with a musty off-flavor. Rinse and dry the container thoroughly again just before use and examine the interior thoroughly with a flashlight to ensure that it is in good condition.

As with retail containers, there are different sizes and types of bulk storage containers available, although the majority of bulk syrup produced each year is packed in 40- or 50-gal drums (**Figure 8.22**). Each producer must determine the appropriate types and sizes of containers for their own operation. The most commonly used types of bulk storage containers include the following:

Figure 8.22. Common types of barrels used in the maple industry include (left to right): epoxy-lined "one-way" steel drums, plastic, stainless, and galvanized barrels. Stainless containers are recommended for maintaining the long-term quality of maple syrup. Galvanized and plastic barrels are being phased out in many locations. Older galvanized barrels with lead solder are no longer appropriate for maple syrup storage.

STAINLESS STEEL The best containers for maintaining syrup quality during bulk storage are made of stainless steel. In general, barrels with fully welded seams are preferred over barrels with rolled/folded/crimped seams, however stainless steel drums in a variety of styles and sizes are presently in use in the maple industry. Care should always be taken to ensure that barrels were never used for non-food purposes prior to using them for maple syrup. Furthermore, it is advisable to determine what kind of food was previously stored in the container as many foods may impart odors and flavors that are difficult to eliminate. Stainless steel provides excellent long-term storage for maple syrup.

PLASTIC Various sizes and styles of bulk plastic containers are available and represent a less expensive option for syrup storage. Sugarmakers that produce smaller volumes of syrup often use 5-gallon plastic containers for storing syrup that will be packed later in the year. However, given plastic's comparatively porous structure, plastic containers should not be considered interchangeable with stainless steel barrels in terms of maintaining syrup quality or longevity. Some styles of plastic barrel are difficult to completely fill, and their porosity renders them and their closures difficult (or impossible) to completely clean. Because of this, syrup stored in plastic bulk containers is at an increased risk of damage from fermentation, mold growth, and off-flavors.

EPOXY-LINED METAL This type of bulk storage container is less expensive than stainless steel and when used properly can maintain syrup quality for long-term storage. Epoxy-lined steel containers are commonly referred to as "one-way" drums since they are designed to be used once and then discarded. With repeated use and handling the epoxy lining may weaken and crack, thereby creating areas of exposed metal. Affected barrels can impart a rusty or metallic flavor to otherwise good-quality syrup. Thoroughly inspect the interior of the drum before using. Drums with any sign of weakened, cracked, or chipped epoxy should be removed from service.

GALVANIZED METAL Galvanized drums were at one time the standard in the industry, but do not meet current regulatory standards for safe syrup storage and should not be used. Drums constructed prior to 1994 may contain lead solder and lead in the galvanizing material. Galvanized drums have largely been phased out throughout most of the maple industry in the U.S. and Canada and replaced with stainless steel or plastic barrels.

STAINLESS STEEL TOTES Stainless steel IBC totes (Intermediate Bulk Containers) are beginning to come into use for large maple operations, with 350 gallons being the most common size (**Figure 8.23**). These have the capacity of roughly eight 40-gallon barrels or six 55-gallon barrels. They can be stacked and take up less storage space. They are also designed with large openings and drains that make them easier to clean than traditional bulk containers. Although expensive, totes offer producers cost efficiencies by reducing labor and material expenses, given that fewer people are needed to fill and move barrels around the sugarhouse. Totes do require a trained operator, solid and level floors, and equipment capable of lifting the weight (e.g., a forklift) to be safe and effective.

Of all the special qualities of pure maple syrup, flavor is the most important. By following the recommendations described in the preceding pages, producers can be sure of consistently offering consumers a superior product. Effective filtering, careful grading, and proper packaging will ensure that each product sold meets the highest standard.

FIGURE 8.23. Totes are becoming increasingly popular to store large quantities of maple syrup (250+ gallons).

CHAPTER 9

Maple Sugar, Maple Cream, Maple Candy, and Other Value-Added Products

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Perkins, T.D., R.B. Heiligmann, M.R. Koelling, and A.K. van den Berg (Editors). 2022. *North American Maple Syrup Producers Manual. Third Edition.* The University of Vermont and the North American Maple Syrup Council, Burlington, Vermont. www.mapleresearch.org/manual/

INTRODUCTION

Pure maple syrup, while a high-value product on its own, also serves as the raw material for many other maple products (**Table 9.1**). These additional products enable individual maple producers and processors to expand potential markets for the maple industry by manufacturing a variety of products that appeal to a broader section of consumers. Additionally, opportunity exists to obtain greater total returns from the maple crop because of the significant value-added component that results from producing secondary, higher-priced maple products. The increase in product value needs to offset the added labor, equipment, and marketing costs involved in handling a value-added maple product. It is not unusual to double or even triple the monetary return on a quantity of maple syrup by converting that syrup into other products. As a result, it is not surprising that some producers process most of their annual syrup crop into maple confections, such as maple sugar, maple candy, and maple cream.

GENERAL CONSIDERATIONS

Maple syrup is primarily composed of a mixture of sugars, water, and minerals. In addition to these three components maple syrup will contain small amounts of various other organic compounds such as organic acids, amino acids, proteins, phenol compounds, and even a few vitamins. Variation in the levels of these various components gives maple syrup the broad spectrum of flavors experienced with syrup from different producers and from different sap runs at the same location.

When making any maple confection, it is critical that the syrup used has good flavor. Most

TABLE 9.1 A wide variety of confections and other value-added products can be produced using maple syrup.

Product Name	Other Names	Cook to Boiling Point of Water Plus:	Process	Characteristics
Rock Candy		8–10° F (4–6° C)	boil, allow to set for weeks	hard, clear sucrose crystals
Maple Cream	Maple Spread Maple Butter	22–28° F (12–14° C)	boil, cool, and stir	creamy smooth, paste-like
Sugar-on-Snow	Jack Wax Leather Aprons	22–27° F (12–15° C)	boil, pour over packed snow	chewy to brittle, depending on boiling temperature, no crystals
Taffy	tire d'érable (Fr.)	23–26° F (13–14° C)	freeze immediately	thick and chewy, no crystals
Fondant Type Candy	Maple Cream Heavy Maple Cream	27–29° F (15–16° C)	boil, cool, stir, and mold	smooth, putty-like
Molded Sugar	Soft Sugar, Maple Candy	32–37° F (18–19° C)	boil, stir hot, pour into molds	firm, but not rock solid, very small crystals
Hard Sugar	Block Sugar	34–38° F (19–21° C)	boil, stir hot, pour into molds	harder than molded sugar candies, in block form
Granulated Sugar	Indian Sugar Stirred Sugar	50–70° F (25–28° C)	boil, stir until granulated, sift	loose granulated, like brown (cane) sugar

off-flavors are concentrated by processing, resulting in poor-tasting products. Once you have selected syrups with excellent flavor, your next major concern should be selecting syrups based on correct chemistry for the desired confection. Third, you must select the cooking, cooling, and stirring methods that will give you consistently high-quality confections.

Collections of sugar molecules can adhere to each other form solid structures that are no longer in solution. These formations, called crystals, are key to many confections. Different sizes of crystals are preferred in different kinds of confections. Recipes for maple confections are aimed at controlling the conditions under which crystals are induced to form and grow. The important factors affecting the nature of the crystals formed include:

- the amount of excess sugar in solution;
- the characteristics of the seeding material (syrup added during processing that has already formed crystals or granulated maple sugar);
- the rate and extent of cooling;
- syrup chemistry (particularly invert level); and
- the speed, power, and length of stirring time.

Maple syrup at 66.0°Brix is a stable sugar solution at room temperature. The concentration of sugar in the solution will increase with continued boiling as more water is evaporated. When the syrup reaches the desired temperature for a particular confection and begins to cool, there is more sugar than can remain in solution at these lower temperatures. The solution is said to be supersaturated. All maple confections depend on producing a supersaturated syrup solution and then either encouraging, controlling, or preventing the subsequent sugar crystallization process through various thermal or mechanical manipulations as the solution cools. This is why accurate measurement of the temperature of heated syrup is so important.

Crystallization inhibitors, such as various acids, fats, and proteins, can be used to modify the process and product. Fat and protein inhibit crystallization by providing physical barriers, coating the crystal faces and preventing one molecule from locking onto another, thus keeping the crystals small or stopping crystallization altogether. Corn syrup or honey is often used in candy making since they promote supersaturation by inhibiting the formation of crystals. Many specialty products can be made using maple syrup along with various crystal inhibitors. These candies do not have sugar crystals when they have sufficient crystal inhibitors in them or when they are cooked to such a high temperature that most of the water has evaporated to the point where the syrup is too viscous for sugar molecules to orient themselves into a crystalline structure. Examples include caramels, taffies, brittles, hard candies, marshmallows, fluff, meringues, frostings, and gumdrops. The excessive use of a fatty defoamer in making crystalline confections may result in unexpected soupiness or lack of proper crystal formation.

As opposed to crystal inhibition, seeding of supersaturated syrup solutions provides sites for additional crystals to rapidly form. Adding crystals encourages the formation and growth of additional crystals. By adding crystals, the solution can be induced to rapidly crystallize.

Allowing the supersaturated solution to sit undisturbed inhibits crystallization. As the solution cools, it becomes more highly saturated and more unstable. Any agitation (stirring) will cause the sugar to crystallize out of solution until the solution reaches a stable concentration for its temperature. The more highly supersaturated the solution is, the faster crystallization can occur. Therefore, delaying or inducing crystallization, depending on the product desired, is a useful tool for confection-makers.

While most of the sugar in maple syrup is sucrose, there are small, varying amounts of other sugars. In particular, invert sugars (so called because polarized light is rotated in the opposite direction in a solution of invert sugar compared to a regular sugar solution) play a large role in determining crystallization properties. Sucrose crystals are akin to cement blocks that fit together very nicely. Invert sugars can be thought of as bowling balls. Building a structure (crystals) from cement blocks is simple and easy. But if you toss in a few bowling balls here and there it makes the process of structure (crystal) building a lot more difficult. However, just as there will be times when you want a nice, rigid, strong structure, there will be other instances when you want a loose and fluid-like structure. By manipulating the level of invert in the mix, you can achieve either result (rigid or loose structure), or something in between. Therefore, maple confection makers exploit the level of invert sugar in confections to alter the process of crystallization and hence the properties of the product. Further discussion of invert sugars occurs later in this chapter.

Finally, the nature and speed of the mixing process will influence crystal type and formation. Large crystals, called rock candy, form when slightly supersaturated syrup (69°–72°Brix) is cooled slowly and stored for a long time with no agitation. At the other extreme, a glass-like noncrystalline product is formed when highly supersaturated syrup (the boiling point is elevated 18°F or more above the boiling point of water) is cooled rapidly to well below room temperature without stirring, such as sugar-on-snow, a taffy-like, amorphous candy. In contrast, if a hot supersaturated sugar solution is stirred while it is cooling, the tendency to form crystals will increase. The mechanical shock produced by the stirring causes microscopic crystal nuclei to form. Continued stirring mixes the crystals throughout the thickened syrup, and they grow in numbers and in size. For example, granulated sugar (large crystals) is made by the stirring syrup hot supersaturated syrup with little cooling. To produce the smooth texture of maple cream (very small crystals), the supersaturated syrup is first cooled (without agitation) to between 45°F and 90°F (7.2° and 32.2°C), then stirred.

Invert Sugar

Sucrose is a large, twelve-carbon, disaccharide sugar with the chemical formula $C_{12}H_{22}O_{11}$ (see the Figure on the first page of the Appendix). Sucrose is commonly made by plants, including maple trees via photosynthesis. Structurally, sucrose is composed of two smaller, monosaccharide sugars—glucose and fructose—that are connected via a specific type of linkage. Glucose (also called dextrose) and fructose (also called levulose), while both 6-carbon sugars (hexoses) having same chemical formula $C_6H_{12}O_6$, are slightly different structurally. In this chapter they will be identified independently as glucose and fructose, or collectively as invert sugars.

Invert sugars are produced in sap or syrup by the enzymatic splitting of sucrose, generally as a result of microorganism activity or interaction with acids. Sucrose is common table sugar and is the vastly predominant form of sugar in sap when it comes from the tree. Some of the sucrose in sap is converted to invert sugar as a result of microbial fermentation during collection, storage, and processing. Ensuring that tubing, tanks, and other equipment that comes into contact with sap are clean, keeping sap cold, and processing sap quickly will reduce this effect. The rise in invert sugar levels occurs in all sap and is most clearly evidenced by the differences in color and flavor of syrup made from sap collected late in the season when temperatures are warmer.

A small amount of invert sugar is desirable in maple syrup destined to be made into maple confections. Invert sugars are more soluble in water than sucrose at room temperature meaning more total sugar can be held in solution before crystallization occurs. This characteristic of invert sugars helps keep the product moist, and it also encourages smaller sugar crystals to form. Too little invert sugar in the syrup can cause the product to be grainy; too much can prevent proper crystal formation. Other properties of invert sugar include increased sweetness compared to that imparted by sucrose alone; reduced viscosity (making it easier to spread creams or frostings); softened texture; reduced water activity, which makes products more resistant to yeast, mold, and bacteria fermentation; and depression of the freezing point so that when products containing invert sugar are stored in the freezer they are less likely to crystallize or undergo changes in crystalline structure. Recommended invert sugar levels for specific confections, where important, are provided toward the end of this chapter in the specific directions for making each confection. Though observing the prescribed invert sugar level when making maple products is essential, using the right temperatures, equipment, and processing method for the desired product is equally important.

Invert sugar is one of the more important participants in the Maillard browning and caramelization reactions in maple. Maillard browning occurs when invert sugars, amino acids, and heat react. It is one of the chemical reactions that happens when heating syrup, which leads to darker color and stronger flavor. Caramelization happens at different temperatures with different sugars. At 365°F (185°C) sucrose will caramelize, glucose at 295°F (146°C) and fructose at 219°F (104°C). When cooking syrup for confections, producers should recognize that higher invert levels may increase darkening. Too much invert sugar can produce a taste distinctly different from that of maple syrup and more characteristic of honey or caramel.

Generally, all grades of maple syrup will contain some amount of invert sugar, often corresponding to the different syrup classes. Lighter syrup, particularly that made early in the production season, generally has the lowest amount of invert sugar; very dark syrup, particularly that made late in the production season, typically has a higher invert sugar level.

INCREASED INVERT REQUIRES HIGHER TEMPERATURE One of the factors a maple producer who is making value-added products may need to take into consideration is how the concentration of sucrose is affected in syrup that has invert sugars present. Sucrose is the sugar that normally is going to crystallize in making a confection. Unless the syrup has been treated with invertase, sucrose is the only sugar concentrated enough to form crystals. The invert sugar in the syrup reduces sucrose crystallization simply by getting in the way, but it also reduces the sucrose concentration, requiring more cooking to bring it to the level where it would act more like it would if no invert sugar were present. **Table 9.2** illustrates how finish temperature of maple cream will increase with increasing level of invert sugar. A maple producer making maple cream with a syrup having little or no invert sugar does not need to boil the syrup mixture to nearly as high a temperature compared to a syrup at the same Brix level but with a higher invert sugar level. This demonstrates to maple producers why a higher finish temperature is needed to get the sucrose to the same concentration to achieve a similar crystallization result. You need the higher finish temperature to equalize the Brix of sucrose in the mix.[1]

TABLE 9.2 The effect of invert level on finish temperature on a syrup with total sugar content of 80°Brix.

°Brix Sucrose	°Brix Invert	Required Finish Temperature Elevation Above Standard Syrup °F (°C)
80	0	23 (12.8)
79	1	24 (13.3)
78	2	25 (13.9)
77	3	26 (14.4)

MEASURING AND ADJUSTING INVERT Testing syrup and adjusting to a proper invert sugar level can eliminate batch failures and help maple producers make confections of consistent quality. For many years the use of the Clinitest® tablets was suggested as the way to measure invert sugars in syrup. More recently, over-the-counter blood glucose meters have been used to provide an inexpensive, quick, and simple method to determine the amount of glucose sugar in maple syrup (**Figure 9.1**). Such meters cannot be used directly because syrup is too thick to enter the test strips and because glucose concentrations from undiluted maple syrup are often higher than the range of most meters. To solve these problems, dilute the maple syrup with water before testing. The most accurate and easy method is to dilute by weight. This is best done with a scale. Inexpensive and accurate electronic scales with a precision to 0.1 gram and a range of 0–200 or 300 grams are readily available. A 1 to 10 dilution of syrup to water generally works well, is easy to calculate, and gives a reading on the glucose meter that is

[1] Pitcoff, W. 2015. Understanding impacts of invert sugar on maple products. *Farming*. June. https://mapleresearch.org/pub/farmingjul15column/

Figure 9.1. Blood glucose meters can be adapted to test for invert sugar (glucose) in maple syrup.

in the range for invert sugar concentrations required for most confections. This ratio can be achieved by following these simple steps:

- Place an empty cup on the scale.
- Tare the scale (i.e., adjust the displayed weight to 0).
- Pour 5–10 grams of syrup into the cup.
- Multiply the weight (number of grams) of syrup in the cup by 10.
- Add warm water to the cup until that number is reached on the scale (for example if the syrup in the cup showed a reading on the scale of 5.6 grams, add water until it reads 56 grams).
- Remove the cup from the scale and stir vigorously until completely mixed.

A wide variety of glucose meters are available in drugstores, in the pharmacy section of department stores, and on the internet. Most glucose meters should be useful for measuring glucose in maple syrup, but meters that give numerical readings throughout their range (rather than Hi/Lo at the extremes) are best. These can range in price from nearly $100 to less than $15. Test strips for the various meters also range widely in price. Consider both the initial cost of the meter and the cost of test strips in determining which to buy. The more expensive meters offer options that are not generally of use to maple producers. The Accu-Chek® Aviva is one example of a model that has worked well with maple syrup samples.

Chemicals in the test strips deteriorate over time—don't use test strips past their expiration date. If your meter generates error messages, check the expiration date on the test strips. Glucose meters should be used at normal room temperatures and humidity. Some meters have automatic calibration, others require manual calibration—follow the directions supplied with your meter. Store your meter and test strips in a place protected from dust, fluids, and extremes of temperature and humidity. Become familiar with the basic operation of your glucose meter. Procedures for most meters follow the same generic directions:

- Open a test strip being careful to only touch it in the middle.
- Slide the proper end of the test strip into the meter with the correct side of the strip facing up.
- When the meter indicates it is ready for a sample, dip the extended end of the test strip about ½ inch into the syrup dilution and hold for about 5 seconds or until the meter indicates the sample has been activated.
- Move the meter to a horizontal position with the test strip in place and wait for the reading to appear.

The reading that appears on the screen will either be a number, or it may say "Hi" or "Lo." Read the manual that comes with the meter to determine what range this represents. The reading on the screen is typically in milligrams per deciliter (mg/dL). Most meters read glucose concentration in whole blood. Some meters convert these reading to glucose in blood plasma, which is 10–15 percent higher. Recommendations in this chapter are based on the whole blood readings.

The mg/dL readings on the meter should be multiplied by 0.02 to get the percentage of invert sugar. Accuracy of most glucose meters is within the range of 10–20 percent, meaning that repeated readings may be different, but still be within the accuracy tolerance. At these low sugar levels this amount of variation is acceptable. As invert sugar levels increase, variation also increases. Check your meter periodically with repeated measurements on the same sample (with different test strips) to get a feel for what to expect. Be sure the sample is well mixed. Test Quality Control Solutions are available from some pharmacies or meter manufacturers to check a suspect meter, or readings from two meters can be compared. Despite these minor limitations, these meters are a substantial improvement over the previous method of measuring invert using Clinitest tablets.[2]

Once in a barrel, the invert sugar level in syrup should be stable unless the syrup ferments or is heated again. An invert sugar test can be run on barrels or other syrup containers as they are packed, or a small sample can be retained from each barrel and from samples tested shortly after the season ends, eliminating the need for further testing to determine which syrups to use in confections or blending. The invert reading should be recorded for later reference.

Alternatively, testing can be performed on each batch of syrup set aside for potential use in confections just prior to processing.

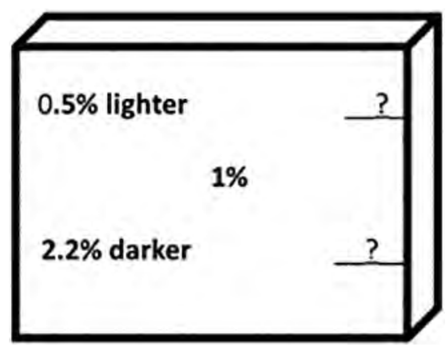
BLENDING FOR OPTIMAL INVERT LEVELS

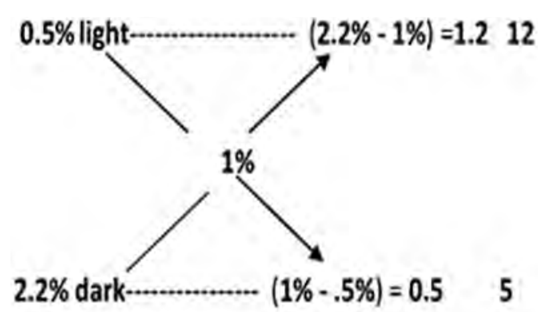
Determining the proportions of two syrups of known invert sugar levels to obtain a blend with the desired invert sugar level can be done using the mathematical rule of allegation.[3] The method is best explained by example.

Using two syrups with invert sugar levels of 0.5 percent and 2.2 percent, we wish to obtain a mixture with a target invert sugar level of 1 percent. For simplicity we will call the 0.5 percent syrup "light" and the 2.2 percent syrup "dark." Allegation determines the proportion of each syrup by weight to be blended.

Visualize allegation as a simple box diagram. In the upper and lower left-hand corners write the percentage (%) of invert sugar of the two syrups to be blended; in the center of the diagram write the percentage (%) of invert sugar of the desired blend.

Subtracting across the two diagonals provides the proportion (by weight) of each syrup required to produce the desired invert sugar percentage. Always subtract the smaller number from the larger, irrespective of its location. The proportion (by weight) of each syrup to be blended is the number located directly across from it in the diagram. In this example, the results are as follows:





The resulting ratio is 1.2 units of the lighter syrup with 0.5 percent invert sugar to each 0.5 units of the darker syrup with 2.2 percent invert sugar. To further simplify this, change the ratio to the simplest whole numbers. In this case, the result would be 12 to 5. If the two syrups have similar densities, the ratio

[2] See the Second Edition of the *North American Maple Producers Manual* if more information on this method is desired. https://mapleresearch.org/pub/mproducersmanual/

[3] Cornell University Maple Program. Cornell Maple Calculators—Calculators and Other Tools. https://mapleresearch.org/pub/4221cor/

can be expressed in whatever unit of measurement (e.g., pounds, cups, barrels, liters, grams) is most convenient for you. For example, you could blend it as 12 pounds of lighter with 5 pounds of darker, 12 liters of lighter to 5 lighters of darker, 12 cups of lighter with 5 cups of darker, or 12 barrels of lighter with 5 barrels of darker. However, if blending liquids of dissimilar densities, like syrup and water, only weight (pounds, grams, kilograms) can be used to determine the correct proportions, not volume.

Once syrups have been tested with the glucose meter, blending using allegation to achieve a desired invert level is simple and very helpful in achieving consistent confections. However, special care should always be taken when blending strong flavors in dark syrup, as these flavors are often more pronounced in the final product than you might expect.

SOLUTIONS TO INCREASE INVERT Some confections such as the shelf-stable maple cream or maple suckers or hard candy (made when no corn syrup or glucose sugar is added) require higher than normal invert sugar levels to achieve the desired characteristics. If syrup with high invert sugar level is not available, it can be created using a "processing aid" that converts sucrose to glucose and fructose. In this process, nearly all the sucrose will be inverted to create a "doctor" or additive solution.[4]

hold at 120°–150°F (49°–66°C) for 24 hours (note—boiling will inactivate the enzyme and stop the conversion). If time is not a limiting factor, stir the mixture thoroughly and allow it to stand at room temperature (65°F/18°C) or above for several days. This will convert the sucrose in the syrup to 67 percent invert sugars (this range is beyond that of blood glucose meters). Last, heat-treat the doctor solution to above 170°F (77°C) before adding to untreated syrup; otherwise the inversion reaction will continue in any syrup you add the doctor solution to. The allegation method is then used to create a desired invert sugar level by blending the doctor solution with the syrup containing the lower level of invert sugar.

Another convenient type of processing aid (where allowed by state or provincial regulation) is an acid salt such as cream of tartar (potassium acid tartrate). Adding ½ teaspoon (2.5 milliliters) of cream of tartar to 1 gallon (3.8 liters) of low invert syrup just before it is boiled for candy making will cause sufficient acid hydrolysis or inversion of the sucrose to form the desired amount of invert sugar. Cream of tartar is available in the spice section of most grocery stores. The difficulty here is that testing can only be done after the fact, and the results may not have produced the exact level of invert sugars you were expecting.

Verify before using a processing aid or doctor solution that this approach is in regulatory compliance with state or provincial laws.

To 1 gallon (3.8 liters) of standard-density maple syrup, add 1 tablespoon or ½ liquid ounce (15 milliliters) of invertase (an enzyme that causes the conversion of sucrose to invert sugars). Invertase can be purchased from many confection manufacturers and should always be stored according to directions. For rapid conversion stir the mixture, then heat and

Safety Concerns

Most maple confections call for additional boiling to increase the sugar concentration of the syrup. Care should be taken when handling hot syrup. Sugar solutions at elevated temperatures stick to the skin and cause severe burns. Make sure children and pets are not nearby. Boiling syrup must be watched closely due to its tendency to boil over or scorch. Scorched syrup will catch fire if it gets hot enough. When transferring hot syrup from one place to another be sure to wear protective clothing, including gloves, apron, full-length pants, and

[4] Childs, S. and B. Chabot. 2007. Measuring and adjusting invert sugar in maple sugar. *Cornell Maple Bulletin*. 6pp. https://mapleresearch.org/pub/measuring-and-adjusting-invert-sugar-in-maple-sugar/

protective work shoes. Follow the manufacturer's directions carefully when using a mechanical candy or cream machine and always be aware of moving parts. Remember that a food product is being prepared and all requirements and recommendations regarding food quality and sanitation must be observed. In keeping with these requirements, use only clean sanitary molds, utensils, and equipment; handle molded maple sugar pieces with plastic food service gloves; and keep hair retained in a hairnet or other suitable head covering.

Facility and Equipment Requirements

Producing maple products is easier and more efficient in a spacious, well-equipped kitchen or similar facility (**Figure 9.2**). The complexity of the facility depends on the size of the operation and the amount of product to be produced. A convenient layout and arrangement of necessary equipment facilitates smooth workflow. Processors should check with local health departments or food production authorities concerning construction codes and applicable food processing requirements.

Remember that flavor will be intensified as syrup is concentrated to a higher density; therefore, any syrup with even a hint of an off-flavor should not be used. As syrup is drawn off the evaporator, some producers will identify a batch with excellent flavor and reserve it for later use in making confections.

Figure 9.2. A spacious, clean, ordered, well-equipped area is desirable for making and packaging maple products. Equipment visible includes container and basket for crystal coating candy (left front), soft sugar candy machine with molds (left middle), maple cream machine (left rear), syrup barrel (rear center), propane-fired syrup reheating pan (right rear), canister pressure filter (right middle on floor), and syrup canning equipment (right front). (OBER)

Suggested equipment and ingredients include the following:

- **An efficient heat source:** High-pressure remote steam or high-quality steam kettles are considered ideal for secondary processing of maple syrup because heat can be precisely controlled, and there is almost no chance of scorching. For producers who do not have steam, gas heat is preferable to electric, because it maintains steadier temperatures, is easily controlled, and is often more economical. Another good alternative is an induction stovetop, which ensures very steady heating and is easy to control.
- **A collection of appropriately sized cooking utensils:** Utensils such as pans, kettles, mixers, stirring machines, ladles, spoons, scrapers, and measuring cups are not unique to the maple products industry and can be obtained from conventional kitchen or restaurant supply sources. These should be good quality and food grade to facilitate long wear and transmit heat uniformly. Food-grade stainless steel equipment is recommended. Boiling pans should be deep and large enough to hold four to six times the volume of syrup being heated due to the tendency to develop substantial amounts of foam. A spray bottle is handy for dispersing bubbles and preventing crystal formation on the surface of cooling syrup solutions.
- **Thermometers with a temperature range of 200°–300°F (90°–150°C) (Figure 9.3):** Durable high-range thermometers calibrated to indicate 0.5°–1.0°F (0.25°–0.5°C) differences are essential. Either dial units or standard stem-type candy thermometers can be used. Digital

Figure 9.3. Digital, dial, or stem-type candy thermometers can all be successfully used to make maple confections. Mercury thermometers should never be used in maple syrup or maple product production.

thermometers are especially convenient when accurate to 1 degree or better. Suitable candy thermometers are available from kitchen and restaurant supply sources and from maple equipment suppliers. Infrared thermometers are especially handy for reading the temperature of cooling maple products without inserting a probe, which can initiate crystal formation before it is intended.

- **A mechanism for rapidly cooling cooked products:** Several specialty maple confections require rapid cooling after reaching the desired boiling temperature. Some type of water bath or similar means of cooling boiled syrup must be available (**Figure 9.4**). While large refrigeration units can be used, many producers prefer to use a large shallow container or pan through which cold water is circulated. Containers of cooked syrup are placed on a rack in the water-bath pan, where rapid cooling occurs as cold water flows into the cooling pan, around the container of hot syrup, and overflows into a drain. In lieu of a circulating cold water bath, a large pan containing ice water can be used. When a container of hot syrup is placed in the ice water, it may be necessary to keep adding ice to maintain a cold temperature. Depending on the location, pans can also be covered and set in snow when it is present. Commercial restaurant supply stores are a good source for large shallow pans. Vacuum

(a)

(b)

Figure 9.4. A water bath provides the rapid cooling required for several maple products during processing. Depending on the size of the batches and the frequency at which they are made, a small bowl in a dishpan (a) or a large pot in a stainless sink (b) can be used a cooling bath. (douglass, freeman)

Note that in many jurisdictions, transforming maple syrup into another product requires additional permits or licensing and may entail other regulatory requirements. It is important that producers familiarize themselves with all applicable rules and regulations in their area.

cooling, which places hot syrup under high vacuum, offers a very rapid method of cooling hot concentrated maple syrup that ensures the whole batch ends up at the same temperature, unlike water-bath cooling, which can cause syrup temperature to vary dramatically across the pan from its edges to the center.

- **Sugar molds:** These are required for making hard block maple sugar, soft-molded maple candies, or maple lollipops. Rubber candy molds are available from maple equipment suppliers or confectionery suppliers. Rubber molds should only be washed using hot water—soap may impart an undesirable flavor. Water that is too hot can damage molds. Metal molds are usually used to make blocks of sugar; individual metal candy molds can also be used.
- **Defoaming agent:** A few drops of vegetable oil or commercial defoamer added to syrup will help keep the boiling foam under control. Dairy- or nut-based defoamers should not be used as they can cause allergic reactions or may interfere with consumers' dietary restrictions. The use of food-grade and kosher-certified maple syrup defoamer is highly recommended. These products are available from maple equipment suppliers. Organic defoamers should be used if the product will be organic certified.
- **Other equipment:** Maple candy, maple sugar and maple cream machines, cotton candy machines, ice crushers, ice cream machines, commercial popcorn poppers and stirrers, power sifters, commercial mixers, steam kettles, vacuum cooling chambers, and mechanical packaging devices are all likely to be found in the modern maple kitchen. While these represent a costly investment, they are necessary when making large batches of some maple confections (**Figure 9.5**).

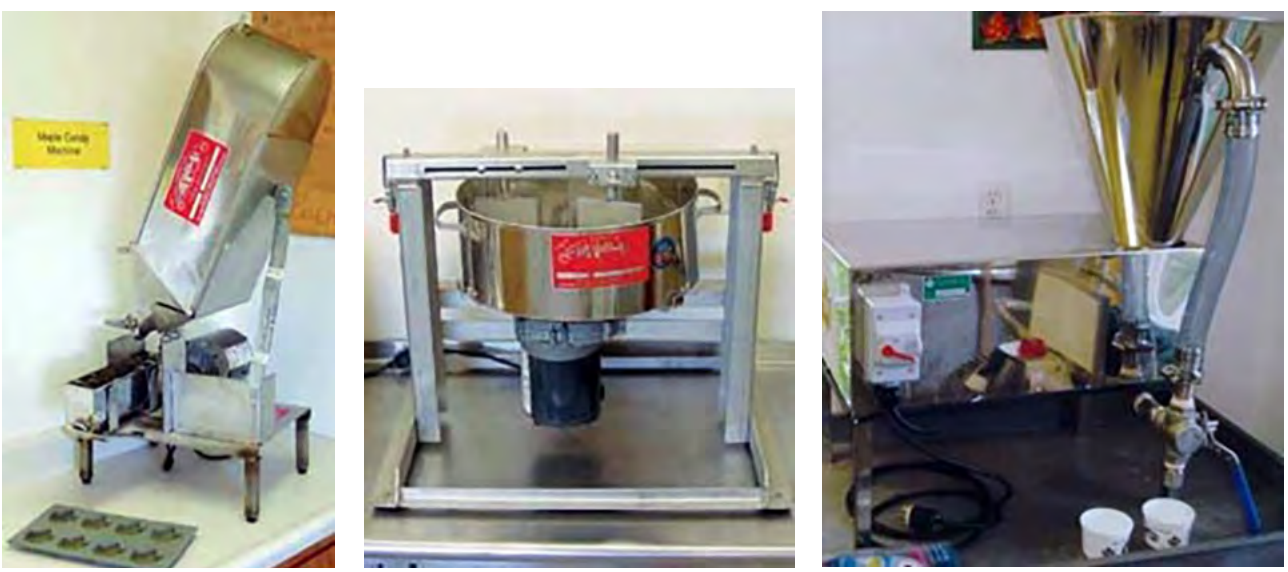


FIGURE 9.5. Commercial candy machine (left) and two styles of cream machine (center, right). (DOUGLASS, OBER)

COMMON MAPLE PRODUCTS

Maple Sugar Cakes or Blocks

Maple sugar in its various forms (molded soft candies, hard blocks, loose granulated) has long been a common product produced from maple syrup. In 1860, one maple-producing state in New England produced over 5,000 tons (4.5 million kilograms) of maple sugar. As a solid, maple sugar was easier to transport and store and could easily be reconstituted to syrup by adding water.

Hard maple sugar is produced by heating maple syrup to a temperature of 34°–38°F (19°–21°C) above the boiling point of water. At the lower end of this range, a softer product, such as the maple candy, can be produced, while boiling to the upper end is best for making larger blocks of hard sugar. The boiling point of water varies from region to region according to the weather, barometric pressure, and elevation above sea level, so producers should determine the boiling point of water before making any maple confections is important. Observe carefully as the syrup temperature begins to increase; it can get too hot very quickly as the desired temperature is approached. The froth that forms as the syrup boils should be skimmed off as necessary. As soon as the boiling syrup reaches the proper temperature remove it from the heat source and stir (**Figure 9.6**). Some maple producers allow the syrup to cool to 210°F (99°C) before stirring, although this is not necessary. Stirring continues until the solution begins to crystallize, stiffen, and become slightly opaque in appearance. At this point, it can be poured into molds. The sugar will solidify in the cooking container if stirring continues for too long or the contents of the cooking container are not promptly transferred to molds. If this occurs, adding some hot water and reheating to the proper temperature will allow reuse of the hardened sugar. Maple sugar will naturally absorb moisture when humidity levels are high. When atmospheric humidity is very low, maple sugar can dry out, become hard, and may have white spots appear on its surface. Maple sugar blocks should be stored in dry, airtight containers or other appropriate packages once the production process is complete.

FIGURE 9.6. When making block or cake sugar, remove the boiling syrup from the heat as soon as it reaches the proper temperature and stir vigorously.

Granulated Maple Sugar

Granulated maple sugar is the most versatile product that is made from maple syrup. Because it contains no available water, this product is totally shelf stable. It will not separate or mold. It can be stored indefinitely at room temperature and with proper packaging and moisture control will not lose its granular nature. It can be used in recipes as a replacement for brown or white sugar at a one-for-one exchange by volume or by weight. It can be reconstituted into maple syrup of any density or converted into any of the other maple confections. It can be an easier product for chefs or restaurants to use because of its storability and versatility. It can also be used as a topping on cereal, placed in sugar straws, or incorporated into any products or dishes that normally include other types of sugar to add flavor or sweetness. The flavor of many products is enhanced by using maple sugar in place of white sugar and is prized by many consumers for its natural and sustainable origin.

Granulated maple sugar is prepared by heating maple syrup until the temperature is 50°–70°F (27°–38°C) above the boiling point of water. When selecting syrups to be made into granulated sugar select or blend the syrup to be less than 2 percent invert sugar. Use the higher finishing temperature for syrups closer to the invert sugar while the lower temperature can be used with syrups with low invert sugar content. Syrups with invert sugar levels above 2 percent are likely to make partially granulated batches that will not finish properly. The glucose meter readings preferred when making granulated maple sugar is shown in **Table 9.3**.

Following cooking the syrup can then be either stirred immediately or allowed to cool to about 200°F (93°C) and then stirred. Due to the high temperature of the syrup when it is being handled and stirred, several precautions should be observed. The producer should wear protective gloves (with arm protection up to the elbow), protective apron, long pants, closed shoes, and eye protection.

Stirring can be done by hand or with a mechanical stirring machine. There are a couple of types of mechanical stirring machines used by maple producers. The most common is a commercial mixer (**Figure 9.7**). The mixer must have a slow range, and a beater with few cross bars will generally work best. Using a home-quality mixer is not recommended as the stress on the engine and drive is high after crystallization begins and often burns out a kitchen-quality machine with just a few uses. Some producers make maple sugar on the turntable and paddle machine commonly used to make maple cream. Unlike in maple cream production where the turntable machine stirs the chilled syrup, in granulated sugar processing the syrup is removed directly from cooking and poured into the turntable pan and immediately stirred. With the turntable it

TABLE 9.3 Preferred glucose meter readings for making granulated maple sugar.

Reading (mg/dL)	1:10 dilution invert %
20	0.4
30	0.6
40	0.8
50	1.0
60	1.2
70	1.4
80	1.6
90	1.8
100	2.0

Figure 9.7. Stirring can be accomplished with a commercial mixer.

is recommended that the outside paddle be moved away from the pan wall as the sugar will climb the paddle and spill over the side when it starts to granulate. Over-filling some turntable machines can cause them to stall when the sugar begins to crystallize and becomes very thick. Some producers have created a mixing impeller that they place in an electric drill and use this to stir the syrup with good success. Granulated sugar will ride up high in the pan as it is stirred. When the syrup crystallizes, the crystallization process can release a significant amount of heat, resulting in a burst of hot steam that can catch the person stirring the mix by surprise and cause burns if protective equipment is not being used. Stirring aggressively tends to make a finely textured, more powdery sugar; slow and even stirring tends to make a grainier sugar similar to common brown sugar. Stirring continues until most moisture is removed from the cooked syrup and only crumbly, granulated sugar remains.

Granulated maple sugar made with syrup higher in invert sugar tends to make a finer powdery sugar, while syrup low in invert sugar tends to make a grainier sugar. Products made with lighter, low invert syrup tend to be "drier" than those made with darker, higher invert syrup.

Sugar is generally sifted through a coarse screen to separate granules into consistent and convenient sizes for the producers market and consumers intended use. Stainless steel sieves with handles are available at restaurant supply stores. Various sizes of are commercially available or a ⅛-inch (3 millimeter) stainless steel hardware cloth can be used. Allowing the sugar to stand exposed to air in a moisture-controlled room and sifting a second time before packaging will reduce clumping after placed in packaging, but the finished sugar should be stored dry in airtight containers. Some producers sell the pebble sized clumps that don't pass through the sieve as specialty sugar for use in hot drinks such as coffee or hot chocolate—otherwise the clumps can be broken up in a blender. Clear packaging is ideal in that the consumer can see the product being purchased. One quart (1 liter) of syrup will yield about 2 pounds (1 kilogram) of granulated sugar.

The moisture content of the sugar as it is packaged can be important. The drier the sugar, the less likely it will end up becoming a hard lump. One way to check for the proper moisture content is to use the creep test. To conduct the creep test, you simply make a small pile of granulated sugar on a clean dry surface and then pour additional sugar on the top with a spoon. Sugar that still has too much moisture will not creep, but rather will cling together. Sugar that is very dry will also not creep but rather just slides down. Creeping begins to occur about the time the pile is an inch high. You will see the sugar begin to move (creep) down the slope with a thick fluid motion as if the crystals are crawling. If the sugar creeps it is still about 2 percent moisture and is more likely to have moisture-related problems. Increasing the finish temperature will create a drier sugar. If the moisture content is too high, maple granulated sugar hardens as remaining water evaporates when packaging is not properly sealed. If maple sugar does harden, let it stand overnight in a sealed jar with a damp paper towel. For a quick fix, heat the needed amount in a 200°F (93°C) oven for a few minutes or in a microwave oven on low for 1–2 minutes per cup. Softened maple sugar should be used immediately.

Maple Cream (Maple Spread, Maple Butter)

Maple cream is a value-added product made from pure maple syrup. Maple cream is often referred to as maple butter, incorrectly implying that dairy products are involved. Maple cream is made by further concentration of syrup by evaporation followed by rapid cooling and stirring. Finished maple cream should be light colored with a smooth, creamy texture. It is often spread on toast, bagels, muffins, pancakes, or doughnuts or combined with other bakery or confection products.

There are two types: traditional and shelf-stable maple cream. Producers can also choose to use a variety of available maple candy-cream machines (**Figure 9.5** center and right) or the hand method to perform the required agitation to crystallize the maple cream. Each method offers its own advantages and disadvantages. Primarily the faster, more aggressive the stirring, the smoother the cream will be.

TRADITIONAL MAPLE CREAM Generally, maple cream is made from golden or amber maple syrup; however, choosing a syrup based upon its color alone can result in poor quality maple cream or batch failures. Testing for invert level is recommended. The levels of invert sugar recommended in syrup for making traditional maple cream is between 0.5 and 4 percent with 1.5 percent suggested as ideal. When the invert sugar level is between 3 and 4 percent, use the higher suggested boiling temperatures to finish. **Table 9.4** shows the ideal reading on a glucose meter for traditional maple cream when using a 1 to 10 syrup dilution.

All cooking utensils, thermometers, and, in particular, stirring equipment used when making maple cream should be thoroughly washed in hot water and completely cleaned after each use to avoid crystals causing premature crystallization, contamination of future batches with bacteria and molds that can destroy the product quality, and cross-contamination with allergens in other products.

To prepare traditional maple cream/maple spread, heat syrup to a temperature of 22°–28°F (12°–15°C) above the boiling point of water. Boil to the higher temperature on rainy or humid days or when your invert sugar level is above 3 percent. If invert sugar is over 4 percent, a finish temperature even higher than the suggested range will likely be

TABLE 9.4 Reading on a glucose meter when using a 1 to 10 syrup dilution to make maple cream. Entire range shown is usable, grey area indicated is ideal range.

Reading (mg/dL)	1:10 dilution invert %
30	0.6
40	0.8
50	1.0
60	1.2
70	1.4
80	1.6
90	1.8
100	2.0
110	2.2
120	2.4
130	2.6
140	2.8
150	3.0
160	3.2
170	3.4
180	3.6
190	3.8
200	4.0

necessary. As soon as the syrup reaches the desired temperature, it should be removed from the heat and rapidly cooled. Spraying the surface of the batch with a fine water mist as soon as you turn off the heat may help to prevent crystals from forming on the surface or edges. The cooler the batch is when you commence stirring, the smoother the cream will be. A temperature in the 50°–60°F (10°–16°C) range works well if your cooling system can reduce the temperature to that level.

If using a paddle and turntable machine for stirring a single batch, cool the syrup in the pan that will be used during stirring. If stirring by hand, the syrup can be chilled and stirred in the boiling pan. Rapid cooling prevents premature crystallization. Cooling the cooked syrup in large shallow pans will facilitate quick cooling. Place the pans in refrigeration units or in troughs with circulating cold water and elevate the pans off the bottom (**Figure 9.8**). Small batches can be efficiently cooled in a sink partially filled with cold water. Ice may be added to the water to speed the process. The cooling syrup solution must be kept still—agitation will cause crystals to begin to form, resulting in a grainy maple spread. Cooling with the use of vacuum has the advantage of being rapid, and the whole batch will tend to have a uniform temperature. Cooling in a water bath can result in syrup cooling at the edges but remaining warm in the center. A non-contact infrared thermometer allows temperature readings to be made without pushing and pulling a thermometer into and out of the cooling syrup, which can initiate crystallization. The cooler the syrup before stirring the smaller the sugar crystals that form will be. Cooling to between 45°F and 55°F (7.2° and 12.8°C) will tend to make the finest cream that will maintain that quality longer in storage. Syrup cooled this much can be difficult to remove from the pan used for chilling into the equipment and make stirring by hand very difficult. Extremely cool syrup may be so thick that it stalls the machines used to stir it. For good results, the syrup should be cooled to 75°F (24°C) or below before stirring with any stirring equipment. Stirring the chilled syrup at higher temperatures tends to make a cream that will separate sooner. If cream will be consumed immediately, this problem is not as critical. If crystals should form on

Figure 9.8. A flowing cold water bath for cooling syrup.

the surface of the cooling solution, mist the surface lightly with clean water to create a thin layer of low-density syrup on the surface, which tends to dissolve the surface crystals and disperse any bubbles or foam.

Upon stirring chilled syrup will initially warm up and become more fluid. This is normal and happens as crystallization occurs. This phenomenon, called the "heat of crystallization" and is not due to the room being too warm or the stirring being too vigorous, but rather is a natural reaction to crystal formation. If using a stirring machine that has a paddle and turntable, adjust the paddles so that one gently scrapes the side of the revolving pan while the other is positioned about a third of the way from the edge of the pan. When the cream reaches the proper consistency, it can easily be scooped out as the pan turns by using a thumb-operated, 2-ounce portion control scoop.

While being stirred, the cooled syrup initially tends to become more fluid (less stiff) and glossy, then gradually becomes thicker and lighter in color before eventually turning a smooth paste-like consistency with a dull appearance. When this occurs, the crystallization process is complete enough for the cream to be transferred to appropriate containers. If stirring is halted too soon, the final product may become somewhat grainy due to the formation of larger crystals. Likewise, if the cooking process did not reach the correct temperature, some separation (presence of liquid syrup on top of the crystallized cream) can occur while in storage. If the cream separates, slight heating and stirring will bring it back together. Stirring the mixture too long may cause it to start to harden in the pan. If this occurs, add a *small* amount of hot water as a mist and stir to soften. If the syrup solution does harden in the pan, it can be immersed into a pan of hot water, heated with a heat gun, or placed in a warm oven until it can be easily stirred again. Another proven approach to handling the stiff maple cream is to let it stiffen and then store it tightly covered with plastic wrap overnight or in a Tupperware container. Then restir the next day, and it will loosen up. Adding water instead of syrup seems to cause less separation over time.

When making maple cream with the candy machine, start the worm drive, and then slowly add chilled syrup until the trough is about half full and stir until the syrup in the trough forms crystals. This takes anywhere from a few minutes to 20–40 minutes depending on many factors. Seeding the trough with some good quality maple cream can dramatically speed up the process. There will be a few minutes before the syrup warms from the heat of crystallization when it will tend to bunch up at the far end of the trough. If the trough contains too much syrup, it can easily overflow the sides near the far end. When the cream looks like finished cream, begin gradually adding more syrup to the trough from the pan or pig[5] and gradually fill jars or containers with finished cream by opening the end of the trough. One of the advantages of using the candy machine to make cream is that jars can be filled directly from the machine—hand scooping will not be necessary. This machine also allows multiple batches to be run without stopping because it continually adds more syrup to the trough.

When making maple cream with the gear pump maple cream machine, start the pump before you fill the top funnel with syrup. Also lightly mist the funnel and pump with warm water, and gradually add the chilled syrup to the cone at first, and until the syrup begins to circulate. Too much chilled syrup at once has been known to stall the pump or cause circuit breakers to pop. The aggressive stirring implemented by the machine tends to promote rapid crystallization, reducing processing time to just a few minutes and enabling canning to begin very soon. Continually scrape the interior of the funnel while you are filling containers so it will completely empty. The gear pump cream machine allows for continuous operation with multiple batches. When switching to an additional batch be sure that all the syrup gets into circulation as it is possible for some to stick in the funnel and get pumped directly into a jar without proper stirring. Do not try to rinse the funnel between batches as water will be

[5] A pan for heating, holding, and dispensing maple syrup and cream so named due to having one end funnel-shaped and thus roughly resembling the snout of a pig.

trapped and affect the density of the next batch. With this machine, containers can be quickly and easily filled without any scooping or extra handling. Be sure that all the syrup has moved through the pump and crystallized before you begin filling jars. Having the ability to adjust the speed of the gear pump allows for better control of the stirring and filling processes and can significantly reduce the amount of air introduced into the cream in the last few containers filled. Controlling gear pump speed can be accomplished by using three-phase electric, single-phase electronic controls, or a transmission between the motor and gear pump.

With any method of stirring, you can hasten crystallization by adding a small amount of "seed" crystal (previously made maple cream) to the chilled syrup immediately before or as stirring is started. The addition of at least 1 teaspoonful (4.2 grams) of seed for each gallon of cooked syrup provides small particles to serve as nuclei so crystals will form more rapidly. Overseeding doesn't negatively impact the process. Use seed from the smoothest maple cream you have available for best results.

Maple cream should be packaged in food-grade glass or plastic. Containers with wide mouths are best for easy filling and consumer use. Care must be taken to prevent air bubbles from forming during stirring or filling, especially when the maple spread is packaged in glass. Air bubbles are unpleasing in appearance and create the impression that the package is underweight. Separated syrup may collect in air pockets, further adding to a poor appearance.

Two problems may occur after production: spoilage and separation. During the first steps of cream production, maple syrup is heated to high temperatures, eliminating pathogenic microorganisms. However subsequent steps when syrup has cooled can lead to cream becoming contaminated. Unfortunately, despite the high levels of sugar in maple cream, some molds and yeast can grow slowly and result in spoilage of traditional maple cream. This growth occurs mostly on the surface and is highly temperature dependent. Shelf life can be less than 1 month for cream stored at room temperature and up to 6 months when it is refrigerated. For long-term storage (up to a year), traditional maple cream should be stored in a freezer to prevent mold and separation. These storage and handling requirements significantly reduce marketability, distribution, and availability and increase final cost of the product to the consumer.

SHELF-STABLE MAPLE CREAM AND POTASSIUM SORBATE At room temperature, traditional maple cream will separate over time. Mold growth on the surface is also likely. Research at the Cornell Food Venture Center working with maple producers Chuck Winship and Lyle Merle investigated ways to make maple cream stable for longer periods at both room temperature and when refrigerated.[6] The researchers found that increasing the concentration of invert sugar in the syrup used to make the spread helped prevent separation of maple cream/spread during storage. A mix of regular maple syrup and syrup treated with the enzyme invertase to break down sucrose into invert sugars can be used to make shelf-stable syrup. This enzyme-treated syrup is called "invert syrup."

Add 1 tablespoon (15 milliliters) of invertase (available from confectionary and baking supply sources) to convert 1 gallon (3.8 liters) of pure maple syrup to invert syrup. Invertase performs optimally at a temperature of 120°F (49°C). The syrup plus invertase should be held at 120°F (49°C) for 24–48 hours or can be held at room temperature for several days. The use of an oven or crockpot is ideal for this purpose. Heating over 160°F (71°C) will deactivate invertase and halt the conversion process. Syrup that has been inverted should be refrigerated until used.

Invert sugar concentration in the syrup mix to make shelf-stable maple spread should be 15–20 percent, a level that is not practical to test using blood glucose meters since these will typically give a "Hi" (indicating a value too high) reading on any syrup with an invert sugar level above 12 percent. Rather than checking the invert sugar level of each batch with a meter, use the mixing chart (**Table 9.5**)

[6] Padilla-Zakour, O.I., R.W. Worobo, K. Tandon, J. Churey, C. Winship and L. Merle. 2004. Shelf-life extension of maple cream. *Maple Syrup Digest*. June. pp. 20–31. https://mapleresearch.org/wp-content/uploads/0604maplecreamshelflife.pdf

TABLE 9.5 Maple spread batch sizes and amounts of ingredients needed to make them.

Final Batch Size	1 Gallon	2 Gallons	3 Gallons
Inverted Syrup*	21 oz.	42 oz.	64 oz.
Invertase needed	0.5 teaspoon	1 teaspoon	1.5 teaspoons
Regular Syrup	107 oz.	214 oz.	320 oz.

* Syrup should be inverted ahead of time. The amount shown is for ease of use and should be adjusted to suit the desired amount needed. Start stirring at 45°–50°F; final stirring temperature should be lower than 90°F.

to determine the proportions of ingredients needed to make a shelf-stable batch of the desired size. Inverted syrup should not be cooked as heating this type of syrup tends to impart an overly strong and generally undesirable flavor. Instead, cook regular syrup to a higher temperature. For example, to create a 3-gallon batch of maple spread, cook 2.5 gallons of regular syrup 36°–38°F (20°– 21°C) above the boiling point of water. In the pan for cooling, add this to ½ gallon of inverted syrup that has been warmed to 120°–160°F (49°–71°C). Warming will help to mix the two syrups without physically stirring—which should be avoided to prevent the start of crystallization. After the cooked regular syrup is poured into the inverted syrup, the mixture is moved to a cooling bath, sprayed with a fine mist of water, and allowed to cool to 40°–50°F (4.4°–10°C) overnight (typically). The ideal reading on a glucose meter for shelf-stable maple cream when using a 1 to 10 syrup dilution is shown in **Table 9.6**.

Any of the stirring methods and equipment listed under the traditional maple cream section above can be used as well with shelf-stable maple cream/spread. Once cooled, the mixture is stirred with a paddle machine, gear pump machine, or the Sunrise Sugar/Cream machine. To facilitate transfer to a machine, set the cooling pan in a hot water bath just long enough for the mixture to move a little—leaving it in too long will increase probability of separation. Stir until glossiness has faded. Start stirring at 45°–50°F (7.2°–10°C); final stirring temperature should be lower than 90°F (32°C). Since the spread will not set up hard in the stirring process, it can be jarred directly from the machine.

Extended–shelf-life maple cream will not develop mold or separate for six months when held at room temperature. For the benefit of consumers, it is recommended that maple spread containers be labeled "Best if used by" and dated six months after production as well as display the statement "Refrigerate after opening."

Powdered potassium sorbate, a food preservative available in wine making stores, can be added after the boiling stage to prevent mold growth in

TABLE 9.6 Reading on a glucose meter when using a 1 to 10 syrup dilution to make maple cream. Entire range shown is usable, grey area indicated is ideal range.

Reading (mg/dL)	1:10 dilution invert %
300	6.0
310	6.2
320	6.4
330	6.6
340	6.8
350	7.0
360	7.2
370	7.4
380	7.6
390	7.8
400	8.0
410	8.2
420	8.4
430	8.6
440	8.8

the manufacture of both traditional and shelf-stable maple cream. Potassium sorbate is added at the rate of 500 parts per million (ppm) based on volume to the concentrated cooled product prior to stirring. If the cooled product was produced by cooking 1 gallon (3.8 liters) of syrup, then add 0.3 teaspoons (1.4 milliliters) of potassium sorbate to the surface of the syrup after it has been concentrated by cooking.

In some jurisdictions invertase and potassium sorbate are considered "processing aids" and do not need to be declared on the maple cream/spread label. In other areas, these substances are not permitted in the manufacture of "pure" maple cream. Producers must check their own state or provincial food processing regulations regarding the use of these additives.

Fondant-Style Maple Candy

Maple fondant is a nougat-type candy produced in some areas of the maple region. While it is called "maple cream" in some locations because of its very fine crystalline structure, it should not be confused with what is commonly called "maple cream" or "maple butter." Maple fondant (heavy maple cream) is made in the same manner as maple cream except that the syrup is heated to 27°–29°F (15°–16°C) above the boiling point of water. The thickened syrup is then cooled to 100°F (38°C) and stirred as in making maple cream. Because there is less syrup left in the fondant than in maple cream, it will set up much more quickly at room temperature, forming a soft solid similar to cold butter. Remove the stiff cream from the pan in large chunks and knead it like heavy dough until it can be formed and cut into pieces of desired size. Small amounts can be dropped onto a clean, hard surface such as a marble slab or metal sheet. The fondant can also be packed into molds or dipped in chocolate. The invert sugar levels recommended for heavy maple cream are the same as those for traditional maple cream.

Molded (Soft) Sugar Candy

Molded sugar candy has become a popular maple value added product. Molded sugar is best made from syrup with an invert sugar level between 0 and 1.5 percent, ideally below 0.7 percent. Low invert sugar tends to produce large crystals, a grainy texture, and crystallization in the pan during cooling. Stirring at a lower temperature can help overcome this issue. High invert levels impede crystallization, resulting in candy that is very slow to harden or too soft. In either case, pieces can be difficult to remove from the molds and easily damaged when handled. Preferred glucose meter readings for making molded maple sugar are listed in **Table 9.7**.

To prepare molded maple sugar candy, heat syrup to 32°–34°F (18°–19°C) above the boiling point of water and begin stirring after it has cooled to an appropriate temperature for making candy with the desired degree of hardness. Results will vary depending upon the temperature at which stirring is initiated.

A relatively hard piece of molded sugar candy is generally desired for candy that will be crystal coated or packed into bulk packages. To achieve the proper degree of hardness, begin to stir the cooling syrup at around 200°F (93°C). Crystal coating softens the candy, making it more desirable to the

TABLE 9.7 Suitable and preferred (grey) glucose meter readings for making molded sugar candy.

Reading (mg/dL)	1:10 dilution invert %
25	0.5
30	0.6
35	0.7
40	0.8
45	0.9
50	1.0
55	1.1
60	1.2
65	1.3
70	1.4
75	1.5

consumer. Filling the molds with hotter syrup is easier since the syrup flows better. A medium-hard molded sugar candy can be made by stirring when the syrup temperature cools to 175°–190°F (79°–88°C). This medium hardness makes the molded sugar durable for handling, yet suitable for crystal coating and with a nice level of hardness for the consumer. Allowing the syrup to cool to less than 170°F (77°C) before stirring produces a softer molded sugar candy with more appeal to the customer. Softer candy is recommended when doing demonstrations where the candy will be consumed relatively soon such as at fairs or farmers markets. Softer candy is more easily squashed or broken in handling and more easily dissolved by attempts at crystal coating. Syrup may need to be cooler to form a crystal coating. Filling the molds to make softer candy is also more difficult. The syrup can be very thick and come out in globs that may need to be pressed into the molds with a table knife or putty knife and may lack detail from the molds. Using the water-jacketed maple candy-cream gear pump machine can help alleviate this problem. When syrup is cooled to around 150°F (66°C) before filling molds, there will be much less of a problem with white spots forming on fresh pieces than if molds are filled at a higher temperature.

Once syrup intended for candy making has been properly cooked, then cooled to the temperature that will allow it to reach the desired degree of hardness, it must be stirred either by hand with a spoon, a drill with an impeller, a high-speed mixer, the worm drive candy machine, or with the water-jacketed maple candy-cream gear pump machine. The lower the temperature of the syrup before stirring, the finer grained (smaller) the sugar crystals formed in the candy will be.

The syrup solution must be watched carefully during stirring. It will turn lighter in color and somewhat thicker and develop a creamy, opaque appearance as tiny sugar crystals form. These will increase in size in response to agitation of the syrup. Stirring should require only a few minutes. Experience will help inform the decision on the proper time to pour syrup into the molds. If the mixture is stirred too long, the thickened syrup will "set up" (harden) in the pan. It's best to err on the early side. A handheld bottle of warm water with a mist pump to lightly mist the mixture can help prevent sugar getting too hard in the trough of the candy machine or mixing pot. This will reliquefy the hard sugar and allow it to flow into the molds; however too much water can negatively impact the quality of the molded sugar.

While the sugar is still soft and plastic, pour or pack it into rubber or metal molds of different shapes. If packing the molds is necessary, use a wide-blade putty knife or spatula. When using a maple candy machine, the semi-liquid sugar can be run directly into the molds without packing or leveling. A rigid support under the rubber molds will prevent them from flexing. Place filled molds on a rack to thoroughly cool, after which individual pieces can be removed. The candy should set up in 20–45 minutes. Candies formed by pouring have an attractive glazed surface compared to those that are packed. Fresh maple candies can be stored under cool, dry conditions for a few weeks.

Method by hand, drill/impeller, or mixer When relatively small batches of maple sugar candy are made, syrup can be stirred by hand, with a drill with impeller, or with a high-speed mixer. Stirring can begin when the syrup has cooled to the temperature desired. Stir until crystallization is obvious, then pour the mix over the top of the mold and trowel the liquid immediately and quickly into the mold with a stainless-steel hand trowel.

Method using a worm drive candy machine Worm drive candy machines work well when making medium to large batches of maple sugar candy. The metal pan holding the boiled syrup is called a "pig" because of its overall shape and the pouring snout at the front. The syrup is sometimes boiled directly in the pig. If not, it is poured into the pig after reaching the proper temperature. The pig is placed on the candy machine shelf and tipped up into the locked position with the nose and trough valves shut. Open the pig nose valve slightly, allowing a half-inch or less of syrup to flow into the trough. Close the nose valve and turn on the motor so the stirring coil slowly rotates. After a few minutes the syrup in the trough will begin to crystallize, turning lighter in color and becoming thicker with a creamy, paste-like appearance. This change should take only a few minutes of stirring, typically under three.

Open the trough valve and allow the partially crystallized syrup to flow into your mold. Do not take too long to complete this step, otherwise the sugar will completely solidify in the nose of the trough. It is better to open the trough valve a bit too soon so only semi-crystallized sugar flows out for the first few molds. These pieces will generally harden in time. At the same time, crack open the nose valve of the pig to allow more syrup to slowly flow into the trough. The goal is to have a small amount of fresh hot syrup flow continuously from the pig into the trough, while, at the same time, the stirring coil is crystallizing the syrup, and liquid crystallized syrup flows out from the trough into the molds. Try to balance the flow of liquid from the pig into the trough with the flow out the trough into the molds, keeping the syrup being stirred only a ¼–½ inch (0.6–1.2 centimeters) deep. This continuous flow reduces the chance of sugar hardening into a solid mass in the trough. Should the syrup crystallize in the trough valve and stop the flow, a small knife can be used to quickly clear the clog (being careful to avoid the turning coil). Misting the trough with a light spray of warm water may cure a temporary clog of sugar that has hardened there—usually very little is needed. With experience it will be possible to make perfect candy in a smooth and continuous operation.

Method using a water-jacketed machine The water-jacketed gear pump candy-cream machine by Sunrise Metal Shop is a recent addition to the specialized equipment available for efficient production of maple sugar candy. With this unit the temperature of the funnel and piping is automatically controlled with a thermostatic heating element in the water jacket. Original versions of this machine should be upgraded from 1 to a 1.5 horsepower motor and converted from 110 to 220 volts to resolve issues with the gear pump stalling due to the thick mix.

This machine can be used a variety of ways to successfully make maple sugar candy—each approach with its own advantages and disadvantages. One of the advantages of the water jacket is that the candy can be stirred when it's cooler, which makes for very smooth, soft candy that melts in your mouth. If the stir temperature is kept near 150°F (66°C) the sugar pieces can be made without white spots forming during molding. Though the equipment comes with only a single spout for filling molds, it can be made more efficient by adding two- or four-head spouts for more rapid mold filling (**Figure 9.9**). Each producer will need to experiment with the right finish boiling temperature, the stir temperature, the water-jacket temperature, and the invert sugar levels to determine the best-quality pieces and longest shelf life. The invert sugar levels recommended for syrups used in making maple sugar candy in the candy-cream machine are the same as those for other stirring units.

Method directly in a candy-cream machine Maple syrup is cooked to 33°–35°F (0.6°–1.7°C) above the boiling point of water, cooled to about 150°F (66°C) with either air cooling, a water bath, or vacuum cooling. The cooled mix is then added to the funnel of the candy-cream machine and stirring is begun, with the water-jacket temperature held at 150°F (66°C). Stirring should continue until the concentrate becomes a very creamy, smooth blend. Once

FIGURE 9.9. A multi-head candy mold filler.

the concentrate in the funnel has this creamy look, it is ready to be placed in the molds.

Method using a soft fondant mixed with freshly cooked maple syrup With this method the water jacket of the candy machine is consistently held at 148°–152°F (64°–68°C) as experience has shown that going above this level causes the candy to develop an unacceptable number of white spots. A soft fondant, much like a very thick maple cream, is first created in the gear-pump cream machine by cooking the syrup to 26°–27°F (14.4°–15°C) above the boiling point of water and allowing it to sit in a cooler or refrigerator for 1–2 weeks. Then it is added at between 38°F and 42°F (3.3° and 5.6°C) to an equal weight of syrup cooked to 42°–43°F (23.3°–23.9°C) above the boiling point of water. The hot syrup and cold fondant are placed in the candy machine funnel and stirred in the funnel with a mobile commercial long-stem mixer to instantly bring the mix in the funnel to between 145°F and 150°F (63° and 66°C). When the mix looks smooth and creamy, the molds are filled from the candy machine. This method consistently makes sugar pieces with no white spots. Occasionally candy pieces may be too soft for handling—this problem can be avoided by cooking syrup to a slightly higher temperature or using syrup with an invert sugar level below 0.7 percent.

Method using premade fondant With this method, syrup is cooked to 33°–35°F (18.3°–19.4°C) above the boiling point of water and cooled to about 150°F (66°C) with either air cooling, a water bath, or vacuum cooling. This cooled syrup is stirred in either a commercial mixer or a turntable cream machine until it is crystalline, looking similar to cookie dough while maintaining a temperature of around 145°–150°F (63°–66°C) to reduce white spots. If a maple turntable cream machine is used instead of a commercial mixer, the mix will often pile up when it first crystalizes. This tendency can be managed with proper attention and altered paddle position. The fondant is then loaded into the funnel of the candy-cream machine where the water-jacket temperature is held a 150°F (66°C). The candy-cream machine will stir this cookie dough–like batch into a very creamy, smooth blend. Once the concentrate in the funnel has a creamy look, it is ready to be placed in the molds.

Careful attention to temperature must be observed at several points in the process: the finish temperature of the cooked syrup, the temperature going into the mixer, the finish temperature coming out of the commercial mixer, and the temperature of the water jacket on the candy-cream machine. Letting any of these get out of control will have negative effects on the resulting maple sugar pieces. Experience will help educate the producer on how closely to adhere to various limits. The creamy concentrated syrup often will mound up in the mold cells more than when filling molds using other methods. When these mounds overfill the molds, it can be useful to trowel over them to make the back of the pieces flat and return any excess to the funnel. It can also be helpful to slap the bottom of the rubber mold on a hard, flat surface to better lodge the sugar into the molds.

MAPLE CANDY ACCESSORIES Another area of labor efficiency is the maple mold popper. This is a grid of stainless-steel bars set up to match the spacing of the maple sugar pieces in the mold. When the mold is properly placed on the grid the mold can be emptied very quickly by pushing a rolling pin over the back of the mold allowing the pieces to fall through the grid into a waiting tray. This approach requires about a tenth of the time compared to that needed for removing the pieces by hand (**Figure 9.10**).

VACUUM COOLING The most recent development in efficiently making high-quality maple value-added candy and cream is cooling the fresh cooked maple syrup to stirring temperatures using vacuum. Tests have shown that syrup can be cooled from candy finishing temperatures of 24°–30°F (13.3°–16.7°C) above the boiling point of water to a stirring temperature of 150°F (66°C) in as little time as 45 seconds or as much as 6–8 minutes, depending on batch size, vacuum level, and the capacity of vacuum pump. One advantage is that vacuum cooling produces a homogenous temperature through the

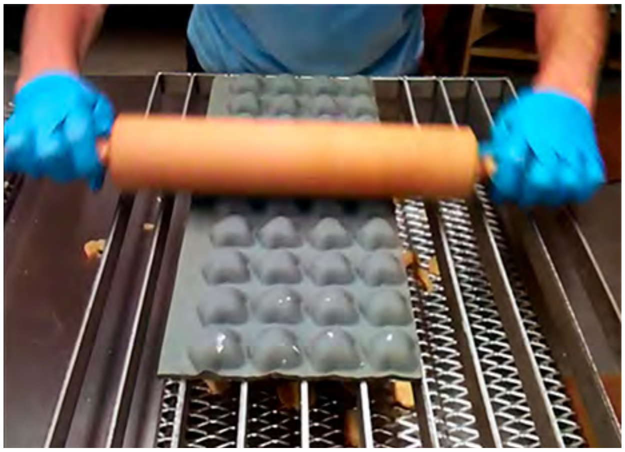


Figure 9.10. The maple sugar candy mold popper.

whole batch of syrup, unlike that of air- or water bath–cooled syrup, which tends to be cooler on the edges and warmer in the center of the pan unless cooled for an extended time. The second advantage of vacuum cooling is the reduced chance of crystal formation that can degrade the product quality. Third, the short cooling time allows for more of an assembly line production system, improving labor efficiency. Fourth, the heat of the cooling syrup is expelled into a condenser or out though the vacuum pump and vented outside, keeping the production area temperature and humidity lower than when open pans of hot syrup are cooling. When vacuum cooling, additional water is removed from the concentrated syrup so finishing temperature needs to be lowered or water added back to keep the final density the same. This can be accomplished easily by finishing the candy at 24°–30°F (13.3°–16.7°C) above the boiling point of water, but some experimentation may be necessary to determine proper conditions. A vacuum chamber designed to handle high vacuum levels is necessary. Vacuum cooling works very well with maple candy. When using vacuum cooling to make maple cream/spread the mix stops cooling at around 100°–118°F (38°–48°C), depending on the capacity of the vacuum pump. For the highest-quality cream, additional cooling is necessary.

CRYSTAL COATING MAPLE SUGAR CANDY Over time individual pieces of maple sugar candy tend to dry out. Coating them with a moisture-resistant shell made from crystalline sucrose can prevent this. If possible, sugar candy should not be crystal coated on humid or rainy days. If rescheduling is not possible, the work should be done in a humidity controlled room; otherwise pieces will not dry properly. If the sugar is not thoroughly dried after soaking, the coating can dissolve when it is packaged.

To make the crystallizing syrup to soak candies in, heat low invert sugar maple syrup to a boiling point 9.5°–11°F (5°–6°C) above the boiling point of water. This syrup should have a Brix value of 70°–73° at a temperature of 68°F (20°C). One gallon (3.8 liters) of standard-density syrup (66°Brix) will make 7 pints (3.3 liters) of crystallizing syrup soak (70°–73°Brix). The invert sugar level in syrup used to make the crystallizing soak should be between 0 and 1 percent—the lower the better (**Table 9.8**).

Set the hot soak solution aside to cool where it will not be jarred or shaken or transfer it immediately to pans that will be used to treat the maple sugar. To discourage crystals from forming on the surface of the syrup in the holding pan (caused by rapid cooling of the surface), cover the syrup with a piece of damp cheesecloth or paper (preferably the same kind used as a syrup prefilter, because it has a high wet strength). The cloth or paper must be in contact with the entire surface of the syrup. If crystals do form, they attach to this cover and can be removed along with the covering. The sugar crystals can be recovered by rinsing the cover in hot water, or the cover can be allowed to dry for a few days and the sugar crystals will peel off easily. Crystals left on the surface of the soak will stick to sugar pieces as they are being added or removed from the syrup soak, giving the candy an unacceptable appearance.

TABLE 9.8 Acceptable and preferred (grey) glucose meter readings for making the soak solution for crystal coated maple candy.

Reading (mg/dL)	1:10 dilution invert %
20	0.4
30	0.6
40	0.8
50	1.0

Some producers have success without covering the coating solution, and some lightly mist the surface with warm water to reduce the crystal formation.

The sugar pieces to be coated should be cool and dry (24 hours old). Pack the pieces loosely in a mesh basket or other container that will allow them to be completely submerged in the coating solution (**Figure 9.11**). The covering is removed from the cooled (90°–100°F/32°–38°C) crystallizing syrup soak solution, and any crystals remaining are skimmed off. Submerge the sugar pieces completely in the coating soak solution and place a fresh cover directly over the solution in contact with the entire surface of the coating solution. Leave the candies in the coating soak at a temperature of 65°–80°F (18°–27°C) for 6–12 hours or overnight if desired. Most of the crystal coating will form during the first few hours, so leaving candies soaking beyond 6 hours is not critical.

The most important factor related to crystal coating is the Brix value of the coating solution; coarse crystals will result if it is too high. Sugar precipitates out of the thick (over-density) syrup and grows on the surface of the maple sugar pieces. When the coating is sufficient, remove the paper or cloth cover, lift the wire basket of coated candy out of the soak solution, and allow it to drain. The outside of the candy will have a texture resembling that of fine sandpaper when sufficiently coated. A single batch of sugar-coating solution can be reused six times to eight times before the invert level gets too high to sufficiently coat the candy pieces. The used solution should be boiled again each time to maintain consistent density. Different approaches can be tried to determine what works best for each individual situation.

Figure 9.11. Mesh basket and coating solution pan.

After any liquid coating syrup has drained off (about 30 minutes), manually remove all remaining drops of syrup from each candy piece. Failure to do this results in areas having a glazed (noncrystalline) surface that is not effective as a moisture barrier, thus permitting the sugar to dry out during storage.

There are two ways to remove excess crystallizing syrup: either spread the sugar pieces out in a single layer on a clean sheet of paper and turn each piece over at intervals of 1–4 hours, or wipe each piece of sugar with a clean, slightly damp sponge or cloth to remove moist areas. Some producers have developed ways of turning large batches at a time between two screens. The batch is turned over and the new top removed until time for the next rotation. This system can save substantial labor. The air drying process takes place at room temperature, generally on racks. Complete drying usually requires 4–7 days, but the process can be accelerated using a fan and/or a dehumidifier. When dry, coated sugar candies are ready for packaging. Crystal-coated maple sugar has a relatively long shelf life of several months.

PACKAGING AND STORING MAPLE SUGAR CANDY

Molded sugar can absorb moisture or dry out depending on packaging and moisture conditions. Sugar that is not crystal coated may do either, depending on the humidity of the room in which it is stored. In a dry environment it will lose moisture. Oried-out areas appear as white spots and candy will become stone-like in hardness. If the humidity is high, the sugar will absorb moisture and damp areas or water droplets may appear on the surface. Such droplets are good sites for mold growth. The humidity of the packaging room and the candy storage area should be kept relatively low. Use a dehumidifier or air conditioner when the situation warrants.

Packages for molded maple sugar candies have two functions: to display the candies in as attractive a fashion as possible and to keep them in good condition (**Figure 9.12**). Boxes, individual wrappings, and paper candy cups can be purchased from

Figure 9.12. Maple sugar molds and packaging.

confectionary supply houses or maple equipment suppliers. Regulations generally require the net weight of the sugar pieces to be stated on the package. Consult local health officials or food production authorities for specific requirements.

The best type of wrapper for the outside of the sugar package should not be 100 percent moisture proof, but instead allow the sugar to breathe slightly but not totally dry out. Consider that the emulsion applied to cellophane to make it heat seal with a hot iron also makes the cellophane moisture proof. Some packers of maple confections facilitate longer storage by poking pinholes in the moisture-proof wrapper to permit a small amount of air exchange. Humidity and temperature will affect length of storage time. A cool storage temperature with 50–60 percent humidity works the best.

OTHER MAPLE PRODUCTS

Sugar-on-Snow

Sugar-on-snow is a perennial and traditional favorite of guests at sugarhouses during the sugaring season, particularly in eastern Canada and northern New England. Similar to the technique used to make maple cream, the production of this treat calls for heating syrup to 22°–27°F (12°–15°C) above the boiling point of water and then immediately (without stirring) pouring out ribbons of the hot candy onto clean, fresh snow[7] or crushed ice. The final syrup temperature for making sugar-on-snow depends on individual preference. Boil the syrup a few degrees hotter for a stiffer product, less for a chewy, softer product.

The syrup should stay on the surface and form a thick, chewy, taffy-like layer. Generally wooden sticks or utensils are provided for guests to twist or wrap the taffy around. Because the concentrated solution cools so quickly, there is not enough time for it to crystallize.

Rock Candy

Making rock candy is often unintentional as it tends to form in syrup that has been finished at higher than standard density. It is not generally considered a product of maple syrup since it is pure crystalline sucrose possessing little maple flavor. When maple syrup is finished at a density between 68.9° and 72°Brix (heated to 9°F/3°C above the boiling point of water) and the syrup is stored for a considerable length of time at room temperature or lower, a few well-defined crystals of sucrose (rock candy) appear. These will continue to increase in size if the syrup is left undisturbed for a long time. A length of string suspended in the supersaturated syrup solution can be used to "seed" rock sugar crystals, which are "harvested" by removing from the solution when they reach the desired size and hanging until dry.

Maple Snow Cones

This product is easy to prepare and is a favorite at many country fairs and festivals. Pour 1 ounce (28 grams) of dark maple syrup on a cupful of

[7] Weathered snow can contain substantial amounts of impurities (ash, invertebrates, bark, etc.). Only fresh snow collected from an area known to be free of contamination should be used. Regulations in some areas do not permit the use of snow.

ground or crushed ice (resembling snow) that has been compressed with a scoop and placed in a paper cone. A hand operated syrup pump (available at a restaurant supply source) that can be attached directly to the top of a standard syrup jug works best for consistent and convenient syrup dispensing.

Maple Cotton Candy

Maple cotton is a very popular value-added product. Maple cotton sells very well at fairs, craft shows, festivals, farmers markets, and open houses, such as Maple Weekend. The maple cotton mix is made by combining maple sugar with cane sugar. Blends of one part maple sugar to three parts cane sugar or one part maple sugar to four parts cane sugar are the most common. The mix rate does influence the economics of the product. Labor costs for making the cotton can vary greatly depending on the speed and capacity of the cotton machine used and the skill of the operator. Maple cotton is most commonly sold in a plastic bag sealed with a twist tie or an adhesive strip. Some maple producers market maple cotton in a semi-transparent plastic tub,[8] which can help to maintain cotton candy for months (shelf test container before any large production, some types of plastic are better than others). Understanding the weight and associated costs are an important part of setting price and selling the product.[9]

Weather conditions, in particular high humidity, can be a problem when making maple cotton. Invert sugars in the maple sugar tend to absorb water on humid days, making the cotton sticky and difficult to handle. On humid days, a mix with a lower proportion of maple will absorb less water, making it less sticky. Another approach is to use a mix of maple sugar with very low invert sugar on humid days. For those reasons, maple producers might consider having more than one mix available so they can use the mix best suited to the prevailing level of humidity.

When purchasing a cotton candy machine, producers should consider the setting in which they are producing and selling to determine the capabilities of the machine to purchase. If the site has a high volume, a large-capacity machine with higher voltage and amperage rating is desirable. If you will always be in the same location and have access to 220 volts and 20–30-amp circuits, very high capacity machines are available. If you anticipate moving the machine among a variety of locations, it is more practical to select a machine based on the capacity of the power sources that are likely to be available. When moving among various sites, finding a 220-volt source and a matching outlet is sure to be a problem. In this case, purchasing a cotton machine that operates on 110 voltage and 15 amps or less is suggested. Each machine should come with a full set of instructions. Follow the manufacturer's instructions carefully for regular cleaning.

Each state and province or even localities can have its own regulations regarding sales tax and health permits. Anytime maple cotton is made it should only be handled with sanitary food service gloves. A bubble or a display stand to protect bystanders from sugar ejected from the spinner should always be used. Airflow control leather straps on the machine can deliver a painful slap if the operator allows his or her hands to get too close to the spinner (**Figure 9.13**). These flow control leather straps should be twisted to pull air up and out of the collection pan. If twisted to force air

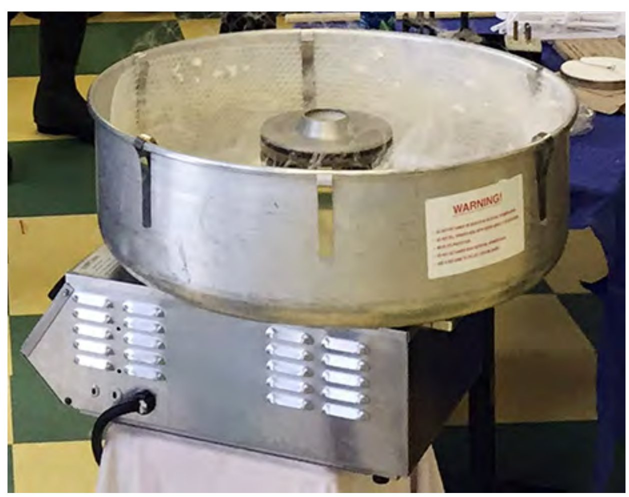


Figure 9.13. Maple cotton candy is typically a good seller at events. Care should be taken to avoid painful slaps from the rapidly-spinning leather straps on the central heating head.

[8] PTE plastic is not recommended for this use due to the relatively short shelf life of products stored in this type of container.

[9] For more information on pricing, see the *New York State Maple Confections Notebook*, 5th Edition, available at https://mapleresearch.org/pub/confection-notebook5th-edition-2/

down, the straps will force the cotton to the bottom of the pan, where it will be difficult to work with.

Granulated sugar with large crystals is preferred for making maple cotton. With granulated maple sugar, larger crystals are made by stirring when the syrup is the hottest and stirring slowly and continuously. Stirring when the concentrated syrup has partially cooled, stirring too aggressively, or having a high level of invert sugar in the syrup produces smaller crystals. Smaller crystal may slip through the heaters and grill of the spinner without melting, making grainy cotton and allowing a buildup of sugar around the edges of the cotton machine pan.

Maple Coated Nuts

Nuts to be maple coated can be stored in the freezer until you are ready to use them, but you should allow them to come to room temperature or above and to dry before attempting to coat them with syrup. If nuts are too cold, the syrup does not have sufficient time to grow good crystals or water can condense on the nuts, preventing the sugar from sticking completely. Using high-quality nuts makes a big difference in the quality and consistency of the coating. When using freshly roasted nuts, make sure they have had a couple of days for the oils to completely soak in.

> **WARNING**
>
> **Nuts pose a serious allergen problem for many people. Care must be taken to avoid cross-contamination of ingredients, mixing and storage containers, and equipment used to process foods containing allergens. See Chapter 14 for more details.**

Use 7 ounces (207 milliliters) of Dark Color Robust Flavor or Very Dark Color Strong Flavor Maple Syrup per pound (454 grams) of nuts. Darker syrups with a robust flavor work best with the intense flavor of most nuts. For batches of less than 2.5 pounds (1,130 grams) increase the syrup to 8 ounces (237 milliliters) per pound (454 grams). Syrup used to make maple coated nuts should have an invert sugar level of 1.5 percent or less (**Table 9.9**). Maple syrup with higher invert levels will not crystalize on the nuts or will tend to stay sticky. To optimize the level of invert sugar in the darker-colored syrups, you may need to blend with some lighter-colored, low invert syrup.

Cook the maple syrup to 32°–36°F (18°–20°C) above the boiling point of water if you plan to consume the coated nuts immediately or dry them in the oven for the longer shelf life. Cook the syrup to 40°–45°F (22°–25°C) above boiling water if you plan to consume the coated nuts within a few weeks but don't plan to dry them in the oven. The sugar will tend to break off the nuts more easily when higher syrup cooking temperatures are used, however, the application of more intense heat makes it possible to store the nuts for a short period without oven drying by cooking off the extra moisture in the sugar that might otherwise make the stored nuts soggy. To avoid damaging the nuts, use mixing equipment with paddles or hand stir with a spoon to combine the nuts with the syrup.

If using the simple one pan method, be sure to cook the syrup in a vessel with the capacity of five times the volume of syrup used. This will permit boiling the syrup and stirring in the nuts in a single pan. Stir the nuts and syrup mixture with a heavy-duty spoon and continue until the syrup crystallizes and coats the surface of the nuts. Stirring will be relatively easy at first, then become more difficult for a short time, and then easy again when crystallization is nearly complete. Stop stirring when completely crystallized and dry to the touch. Warming the tray or pan prior to adding the syrup to the nuts can help keep syrup from sticking to the pan.

Maple sugar nuts can be eaten immediately or packaged and stored for a couple of weeks. If storage will be longer or the coated nuts will be out for retail sales for an unknown amount of time, bake the finished coated nuts at 110°–130°F (43°–54°C) for 2–3 hours. This optional step extends coated nut shelf life by several months. Always store coated nuts in a sealed container. This procedure for coating nuts will work with most any kind of roasted nut.

Maple Lollipops

Mix equal parts maple syrup, white corn syrup, and cane sugar, stir, and heat to 295°F (146°C). Allow the mix to cool undisturbed to about 250°F (121°C), then pour into molds. If the mix is poured hotter than 250°F (121°C), the syrup will boil out of the molds. Sticks should be inserted before pouring. Amber Color Rich Flavor and Dark Color Robust Flavor Syrup work best. Molds must be made from materials that will withstand high temperatures. After the lollipops cool to room temperature they are easily removed from the molds. They should be wrapped immediately, or they will become sticky, especially when the humidity is high.

Maple Taffy

Taffy is a non-crystallized form of maple sugar. Heat syrup to a temperature of 23°–26°F (13°–14°C) above the boiling point of water. Allow the syrup to cool for a few minutes without disturbance, and then pour immediately into heat-resistant containers. A very light misting of water helps eliminate bubbles on the surface. Cool as quickly as possible by placing containers gently into a freezer; be careful not to agitate the syrup or crystals will form. Once allowed to warm up to room temperature, maple taffy can be eaten with a fork or wooden taffy spoon. Individual servings can be packaged in small plastic cups with snap-on covers. The taffy will last indefinitely when frozen.

Maple Jelly

Maple jelly is made with the addition of a jelling agent, such as CP Kelco's GENUGEL®, available from maple equipment dealers. Regular pectin used for other jellies will not work with maple syrup. GENUGEL is a food-grade, natural product, derived from ocean-grown plants. A tablespoon (15 milliliter) or less of GENUGEL is sufficient for a half gallon (1.9 liters) of syrup, which will yield seven 8-ounce (227 gram) jars of jelly. Whisk the GENUGEL into 2 cups (½ liter) or more of cool water. When completely dissolved, add to hot (but not boiling) maple syrup. Be sure to use a container with at least three times the volume of the amount of syrup used since it will foam extensively while boiling. Boil the mixture to 6°–7°F (4°C) above the boiling point of water, reduce heat, gently skim the surface, and ladle immediately into containers. Fill containers gently to prevent the formation of air bubbles in the jelly. A single pouring from a large cup works best. The amount of skimming required to remove surface foam will be reduced if the cooking container is kept covered with a lid as much as possible. The jelly sets quickly as it cools, so it is helpful to keep the heat low under the pan while bottling. Cap the filled containers and process in a hot water bath for ten minutes at 180°F (82°C). Some experimentation may be needed to find the right proportions for the desired thickness of jelly.

Maple Infusions and Barrel Aging of Syrup

A recent trend in the maple industry is the blending of different flavors into maple syrup via infusion or barrel aging. The concept of infusion is not to merely add an ingredient to maple syrup, but to transfer the essential flavor from the material into syrup. The use of infusions such as coffee, cinnamon, ginger, fall/pumpkin spice, smoke, vanilla, and elderberry is limited only by your imagination and tastebuds (**Figure 9.14**). Barrel aged maple products include rum, whiskey, rye, and bourbon varieties. Often the results are quite particular to the taster. Some maple producers consider infusions and barrel aged maple to be blasphemous; however, there is a good segment of the market that is attracted to these unique flavor combinations, and they represent a broadening and fast-growing market segment for maple syrup. Generally, these products cannot be labeled as "pure maple syrup."

Infusion is typically done by adding the flavoring agent to the syrup and allowing enough contact time for the flavor to permeate the syrup. This can be done either by adding a small amount of the product directly to syrup in storage or to maple syrup during packing. This process can take a fair amount of time, and the results, when packed in glass, are not always the most attractive. An alternative approach that is considered faster is to circulate syrup heated to 180°–190°F (82°–88°C) through a container (filter bag, funnel, or stainless mesh cage) holding the infusing agent. With this method, the

Figure 9.14. Maple syrup can be infused with several different flavors. Infusing means the product is no longer "pure" maple syrup and may require additional attention to pertinent food preparation and labelling regulations.

syrup is circulated until the desired flavor intensity is achieved. Often it is better to let the flavor build to a higher intensity than what you think it should be, and then to dilute back to a desired taste (customers can do this in their own home as well if a variety of intensity levels are desired in their household). This approach is especially desirable when infused syrup is to be used as an ingredient. Note that it is good to have several people taste the product as it nears the desired endpoint. Some of the infusions can overwhelm the tongue very quickly, so it is easy to undershoot or overshoot the desired endpoint. After infusion, syrup should be filtered and packed while hot. Small particles of infused material may settle on the bottom of the container and be unsightly unless good filtering is done. If the density of the syrup slightly exceeds the proper level, these particles will serve as nuclei for rapid crystal formation.

Barrel aging is performed by packing syrup into wooden barrel previously used to age alcoholic spirits. The idea is not to simply add alcohol to syrup. Rather, a barrel freshly emptied of its previous alcoholic contents is filled with hot syrup and allowed to sit for a time for the flavor of the wood (typically charred white oak) and any minute amount of residual alcohol to imbue the syrup with flavor (**Figure 9.15**). The process requires several months for a small barrel (5–10 gallons/23–44 liters) to a year or more for a larger barrel. Typically, the barrel is stored in a cool place and kept moist with a periodic light spray of water to keep the barrel staves from drying and opening up (a tub to contain syrup seepage or other secondary means of containment is recommended in case this happens). Again,

Figure 9.15. Aging maple syrup in barrels that previously contained various spirits is becoming popular. (TAPPED MAPLE SYRUP/LEAH KNIGHTS CREATIVE)

allowing the flavor to build to a higher intensity than desired and blending back to a target level is the favored approach. Once opened, the syrup should be heated to packing temperatures, filtered, and packed. Boiling of syrup should be avoided as doing so will reduce the flavor intensity acquired during the aging process. Sometimes a barrel can be used for aging syrup a second time; however, a much longer period will be required to achieve the desired flavor transfer.

Other Value-Added Products

Other value-added products are limited only by your imagination. Examples include

- maple ice cream,
- maple-covered popcorn,
- maple fudge,
- maple vinegar,
- maple chocolate,
- maple meat additives,
- maple wines and beers,
- maple soft drinks,
- maple wafer cookies,
- maple kombucha,
- maple milk,
- maple mustards and barbecue sauces,
- maple marshmallows,
- maple granola,
- maple frosting,
- high-flavored maple sugar.

Experimentation may be needed, but you get to try the results.

Most maple cookbooks offer a wide variety of suggestions and recipes for other value-added maple products. Anywhere sugar is used maple can be used. Darker syrup with a strong flavor is preferred for many products. Experiment and remember there are no failures; even the mistakes can be eaten—and they taste good!

Tips for Success with Maple Confections

- Always check the boiling point of water before starting to make any confection. Water boils at a different temperature depending on the specific location above sea level and current weather conditions. The boiling point of water will be lower at higher elevations, and it will be lower on days with lower atmospheric pressure.
- Use caution—boiling syrup is very hot and sticky and if it lands on you or others can inflict severe burns.
- Watch the boiling syrup closely as the temperature increases. Temperature will increase very quickly as syrup density increases, resulting in scorched syrup or a fire.
- When using a mechanical candy or cream machine, follow the manufacturer's instructions carefully; always be aware of moving parts.
- Always use the best-quality, freshest, and best-flavored of syrup available.
- Follow recommended food sanitation procedures for maintaining clean molds, pans, and utensils.
- Clear, sunny days with high atmospheric pressure tend to be best for making confections. On rainy or humid days, boiling the syrup about 1 degree hotter might work better.
- After syrup has reached its proper temperature and is cooling, do not disturb it. Any movement may cause large crystals to form. Don't even remove the thermometer at this stage.
- Boiling maple syrup will foam extensively. Watch the pan closely when it first begins to boil and be prepared to remove it from the heat or stir it to keep the foam down. Be sure to add a nonallergenic defoamer. It is important that the boiling pan should have a minimum capacity of four times the volume of syrup being boiled.
- Failed batches of sugar or candy can be used as a sweetener or added to more boiling syrup for another batch.
- Never use soap to wash rubber candy molds because the soap can impart off-flavors.
- Don't be afraid to experiment with temperatures. Experienced producers

can make good candy and cream in any weather. A difference of a degree or two in temperature during heating or cooling can determine whether a particular confection can successfully be produced under a particular set of weather conditions.

- Likewise, different syrup lots may produce the identical desired result when boiled to different temperatures. The key to success is to experiment to find out what temperature results in the best product.
- When candy making with a machine, place each rubber mold on a small tray or small sheet of plywood, and stack them next to the candy machine. By doing so the time delay in filling the molds will be minimized and candy can be produced in a smooth continuous manner.
- A spray bottle of water is very helpful for discouraging the formation of crystals on the surface of the cooling syrup and the sides of the cooling pan when making maple cream. Lightly mist the surface of the syrup and the edges of the pan when the cream pan is first placed in the cold water bath.
- As experience is gained in making maple cream with a machine, carefully watch the thickness of the mixture as it is stirred. If it starts to get too thick, a bit of hot water can be added to the syrup or you can apply medium heat to the edge of the pan as it turns. For example, a heat lamp suspended over the rotating pan can be used to soften the cream. If this technique is used, be sure to use a shatterproof bulb in the heat lamp. Such bulbs are available from a restaurant supply business. Other producers have successfully used an electric heat gun as a heat source.
- If maple cream has been stirred for a long time and hasn't started to set up, turn off the machine for about two minutes and allow the contents to set undisturbed. Then turn the machine back on and it will usually start to set up quickly. Use this technique very carefully because too much time at rest may cause the cream to quickly set into one firm mass.
- Pay strict attention to use of utensils, cookware, and bowls when using allergens (nuts, milk, etc.) to avoid cross-contamination of different batches.

CHAPTER 10

Marketing Maple Products

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CHAPTER CONTENTS

Perkins, T.D., R.B. Heiligmann, M.R. Koelling, and A.K. van den Berg (Editors). 2022. *North American Maple Syrup Producers Manual. Third Edition.* The University of Vermont and the North American Maple Syrup Council, Burlington, Vermont. www.mapleresearch.org/manual/

INTRODUCTION

Maple syrup is one of the oldest agricultural products produced in North America. In the years following European settlement, it was produced on family farms, primarily for personal consumption. Over time the production of maple syrup and maple-derived products has become a nearly full-time business endeavor for many individuals. As production surpassed what was needed for personal consumption, marketing and sales became a necessary component of the production process. Originally, most maple syrup was processed to maple sugar, and this product, principally in block form, was the primary product bartered or sold to wholesale and retail markets. Today the demand for pure maple syrup, maple sugar, and a wide variety of other maple products persists. Maple syrup has many attributes that make it an attractive and profitable product. It is natural, great tasting, and versatile and represents a historic North American tradition.

Traditionally and historically, marketing efforts for pure maple syrup were largely concentrated within the maple production region, where competition among producers for market share is often intense. However, increased supply and increased consumer acceptance is prompting expanded marketing outside this region and indeed, globally. Promotional efforts to increase consumer awareness and knowledge of maple products are an essential part of the marketing process for pure maple products, especially outside of the areas of production. Consumer education is a critical step in development and expansion of maple product markets.

Marketing strategies are most effective when customized to each maple producing operation and the targeted consumer. This chapter contains information intended to help producers increase sales and enhance promotional communications of their maple operation by establishing goals and effective marketing plans.

It is important to note that marketing and promotion come with added costs. Producers need to keep track of and factor in these costs when making decisions about how best to sell their syrup and other maple products. There is little point in making and selling a great product if the income it generates is less than the cost of producing and marketing it.

ESTABLISHING GOALS

The priorities of maple producers can be quite varied. For many small producers, the most important goal is to enjoy the experience of making maple products and the opportunity to involve family and friends. The satisfaction they derive from making small quantities of maple syrup for their own use and as gifts for family and friends tends to outweigh the financial rewards, which are generally viewed as being a bonus rather than the principal objective. For others, income from production is a high priority and directly influences the amount of effort put into promotion as well as the manner of marketing. The goals of different producers are influenced by the amount of time available to devote to the maple operation, personal preferences, the location and availability of the maple resource, access to labor and financial resources, and the size of the operation.

Time Constraints

Most maple producers have numerous demands on their time in addition to those involved in the production of maple syrup. These include other employment, family commitments, and social obligations that often make it difficult to dedicate the time necessary for extensive promotion and marketing efforts. To larger producers who lack the time required to develop retail packaging and marketing efforts, selling their syrup in bulk may seem like a better option.

Although more time and effort are required to package and market maple products for the retail market, the potential for greater profits resulting from a higher sales price is increased by a well-planned and well-executed marketing strategy. Producers may choose to take the time necessary for wholesale or retail sales if they can be confident that doing so will increase sales revenues enough to offset the costs of marketing.

Personal Preferences

The personal preferences of maple producers will be reflected in the goals and structure of their business. Producers who enjoy meeting and working with others may be well suited to retail sales or dealing with wholesale customers. Producers who prefer limited distractions during production or who have less desire to interact with people may choose to focus on wholesale, bulk, or mail order retail sales rather than attracting customers to their sugarhouse or sales location. It is important to acknowledge that financial returns may be significantly lower where bulk sales are emphasized. An alternative to focusing on this market may be to incorporate a person into your business whose background will complement your production experience, but who has the skills to develop effective retail and wholesale sale procedures.

Location

Location is an important consideration when establishing a new maple operation. Producers who are situated close to large population centers or on well-traveled routes have an advantage with respect to promotion and attracting customers to their retail business (**Figure 10.1**). A few well-placed signs and targeted advertising can produce significant results. Little additional effort may be required to inform potential consumers of your location and what products are available for purchase. However, producers in rural areas that are distant from population centers may have to rely on more intensive advertising or other creative marketing strategies to attract customers. In some instances, expanding their customer base may require establishing a separate location to develop a retail business with its own clientele. The success of this new business will be influenced by its distance from wholesale markets and the availability of transportation alternatives for transporting bulk maple products.

Figure 10.1. Producers located on well-traveled routes, in tourist areas, or close to large population centers have an advantage with respect to attracting customers to their business.

In addition to location, other aspects such as quality of roads, availability of adequate parking, and attractiveness of production and sales facilities are important considerations when contemplating the establishment of either a retail or wholesale maple business. One other aspect should be mentioned—make certain that local zoning regulations related to type of business, method of sales, traffic concerns, and conformity of signs have been checked and appropriate permits have been obtained to ensure that requirements have been met.

Size of Operation and Labor Capacity

Marketing methods and strategies are related to the size of the operation and labor capacity. If only small quantities of syrup are produced, most of it will probably be sold locally to neighbors and others who visit the operation during the maple season. Owner-operators are likely to volunteer time to both production and marketing activities that can impact market channel sales strategies. Small quantities of consistent product are more appropriate for direct sales to consumers and less suitable as a source of business-to-business wholesale sales. Enterprises with larger quantities of sellable product can consider different and potential mixed marketing methods. With a larger supply of goods, developing a marketing strategy before the crop is produced becomes essential. As with many other agricultural commodities, simply having a quantity of product available does not ensure there will be a market ready to receive it. Producers who intend to sell most of their crop wholesale need to develop contacts and pre-season agreements with wholesale buyers. At larger scales of production, the size of the business and sales revenues may support the hiring of additional employees to conduct marketing activities. While the addition of paid employees increases costs, it also enables a specialized individual to focus (at least for part of the year) on promotion and sales efforts that may exceed the capacity of the business owner alone.

A key feature of establishing a sustainable marketing strategy is identifying the capacity of the current owner and the business as a whole to execute marketing activities. Owner-operators must discern their capacity for marketing activity, their intention for income generation from the enterprise, and their ability to manage employees. Similarly, the scale of production and the overall sales potential contributing to business finances will determine if and when owner-operator activities will shift to paid employees. It is important to be able to continually fulfill the demand a developed market generates. If substantial efforts are put into developing a brand and establishing a customer base, it is essential that adequate supplies of maple products be available to meet the demand. This may require the purchase of sap, syrup, and other maple products from outside sources during poor maple seasons and when demand for your products grows.

MARKETING AND PROMOTION—WHAT ARE THE DIFFERENCES?

Marketing consists of all the activities carried out by a business to promote and sell its products. As identified in **Table 10.1**, it encompasses all aspects of the selling process.

Promotion is an important component of marketing. The primary objective of promotion is to communicate information about a product in such a manner that consumers are persuaded to purchase it. Four different types of promotion strategies that could be adopted by maple producers to promote their business are described in the **Table 10.2**.

TABLE 10.1 Aspects of marketing.

Marketing Aspect	Purpose
Market Research	Evaluate consumers' needs and preferences
Product Presentation	Tailor products to correspond with marketing objectives and consumer preferences (e.g., value-added products, types of containers, and packaging)
Promotion	Increase awareness of the product and likelihood of purchase
Pricing	Ensure profits for producer and meet with consumer perceptions of value
Distribution	Select and choose how the product is made available to customers (e.g., retail location, internet, wholesale, bulk)

Need for Marketing and Promotion

Effective marketing and promotion are among the most important keys to operating a successful business. Obviously, producing and maintaining an adequate supply of high-value products that appeal to consumers is fundamental. However, if these products are not effectively marketed, the business is not likely to succeed. Promotion and marketing are useful as tools to ensure that the product can be sold in a reasonable length of time for a profit that will justify the effort and expenses incurred.

A producer who enjoys making syrup but chooses to avoid the business side of the operation may be realizing only a portion of its potential profitability.

The effort put into promotion and marketing should be proportional to the need. Greater effort may be required by a new business to attract new customers. Promoting maple products is beneficial not only to the individual producer but also to the entire industry if an increase in consumer purchases is achieved. Cooperative efforts and the pooling of resources by associations or groups of producers may make it easier to reach more people. Promotion efforts by state, provincial, and local maple syrup producers' associations can also be very effective.

TABLE 10.2 Types of promotion strategies.

Promotion Strategy	Purpose
Advertising	Purchased presentation of information in a public medium (e.g., newspaper ad) to draw favorable attention to the product or business
Sales Promotions	Direct encouragement to customers to make a purchase (e.g., coupons or special deals)
Personal Selling	Direct personal interaction between salesperson and customer in which product information is conveyed
Publicity	Non-purchased communication that draws attention to the business or product (e.g., coverage on local television of an event at a sugarbush)

MARKET RESEARCH

Value of Market Research

Customers are essential to any successful business. In developing an effective marketing plan the producer/seller should attempt to understand potential consumers and what aspects and characteristics of his or her product influence their decision to purchase. The principal purposes of market research are to identify:

- potential customers;
- effective methods that make potential customers aware of the product; and
- how the desires of customers can be satisfied most effectively.

Primary and secondary market research sources may be needed at different times. Primary market research is the collection of your own information and is described further in this chapter. Secondary research refers to existing research conducted and published by other sources. There are an increasing number of sources of consumer market research on maple products conducted by universities and agencies that can inform aspects of a business marketing plan.[1]

Market research is particularly important when new businesses are being contemplated and established. By identifying some of the characteristics and locations of potential customers, dollars allocated to marketing efforts can be spent most effectively. One component of market research is observing the competition and attempting to identify what is and is not effective in their advertising strategies. If local competition is intense, it may be necessary to promote your products in less saturated markets or to create a new niche market for the specific products available for sale.

Market research can also be helpful to a well-established business. The current customer base may be characterized by informal observations and conversations with customers or by conducting a simple survey. This information can be used to assess the effectiveness of existing marketing strategies and to identify new target markets that could prove profitable.

Consumer Surveys and Trends

Conducting a consumer survey may be a very helpful component of market research. If a survey is to be conducted, consider the following suggestions that have often proven successful. The survey instrument should be designed so meaningful information will be obtained, and questions presented so they are clearly understood by the consumer. Response will be better if the survey is brief and easy to complete (multiple choice as opposed to written responses). Offering an incentive (e.g., discount coupon) for people to participate may also be helpful. Sometimes entering the names of all respondents in a drawing for a significant prize can also be helpful in obtaining participation. Collecting

[1] https://agriculture.vermont.gov/sites/agriculture/files/documents/AgDevReports/Maple%20Syrup%20Market%20Research%20Report.pdf,
https://maplemaps.gitlab.io/,
https://www.youtube.com/watch?v=erII6OpcaXI,
https://www.uvm.edu/extension/agriculture/maple/bizmodules/sites/default/files/imce/uploads/FBFS047-Maple%20Market%20Insight.pdf

the names and addresses of surveyed individuals is an efficient way to begin creating a mailing list.

A basic consumer survey may include questions pertaining to the following type of information:

- Age group
- Where they live
- How did they find out about your business
- Family status
- Reasons for purchase
- Amount and frequency of purchases
- Products purchased
- Suggestions
- Other questions specific to your products or market

After collecting a significant number of survey responses, the information obtained can be studied for characteristics and desires of customers. This will be helpful in making decisions related to future product production, promotion, and marketing activities. Results from industry and/or government-sponsored surveys may also be available in some areas. These results can also provide useful information for future marketing strategies.

New market surveys and tools to understand them are being introduced at the time of writing of this manual. Obviously, the market for each type of product and each region will vary considerably but searching out these tools and using them to develop a better and deeper understanding of the market can be of tremendous value.

Market Segments

A market segment is a group of consumers that have common characteristics or attributes that make them unique. The grouping may be made based on age, income level, gender, interests, or purchasing criteria and trends. A market segment could be a group of people who are health conscious, traveling, or retired; own large businesses; have young families; or share any other common characteristics. By focusing marketing efforts on specific market segments, strategies can be adapted accordingly. For example, if the decision is made to focus on individuals who are particularly health conscious, it may be advantageous to emphasize the natural, additive-free characteristics of pure maple products. If the decision is made to target the tourist market, attractive souvenir-type containers may be more appropriate. Once the specific market segments have been identified, appropriate promotion, marketing, and packaging strategies for the products that are offered can be adopted.

It is possible to develop market segments unique to the products that are produced and available. As an example, if a significant amount of high-quality dark syrup is produced, its use as an ingredient in cooking and baking could be promoted. Identifying a group of individual consumers as well as commercial accounts (e.g., bakeries, restaurants) that would be interested in purchasing and using this particular product could be pursued.

PRODUCT PRESENTATION

Packaging is an important component in marketing pure maple syrup and related maple products. For maple syrup, containers are available in a variety of different styles, sizes, and materials. Each type, style, and size of container has attributes that are used to identify and enhance the appearance and appeal of the product. A savvy maple retailer will offer maple syrup in a variety of sizes and styles of containers. It is a mistake to package and offer maple syrup in only a few containers that do not vary significantly in size.

Containers should be chosen that present the product most favorably and in a manner that suits the needs of the customer. Large, simple containers such as half-gallon or gallon cans or jugs are preferred by customers who buy larger amounts of syrup for personal consumption. However, smaller, attractive plastic or glass containers are well suited for gift giving and souvenirs. Consumers will sometimes buy an attractive bottle simply because of the appeal of the container (**Figure 10.2**). Offering a variety of containers will allow the desires and demands of consumers to be met. Additionally, some types of packaging are better suited for mail order and commercial shipments due to their weight and resistance to breakage. Recyclable containers are important to many because of environmental concerns. Finally,

Figure 10.2. Consumers will sometimes buy an attractive bottle simply because of the appeal of the container.

some people enjoy the comfort of familiarity. Displaying your products in mix of unique and traditional packaging will make it easier for consumers to quickly find your product on the shelf, thus facilitating repeat business.

BENEFIT OF VALUE-ADDED PRODUCTS

Maple syrup is a very desirable and salable product, and much is sold directly to consumers. Since the needs of consumers vary, most producers offer syrup in containers of various sizes and shapes. The price charged to consumers reflects not only the quantity of syrup (smaller-sized containers are priced proportionally higher than larger containers on a per unit of syrup volume basis), but also the style and type of container or package. By packaging syrup in smaller containers, producers can obtain a higher total price for a given quantity of syrup than if it were sold only in a larger size, such as a 1-gallon container.

Processing maple syrup into secondary products, such as maple sugar, maple candy, or maple butter or cream, can also significantly increase total returns. While additional facilities, equipment, and labor are required, the increase in the price received when the total value of the additional effort required is factored in is significant and adds to total income received from the maple enterprise. Refer to **Chapter 9** of this manual for information regarding the production and handling of a variety of "value-added" maple products.

PROMOTION

The objective of promotion is to increase awareness among potential consumers of a business and the products offered and thus increase sales. There are many marketing strategies that may be effective in accomplishing this. Each business is unique. Who the customers are and what is important to them will influence what marketing techniques will succeed. Market channels (direct sales versus business-to-business) will impact the type and methods of communication used to reach commercial buyers, chefs, and household consumers.

Developing Effective Marketing and Promotional Strategies

The following are examples of factors that have been identified as important. They should be considered when striving to develop effective marketing strategies for promotion of maple products.

Continuity of Supply—To be identified as a dependable source of pure maple products, producers need to make sure that every product they sell is available for purchase all year long. Doing so may require the purchase of additional syrup if a "short season" occurs. The purchase of sap is also a successful strategy for producers that have developed a growing market for their products and have the physical capacity to process more syrup. Some producers may object to this, preferring to sell only what they produce, and when that is sold out, sales for the year cease. Ideally, many producers would like to sell out of their crop of syrup just before the following sugar season begins and not have to purchase syrup to maintain their product inventory. However, the professional image of a successful retail establishment will be enhanced when a complete product inventory is available throughout the year and consumers associate both quality and dependability with the business.

Environmental Awareness—Many consumers of pure maple are environmentally conscious. This is reflected in different ways from an increased desire to maintain forests and other features of the landscape to using products that can be readily recycled. Maple producers are in a good position to identify themselves and their operation as "environmentally friendly." Research has enabled producers to increase yields while also adopting sustainable tapping methods that minimize harm to individual trees.

To further increase consumer awareness of the positive environmental aspects of pure maple products, some producers may wish to consider joining organizations that identify and promote environmentally friendly and organically produced products. These include but are not limited to seal of quality programs and forest certification programs. Producers should bear in mind the importance of verifying the authenticity of such organizations before committing to membership.

Some producers may wish to incorporate ecotourism into the business. The establishment of walking trails through the sugarbush and the hosting and conducting of ecology-focused seminars may attract certain groups of consumers, while promoting environmental awareness and a favorable business image.

Organic and bird-friendly certifications can appeal to some types of consumers (**Figure 10.3**). These do require some effort to obtain but doing so may open more market avenues for some producers if combined with the development and dissemination of appropriate public relations and marketing information. Similarly, climate-based arguments favorable to maple production in terms of enhanced carbon capture and storage is a rapidly developing field worth watching and taking advantage of in the marketplace.

Diet and Nutrition—Pure maple syrup is well positioned in a marketplace that now recognizes more value for alternative and lightly processed sweeteners. Consumers are increasingly aware of their diet and its impact on health and nutrition.

Figure 10.3. Various certifications (bird-friendly, organic) or locally made syrup may have special appeal to some customers and allow for a premium price to be charged.

Maple products have a reputation for being natural and lightly processed: many pure products are produced by simply exposing to maple sap to heat and removing water. No preservatives are added to the sap, and aside from reverse osmosis (if used), boiling, and filtering, no other processing is necessary to produce the final product. These attributes and characteristics can be used to promote the value of pure maple products to nutrition-conscious consumers.

In recent years, advances in food chemistry and nutritional research are developing a better picture of the physiochemical profile of maple sap, sugar, and syrup that goes beyond flavor. However, maple promoters are encouraged to remember they are promoting a sugar-based sweetener and that exaggerating health claims without evidence is a risky marketing decision. Nevertheless, consumer concerns about the prevalence of high fructose corn syrup in the modern diet and the negative aspects of other highly processed sweeteners have created an opportunity to present maple syrup and maple sugar as appealing alternatives.

Maple Syrup Grades—Although production processes are the same, the grade of maple syrup produced throughout the season varies. The emphasis placed on grading is different throughout the maple region, with grading being mandatory in some areas and voluntary in others. In areas where grading is widely recognized and promoted (even if grading is not mandatory), it is recommended that producers grade at least a portion of the syrup that is offered for sale. Preferences among consumers for different grades of syrup vary since flavor varies between the grades. Offering syrup that is graded allows customers to consistently purchase syrup that matches their preference, resulting in a satisfied customer. Although it was once common practice to charge less for darker syrup in some regions, there is no economic justification or other good reason for this price differential since the production practices and costs for all syrup are essentially the same for the producer, and many consumers prefer darker syrup.

Food Safety—Pure maple syrup and derived maple products are food products. As such it is essential that all production practices; processing facilities; and packaging, storage, and display areas be designed and maintained to avoid compromising any aspect of quality, cleanliness, or safety. It is crucial that consumers have no cause for concern regarding the safety of maple products offered for sale. All production facilities and sales areas must be cleaned regularly and maintained in an attractive condition. All potential sources of contamination should be identified, and efforts undertaken to minimize or eliminate any facility or production practice that could result in compromising quality and/or safety. Producers should familiarize themselves with food safety regulations, compliance requirements, and voluntary certification programs. Adoption of best practices is not only a matter of legal compliance, where required, but also an opportunity to communicate the integrity of your process and products to potential customers.

Emotions/Traditions—Pure maple syrup is a very "traditional" product. The production of maple syrup is one of the oldest agricultural enterprises in North America. Although the methods and equipment used for sap collection and processing have changed, the process used for transforming sap into syrup remains the same. The "maple syrup tradition" can be used in the promotion and marketing of pure maple products as a "comfort" food. Many adults, especially those who reside in the maple production region of North America, have fond memories of sugarbushes and "sugaring" when they were younger. Drawing attention to the nostalgic aspects of maple syrup production is an excellent approach to attracting customers who long for simpler times. Introducing younger potential customers to pure maple products via social media and through tasting activities takes time but is often effective. Establishing and promoting a family atmosphere at the sugarbush or sugarhouse with traditional activities such as sugar-on-snow parties, sleigh rides, and weekend tours may help attract people to the business and encourage purchases of maple products.

Population Demographics—Primary and secondary research sources provide information that can help identify potential buyers and demographic trends within a targeted market area. Many traditional and rural maple-producing regions in North America are experiencing demographic trends such as aging populations and declining population numbers. Other locales are seeing growth in younger age groups and increased discretionary spending linked to factors such as income, household size, age, and educational background. Maple sellers should consider these differences in demographics when offering a customer experience at a specific retail location as opposed to creating a communications campaign that seeks to recruit specific consumer segments to visit in person or purchase product online. The purchasing preferences revealed in various customer profiles will help predict how different individuals will respond to a product, its price, and the "experience" it provides and the likelihood of their becoming repeat customers.

Involvement—Becoming a member of a local, regional, or national maple syrup association or tourism association, chamber of commerce, or other local business association can be very beneficial to a business. These organizations represent a good source of current research findings on equipment innovations and/or improvements and trends in consumer markets, marketing techniques, and educational programs. Attending annual meetings of these groups can help individual producers remain current about what is going on in the maple industry as well as become more knowledgeable about promotion and marketing methods. Membership and participation also provide opportunities to include the business in collective advertising campaigns and allow for the owner's input on issues that may be important to local maple producers.

CONSUMER EDUCATION

Education of the public is a valuable component of marketing maple products. In contrast to pure maple syrup and maple sugar, alternative pancake syrups and cane sugars are inexpensive and readily available. The higher prices charged for pure maple products have made them more of a specialty product than a primary source for syrup and sugar. However, consumers who value the unique flavor and wholesomeness of pure maple products continue to make regular purchases when they are assured of a dependable supply of a high-quality product. The authentic taste may be enough to maintain some consumers as repeat purchasers; however, additional information will help others make their first purchase. The following represent some areas where additional information can be offered to further promote and market pure maple syrup and related products.

Uses

Consumers generally prefer to buy only a small quantity of maple syrup at a time, even when price is not an issue. The primary reason for this is the perception that maple syrup has a limited number of uses, the most important of which is as a topping for pancakes and/or waffles. However, as we all know, this is not the only use that can be made of maple syrup. It is important for consumers to understand that maple syrup can be used as a substitute for sugar in nearly every situation where sugar is used. The addition of maple syrup to meat or vegetable dishes adds an attractive flavor. As a sweetening agent for coffee, tea, and cereal, maple syrup is a good substitute for sugar. To acquaint consumers with the many uses of pure maple products, producers can hand out recipe cards that include maple syrup as an ingredient or sell cookbooks that offer suggestions for using maple products in the preparation of a wide variety of foods.

Grades and Handling

Not all consumers are aware that different grades exist for maple syrup. Federal and state grading guidelines are available and are rigidly adhered to in some areas of the maple-producing region. However, grades do not imply any differences in composition, density, or purity; the primary differences are color and flavor. Darker grades of syrup usually have a more intense or stronger flavor than lighter grades and are preferred by many for use in cooking. Retailers who want their products to appeal to the many different preferences of consumers may want to host tasting opportunities in their retail sales outlets.

To maintain quality, maple syrup must be handled properly following purchase. Purchases of larger quantities of syrup are more likely if consumers realize there are storage methods that will maintain syrup in a fresh condition for a prolonged period. Storing maple syrup in a freezer is an excellent method of maintaining the quality and flavor of syrup until it is used. A smaller jug may be kept in the refrigerator and refilled as necessary from a large bottle of maple syrup kept in the freezer. Once a syrup container has been opened it should be stored under refrigerated conditions. Failing to refrigerate opened syrup containers can result in the growth of mold and spoilage.

Basic handling guidelines should be included on the label on each container. Additionally, brochures containing storage and handling information are helpful in increasing consumer awareness.

Nutritional Labeling

Labels containing information about the nutritional value of a particular food product are common for most processed and packaged food (**Figure 10.4**). Many containers in which maple syrup is packaged display such information; their use on all other maple products is recommended as well. Providing basic nutritional information on the package label may encourage the purchase of maple products and

[2] https://inspection.canada.ca/food-label-requirements/labelling/industry/eng/1383607266489/1383607344939#
https://www.nal.usda.gov/fnic/food-labeling

Nutrition Facts Valeur nutritive	
pour 1/4 tasse (60 ml) Per 1/4 cup (60 ml)	
Calories 220	**% valeur quotidienne* % Daily Value***
Lipides / Fat 0 g	0 %
saturés / Saturated 0 g + trans / Trans 0 g	0 %
Glucides / Carbohydrate 54 g	
Fibres / Fibre 0 g	0 %
Sucres / Sugars 53 g	53 %
Protéines / Protein 0 g	
Cholestérol / Cholesterol 0 mg	
Sodium 0 mg	0 %
Potassium 200 mg	4 %
Calcium 75 mg	6 %
Fer / Iron 0,4 mg	2 %
Thiamine 0,05 mg	4 %
Riboflavine / Riboflavin 0,35 mg	27 %
Niacine / Niacin 0,2 mg	1 %
Magnésium / Magnesium 15 mg	4 %
Zinc 0,3 mg	3 %
Cuivre / Copper 0,15 mg	17 %
Manganèse / Manganese 1,65 mg	72 %

* 5% ou moins c'est **peu**. 15% ou plus c'est **beaucoup**
* 5% or less is **a little**. 15% or more is **a lot**

Nutrition Facts	
servings per container	
Serving size	**2 tbsp. (30mL)**
Amount per serving Calories	**110**
	% Daily Value*
Total Fat 0g	**0%**
Cholesterol 0g	**0%**
Sodium 5mg	**0%**
Total Carbohydrate 27g	**10%**
Total Sugars 24g	
	48%+
Protein 0g	**0%**
Calcium 30mg	2%
Potassium 90mg	2%
Riboflavin (Vit. B2) 0.51mg	40%
Magnesium 8mg	2%
Zinc 0.3mg	2%
Manganese 0.9mg	40%

* Percent daily value are based on a 2,000 calorie diet.
* Not a significant source of Saturated fat, transfat, dietary fiber, vitamin D and iron.
*+ One serving adds 24g of sugar to your diet and represents 48% of the daily value of added sugars

Figure 10.4. Nutritional information printed as part of a maple syrup container label. Note: always check Provincial, State and Federal guidelines for updated requirements.

is required by law in many instances. Information on nutritional values and labeling requirements of pure maple products are available through the Canadian and U.S. governments.[2]

Organic Maple Syrup

Interest among consumers in the purchase and use of organic products has increased over the past decade and is continuing to strongly grow. Some consumers will select certified organic food products over products that are not certified organic. For some producers, it may be worth the effort to obtain organic certification. The maple production process and the maple products lend themselves well to being organically produced. However, official organic certification (which is what consumers look for) requires that all aspects of the production process be certified according to the methods of the organic certifying agency in compliance with established standards. Certification guidelines focus on the sugarbush and its management and the methods of sap collection and processing, as well as procedures involved with packaging and handling. A forest management plan is generally required, and good recordkeeping to prove compliance with guidelines is necessary. Despite the added requirements of the certification process, the additional value of certified organic maple syrup production in the bulk and retail market is often worth the extra effort. Bulk maple syrup buyers typically pay a 5–10 percent premium for certified organic syrup. In some cases, there is governmental subsidy toward the cost of certification, reducing the economic barrier to entry even more.

If maple syrup is purchased to supplement production, it must also be certified as organic for it to be sold as such.

Local Maple Syrup and Origin

Much like organic, "local" seems to be in vogue for food shoppers. Syrup produced by friends and neighbors evokes a sense of familiarity and comfort in many consumers. This attribute can be an important focus of many types of promotional efforts. Coupling the "local" aspect of production with visits to the sugarhouse can help to provide consumers with a connection or "experience" that many feel adds significant value.

Using an "origin-based" promotional attribute will potentially have a different impact if target customers live in a geographic region that extends beyond that where the syrup is produced. The expansion of maple markets to non-maple–producing regions will prompt consideration of how origin and locale are expressed in marketing materials. Sellers can research if customers in different regions have a preference in terms of "origin" and how that preference impacts buying decisions or pricing.

ADVERTISING

Advertising is the most visible form of promotion. Advertising is a paid-for presentation of information about an individual business or product presented in a public medium. Well-designed and well-placed advertisements can be effective in creating a positive awareness of the business and the products offered. Among the many objectives of advertising are maintaining an awareness of the existence of the business among current customers, presenting a message to attract new customers, and establishing and/or maintaining a favorable competitive position among other businesses selling similar products.

The quality of the advertising message and the medium in which it is placed should reflect the quality of products being sold. Pure maple syrup and other maple products are by nature high in quality. Advertising that promotes these products should likewise be of high quality. Important considerations when developing an advertising strategy include identifying advertising goals, establishing a budget, and selecting the most effective media.

Advertising Goals

To develop an effective advertising plan, you need to clearly identify what you want the plan to accomplish. From a general standpoint, the primary objective of advertising is to get the right message to the right audience at the right time. A secondary objective is to develop and establish a desirable image of the business in the minds of consumers. Uniformity and consistency in all types and methods of advertising help to continuously reinforce this image.

Specific advertising goals can be identified in several different ways. While the overall objective is to increase the awareness of an individual business among consumers, this message may assume several different forms. For example, in some locations advertising may focus on messages to make potential customers aware of where the business is located. Another goal may be to seasonally inform consumers that the "sap is running" and fresh maple products are now available. Still others may focus on the diverse array of maple products that are available, and advertising that conveys images and uses of pure maple products may be helpful in creating a demand. Advertising can also capitalize on the nostalgia and tradition associated with maple, creating a desire to visit a sugarhouse where "history" can be relived. It is up to each producer to establish specific advertising goals and to select the best advertising medium for accomplishing them.

Advertising Considerations

BUDGET Because significant costs are involved in effective advertising, it is wise to establish an advertising budget and make decisions that obtain the greatest value for dollars spent. The necessity for advertising may be based on need; for example, how well a particular business is established within a particular area. If the business is new, the need for advertising that focuses on the location of the business and the products and/or services that are offered will be greater than for businesses that have been established for some time. Advertising guidelines suggest that a reasonable advertising budget for new businesses should be between 5 and 10 percent of projected gross income per year. For well-established businesses this amount may be reduced to as little as 3 percent or less per year. Maple producers have found it effective to develop a detailed advertising plan for the entire year so that advertising dollars can be allocated monthly, or to correspond with anticipated sales. Maintaining a record of response to advertising is an effective means of determining where placements of advertisements are most effective as well as what messages were responsible for promoting sales.

THE ADVERTISING MEDIUM After establishing advertising goals that are specific in terms of both the message and the target audience, an appropriate medium can be selected. To ensure greater exposure, it is recommended that a variety of different media be used. Not all potential consumers will respond to the same type of medium—using a variety of media to convey your advertising messages is likely to be the most effective way to reach a wide audience. Important forms of advertising media appropriate to maple producers and sellers include the following:

Road Signs—Many producers find that well-placed, attractive signs are among the most essential and cost-effective form of advertising and that they often reduce the need for more extensive advertising (**Figure 10.5**). Ordinances relating to signs exist in many municipalities and all permits and guidelines relating to size, position, and location must be observed. In some locations it is possible to place directional signs close to highway that may help consumers locate your business. The effectiveness of signs is largely dependent on their appearance, content, visibility, and location. Good guidelines include the following:

- Appearance—Signs should be bright, clean, and neatly painted. Originality and attractiveness help. The area around the sign should be kept well maintained and tidy. Shabby, neglected signs convey the

Figure 10.5. Many producers find that well-placed, attractive signs are among the most essential and cost-effective forms of advertising.

impression that the business may also be untidy and poorly managed.

- Content—All advertising materials, including signs, should be consistent so they can easily be associated with the business. When placed on a sign, a logo or trademark can be very effective, especially if its identity has already been established in other forms of advertising. Use as few words as possible to avoid confusion. Short, simple words are preferable to big, fancy ones. Use left or right for turning directions rather than north or south to eliminate confusion. Be sure to include the specific location of the business on the sign (i.e., the address).
- Visibility—To be effective, the message on a sign must be clear, uncluttered, and easy to read. Remember the target audience for the sign is someone driving by at a fairly fast speed. For example, a sign must be visible for 225 feet in order for a driver going 50 mph to see it for 3 seconds. The height and line thickness of the letters of a sign influence the distance at which it can be read. Guidance are available for designing suitable roadside advertising signs.[3] Signs placed at a 45-degree angle to the road are much easier for motorists to read than signs placed at right angles. (**Figure 10.5**).
- Location—Choose locations for signs that will be seen by numerous potential customers and from which it will be easy to find the business. Locate signs at turns in the road and place a prominent sign close to the entrance to the business. For maximum visibility, select sign locations that are in open and uncluttered areas.

Radio—Radio is one of the more expensive forms of advertising. It is well suited for operations that want to reach a large audience of potential customers. The number of potential customers reached will depend on the selection of the radio station and time of day the advertising messages are broadcast. By design, radio stations conduct programming that will appeal to different types of listeners. Discussions with managers or the marketing department of local radio stations about the objectives of the advertising message as well as the desired target audience can be helpful in determining the content of the advertising message and when it should be aired. To be most effective, it is recommended that radio ads be professionally designed and presented.

Television—Television advertisements have the potential to reach a large audience; however, they are the costliest of all advertising options. For many small producers, the costs may outweigh the potential benefits. Larger operations that offer many products and services may consider television as an effective advertising option. Professional guidance should be sought concerning the appropriateness and cost-effectiveness of television advertising. To maximize the effectiveness of television advertising, it is essential that the advertising message be professionally prepared.

Newspaper or Magazine—Advertising in local newspapers is one of the most common forms of advertising used by maple syrup producers. Seasonally placed ads can generate interest and be very effective in promoting increased sales of maple products, especially at certain times of the year such as during the maple season when "fresh syrup" is available or at Christmastime when consumers are looking for unique gift ideas. To be most effective, printed advertisements should integrate a clear message with an eye-catching design to provoke interest, create desire, and suggest action. Advertising that is distinctive and tastefully done is most effective. The use of attractive borders and illustrations, the business logo, or product trademarks can help an ad stand out and capture attention. A distinctive business logo that is prominently displayed in advertising helps consumers recognize the business. Generally, it is not recommended that prices be listed in advertising unless a special promotion or product is offered. The listing of prices for all products in advertisements tends to attract mainly price-conscious consumers. Make certain the name

[3] Bertucci, A. 2006. *Sign Legibility Rules of Thumb.* United States Sign Council. https://amsigns.com/wp-content/uploads/2017/07/USSCSignLegiRulesThumb.pdf

of the business, telephone number, products available, and location are clearly visible in all ads. In some areas, newspapers publish directories or guides to local maple syrup operations. Participating and advertising in such cooperative advertising can be effective; however, it may be difficult to distinguish an individual operation from others. Smaller local or regional newspapers and periodicals will also often feature stories about local maple operations during the sugaring season. An article about your operation serves as excellent advertising.

Brochures—An attractive, informative flyer or brochure can be a very effective advertising tool in certain markets. A well-designed brochure should include the following:

- Brief background of the business
- Listing of available products
- What to expect on a visit
- Photos/illustrations
- Location, including a map and specific directions
- Contact information

Brochures can be placed in tourist information booths and hotels, as well as motels, grocery stores, restaurants, service stations, and other facilities frequented by the public. It is often useful to make brochures available at any location where your products are sold. This strategy is a good way to better acquaint existing customers with your business and to introduce potential new customers to your product offerings.

PRICING SHEETS AND POINT OF PURCHASE MATERIALS FOR WHOLESALE

Accurate pricing sheets and timely notice of availability are essential for business-to-business transactions. Provide potential and current buyers with a list of products, package size, number of packages per case, price, and other information that enables them to make a wholesale purchase decision. Grocers and other retailers will not necessarily promote your products as effectively as you may wish once the product reaches their shelves. In many cases, an opportunity exists for the maple seller and wholesale buyer to coordinate point-of-purchase promotional materials or offer in-store samples. These efforts can educate shoppers and motive them to choose your products over competing offerings. Speak with wholesale buyers to understand their clientele and how best to support promotion of your products at the seller's location.

INTERNET

A great deal of marketing and sales of maple syrup occurs through the internet. There are several different possible venues for sales online.

Web Pages

Modern maple sellers rely on web pages to promote their business and advertise their products on the internet. Digital marketing can reach many potential customers at a relatively low cost. Creating and maintaining an attractive and informative website is very effective in establishing the identity of an individual business as well as informing customers of the facilities and products available. Effective websites need to be attractively designed, maintained, and updated on a regular basis. In addition to identifying and describing a business, the website can also be designed to sell products directly from the business to individual consumers. If this is done it is essential that the site be monitored daily and that it includes a means of responding to marketing inquiries and sales orders. Once a decision is made to maintain an online store, security of the website must be a primary concern when selecting web-hosting firms and online sales platforms.

A well-designed web site should contain the following information:

- Name and description of business
- Location and directions
- Hours of operation
- Photos of the business
- Upcoming activities and events

Some of the several options available for businesses that want to take advantage of using the internet for promotion and advertising are summarized in **Table 10.3**.

TABLE 10.3 Various types of internet presence.

Option	Description
Listing	Advertise or post a listing on an existing website (e.g., Maple Association website).
Host Page	Establish a host page in an existing domain—many internet accounts allow for free web space. Drawbacks to this option are that the URL[1] may be lengthy, and most service providers will not allow free space for business purposes.
Website	Create a personal website. This involves registering a unique URL (e.g., http://www.maplefarm.com) and requires payment of a yearly domain hosting fee as well as a monthly service fee to maintain the server that hosts the page or pages. Individual website pages can be personally or professionally designed. If the pages are professionally designed (this is recommended), a design fee must also be paid.
Social Media Profile	A profile on Facebook, Instagram, or other social media platform. Setup and maintenance are relatively simple, but fresh content should be added regularly to keep the site fresh. Gathering followers can take some effort. This is a good way to advertise upcoming public events.

[1] URL is the abbreviation for Uniform Resource Locator, the address of a resource on the internet. World Wide Web URLs begin with http:// or https://.

To ensure that your website will be found by potential customers, be sure it is registered with two or three commonly used search engines. This can be done by the individual or company that created and maintains your website, or you can do it yourself through the search engine home page.

Savvy users of the internet sales route make use of various analytics tools to get insight into their customers. A great deal of information can be harvested from "hits" to your website. Using this information, you can better target your advertising to your desired customer base and evaluate the potential for growth in new areas. Web page managers should also explore search engine optimization (SEO) strategies to improve the site's visibility and increase web traffic from organic searches.

Social Media

Social media has exploded in the past decade. Facebook, TikTok, Instagram, Twitter, and other apps have huge user bases and are rapidly expanding. An advertising campaign can be implemented at relatively low cost via this route; however, the sheer amount of material in these venues makes it hard to stand out amidst the other content vying for attention. Despite this, a well-designed and well-executed advertising campaign can reap tremendous rewards, particularly if it goes "viral." If you are well acquainted with these forms of media, your advertising can be a "do it yourself" venture, or companies can be hired to assist in the design and dissemination of the material. Understanding and targeting your advertising to the correct audience is crucial to turning views and hits into actual sales.

Amazon and eBay

Sometimes building and managing a website is a bit too much for maple producers. However, it is still possible to tap into maple sales via established stores. Amazon and eBay both provide a path to internet sales with a low barrier and little investment; however, the downsides are that there is likely to be lots of competition and that these online sales venues will take their "cut" of the profit. Still, for some producers, it is an easy way to make their product available to a broader audience online without managing the full marketing process themselves.

LABEL ADVERTISING

Containers in which maple products are packaged should be neat and attractive and should reflect the quality of the products contained. The container/package should contain an attractive label that identifies the product, and the quantity present as well as providing additional information such as origin of maple syrup production, suggested uses, nutritional information (if appropriate), batch codes, and the name and address of the producer (or other legal entity such as the packer or seller as defined by the governing agency). Containers of several different styles and sizes that are attractively designed are available from commercial sources and contain much pre-printed helpful information. There is also the option of having containers or labels printed with a producer's own design. The cost of custom printing is greater, but the benefits may outweigh the additional expense. Simple name stickers can also be obtained for use with generic labels or printed containers. If a business logo has been developed it is recommended that it be incorporated into the label.

An attractive label as a method of advertising is not limited to only those consumers who purchase your maple products for their own use but is also informative for those who receive them as gifts, increasing awareness of the products available from your business.

Imagery

Maple marketers today can be observed blending historic imagery of sugaring with more modern concepts of specialty food branding. Traditional imagery and packaging depicting clouds of steam rising from a sugarhouse and woolen clad workers alongside hanging buckets are very common. Visitors to on-site events still relish opportunities to see or participate in tapping a tree with brace and bit, to enter the steamy sugarhouse, and to experience the tradition of sugar-on-snow.

At the same time, more modern maple imagery continues to emerge. New logos and communications strategies emphasize more expansive imagery of forested landscapes or clean-cut logos that demonstrate the modern look of a high-end food product rather than a rural heritage scene. Neither strategy is necessarily superior to the other. What becomes clear, however, is that maple sellers can now communicate their brand and influence consumers by evoking both the past and the present with forward-looking images. This innovative design strategy will also influence the consumer education elements of a marketing plan as consumers may need explanations to clarify distinctions between historical sugaring practices and more modern elements of sap collection and processing technology now commonplace at all scales of production.

SALES PROMOTION

The objective of a sales promotion is to directly encourage consumers to make a purchase. Free samples are among the most common type of sales promotion used by maple producers. Sampling engages the consumer and increases the likelihood of purchase. Coupons or special offers are other types of sales promotions that may be used. For example, coupons that offer a free item or a price break on purchase may be included in a newspaper advertisement as part of a sales promotion. As an example, a coupon could be redeemed for a free piece of maple sugar with any purchase. Some producers offer a reduced per unit price if a customer makes a substantial purchase such as a case or more of maple syrup. This encourages larger purchases and the use of maple syrup for gift-giving purposes.

PERSONAL SELLING

Personal selling is the direct personal interaction between a salesperson and a potential customer in which product information is conveyed. It can be a very effective form of promotion since the salesperson can respond directly to the individual needs and interests of the customer with the result being an increase in sales. The maple business lends itself well to personal interactions since it is often the producer who is directly involved in sales. Producers are in a position to know more about the products that are offered for sale than anyone else; thus they can answer questions as well as offer suggestions related to various maple products, their characteristics, and their use. Most consumers like to make purchases directly from the producer. Many consumers believe that products purchased directly from the producer are fresher and higher in quality than similar products bought elsewhere. Personal selling can also be involved when producers sell maple products directly to retailers. The image, knowledge, tact, and interest of the individual involved in direct interaction with either the consumer or retailer can contribute to the likelihood that a sale will occur. Additional information regarding personal selling is contained in the "Distribution Options" section of this chapter.

PUBLICITY

Publicity is any unpaid communication in a public medium regarding a product or business. In some instances, it can be equal to or even more effective than purchased advertising. Since publicity is not presented directly by the business its credibility is enhanced in the minds of many consumers. Publicity can be difficult to manage and although it is usually positive it can be negative if some unfortunate situation or circumstance is described and publicized. Innovative, progressive maple producers can encourage the opportunity for positive publicity. The following are a few ideas that have been proven to be helpful:

- Invite local newspapers to a special event at the sugarhouse or sugarbush. Encourage the taking of photographs and provide printed information that describes activities that occur in the operation.
- Spread the word of events, specials, sales via social media.
- Donate maple syrup or maple products to a local radio station for contest prizes.
- Send prepared press releases to local television stations, radio stations, and newspapers for any event or special activity that is being held at the sugarbush. A well-designed and thoughtfully composed press release can be very useful. It is most effective if it is kept short and simple. It should contain the following information:
  - The five Ws and H (who, what, when, where, why, and how)
  - Accurate, unique, and interesting information about the operation
  - Contact information

PRICING

Pricing is an important aspect of a successful marketing plan. It is important to determine a price that balances the producer's costs and the value derived by the buyer. Since not many consumers purchase a particular product based solely on price, the concept of quality and uniqueness are product attributes that can encourage purchase. Consumers are often willing to pay more for a product that is of higher quality or can be considered as special or unique. In some cases, consumers may hesitate to purchase lower-priced products because they associate low prices with low quality.

Price setting generally follows the following key concepts. Competitive pricing occurs the sellers set their prices based on what their competitors charge for similar products. This is the most basic and common form of price setting when products are not easily differentiated from each other. An offshoot of competitive pricing is known as price signaling. When price signaling, the seller uses a competitive pricing model to establish a starting point and then adjusts their product prices up or down to send a signal to consumers. A higher price may be used to signal higher quality while a lower price may signal a major sale. Be careful! Low prices may also signal lower quality to consumers. Cost-based pricing is the recommended pricing strategy to maintain a sustainable and viable enterprise. Business owners can analyze financial records to estimate the total cost of producing their maple products. Additional analysis related to the market demand for various product forms must be considered. Labor cost to package/sell/deliver products and specific packaging materials costs can be factored into a cost-based pricing strategy.

Maple producers are advised to refrain from lowering prices below those of competitors simply to increase sales. If producers compete for customers by lowering prices below the cost of production, profits continually decline and cause harm to the entire maple industry. It is more beneficial to establish a fair price and develop a positive reputation for your business. By establishing a reputation for fair prices, high product quality, and personalized service, a good customer base will be established. There is often a tendency for family operated businesses to set prices too low simply because lower labor costs are involved in production and processing (either because family members are not paid or are paid less). This is a mistake; lower expenses associated with labor should be seen as a benefit that allows for a greater profit potential rather than a reason to reduce your prices.

A common method of pricing used by many maple producers is to establish prices for smaller containers of maple syrup that are based on percentages of the price of a 1-gallon or 4-liter container. Once the price has been established for this sized container, prices for smaller sized containers are established according to the percentages suggested in **Table 10.4**.

The price for a 1-pint or 500 milliliter container, for example, based on a 1-gallon or 4-liter price of $50 would be $10.00 ($50 × 0.20). This system of pricing only applies to simple, basic containers. Maple syrup in more elaborate or otherwise unique and thus more expensive containers would be priced correspondingly higher.

BALANCING PRODUCTION AND MARKETING COSTS

The production costs associated with pure maple syrup and related maple products are substantial. Specialized equipment that is used for only a small portion of the year is required, as are significant amounts of mechanized and hand labor.

Various amounts of capital and labor are required for sugarbush management, tapping, sap collection, processing, and packaging. These many inputs necessary for production require that the total crop be sold at the best possible price if maximum profit is to be realized. A more complete discussion of the economic aspects associated with maple syrup enterprises is contained in **Chapter 11** of this manual.

A relatively small investment of effort and funds in marketing can make a huge difference in gross revenues. The amount of marketing required is related to the quantity of syrup and related products produced, and the unique or individual characteristics of the operation. More marketing is required in some situations than in others, particularly for large or relatively remote operations, as well as those in competitive markets. Improved marketing of maple products can help to offset increases in wages and equipment costs.

Care must be taken to not overspend on marketing. It is a waste of time and money to conduct large marketing campaigns and not put similar efforts into improving production. Producing adequate quantities of products of the highest quality is necessary for meeting all demands resulting from promotion and marketing efforts.

TABLE 10.4 Pricing suggestions for various sized maple retail containers.

Size of Container	Price Relative to 1-Gallon or 4-Liter
Gallon or 4 Liters	100%
½ Gallon or 2 Liters	60%
Quart or 1 Liter	35%
Pint or 500 milliliters	20%
½ Pint or 250 milliliters	20%

DISTRIBUTION OPTIONS

Most maple producers sell their maple syrup and related maple products through one or more of three principal distribution channels: retail sales directly to consumers, wholesale to other businesses for subsequent retail sales, and in bulk to processors and/or packers. The percentage of syrup sold by an individual producer via retail, wholesale, or bulk sales will depend on the amount and quality of syrup produced and the objectives of the producer. Some maple syrup may be bartered locally to equipment or other maple syrup suppliers. Retail sales are important to many individual producers. However, as desirable and important as this method of sales may be, only a small percentage of the total annual crop of maple syrup is sold directly to consumers. Most syrup is sold wholesale to other retailers and processors or packers who market most of the annual production. This is because most producers can produce more syrup than what can be marketed directly to consumers. Direct marketing maple syrup is labor intensive, making it a high-cost activity for producers seeking to earn a livelihood or paying employees from the business. Producers may also prefer managing a maple sugarbush and maple sugarhouse rather than serving retail customers. Selling syrup in bulk reduces the gross revenue potential for the producer; however, large processors are often better positioned to efficiently and affordably distribute syrup to a much larger market.

Two additional sales opportunities that may be important to a limited number of producers are cooperatives and the export market.

Retail (Direct) Sales

Retail sales directly to consumers represents the greatest opportunity to maximize sales revenue from maple syrup and related products (**Figure 10.6**). However, significant amounts of time and labor are required. An attractive sales facility with appropriate display cases and proper handling and storage facilities and procedures are essential to success. For example, producers should make certain that containers displayed in the sugarhouse or other retail sales facility, including roadside stands, are clean and free from rust or other defects. Furthermore, maple products such as maple sugar, maple candy, and maple cream should be fresh and displayed under conditions that will maintain freshness and an attractive appearance. Dirty or otherwise blemished containers do not present a favorable image of the product, nor do old products that are discolored, separated, moldy, or otherwise unattractive. Attractive display cases, including some that are refrigerated, are necessary components of any retail establishment that desires to offer, display, and maintain high product quality.

Sales will be greater if maple syrup is available in containers of different sizes and styles. Likewise, offering other maple products such as maple sugar, maple candy, and maple cream will result in increased total sales. Sales of less well-known maple products, such as maple butter, will be greatly increased if samples are available to consumers.

To help maintain freshness and quality in maple syrup it is recommended that not all syrup be packaged in retail-sized containers as it is produced. Rather, some of the syrup should be stored in larger bulk containers and later packaged in retail-sized containers as necessary to maintain retail supplies. It is also essential that a system of batch coding be used for all maple syrup that is produced during a given season. This approach ensures that all the containers containing syrup from a particular batch are coded with the same code. If a there is a problem with a particular batch of syrup, such as off-flavor, incorrect density, or microbial contamination, or if a particular batch has a desired set of characteristics, then all the containers containing that batch can be identified.

Figure 10.6. Maple products can be effectively displayed in a variety of attractive and eye-catching ways.

Retail sales will also be enhanced if specialty items such as prepared gift packages or baskets are available. Attractively packaged gift baskets that contain a variety of maple products as well as other items such as pancake or waffle mixes are popular options, especially during the holiday shopping season. Specialty food product gifting is at its highest rate during the fall/winter holiday season, and purchases intended for this purpose can make up a major part of the overall annual sales for retail maple sellers.

In addition to retail sales on the farm, several other options are available. These include a well-situated retail outlet, a roadside stand, local farmer's markets, festivals, mail order, or the internet. Suggestions on how to enhance the sales potential of each of these outlets follow.

Sugarhouse (Farm Gate)

Producers who want to sell as much of their annual production as possible directly from the sugarhouse have found it advantageous to offer activities or special events that will attract potential consumers to the farm. This may include scheduling an open-house weekend or participating in state or provincial maple weekends or tours where the public is invited to view syrup production during the season and taste freshly made syrup. In other cases, maple tours are offered in the fall foliage or fall harvest season. Other activities such as tours for school children or other visitor tours (e.g., fall foliage visits, sugar-on-snow parties) are all possibilities. When these events are scheduled, it is important to ensure that the sugarhouse is presentable and that there is an attractive display area where the variety of maple products offered for sale can be prominently displayed. The sales area at the sugarhouse does not have to be devoted strictly to maple syrup. Items made from maple syrup such as maple jelly, maple mustard, maple-coated nuts or popcorn, and maple vinegar may be of interest to customers.

Selling directly from the sugarhouse is an excellent means of encouraging sales since the customer can become more familiar with the production process for pure maple syrup and secondary maple products. Most consumers will enjoy seeing the sugarhouse in operation; the sights, smells, sounds, and atmosphere are effective in promoting increased sales of pure maple products. Direct consumer selling at the sugarhouse is well suited for businesses that have addressed the following issues:

- Are the facilities suitable for dealing with the public (e.g., size, parking, accessibility, restrooms, safety)?
- Is adequate help available to monitor guests and/or schedule events or activities?
- Is someone available for selling at the same time syrup is being produced?
- Will consumer demand be sufficient to justify the time and expense involved?
- Is skilled labor available to produce and package maple products other than syrup?
- Are adequate supplies of maple syrup and related products available to meet demand?

It is important that the activities and responsibilities related to selling directly at the sugarhouse be identified and addressed thoroughly before a decision is made to promote sales at this location. A facility that does not accommodate the needs, wants, and safety of consumers may not be suitable. It is important that consumers who visit a production facility are not disappointed by their experience.

Off-Site Retail Shop

Some producers either have or may consider establishing a retail location apart from their production facilities. Often this is an appropriate solution for a producer who wants to sell retail but has difficulties attracting consumers to a remote location or has a production facility that does not accommodate retail sales. Separate remote sales facilities also allow producers to sell other products or commodities such as fresh vegetables, fruit, crafts, and other items that are produced locally or are seasonal in nature. Location is an important consideration in making the decision to establish a separate retail outlet. Other considerations should include traffic patterns, local zoning and health regulations, parking requirements, design and size of the sales facility, availability of labor, anticipated sales volume, and availability of other products to sell.

Roadside Stands

Fruit and vegetable roadside stands are considered good marketing outlets for maple syrup and related maple product sales. Consumers have the general perception that the freshness and quality of produce and products offered for sale are usually higher than of similar items present in grocery stores. Consumers are often inclined to make larger purchases of specialty items when they are offered in such locations. As with all sales outlets, the location and convenience associated with purchasing contribute greatly to the success of roadside stands.

Roadside stands may be either staffed or self-serve. Staffing requires an investment of producer time or labor costs if staff is hired, so this route should only be chosen if traffic is sufficient to support it or if it is easy and fast to get to when visitors stop in. Having a variety of items to sell helps pull people in. Operations can be year-round or seasonal depending upon several things. Self-serve stands are workable in some settings, but unfortunately are likely to suffer occasional losses from theft. The use of signs and cameras and a secure drop slot for payments might help mitigate this problem but is unlikely to eliminate it. Losses due to theft should be factored into revenue projections.

Festivals and Farmer's Markets

Maple syrup festivals are common in some areas of the maple syrup producing region. These festivals effectively promote pure maple products and also provide an opportunity for local producers to display and sell their products. Well-organized festivals that offer a variety of activities attractive to the general public can be very effective in promoting the sales of maple products. Marketing success for individual producers often depends on the location of the sales booth, attractiveness of the product display, reputation of the producer in the community, quality and variety of maple products offered, and friendliness of the sales staff. Producers may offer other products for sale such as maple cotton candy, maple popcorn, maple ice cream, and maple taffy. These products lend themselves well to a festival setting and each one can be effective in promoting sales of other pure maple products. These events in maple-producing regions may become very competitive or potentially inaccessible for new maple producers facing a group of established sellers. Increasingly, maple producers are making attempts to introduce and sell their maple products at events outside the maple producing region.

Local farmers' markets also provide an excellent outlet for retail sales of maple products. Many consumers are attracted to local markets where they purchase locally grown produce and flowers and other locally produced goods. Locally produced maple syrup and other maple products complement the many types of products available at these markets. High-quality products offered in attractive displays promote sales and help in establishing repeat business. Offering samples for tasting, along with providing education about differences in syrup flavor, can help draw in traffic.

Mail Order

Maple syrup has long been available through catalog companies; however, this sales route has been declining in popularity as internet sales and costs of producing and mailing catalogs have risen. Catalogs designed to present products suitable for gifts and those containing specialty products or otherwise unique merchandise are well suited for the sale of maple syrup and maple products. Maple producers who are interested may want to contact publishers of individual catalogs and indicate what type of products they have available. Producers can also develop and/or purchase mailing lists from companies and send a direct mail flyer and order form to those on the list. Mailing lists can be purchased for many different types of potential consumers or clients. It is essential that appropriate packaging is available and that orders are promptly prepared and shipped; otherwise repeat orders are unlikely. Prompt order fulfillment and the use of appropriate packaging are essential for maintaining a steady flow of repeat business. Selling via mail order can be a convenient way for producers to access a retail market or expand their existing customer base without having to establish a separate retail sales facility on the farm. Producers who sell and ship maple products in response to catalog or other mail order inquiries must be able to package the product in such a manner that it will withstand rough handling during shipping. Some types of containers such as those made of plastic are better adapted to shipping conditions than containers made from other materials.

Internet

In recent years the internet has become an increasingly important sales outlet. Furthermore, use of the internet is continuing to increase and has become a dominant sales outlet. In many ways internet sales are similar to mail order and in some cases are used in a complementary fashion. An attractive website that identifies, promotes, and facilitates purchase is key. As noted earlier, Facebook, Instagram, Twitter, and other online social platforms can be used to drive traffic to your website or other distribution channels. The advantages of this approach are many, including the elimination of the costs of producing and distributing either a catalog or other order form; simple presentation of an individual business and the products available to an unlimited audience; and faster service in responding to inquiries and/or orders. Potential customers have the convenience of shopping from home while still being able to purchase what they want. Additionally, email facilitates a rapid response to consumer inquiries or questions. Maple producers who want to maximize sales of maple syrup and related products should make this a priority sales method. Making your website easy to find (through search engine optimization), easy to navigate, and easy to order from is vital. Increasingly people use smartphones or mobile devices for browsing and ordering on the internet, so pages need to be designed to be readable and navigated on both large (computer) and small (phone and tablet) screens.

Online selling is not without challenges. Shipping costs can be high, and sellers will need to find the best options for shipping and establish appropriate freight charges. Additional inventory space for packaging supplies and packing space will also needed be needed to move large amounts of product in a timely manner.

Wholesale

Selling maple syrup and related maple products wholesale allows some producers to expand their total sales. The term *wholesale* in the context used here refers to the sale of packaged syrup and related products to retailers who subsequently sell directly to consumers. Some examples include grocery stores, specialty food or health-food stores, local gift shops, restaurants, and candy shops. Selling wholesale does not preclude the direct sales of small bulk quantities of maple syrup to bakeries, candy shops, catering services, and others for use in various food products, although this option is not the primary interest of most producers. While the total price received by the producer from wholesale sales is less than what would be obtained from direct consumer retail sales, this option can be an important means of increasing total product sales. It is important for producers who want to establish a wholesale market to remain sensitive to the needs of the wholesale purchaser. Attractively packaged, quality products that are delivered in a timely manner are essential for developing a long-term relationship. It is also important that the producer be able to sustain a wholesale market once it has been established. Producers are advised to begin with a small wholesale order and "work their way up" once they have become familiar with the demands. In years when below-average crops of syrup are produced it may be necessary to purchase syrup from other producers to sustain an established market.

Finally, since many retail stores use UPC bar codes for inventory control and pricing, it is suggested that maple producers work with the retailer to include appropriate coding on the package to facilitate scanning at the time of sale.

Bulk Sales

Bulk sales is the term for selling maple syrup to packers or processors, most commonly in large barrels or drums (**Figure 10.7**). These firms may package syrup for distribution and sale to larger wholesale accounts or provide syrup to other accounts for use in syrup blends, candy, or other food products, or they may sell to producers seeking drums of syrup to supplement their own crop. Additionally, some

FIGURE 10.7. Bulk sales are typically in the form of barrels or large totes.

processors will convert large quantities of syrup to maple sugar and other confection products. Large packers are an important segment of the maple industry. They provide a market for large quantities of maple syrup, including syrup for reprocessing that is not suitable for sale in the retail market. Bulk sales are a good alternative for producers who lack the time, resources, or desire to develop a sufficient retail or wholesale market. It is better to sell in bulk than to end up not being able to effectively package, market, and sell the annual crop of syrup.

Many producers may sell their entire crop to bulk processors. Some of the advantages of selling syrup in this manner include the elimination of the costs of packaging in small containers and maintaining a storage or retail sales facility and associated staff and the reassurance of knowing that income for the entire crop will be received shortly after the syrup season is over. The primary disadvantage is that a lower per unit price is received for all syrup that is sold. Producers who sell most of their annual crop via retail or small wholesale accounts may also sell a portion of it to processors. This is an effective way to sell annual production that exceeds the demands of retail or wholesale markets or batches of lower-grade syrup that may not be suitable for other markets.

Selling Through Cooperatives

Maple cooperatives exist in a small number of areas within the maple-producing region of North America, but they have not become widespread. These have been established primarily for the purpose of more efficiently marketing maple syrup produced by members of the cooperative. By joining together, producers increase their ability to obtain better prices for the syrup they produce and to direct and/or influence the industry in their area. Members of the cooperative pay a membership fee that enables the cooperative to operate and develop markets for the jointly produced products.

Selling in the Export Market

The United States and Canada are the largest consumers of maple syrup and maple products globally. As annual maple crops increase and the positive reputation of maple products spreads, the growing potential to export more maple syrup to other nations outside North America presents both opportunities and challenges. In response, maple producers, processors and packers, and cooperatives have intensified their marketing efforts in export markets. Larger packers and cooperatives, in particular, have realized some success in boosting sales of maple syrup through increased exports. A few individual producers have also developed limited export markets, though this has required considerable effort.

The development of export markets is most appropriate for larger producers who can assure buyers of a large, steady supply of syrup and who can negotiate the regulations, permits, licenses, and other requirements of international trade. Aside from promoting their products on the internet to facilitate international sales, the advertising efforts of most individual producers are best directed toward increasing domestic sales, rather than developing an export market, where the costs and difficulties of sustaining the market may not be justified.

CUSTOMER SATISFACTION AND LOYALTY

There is no better advertising than a satisfied customer. Satisfied customers not only provide repeat business but also generate new business by word-of-mouth referrals to friends and families. Word-of-mouth advertising is not only free but is one of the most effective forms of advertising. The average consumer pays closer attention to product recommendations from family and friends and trusts those recommendations more than any other form of advertising. Offering products of the highest quality that are attractively packaged, and sold by friendly, knowledgeable sales personnel will help develop a loyal customer base. It is important to believe in the products that are being sold and to guarantee customer satisfaction.

Providing opportunities for customers to taste some of the products offered for sale may also increase customer satisfaction. Free samples are popular and increase the likelihood of purchase as well as reducing while reducing the risk of customer regret by ensuring customers are familiar with the product before purchasing it (**Figure 10.8**).

The unique flavor of pure maple syrup is a primary characteristic that distinguishes it from imitation maple syrups. For this reason, it is very

Figure 10.8. Samples of freshly made syrup are always welcome and often will lead to sales when visitors come to call at the sugarhouse.

important to closely monitor the flavor of all syrup produced and offered for sale. During production, processing, and packaging make certain procedures are followed that will minimize any likelihood that off-flavored syrup is offered to customers. It is of utmost importance to provide customers with a consistently high-quality product and excellent service because word-of-mouth evaluations can also be negative. A bad customer experience, due to either a low-quality product or unsatisfactory service, can damage your brand reputation and sales potential by generating widespread negative word of mouth.

FUTURE CONSIDERATIONS

Finally, the creation of an effective marketing strategy is not a one-time effort, but a continuing process. Producers need to be open to new ideas and to be quick to adopt marketing techniques that reflect changing consumer attitudes, lifestyles, and wants. Change is inevitable in the maple syrup business, and those producers who are innovative and adapt quickly to emerging and growing market opportunities can expect to have the greatest success.

CHAPTER 11

Economics of Maple Syrup Production

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INTRODUCTION

Many hobby or small maple producers never expect their maple operation to turn a profit. Their interest is more for self-sufficiency, personal enjoyment, or the ability to share the fruits of their labors with family, friends, and neighbors or perhaps make a little money they can spend on new maple "toys." However, for a good share of maple producers, income generation, whether through part-time efforts or full-time employment in maple, is a requirement. This chapter will help the latter group understand whether their maple business is profitable or not.

From a historical perspective, the production of maple syrup and maple sugar has long been one of numerous activities carried out on family farms throughout the northeastern and north-central United States and adjacent Canada. In the earliest days of syrup production, its principal objective was to contribute to the family's self-sufficiency. Maple syrup and maple sugar represented a local source of sugar and provided the primary sweetening component used in food preparation. Quantities of both maple sugar and maple syrup were often traded to local merchants for other food commodities that could not be produced on the farm or bartered for supplies and equipment necessary for the farm operation. Eventually, producers sold surplus quantities as a means of obtaining cash for other products and services.

The production of maple syrup and other maple products assumed more importance in the local farm economy with the development of larger cash markets and improvements in mass transportation. In addition to meeting their own need for sugar and syrup, some producers began to sell their products in a growing and expanding retail market. Over time, maple products morphed into a cash crop, augmenting other farm income. Today, while many individuals still produce small quantities of syrup for family and use by local friends and acquaintances, an increasing number of maple producers are in business to generate income. This growing industry segment includes numerous enterprises where maple production is a significant or even full-time endeavor.

Markets for pure maple products are generally good not only in local production areas, but also in domestic and international markets. As consumers become more aware of these uniquely North American products, opportunities exist to further expand markets outside the region of production. It is important to produce and market high-quality maple products to consumers to maintain the well-established reputation of pure maple products. Maple syrup and related maple products recognized as specialty food items are highly valued for their purity and natural qualities.

The economics of maple syrup production, including expected cash revenues, are dependent on a number of factors. These include the size of the operation, equipment costs, labor inputs, production efficiency, marketing strategies, and product pricing. Annual return on investment will be much greater for individuals who pay close attention to dollar and labor inputs, manage their physical and financial resources efficiently, and price their products competitively. Like most agricultural endeavors, maple sap and syrup businesses must bear with a degree of uncertainty, and their viability is influenced by many internal and external factors. As enterprises increase in complexity, scale, and investment, an increased focus on planning and financial management is required. Over the years many individuals have developed plans for elaborate production facilities yet have failed to achieve their production, quality, and revenue goals. Development of a full business plan that recognizes the importance of both production and marketing components is recommended for anyone contemplating a substantial investment in the maple industry.

Profitability of an individual business venture occurs when all costs of producing and marketing a particular product are less than the selling price. The difference between these two values represents profit. Profit can be expressed as a direct dollar amount; however, it is more informative to compute it as a return on the investment represented in the maple facility and its operation. Profitability is influenced not only by minimizing out-of-pocket costs associated with production, but also by the scale and efficiency of production and selling of the final product. Different business models exist to maximize a firm's competitive advantage in the quest for profitability. Operations of sufficient scale, investment level, and production yield can produce maple sap and syrup at a total cost that is low enough to profitably sell their products in bulk syrup markets. Other enterprises opt for retail marketing to generate higher prices and more cash sales for any given volume of production. However, the additional costs of packaging and labor to market the syrup must be covered by significantly higher sales revenues to ensure profitability for all maple products.

Market channel selection is a key factor in balancing a firm's internal cost of production with viable selling prices that meet profitability goals. Maple operations often select from a few common strategies. One strategy is to maximize yield and reduce overall costs per unit, often through technology adoption and expansion to generate profits in bulk markets. This strategy could also include the specialization to sap harvest and sales, thereby reducing investments and labor in maple syrup processing. Another strategy is a mixed market strategy of selling a minor portion of the syrup crop (10–20 percent) to readily accessible wholesale or direct markets while most of the crop is sold to bulk markets. A third option is to focus solely or primarily on wholesale and retail market channels. This strategy places a greater emphasis on entrepreneurship, sales, logistics, and customer service. Yet another alternative is producing and marketing one-third or more of the operation's total maple syrup crop as value-added products such as maple sugar or other confections to increase its profitability.

Several changes have occurred in the maple industry in recent years. Many of these relate to equipment innovations designed to improve sap harvests (**Chapter 6**) and processing efficiency (**Chapter 7**) while reducing labor and energy costs. Tapping procedures, sap collection and storage systems, and sap and syrup processing technologies are improving rapidly. To achieve economies of scale, many maple operations have increased in size and complexity, not unlike other agricultural enterprises. Producers are now more likely to expand their operations over time than they were in the recent past,[1] and as a result, maple production has expanded rapidly since 2005.[2,3] Markets are expanding as well. The Quebec Maple Syrup Producers (PPAQ) experienced roughly 8–10 percent annual sales growth from 2010 to 2015, generated from both an increase in domestic sales and large increases in Canadian exports.[4] In the 5-year period from 2014 to 2018 the value of Canadian syrup exports increased an average of 7 percent annually (**Table 11.1**).[5] Packers in the United States have seen similar increases in sales. The Covid-19 pandemic spurred a return to "comfort foods," including larger family breakfasts.

Canada is a market leader in maple syrup and maple products and produces roughly 70 percent of the global syrup supply.[6] The global maple price is heavily influenced by a single province and the Quebec Maple Syrup Producers (PPAQ). PPAQ has established a market leadership position by organizing producers, establishing the Global Strategic Maple Syrup Reserve, establishing a bulk syrup market order, and executing a supply management system that is integrated with global maple syrup marketing initiatives.

The United States is the largest consumer of maple syrup and over half of that consumption is

[1] Becot, F., J. Kolodinsky, D. Conner, 2015. *The Economic Contribution of the Maple Industry.* Center for Rural Studies—University of Vermont. https://mapleresearch.org/pub/the-economic-contribution-of-the-vermont-maple-industry/

[2] United States Department of Agriculture. National Agricultural Statistics Service, Retrieved June 14, 2019, from https://search.usa.gov/search?utf8=%E2%9C%93&affiliate=usda-nass&query=maple+syrup

[3] Agriculture and Agri-Food Canada. 2020. Customized Report Service-Canadian Maple Syrup. Retrieved July 7, 2020, from the Agriculture and Agri-Food website: https://www.agr.gc.ca/eng/agriculture-and-agri-food-canada/?id=1395690825741

[4] Gagne, F. 2015. *For a Strong and Competitive Maple Industry.* Quebec, Canada. 70pp.

[5] Agriculture and Agri-Food Canada. 2019. *Statistical Overview of the Canadian Maple Industry 2018.* ISSN:2562-8763, AAFC No: 12999E. 14pp.

[6] Agriculture and Agri-Food Canada. 2017. *Statistical Overview of the Canadian Maple Industry.* ISSN: 1925–3796, AAFC No: 12772E. 14pp.

TABLE 11.1 Largest markets for canadian syrup export by volume (kilograms)[1,2]

	2014	2015	2016	2017	2018
U.S.	24,518,587	26,838,226	27,886,052	28,588,821	30,218,926
Germany	3,177,017	3,549,035	4,540,965	4,622,930	5,003,007
United Kingdom	1,680,317	2,285,402	2,442,606	2,430,610	2,422,084
Japan	3,256,293	2,664,895	2,679,569	2,489,628	2,410,106
Australia	1,462,429	1,615,260	1,958,243	2,179,867	2,130,864
France	1,262,005	1,488,270	1,594,766	1,579,595	1,654,308
Denmark	685,271	760,544	868,629	730,988	908,839
Korea, South	400,586	494,818	471,750	484,602	670,121
Netherlands	323,307	404,083	390,935	388,048	482,083
Belgium	208,253	229,536	319,853	377,755	339,242
Others	1,375,251	1,855,939	1,938,850	2,026,728	2,143,069
Total Kilograms (pounds)	**38,349,316** (84,545,770)	**42,186,008** (93,004,228)	**45,092,218** (99,411,320)	**45,899,572** (101,191,235)	**48,382,649** (106,665,482)
Annual Growth		**10%**	**7%**	**2%**	**5%**

[1] Source: Statistics Canada.
[2] To convert to pounds, multiply the kilogram value by 2.2.

imported to the U.S. from Canada.[7] Maple producers and marketers are increasingly aware of U.S.-Canadian currency exchange rates as global production increases and the international supply, demand, and export dynamics influence syrup pricing. In addition to reflecting regional demand, the price of maple syrup in North America is influenced by trends in grocery supply.

A smaller amount of maple syrup is exported from North American to destinations across the globe. Germany, the United Kingdom, and Japan were the top three export destinations for Canadian syrup (after the United States). The volume of Canadian syrup reaching all nations other than the United States totals approximately 37 percent of total Canadian syrup exports in the period of 2014–2018.[7] Global trade is expanding as the overall maple syrup crop grows. Statistics demonstrate an average increase in Canadian syrup export volume of 6 percent annually from 2014 to 2018. International trade policy, import-export logistics, and foreign economic growth will increasingly influence maple economics into the future.

Food safety best practices, industry initiatives, and regulatory oversight impact the position of individual businesses and the overall development of the maple economy. Much attention in recent years has been placed on the continued removal of lead-containing collection and processing equipment and the reduction of lead levels in finished maple syrup.

The United States Congress approved the Food Safety Modernization Act in 2011 with oversight of the regulations falling to the U.S. Food and Drug Administration. Registrations, inspections, and compliance requirements implemented in 2018 impact certain maple syrup production, packaging, food processing facilities. In 2019 the Safe Food for Canadians regulations went into effect for maple products and established licensing, preventative control, and traceability standards. In both the United States and Canada, compliance requirements and timelines will

[7] United States Department of Agriculture. Economic Research Service. 2019. Table 43: *US Maple Syrup Production, Imports, Exports and Prices by Calendar Year*. Retrieved July 12, 2019, from https://www.ers.usda.gov/data-products/sugar-and-sweeteners-yearbook-tables/

vary based on business factors that include scale of business, type of products produced, intra-provincial (or interstate) distribution, and exports.

ECONOMIC CONSIDERATIONS OF MAPLE OPERATIONS

The production of maple syrup is a seasonal activity that occurs in a 4–8-week period during late winter and early spring. The seasonal nature of the business must be considered when determining labor requirements and appropriate levels of capital investment. The timing and intensity of the sap run can vary dramatically from one year to the next as can the yield and quality of sap produced per tap. Seasonal weather patterns, microclimates, and daily temperature fluctuations influence sap flows and annual yields. Over a period of years, it is common to have low, average, and above-average yields, although the use of modern technology sap collection moderates this variability to some degree. This uncertainty typifies the agricultural nature of a maple enterprise and the economic risks inherent in maple businesses.

It is extremely important to acknowledge that there is no "master production plan" that will ensure success and profitability in the pure maple syrup business. Each operation is unique, and overall viability depends on a combination of production plans, marketing, innovation, and management style.

While there are similarities between a maple sap/syrup operation and other agricultural activities, there are several aspects of maple syrup production that are unique and influence or contribute to the economic success of the venture. The producer can control some of these variables, but others are affected by factors or characteristics beyond the influence of the producer. Weather patterns, most notably extreme temperature fluctuations during the production season, are among the most prominent of these intractable variables. Several characteristics and/or factors that contribute to the profitability of a maple operation are identified and discussed below.

The Maple Resource

The production of maple sap, and eventually maple syrup, requires maple trees. Most commonly these are located in a woodland or forested area, although maple trees growing along roadsides, in lawn areas, or other isolated areas can also be tapped (**Figure 11.1**). While sugar maple and black maple are the preferred species for sap production, maple sap can also be collected from any species in the genus *Acer*. Depending on the part of the maple region under consideration, the composition of woodlands is variable with respect to species, number of trees per unit area, tree size, as well as tree health and productivity. In natural woodlands it is desirable that between 40 and 120 taps per acre (100–300 taps/hectare) be present, largely depending upon the tree size distribution. This number should be calculated based on the application of recommended tapping guidelines that consider tree vigor and diameter. Sugarbushes with a lower number of taps per unit area may be economically viable if sap sugar concentrations or sap yield per tap are relatively high.

Building Facilities and Equipment

Specialized and dedicated equipment is necessary to produce maple syrup on a commercial scale. This equipment includes but is not limited to sap collection tubing systems, vacuum pumps, transfer pumps, storage tanks, reverse osmosis unit, evaporator, filtering equipment, canning equipment, and packaging equipment. Additionally, a separate production facility (sugarhouse) is necessary (**Figure 11.2**), as is a fuel storage facility, the nature and size

Figure 11.1. A suitable forest dominated by maple trees of the appropriate size and density of trees is a necessity for a profitable maple enterprise.

Figure 11.2. A dedicated facility to house equipment and work from is generally required to allow the production of maple syrup.

of which will depend on the type of fuel used and the size of the operation. If maple products such as maple sugar or various maple confections are produced, a dedicated or licensed kitchen facility is usually necessary. All production facilities must meet minimum local, state, or provincial standards appropriate to food preparation and processing plants.

The majority of equipment and facilities necessary for producing pure maple syrup are unique to the industry, with limited potential uses for other purposes. If buildings and equipment can be used for other ventures during the remainder of the year when syrup production does not occur, overall fixed costs can be reduced and the potential for profit increased. However, in most maple syrup operations the equipment and facilities are only used for a few months each year during the sap and syrup production season. Examples of strategies to reduce fixed costs include the purchase of additional sap to increase the return on syrup processing investments during the short season or the purchase of finished syrup to extend packaging activity and increase resale marketing activities for the entire calendar year.

The Production Season

The production season for collecting maple sap and producing maple syrup is a short 4- to 12-week period in late winter to early spring each year. Sap flow occurs in response to temperature changes, and depending on location, sap runs may begin as early as January and continue as late as April. To collect as much sap as possible, producers must ensure that tapping is complete and sap collection systems fully repaired before significant sap begins to flow. A single missed harvest event or "sap run" of consequence will reduce the total harvest potential. Given the producer's substantial investment in trees, land, equipment and other fixed assets, it makes financial sense to maximize the return on that investment by collecting as much sap as possible each season. Syrup produced from sap collected early in the sap season is often of a higher grade and accordingly higher value than that collected toward the end of the season. With modern technologies in vacuum tubing and taphole sanitation, it is possible to tap early to harvest the first runs with a reduced risk of premature taphole closure reducing the late season sap harvest. If sap collection is done with buckets or bags, the season can be considerably shorter due to taphole "drying."

The type of sap collection system implemented can also have a tremendous impact on sap yield and overall productivity. Traditionally, most producers expected approximately 1 quart (1 liter) or 0.25 gallons of syrup from each tap when using "gravity" collection methods (buckets, bags). However, with the use of modern collection practices, including tubing collection systems with vacuum and good

Figure 11.3. Modern sap collection and syrup processing approaches produce the highest yields of sap. If managed appropriately and carefully, a reasonable net profit can be achieved.

taphole sanitation practices (**Figure 11.3**), much higher yields, 0.4–0.5 gallons (1.5–1.9 liters) or 4.4–5.5 pounds of syrup per tap, or more, are routinely attainable, though now many commercial producers are striving for and demonstrating even higher yields. However, this amount can and does vary considerably depending on the sugaring operation and the year. When planning for annual projected revenues from syrup production it is advisable to plan conservatively. Thus, planning for approximately 0.20 gallons (0.76 liters) or 2.2 pounds of syrup per tap with traditional methods, and 0.35 gallons (1.3 liters) or 4 pounds per tap or more syrup can be appropriate when adopting modern sap collection technology and practices. After several years of experience at a particular site, the long-term average production can be used in planning, factoring in annual variation.

The Production Process

The production process for high-quality pure maple syrup requires considerable skill and attentive labor. While the development of automated and efficient production equipment has made the process easier, in the minds of many, making high-quality syrup is both art and science. The production process begins with the prompt processing of high-quality sap. Sap collection systems should be efficiently designed and maintained so deterioration of sap does not occur in the collection system, nor does it become contaminated during storage in unsanitary holding tanks. Processing sap into syrup must be done whenever enough sap is available (**Figure 11.4**). Reverse osmosis units can greatly reduce the length of evaporation time; however, prompt processing is still essential. Sap flow and processing timing and magnitude are unpredictable. From an economic perspective, tubing system repairs and sap-to-syrup processing are required at nontraditional or extended working hours and may contribute to increased production costs, particularly if hired labor is involved.

Income Potential

Because the profitability of maple syrup production hinges on so many unpredictable factors, the prospect of relying on this activity as a primary source of income is inherently uncertain. Maple syrup production can be an excellent source of

Figure 11.4. Sap must be processed into syrup quickly via boiling or reverse osmosis in combination with boiling.

supplemental income when combined with other on-farm enterprises or off-farm jobs. The seasonality of maple production affords producers the flexibility to take on other income-generating projects and ventures throughout the remaining months of the year. The income potential of maple operations varies widely depending on their characteristics and target markets—so estimates of how much producers can expect to earn differ accordingly. For example, while one previous economic study suggested that approximately 10,000 taps are required to provide adequate income for a family unit in Ontario,[8] another found potential for positive economic returns for enterprises 1,500 taps or more that were successful with value-added products and retail marketing.[9] Economic research on U.S. maple operations demonstrates a range of differences in financial performance depending on the scale of an operation, the yields achieved, and the marketing strategies employed. Bulk syrup producers of approximately 8,000–10,000 tap size have been able to generate an adequate owner salary draw to compensate for their labor time when market prices range from $2.35 per pound (U.S.) or higher.[10] The decline in bulk syrup market price in the U.S. from 2013 to 2020, in large part due to currency exchange rate, has demonstrated how income potential and profitability are reduced dramatically at this scale of production as prices move closer to $2.00 per pound (U.S.).

ECONOMIC COST COMPONENTS

In most business endeavors, including maple syrup production, there are two categories of financial costs. These are identified as fixed costs and variable costs.

[8] Canadian Farm Business Management Council and the Ontario Ministry of Agriculture, Food and Rural Affairs. 2000. *Report on the Economics of Maple Syrup Production.* First Edition. 45 pp.

[9] Groupe Hemlock Group. 2013. Planning for Success: The Economics of Maple Syrup Production in Ontario, Ontario Maple Syrup Producers Association, 64pp. https://mapleresearch.org/pub/the-economics-of-maple-syrup-production-in-ontario/

[10] https://blog.uvm.edu/farmvia/?page_id=394
Cannella, M. 2016. The cost of production for Vermont maple syrup. *Maple Syrup Digest.* Oct. pp. 13–17. https://mapleresearch.org/pub/m1016costofproduction/

Fixed Costs

Fixed costs are those that do not vary with the annual level of production, including costs associated with facilities, equipment, and other overhead or management.

THE MAPLE RESOURCE If the forest and trees are owned, they are an investment with real estate cash value. The annual return on the land and tree investment can be represented by a cash value equal to the annual rental for similar land in the local area. This value represents a fixed cost that is present regardless of whether trees are tapped and is not affected by the amount of syrup produced. Similarly, if a maple producer is leasing trees from a nearby landowner, the annual lease payment represents a fixed cost no matter how much sap is collected in a given year. The purchase price of forest land and annual lease rates vary widely by region or site location. The presence of real estate tax abatement programs associated with forestry or agricultural practices can have a significant influence on lease rates and ownership costs.

THE SUGARHOUSE OR PROCESSING FACILITY Although this facility may be a part of another structure on the farm, it is dedicated to maple syrup production and thus represents an investment that must be charged to the cost of syrup production. Usually, the cost of the sugarhouse is depreciated over time (see “Worksheets for Determining Cost-Return Relationship”); calculating the annual depreciation amount may be one method of assigning a per-year fixed cost value to this facility. Like the maple tree resource, the cost component represented by the sugarhouse is not affected by the amount of product produced.

SYRUP PROCESSING EQUIPMENT The majority of maple syrup production facilities incorporate a commercial evaporator and several pieces of related equipment, which can include reverse osmosis units, filtering equipment, various types of sap preheating devices, storage tanks and drums, canning units, and retail bottling units. Additionally, some operations have separate processing kitchens complete with standard kitchen appliances as well as specialized processing and packaging equipment. At the majority of operations, this equipment is dedicated solely to maple syrup and related product processing and represents a fixed investment necessary for the operation to function.

SAP COLLECTION EQUIPMENT The type of equipment used for sap collection varies considerably among different operations. Sap is typically collected using buckets, plastic bags, or plastic tubing. Equipment required for the actual tapping includes a drill, specialized tapping bit, hammer, tubing installation and repair equipment, and fittings. Other necessary collection equipment may include sap transfer pumps, vacuum pumps, releasers, sap collection and storage tanks, wagons or trailers, tractor/trucks/ATVs, and, in some cases, generators. The amount and specific type of equipment required reflects the size and layout of the sap collection system as well as topography, proximity to the sugarhouse, management expectations, and availability of electricity. Like most of the equipment necessary for evaporation, sap collection equipment is quite specialized and has limited use outside the maple operation; thus it represents a fixed cost component of the operation. The exception to this generalization would be items such as tractors or ATVs that are used in other farming operations or household activity outside the scope of the maple business. In such cases, a portion of the equipment value is charged to the maple operation.

INSURANCE A significant investment in facilities and equipment is necessary for successful and efficient maple operations. Furthermore, a substantial liability risk is associated with the operation. To protect the physical assets and to prevent loss in the event of a claim related to a personal liability concern, maple producers carry both property and liability insurance. Producers are also advised to consider product liability policy and other additional policies relevant to their business activity. Participation in different market channels from farmers markets to institutional food service contracts will likely require different policy coverage and different cost profiles for each business. If the value of marketable product in storage is substantial, business owners should determine if additional inventory insurance coverage would be beneficial. Increased investment in tubing systems and woods-based technology that are difficult to insure with standard policies may entail unexpected risk exposure. Federal governments have developed crop insurance policies for many agricultural commodities and business owners can inquire if subsidized crop, revenue, or catastrophic loss policies are applicable to maple sap and syrup enterprises.

The amount of coverage can change from one year to the next; however, the cost of insurance reflects a fixed cost that is not necessarily influenced by annual production.

TAXES Property taxes are a fixed expense for producers that own their forest land or related property and buildings. Property tax abatement programs are common if enterprises meet the established criteria for forestry or agricultural operations in their locale.

Variable Costs

Variable costs are those costs associated with annual sap and syrup production. These are directly related to the amount of syrup and processed products that are produced each year and are expected to increase or decrease with respect to the amount of production. Costs commonly identified as variable costs include the following:

LABOR Maple syrup operations are labor intensive. Labor is required for all aspects of the operation, from sap collection to evaporation, to canning and secondary processing. Some mechanization of the production process is available; however, substantial amounts of manual labor are still necessary. In the process of sap collection, labor is necessary to tap the trees, install and maintain tubing systems, operate and maintain pumps and other equipment, empty buckets (if this method is employed), clean storage tanks, pull spouts, and clean the entire system when the sap collection concludes (**Figure 11.5**). Producers seeking to achieve high yield levels require

Figure 11.5. Many of the activities in a maple operation are quite labor intensive, and frequently do not follow a regular schedule. Long days, evenings, and weekends alike can be tremendously busy.

a large amount of labor to monitor vacuum tubing systems and repair leaks.

In the evaporation process, labor is necessary to run the reverse osmosis unit and evaporator, maintain and monitor sap levels in storage and feed tanks, filter and pack finished syrup, clean equipment, maintain records, and sanitize the facility regularly. New technology can reduce the amount of labor required; however, substantial labor is still required.

Business management is required through the entire calendar year to maintain a successful enterprise. Prior to the season, decisions must be made with respect to fuel production and/or purchase; appropriate production and canning supplies; repair and maintenance of equipment, including tubing systems; new investments; and employee management. Marketing syrup to direct and wholesale markets involves many managerial roles. These may include operation of a retail facility, packing/shipping, promotion, and sales and delivery. Labor and management are required to maintain production records, financial bookkeeping, food safety records, and tax accounting.

It is essential that the cost of all labor required to operate a maple business be identified and valued to accurately calculate the profitability of a business. Unpaid labor is prevalent in maple enterprises as with most owner-operated small businesses. From a cash flow perspective, unpaid labor can appear as a theoretical cost-savings or cost-avoidance. This practice becomes problematic in many situations that require an accurate and realistic measurement of the necessary labor required to sustain the venture. Business succession planning, product pricing, business valuation, and sustainable workload planning are important issues that are best informed with accurate labor tracking. The value of an owner's unpaid labor or "opportunity cost" is determined by selecting the rate his or her labor and management skills could earn in another comparable job or task. The value of labor from unpaid family or friends can be valued at the prevailing wage rates for comparable workers. Combined paid and unpaid labor is the largest economic expense for maple operations. The total labor cost ranges from 25 to 40 percent of total sales for most maple businesses.

Failure to include a cost for the labor provided by oneself and other family members can lead to misleading analyses and inflated or unrealistic estimates of profit margins. An accurate determination of profitability becomes especially important when the current owner seeks to transfer the maple business and property to another family member or new owner.

EMPLOYEE INSURANCE AND BENEFITS Bona fide employees must be covered by appropriate insurance programs. In the U.S. these include Workers Compensation Insurance, FICA, and Medicare; in Canada required insurance includes Employment Insurance and the Canadian Pension Plan. The premium amounts are directly related to the cost of labor and hours worked, which vary depending on the intensity and duration of key aspects in the maple season.

FUEL A single maple business may use multiple fuel sources. Fuel is used to operate gasoline-powered pumps and generators (if present), trucks, tractors, ATVs or other powered collection equipment, and the evaporator. The cost of fuel for the evaporator is usually the largest component of fuel costs. Evaporator fuel may be wood, oil, natural gas, propane, or electricity. There is a common perception that wood is a less expensive fuel. In comparison with purchased fuel oil, natural gas, or propane, this may be true on a cash basis. However, if wood is produced on the farm there are associated labor and equipment costs involved that must be charged against the maple operation.

UTILITIES Charges are incurred for the cost of ordinary utilities necessary for the operation to function efficiently. Common utilities include electricity, telephone/cellular service, water and sewer (some installations), natural gas and/or propane, and internet. The greatest electricity costs are often attributed to reverse osmosis units and vacuum pumps. Those utility charges that relate directly to the maple syrup operation should be identified and accounted for as a variable expense. Adoption of photovoltaic solar systems can reduce usage of traditional energy sources within the maple enterprise. A combination of technological advancements, reduced costs, and government support programs can facilitate the installation of solar electric generation capacity on site.

PACKAGING AND STORAGE Maple syrup is packaged in containers of various sizes, depending on the marketing strategy of the operator. Retail operations typically package a portion of their output in containers appropriate for retail sales (including syrup containers of various sizes and packaging for value-added products such as cream jars, candy cups, and candy boxes), while storing the rest in drums for later repackaging or further processing. Bulk operations will package syrup exclusively in drums or totes for sale to processors or other producers. Drums and totes have multi-year life span and are investments in the fixed cost category. All other non-reusable containers represent an annual variable cost. Storage of the packaged product also represents a variable cost reflecting the amount produced and the conditions under which it is stored.

MARKETING Expenditures for annual advertising, promotion, and other publicity relating to promoting maple products are examples of annual marketing costs. For a producer who sells large volumes of maple products directly to the public and who undertakes an extensive advertising program, marketing costs may be substantial. Delivery/shipping costs and customer service associated with supplying retail and wholesale outlets are important to account for.

Other Economic Factors

The economics of maple syrup production can be complex. Numerous factors come into play each year and across several years of production. Maple producers shouldn't assume that they will be able to calculate the profitability of their operations in one short session. Frequently professional assistance might be required and advised, especially if producers are considering taking on sizeable debt to expand their operations. Well-considered and reasonable estimates, based on real data, if possible, are incredibly helpful. The description below along with the worksheets and links presented hereafter can help guide you in this effort.

COST OF PRODUCTION It is important for producers to determine the actual cost of production for maple products. This information is used to form the basis for pricing individual products, allocating different quantities of product to various market channels, identifying opportunities for decreasing individual cost components, and determining the level of profitability of the operation. Production costs vary significantly among different operations. Large, integrated operations tend to have lower costs primarily due to the economies of scale possible when managing tens of thousands of taps in a single sugaring operation. Large modern maple operations will require a large capital investment. While annualized operating costs can be lower, the initial access to capital to make the investment and the costs associated with this capital must be considered.

Production costs and syrup value can also vary within a season, especially towards the end of sugaring when RO processing and filtering become more difficult. As syrup becomes unfilterable, buddy, off-flavor or ropy, producers need to know when labor, fuel, and other costs of continuing begins to exceed the value of syrup being produced.[11]

SAP COLLECTION SYSTEM COMPARISONS Maple sap is collected using buckets, bags, or a tubing system that can be of different designs and sizes. The initial cost of components and the cost of the labor required for installation, sap collection, maintenance, repairs, and cleaning also differ across various systems. While variations exist among operations, a couple of generalizations have been established. The initial cost of components for each system can vary dramatically, depending on size of the system, composition of the forest, distance of transport, and quality of equipment. Initial material and installation costs for tubing systems are greater than for non-tubing systems; however, after installation, maintenance costs of a tubing system are substantially lower. Once each system has been installed, the sap collection costs, driven by labor, for non-tubing systems are substantially higher than for tubing installations. Furthermore, studies have shown that each inch of vacuum generated at a taphole produces 5–7 percent more sap in an average year.[12] Thus, even though it may cost more to install a vacuum tubing system, the enhanced yield makes it a more profitable investment than traditional bag or bucket systems. **Chapter 6** provides a great deal of information on how to increase sap yields profitably.

COMPARISONS OF EVAPORATOR FUELS The cost of fuel for the evaporator is a significant component of total processing costs to convert sap into maple syrup. The cost per unit of product produced with each type of fuel (wood, fuel oil, propane, natural gas, electricity, wood- or fuel-driven steam) vary widely depending on specific operation properties and geographic location, evaporator technology and features, and annual fluctuations in fuel prices. Producers are encouraged to consult **Chapter 7** and with maple equipment manufacturers to help assess the likely costs of available fuel options for their operations.

ECONOMIES OF SCALE In general, larger operations are more efficient with respect to utilization of collection and processing equipment, and accordingly have a lower per unit production cost than smaller operations. The economies of scale that come into play here can be summed up as the ability to spread out fixed costs over a greater production volume, thereby lowering the average cost per unit produced. There are some exceptions to this generalization, particularly if the operation becomes too large to manage efficiently, causing production per tap to go down and managerial costs to go up. In fact, sugaring operations with low costs per gallon of syrup produced can be found at enterprises of all sizes, indicating that how well an operation is managed has a greater impact on the overall cost of production than the operation's size.[13]

DIVERSITY OF PRODUCTS PRODUCED AND MARKETED For maple syrup producers who package and market maple syrup in containers of various sizes and styles or who process maple syrup into sugar, maple cream, and other maple confections, the value received per gallon of syrup used is significantly higher than if syrup is sold in bulk. Although processing and packaging costs are higher, the total increase in value may range from 35 to 100 percent or more. Results from research studies related to packaging and producing secondary products indicate that total profit from a maple operation will be considerably greater for producers who take the time to manufacture other products and offer them for sale if processing and marketing labor expenses can be managed

[11] Isselhardt, M. and T.D. Perkins. 2015. When to stop: some factors affecting the economics of processing grade syrup. *Maple Syrup Digest*. June. pp. 11–13. https://mapleresearch.org/pub/m0615processingeconomics/

[12] Wilmot, T.R., T.D. Perkins, and A.K. van den Berg. 2007. Vacuum sap collection—how high or low should you go? *Maple Syrup Digest.* Oct. pp. 27–32. https://mapleresearch.org/pub/m1007sapcollectionvacuumlevel/

[13] University of Vermont Extension—Maple Management. https://mapleresearch.org/pub/maple-management/

and factored into pricing accurately. Careful analyses should be conducted to ensure that the additional sales generated by producing and selling maple syrup and other products in retail and wholesale environments is worth the extra time and expense involved.

MARKETING Where and how pure maple products are marketed has an influence on the total price received per unit volume of product sold (see **Chapter 10**). Marketing all maple products only at the point of production will usually result in lower prices received than if specialty marketing outlets are located and developed. Returns from marketing maple products in tourist areas or specialty food stores will generally be greater than if all products are marketed from the sugarhouse. Likewise, those producers who develop a user-friendly, attractive website with provision for direct consumer sales may realize larger total returns than if their products are offered only through local sales outlets. Some producers have developed profitable markets by providing maple syrup to local candy or confection manufacturers or restaurants or by developing attractive gift packages suitable for use by local businesses as customer appreciation gifts or holiday gifts. Opportunities for creativity in marketing are many. Producers who are successful in developing and maintaining niche markets will be rewarded for their efforts.

WORKSHEETS FOR DETERMINING COST-RETURN RELATIONSHIP[14]

Evaluating the sales, expenses, and net income from the maple syrup enterprise is an important step for maple producers. The producer can use this information to manage expenses going into the business and manage a viable marketing plan to sell the product. Measuring cost of production and evaluating profitability include a review of accurate accounting records for direct operating costs and additional financial calculations for capital costs associated with owning multi-year investments and borrowing costs. Facilities, equipment, and management will vary substantially between producers, making it difficult and risky to assume there is an "average production" cost that is applicable to all operations. Previous cost studies tend to be snapshots of individual operations at a specific point in time. It is possible to estimate production costs as a percentage of average sale price (85 percent has been suggested[15]), but this is only an approximation and may lead to erroneous estimates, especially in years of poor production. It is recommended that producers adopt an accurate accounting system and commit to routine financial review to evaluate financial performance and ensure that their goals are met.

It is important to distinguish this financial analysis from the pragmatic cash flow situation facing the business. Cash flow management refers to the real day-to-day flow of cash on hand and payment of bills as they come due. The investments required to operate a maple enterprise require that additional financial analysis steps are undertaken to capture the multi-year dimension of this business. Managers will use bank account statements and current accounting systems to manage cash flow. While separate tools are needed to complete annual analysis, the full income/expense worksheet with be presented first, with the detail to follow.

Table 11.2 shows an example of a completed income and expense worksheet for a well-managed 5,000-tap enterprise with an annual crop yield of 2,000 gallons (0.40 gallons per tap). Sales or gross receipts for the year total $75,000. The sheet includes space for variable costs, fixed costs, owner labor value, and annual depreciation of maple assets. In this example, total expenses equal $73,950, resulting in the net income of $1,050 shown at the bottom of the table. Several important points revealed from this worksheet warrant discussion.

- Sales: This worksheet shows that maple syrup is sold through multiple market channels.

[14] Blank worksheets used in this chapter are available at https://smallfarmcourses.com/p/bf-152-intro-to-maple-syrup-production (Microsoft Excel) and https://mapleresearch.org/pub/economics-worksheet-for-maple-production-pdf/ (pdf) Several other maple business tools are available at https://mapleresearch.org/pub/maple-management/

[15] Sendak, P. E., and J. P. Bennink. 1985. The Cost of Maple Sugaring in Vermont. USFS Research Paper NE-565. 14pp.

TABLE 11.2 Sample income and expense worksheet for 5,000-tap enterprise	
Cash Receipts	
Retail Syrup Sales	$30,000
Bulk Syrup Sales	$20,000
Wholesale Syrup Sales	$25,000
Value Added Products	
Other	
Total Gross Receipts	$75,000
Variable Costs	
Custom Hire	
Evaporator Fuel	$4,250
Freight, Trucking, Shipping	
Gasoline, Fuel and Oil	$1,000
Other Fuel—Oil / Propane	
Packaging and Containers	$4,000
Labor and Payroll	$7,500
Marketing—Advertising/Promotion	$2,000
Purchased Sap	$800
Purchased Syrup	$—
Repairs and Maintenance	$2,500
Supplies Purchased	$4,000
Utilities-Electric	$2,000
Other Expenses: ____________________	
Fixed Costs	
Fertilizers and Lime	
Insurance (other than Health)	$1,000
Interest	$4,000
Marketing-Internet, Events	$500
Professional Services	$750
Rent: Taps	
Rent: Other	
Subscription, Dues, Educational Fees	$400
Taxes: Real Estate	$750
Taxes: Other (sales)	
Other	
Depreciation (Separate Worksheet)	$18,000
Owner Labor (Separate Worksheet)	$20,000
Total Expenses	$73,950
NET INCOME	$1,050

- Costs: The sheet shows that the largest costs to the business are depreciation and owner labor, but these can vary depending on the operation. The next largest expenses in this example are paid labor, evaporator fuel, interest on debt, packaging, and supplies.
- Depreciation: This is not a cash basis expense that the business will write a check for. Depreciation is a calculation used to prorate an annual expense for long-term investments. An owner can use the demonstrated depreciation value as a benchmark to evaluate a feasible amount of loan payment or capital expenditures that the business can support. Owners may also use the depreciation worksheet to determine if and how much to put into a reserve account for future asset replacement.
- Value of Owner Labor: This line indicates the value of owner management required to run the enterprise. In this example, the owner draws $20,000 as compensation. Very often owners will underpay themselves and redirect the funds that would otherwise go to their salary to investments in business assets. This strategy is viable only if the household can afford to forgo the income derived from the owner's compensation for time spent on the job. Owners should also take caution when their labor is unpaid and the balance of funds goes to variable and fixed costs rather than business asset investment. In those cases, the forgone owner draws are used up immediately rather than building equity in business investments. If owner reinvestment becomes a chronic situation to bridge cash flow deficiencies, the viability of the business becomes a concern. The situation is further complicated as owners consider an exit or sale of the business. The long-term implication of reinvestment, capital accounts, and capital gains should be considered with assistance

from a qualified financial and tax professional.

In the example shown in **Table 11.2**, this well-managed maple business can cover the annual costs associated with the business, including owner compensation. In total for the year, there is a small positive net income (profit). However, it is obvious that this worksheet is a very simple summary only, and that some categories require further explanation and expansion for the table to be truly comprehensive.

To fully understand expenses, it is necessary to track annual direct costs associated with maple syrup production and the items related to the non-cash basis expenses of depreciation and owner management.

Depreciation is an annual expense that reflects the aging or wear-and-tear on assets that are used for multiple years. It is calculated by dividing the initial purchase price by the anticipated number of years until the asset is anticipated to be or is replaced (the life span of the item). Assets commonly depreciated over time include machinery, equipment, buildings, improvements, and real estate that will have a useful life of more than one year. Depreciation does not include annual maintenance costs, as these are already factored in on the income and expense worksheet (**Table 11.2**).

A blank worksheet for calculating Annual Straight-Line Depreciation of Maple Assets is shown in **Table 11.3**. Items can be added or subtracted to this table depending on the producer's inventory of assets. Knowing the purchase date and life span is important since the time frame over which these items can be depreciated will vary.

For example, consider the business purchase of a new utility vehicle for $7,500 with an estimated useful life of 10 years. The purchase price of $7,500 is divided by the 10-year life span to generate an annual depreciation value of $750 per year. That same $750 annual depreciation for this vehicle will be included in the financial analysis for 10 years or until the item is sold or taken out of service. This simplified depreciation method does not include salvage or trade-in value (if any) at the end of the asset life and is distinct from other tax-related depreciation methods. Once an item has been fully depreciated, the depreciation cost falls to zero regardless of whether the item is replaced.

Since a maple enterprise often complements an additional farm or forestry infrastructure, the maple analysis may account for less than 100 percent of certain shared assets. An example of this can be seen with a tractor purchased for $35,000 that is used for both maple production and for other farm activities (snow removal, use for other agricultural crops, etc.) throughout the year. If the owner decides that the maple enterprise is responsible for 30 percent of the tractor's annual usage, then the maple analysis should prorate the purchase price of the unit to $10,500 ($35,000 × 30%).

The labor of the owner and perhaps family members does not come free. Time spent on the maple operation could be generating income in other ways. Each owner should independently decide how much their effort is worth and how much compensation they expect to draw from the business. One way to calculate the value of owner's labor is based on the amount of time engaged in various activities related to the operation. These can be estimated using the worksheet shown **Table 11.4** and the resulting amount then entered on the appropriate line on the income and expense worksheet.

With these other worksheets completed, a manager can then move on to evaluate the cost of production and annual profit in relation to productivity. **Table 11.5** calculates several financial measures that provide useful information on the business. It is helpful for the manager to see business expenses expressed in relation to the units of production: in this worksheet example we use gallons of finished syrup. Some managers may decide to convert the metric to pounds, barrels, liters, or whatever unit is most relevant to their operation. Regardless of the metrics used, this worksheet provides information to the manager for comparing the overall costs of production to market prices. In this case, the total cost of production (including owner compensation and asset depreciation) is $36.96 per gallon. This type of financial analysis can inform plans to target appropriate markets and to

TABLE 11.3 Worksheet for calculating annual straight-line depreciation of maple assets.

Category	Purchase Price ($)	Purchase Date (mm/dd/yy)	Estimated Life Span (years)	Annual Depreciation (Price ÷ Life Span)
MACHINERY				
Utility Vehicle/ATV				
Snowmobile				
Off-Road Tractors				
Truck				
Other				
EQUIPMENT				
Buckets				
Chainsaws				
Draw-off Accessories				
Drums/Barrels				
Evaporator and Hood				
Filter and Canning Units				
Forced Draft Unit				
Generator				
Reverse Osmosis				
Tanks				
Tapping units				
Total Farm Equipment				
Trailers				
Transfer Pumps				
Tubing System				
Vacuum Pumps/ Releasers				
Other: ____________________				
Other: ____________________				
LONG-TERM ASSETS				
Sugarhouse				
Transfer House				
Collection House				
Leasehold Improvements				
Real Estate: Owned			n/a	n/a
TOTAL ANNUAL DEPRECIATION				

TABLE 11.4 Owner's labor and management compensation worksheet.

Time Spent in Activity (Hours)	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**TOTAL**
Woods/Lines/Taps													
Sugarhouse													
Packing/Canning													
Marketing/Sales													
Business Management													
Total Hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Labor Rate ($/hr)	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00
Unpaid Labor Value ($) (labor rate × total hours)	$—	$—	$—	$—	$—	$—	$—	$—	$—	$—	$—	$—	$—

TABLE 11.5 Cost of production and profit summary for the sample 5,000-tap operation producing 2,000 gallons (0.40 gal/tap)

Costs of Production	Cost/Gallon
Average Fixed Cost per Gallon of Syrup Produced ($7,400/2,000)	$4
Average Variable Cost per Gallon of Syrup ($28,550/2,000)	$14
Annual Depreciation Cost per Gallon of Syrup Produced ($18,000/2,000)	$9
Value of Owner Labor per Gallon of Syrup Produced (e.g., $20,000/2,000)	$10
Total Costs per Gallon of Syrup Produced ($3.70 + $14.25 + $9.00 + $10.00)	$37
Profit Summary	
Average Sales per Gallon ($75,000 / 2,000 gallons)	$38
Total Value of All Syrup Produced and Sold	$75,000
Net Profit per Gallon	$1
Total of Yearly Fixed and Yearly Variable Costs	$73,900
Total Profit from Production and Sales of Maple Products	$1,100

establish the pricing and market mix needed to maintain a successful business.

These worksheets provide a basic financial analysis of the maple enterprise that can be useful for planning and review. This analysis does not include all the factors required for a comprehensive financial analysis. A more thorough analysis would factor in changes to the fair market value of inventory, annual balance sheet adjustments, salvage values on equipment, and alternative depreciation methods.

Producers seeking to evaluate long-term returns may include time-value-of-money calculations in their financial analysis. These calculations integrate a discount rate to ensure that both principal (starting amount) of owner investment and interest are paid back.

OTHER ECONOMIC CONSIDERATIONS

Many maple syrup producers own their sugarbush and obtain sap by tapping trees that are appropriate in size and are conveniently located for sap collection. However, sap supplies may be supplemented by purchasing sap from other operations or by leasing trees from neighbors. Maple leases are becoming common as more producers seek access to maple forests to start or expand their maple enterprise. In some locations maple trees on public lands are leased for tapping. Additionally, many maple producers do not have adequate quantities of syrup to supply market demand and will purchase finished syrup from other producers or bulk markets to augment their own production.

Tap Rental—A commonly accepted practice or standard for determination of the value of a rented taphole does not exist within the maple industry. There are several approaches to compensating property holders for the value of a taphole, including bartering for other services, providing syrup in exchange for tapping privileges, or annual rental on a per taphole basis or per acre basis. Any method that results in satisfaction for both parties is acceptable; however, the most equitable method is probably one that provides payment on a mutually agreed-upon price per taphole. Taphole rental rates vary throughout the region from $0.50 to $2.00 as of 2020. Variation in rates reflects accessibility, number of tapholes per acre, availability of local electric service (to power pumps), size and quality of the trees present, sugar content of the sap, bulk price of syrup, and the supply and demand for sugarbushes in a given area.

For trees in sugarbushes, a suggested taphole rental rate can be determined based on the average agricultural land rental rate present in the local area. To use this approach, it is necessary to know this value as well as the total size (acres) of the sugarbush and the total number of tapholes per acre (divide total number of tapholes by number of acres in sugarbush). To determine the average taphole rental rate, the land rental rate is divided by the average number of tapholes per acre. This per tap value is then multiplied by the number of tapholes present to determine the total rental amount. These computations are illustrated in the following example:

Average local agricultural land rental per acre: $100
Number of acres in sugarbush: 20
Total number of tapholes in sugarbush: 1,760
Average number of tapholes per acre: (1760/20) = 88
Average taphole rental rate: ($100/88) = $1.13
Total sugarbush rental value (1760 x $1.13) = $1,989

This approach should work satisfactorily for adequately stocked maple stands (more than 60 taps per acre). For stands that are less well stocked or that are inconveniently located in terms of accessibility or distance from the main operation, the tap rental price may need to be lowered to reflect factors such as the decreased revenue potential of the stand and the increased costs of gathering or transporting sap.

Another method for determining a taphole rental rate is by adjusting the prevailing rental cost according to changes in the bulk market price of maple syrup. This can be done by establishing the prevailing rental rate percentage under current market conditions. Once that percentage is known the cash value of the tap rental can be adjusted under new market conditions. These computations are illustrated in the following example:

Current Bulk Syrup Price: $2.25 per pound
Prevailing Rental Rate: $1.00 per tap
Historic or Projected Yield: 3.9 pounds per tap
Projected Revenue per Tap: $2.25 x 3.9 = $8.78
Rental Rate: $1.00 per Tap / $8.78 = 12%

If the bulk syrup price were to increase to $3.00 per pound, the rental rate would increase according to the established rental percentage rate (12% of tap revenue).

New Revenue per Tap: $3.00 per pound x 3.9 pounds = $11.70
New Rental Rate per Tap: $11.70 x 12% = $1.41

This example of an adjustable rental rate introduces the concept of risk and reward sharing between a landlord and a tenant. The prior example demonstrates how a rental charge may increase under favorable market conditions. The same approach can reduce risks to the producers by reducing the taphole rental charge when the market price of syrup goes down.

A formal lease is the legal instrument used to document the specific terms guiding the relationship between landowner and lessee. A written agreement that identifies the obligations and expectations of both the landowner and the lessee is recommended.[16]

Sap Sales and Purchases—Purchase of sap from neighboring farms or other individuals is a common practice throughout the maple industry. Tapping trees and selling sap to producers with evaporators is done by individuals who choose not to process their own sap, but still wish to obtain some income from the maple resource.

Sap purchase can be mutually beneficial to both producer and processor if jointly developed guidelines for collection and quality control are stipulated and agreed to and if an equitable purchase price schedule or arrangement is in effect.

[16] https://mapleresearch.org/search/?_sf_s=lease&_sft_date=2020

It is essential that purchasers receive sap in good condition so quality syrup can be produced. Likewise, the sap collector must receive a fair price that provides adequate compensation for the tapping and collection efforts expended. Suggestions for components of sap purchase agreement guidelines include the following:

1. Sap collection, gathering, and transportation equipment is thoroughly clean.
2. Sap is collected and delivered daily when the sap flows.
3. Sap sugar content will be determined at the time of delivery to the processing facility.
4. All sap will be handled in a manner that will maintain quality.
5. Payment for sap will be made following a mutually acceptable rate and time schedule.

The price paid for purchased sap varies widely throughout the maple region. However, nearly all payment methods relate to sap sugar content and the market value of the equivalent processed syrup equivalent. Prices will also vary depending on whether the sap is delivered by the seller to the buyer's location or must be picked up by the buyer at an off-site collection point.

Because of varying production costs and prices for pure maple syrup, local and regional differences in demand and supply, and sap quality fluctuations, a uniformly accepted price schedule for sap of varying sugar content does not exist. Rather, producers and sellers of sap must agree to a price schedule that will be mutually acceptable. One method of setting prices takes into account the sap sugar concentration, bulk syrup prices, and the percentage of syrup (or bulk syrup price) provided to the sap seller. The simplest way of doing these calculations is to use one of several calculators[17] available online to determine the price paid to sap sellers by the buyer. Although a 50 percent distribution of syrup revenue to the sap seller is quite common, the split can easily be changed using those spreadsheets to be applicable to a given agreement.

[17] https://mapleresearch.org/search/?_sf_s=sap%20pricing

For a simple 50 percent split between buyer and seller, **Table 11.6** can be used to determine a price per gallon paid at different sap sugar content levels over a range of syrup bulk prices.

In some maple regions, increased investment in sap collection technology, sanitation, and the substantial amount of labor needed to maintain vacuum systems, combined with a competitive market for purchasing sap, has led to a 60–70 percent distribution of syrup revenue to the sap producer. Generally speaking, larger and more efficient sugarhouses and processors are often able and willing to pay higher prices for sap. Purchase of sap is an effective strategy for increasing the volume of processed syrup moving through the sugarhouse to increase business revenues without assuming the additional investment or risk entailed in harvesting more sap. Maple processors considering sap purchase should be aware of how the volume of sap purchases can impact their designation as either an agricultural, forestry, or commercial/industrial entity. Jurisdictions in both the U.S. and Canada will have criteria for "processing" activity that may impact taxation, development permitting, and other regulations.

The final split is determined by negotiation and mutual agreement between sap seller and buyer. The agreed-upon split and the methods to be used to measure sap volume and sap sugar content should be stipulated in writing before the season begins, but the parties can decide on the level of formality required to establish the relationship and manage the risk of unexpected events to either business.

Purchasing Finished Syrup—In addition to renting trees and purchasing sap as a means of expanding syrup production, some producers find it necessary or advantageous to purchase finished syrup to augment their own production. Rather than purchasing syrup every year, many producers do so periodically to increase their revenue potential when a "short crop" is produced or when an unexpected marketing opportunity is present and their own supply of syrup or other finished products is insufficient to meet the demand. Purchase price can be set using bulk or wholesale prices applicable to the local region and will likely vary from year to year. For producers who purchase finished

TABLE 11.6 Sap Price Table at 50% Crop Share Based upon Bulk Syrup Price.

	Bulk Syrup Price ($/lb)															
Sap Sugar Content (%)	$1.50	$1.60	$1.70	$1.80	$1.90	$2.00	$2.10	$2.20	$2.30	$2.40	$2.50	$2.60	$2.70	$2.80	$2.90	$3.00
0.6	$0.06	$0.06	$0.07	$0.07	$0.07	$0.08	$0.08	$0.08	$0.09	$0.09	$0.10	$0.10	$0.10	$0.11	$0.11	$0.12
0.7	$0.07	$0.07	$0.08	$0.08	$0.09	$0.09	$0.09	$0.10	$0.10	$0.11	$0.11	$0.12	$0.12	$0.13	$0.13	$0.13
0.8	$0.08	$0.08	$0.09	$0.09	$0.10	$0.10	$0.11	$0.11	$0.12	$0.12	$0.13	$0.13	$0.14	$0.14	$0.15	$0.15
0.9	$0.09	$0.09	$0.10	$0.10	$0.11	$0.12	$0.12	$0.13	$0.13	$0.14	$0.14	$0.15	$0.16	$0.16	$0.17	$0.17
1.0	$0.10	$0.10	$0.11	$0.12	$0.12	$0.13	$0.13	$0.14	$0.15	$0.15	$0.16	$0.17	$0.17	$0.18	$0.19	$0.19
1.1	$0.11	$0.11	$0.12	$0.13	$0.13	$0.14	$0.15	$0.16	$0.16	$0.17	$0.18	$0.18	$0.19	$0.20	$0.20	$0.21
1.2	$0.12	$0.12	$0.13	$0.14	$0.15	$0.15	$0.16	$0.17	$0.18	$0.18	$0.19	$0.20	$0.21	$0.22	$0.22	$0.23
1.3	$0.13	$0.13	$0.14	$0.15	$0.16	$0.17	$0.18	$0.18	$0.19	$0.20	$0.21	$0.22	$0.23	$0.23	$0.24	$0.25
1.4	$0.13	$0.14	$0.15	$0.16	$0.17	$0.18	$0.19	$0.20	$0.21	$0.22	$0.22	$0.23	$0.24	$0.25	$0.26	$0.27
1.5	$0.14	$0.15	$0.16	$0.17	$0.18	$0.19	$0.20	$0.21	$0.22	$0.23	$0.24	$0.25	$0.26	$0.27	$0.28	$0.29
1.6	$0.15	$0.16	$0.17	$0.19	$0.20	$0.21	$0.22	$0.23	$0.24	$0.25	$0.26	$0.27	$0.28	$0.29	$0.30	$0.31
1.7	$0.16	$0.18	$0.19	$0.20	$0.21	$0.22	$0.23	$0.24	$0.25	$0.26	$0.27	$0.28	$0.30	$0.31	$0.32	$0.33
1.8	$0.17	$0.19	$0.20	$0.21	$0.22	$0.23	$0.24	$0.25	$0.27	$0.28	$0.29	$0.30	$0.31	$0.32	$0.34	$0.35
1.9	$0.18	$0.20	$0.21	$0.22	$0.23	$0.24	$0.26	$0.27	$0.28	$0.29	$0.31	$0.32	$0.33	$0.34	$0.35	$0.37
2.0	$0.19	$0.21	$0.22	$0.23	$0.24	$0.26	$0.27	$0.28	$0.30	$0.31	$0.32	$0.33	$0.35	$0.36	$0.37	$0.39
2.1	$0.20	$0.22	$0.23	$0.24	$0.26	$0.27	$0.28	$0.30	$0.31	$0.32	$0.34	$0.35	$0.37	$0.38	$0.39	$0.41
2.2	$0.21	$0.23	$0.24	$0.26	$0.27	$0.28	$0.30	$0.31	$0.33	$0.34	$0.35	$0.37	$0.38	$0.40	$0.41	$0.43
2.3	$0.22	$0.24	$0.25	$0.27	$0.28	$0.30	$0.31	$0.33	$0.34	$0.36	$0.37	$0.39	$0.40	$0.42	$0.43	$0.44
2.4	$0.23	$0.25	$0.26	$0.28	$0.29	$0.31	$0.33	$0.34	$0.36	$0.37	$0.39	$0.40	$0.42	$0.43	$0.45	$0.46
2.5	$0.24	$0.26	$0.27	$0.29	$0.31	$0.32	$0.34	$0.35	$0.37	$0.39	$0.40	$0.42	$0.44	$0.45	$0.47	$0.48
2.6	$0.25	$0.27	$0.29	$0.30	$0.32	$0.34	$0.35	$0.37	$0.39	$0.40	$0.42	$0.44	$0.45	$0.47	$0.49	$0.50
2.7	$0.26	$0.28	$0.30	$0.31	$0.33	$0.35	$0.37	$0.38	$0.40	$0.42	$0.44	$0.45	$0.47	$0.49	$0.51	$0.52
2.8	$0.27	$0.29	$0.31	$0.33	$0.34	$0.36	$0.38	$0.40	$0.42	$0.43	$0.45	$0.47	$0.49	$0.51	$0.52	$0.54
2.9	$0.28	$0.30	$0.32	$0.34	$0.36	$0.37	$0.39	$0.41	$0.43	$0.45	$0.47	$0.49	$0.51	$0.52	$0.54	$0.56
3.0	$0.29	$0.31	$0.33	$0.35	$0.37	$0.39	$0.41	$0.43	$0.45	$0.47	$0.48	$0.50	$0.52	$0.54	$0.56	$0.58
3.1	$0.30	$0.32	$0.34	$0.36	$0.38	$0.40	$0.42	$0.44	$0.46	$0.48	$0.50	$0.52	$0.54	$0.56	$0.58	$0.60
3.2	$0.31	$0.33	$0.35	$0.37	$0.39	$0.41	$0.43	$0.46	$0.48	$0.50	$0.52	$0.54	$0.56	$0.58	$0.60	$0.62
3.3	$0.32	$0.34	$0.36	$0.38	$0.41	$0.43	$0.45	$0.47	$0.49	$0.51	$0.53	$0.56	$0.58	$0.60	$0.62	$0.64
3.4	$0.33	$0.35	$0.37	$0.40	$0.42	$0.44	$0.46	$0.48	$0.51	$0.53	$0.55	$0.57	$0.59	$0.62	$0.64	$0.66
3.5	$0.34	$0.36	$0.39	$0.41	$0.43	$0.45	$0.48	$0.50	$0.52	$0.54	$0.57	$0.59	$0.61	$0.63	$0.66	$0.68
3.6	$0.35	$0.37	$0.40	$0.42	$0.44	$0.47	$0.49	$0.51	$0.54	$0.56	$0.58	$0.61	$0.63	$0.65	$0.68	$0.70

syrup and market it as their own, it is important that syrup quality and grading be consistent with what the established customer base has come to expect and that it be labeled as required by applicable regulations. Purchasing finished syrup will be detrimental to a business if the syrup quality is lower than what the established customer base has come to expect.

The purchase and resale of finished syrup can be profitable. Careful calculations must be made to ensure that the time and money allocated to purchasing bulk syrup, packaging it in smaller containers, and marketing this syrup provides a good return on investment. Sufficient margins or markups (the difference between the purchase price of the bulk syrup and the resale prices) must be calculated to achieve an adequate financial return.

Risk Management

Maple businesses are subject to numerous risk factors that can potentially undermine short-term performance and the long-term viability of the enterprise. These risk factors fall into the general categories of production risk, financial risk, market risk, institutional risk, and human risk. Many of these risks have been discussed in this chapter and other chapters in this manual. Certain risk factors will be mediated within a business through changes in behavior, management practices, and technology. Other external risks, like international trade policy, currency exchange rates, or new regulatory initiatives are likely to fall outside the direct control of a single business owner. In these cases, broad networks of producers and affiliated stakeholders will need to organize a collective response to the factors and conditions disrupting normal business activity.

IMPROVING PROFITABILITY OF THE MAPLE OPERATION

Some of the factors that influence sap flow are largely beyond the control of the maple producer. The outcome of any maple season is unpredictable, including the amount of production that can be expected. Since variations in weather patterns occur from year to year, consistent sap and syrup production is not guaranteed. The application of new sap collection practices enables many producers to reduce this uncertainty, but the risk of a poor crop remains. Yield projections should factor in multi-year averages for the existing business. Incorporating 4-to-5 year averages is a best practice that ensures projections account for a range of high to low production seasons.

Because of the uncertainties in annual production, many maple producers who market syrup directly will maintain a syrup inventory from one year to the next to help meet market demands when below-average production years occur. Others operate with the plan to purchase additional syrup if the season produces a short crop.

Uncertainties in annual production have a direct relationship to profitability of the operation. It's not unusual for maple businesses to operate on tight margins, and in some cases the annual profits generated by a producer's maple crop may be lower than initially anticipated. This is especially true for operations that sell large quantities of syrup to wholesalers or for those that only operate local retail markets, where sales opportunities are often limited.

The following suggestions are offered as possibilities for increasing total revenue and thereby the profitability of a maple operation. Several of these have been identified in other chapters in this manual; however, because of their relationship to economic success, they are listed here and discussed briefly.

Limiting Mistakes during Tapping

Tapping is a critical step in the process of achieving good sap yields (see **Chapter 6**). It is easy to make a mistake in tapping that will continue to impact production for an entire season. Taking the time to make decisions that provide the highest yield for the lowest cost is important. Learning proper tapping techniques pays off greatly by preventing mistakes that reduce sap productivity from tapholes and lead to leaks that reduce yield even more.

Obtaining High Vacuum at the Taphole

There is a common expression in the maple industry that "the money is made in the woods." This refers to the fact that properly designing, installing, and maintaining a vacuum tubing system is the best way to ensure the highest yields of sap, thereby maximizing syrup production. Sap yields increase by 5–7 percent for each additional inch of vacuum achieved at the taphole.[18] Realizing these gains requires the design and installation of properly sized tubing system and vacuum pump. More important, obtaining high vacuum also requires spending sufficient time in the sugarbush identifying and fixing vacuum leaks. Time spent maintaining high vacuum at the taphole is one of the best business investments that a sugarmaker can make (**Figure 11.6**).

Efficiency of Operation

Efficiency is a key component of increasing profitability in a maple syrup operation. Opportunities for increasing efficiency exist in all aspects of maple syrup production. Since one of the most substantial costs of producing maple syrup is labor (time), any change that reduces labor time can reduce total production costs. For example, the use of tubing for sap collection in contrast to buckets requires less total labor when installation, collection, and cleanup are considered. Strategies for increasing the efficiency of sap collection and sugarhouse operations are discussed in **Chapters 6** and **7**.

Limiting Shrinkage

Shrinkage is the loss of product that can occur at any stage of the process. In maple, significant losses of sugar can occur when transferring sap from one tank to another, when desugaring the RO and filtering apparatus, when cleaning the evaporator, when emptying barrels to pack syrup, and during the packing process. Considerable efforts should be made to limit these losses to the extent possible.

Used Equipment

Many producers begin their maple operation with used sap collection equipment, a used evaporator, and other used syrup storage and canning equipment. Others have modified and adapted equipment originally designed for another industry. The use of dairy equipment, such as storage tanks and pumps, is common in many maple operations. Still other producers have fabricated sap handling and syrup canning equipment that meets the needs of their own operation. As long as the quality and safety of the finished product are not affected, the use of used equipment is appropriate and desirable, and can result in substantial savings. Individual innovation and ingenuity have permitted many producers to remain profitable in an industry that characteristically has a low profit margin.

Although used equipment can save money in many situations, it is important to know when it makes more sense to buy new equipment. For instance, the use of a new spout in each taphole every year will result in much higher sap yields than those gained from reusing old spouts – thus a minor investment in the new spout will pay for itself many times over.

Utilization of Family Labor

Labor is a principal cost in producing and marketing maple products. Owner or family labor is common in such activities as cutting and storage of fuelwood, tapping trees and collecting sap, operating the evaporator, canning of syrup, packaging of maple products, and providing essential support for crews working long hours. While the use of family labor does not eliminate labor costs from an economic accounting perspective, it can significantly reduce out-of-pocket expenditures. Rural communities and families garner many benefits from cooperation and collaboration on maple sugaring enterprises.

Location and Method of Sales

Many maple producers sell their maple syrup at the farm gate or at local farmers markets. Marketing maple products at sales outlets specifically designed for tourists or at health food stores may result in higher prices received. There is an expectation among consumers who frequent these facilities that prices will be higher than for similar products purchased at larger-volume retailers, discount outlets, or even at the farm. Producers who identify specialty product marketing outlets can expect to receive higher prices for products that are marketed there.

Prices per unit (volume or weight) of product are predictably higher when the product is sold in

[18] Wilmot, T.R., T.D. Perkins, and A.K. van den Berg. 2007. Vacuum sap collection—how high or low should you go? *Maple Syrup Digest*. Oct. pp. 27–32. https://mapleresearch.org/pub/m1007sapcollectionvacuumlevel/

a smaller container or in a unique or different style container. Container size, style, and attractiveness all have a significant influence on appeal to consumers and their purchases. Aspects related to packaging are included in the **Chapters 8** and **10**; however, it is important to emphasize the importance of overall branding and its effect on total sales and prices received from the sales of maple products. The cost of packaging, branding, and servicing premium market channels are also elevated. Sound pricing strategies and efficient logistics are necessary to retain adequate net margins after these elevated costs are factored in.

Retail and wholesale sellers will require new equipment and practices that offer labor-efficient packaging, shipping, and customer service. Automated bottling units, online sales platforms, packaging lines, warehouse space, inventory management, and food safety/traceability recordkeeping may be required to maintain advanced market outlets effectively.

E-commerce opportunities to market and sell maple products may be a viable sales strategy for owners seeking to expand sales and provide convenience to customers both within and outside their region. Digital marketing, e-commerce, and online transactions provide a new set of opportunities and considerations for the owners seeking profits. Strategic digital advertising plans can be enhanced with use of various e-commerce platforms and search engine optimization. As more maple sellers shift to online sales, however, the task of differentiating products and the price competition from other sellers become more challenging.

Product Diversification

Traditionally maple syrup has been the principal maple product offered for sale. However, several other consumer products can be derived from maple syrup through further processing. Maple cream, maple sugar, and various forms of maple candy are among the most common. Additional options for diversifying your product line include maple-flavored popcorn, maple cotton candy, maple ice cream, and infused syrups. When maple syrup is processed into other maple products or added as a component to other food or confection products, the total value received for the syrup used to produce such foodstuffs is increased. Entrepreneurial producers are aware of the potential for additional profits and can adapt their operation and facilities to accommodate both production and marketing. Successful marketing may require that additional outlets be located, including establishing concession outlets such as local county and/or state fairs, food festivals, regional expositions, shopping malls, or any other location where large numbers of potential customers are present.

Production of Other Compatible Products

Some maple syrup producers operate retail sales outlets that offer other farm-raised products to the consumer. These may include seasonally available fresh vegetables, locally produced fruits of various types, homemade jams and jellies, honey, apple cider, pumpkins, and even firewood for campground use. Occasionally operators also include a bakery that specializes in high-quality baked goods, including fresh bread. When strategically located, established farmer's markets with high-quality products can become a convenient food source for consumers. Such sales outlets have a strong appeal to summer vacationers, weekend campers, seasonal cottage residents, and year-round residents who appreciate the convenience and value associated with establishments that feature local products of high quality.

Operation of Additional Farm Production Activities

Maple syrup production has traditionally been viewed as one of several different farming activities conducted throughout the year by the landowner. Dairy production is probably the other agricultural activity commonly associated with maple, but there are certainly other possibilities. Cash crops, cow-calf beef operations, fruit orchards, wholesale vegetable production, logging and/or other forest product production, and Christmas tree and/or nursery stock production are all activities compatible with the production of pure maple products. You can even use your hard-won tubing installation skills to set up tubing systems for others for payment. Or you could become a seller of maple equipment. If you enjoy marketing and can expand your packaging and distribution capabilities, you may want to buy syrup from other local producers to capitalize on emerging sales opportunities. These activities may permit the profitable use of equipment such as tractors, wagons, trailers, and possibly pumps in additional ventures or during the off-season. The range of income-producing ventures is limited only by the imagination, resourcefulness, management competency, creativity, marketing skills, and energy of the operator. When combined with other production activities the incorporation of maple syrup production into the total farming enterprise can be a significant additional source of income for the owner. Marketing pure maple products alongside other farm products can help boost revenues from both product lines as maple sales tend to help sell other products and selling other products often leads to increased maple sales.


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CHAPTER 12

Maple Production Facilities[1,2]

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CHAPTER CONTENTS

INTRODUCTION

Facilities that accommodate the activities involved in maple production provide a safe and efficient workspace and are consistent with the requirements, regulations, and expectations of making a pure food product are a necessary part of maple production. At a minimum, the maple production facility (variously

[1] Portions of this chapter have been adapted from work originally done by Grant D. Wells, University of Vermont Extension Agriculture Engineer.

[2] This chapter presents general concepts for facilities design and is not meant to supersede building, health or other codes and regulations in effect in various jurisdictions.

Perkins, T.D., R.B. Heiligmann, M.R. Koelling, and A.K. van den Berg (Editors). 2022. *North American Maple Syrup Producers Manual. Third Edition*. The University of Vermont and the North American Maple Syrup Council, Burlington, Vermont. www.mapleresearch.org/manual/

Figure 12.1. The cleanliness and overall appearance of the production and storage facilities can impact both the consumer's perception of quality and the actual purity of the finished product.

known as a sugar shack, sugar cabin, sugar shanty, or *cabane à sucre*, depending on its geographical location, but most commonly called a sugarhouse)[3] protects stored sap from the weather and provides a sanitary environment for processing sap into syrup. In addition to housing this activity, sugarhouses often comprise areas for canning, packaging, and warehousing maple syrup; the production of candy and other secondary products; and retail sales. Therefore, consideration should be made of how these other activities affect the design, layout, and maintenance of the building as well as its efficiency in terms of workflow.

Maple production facilities should be designed for efficiency of operation, provide adequate space necessary to complete all planned operations, and present an image consistent with the products produced. Ease of cleaning and maintenance of sanitary facilities associated with the production of a high-quality food product is also essential. The cleanliness of the production and storage facilities can impact both the consumer's perception of quality and the actual purity of the finished product (**Figure 12.1**). This chapter is designed to help sugarmakers in the planning of a new sugarhouse or upgrading an existing facility.

One way to get ideas for construction or expansion of maple-business facilities is to take advantage of sugarhouse tours, often offered during the summer or fall, or to visit maple producers at other times and ask how they have dealt with issues like those entailed in your project. Producers near and far generally face similar problems. Many have come up with or adopted clever ways of solving them.

Every newly constructed sugarhouse must include the minimum basic requirements: a concrete floor with adequate drains, ample ventilation for steam, sufficient lighting, and doors large enough to allow the movement of equipment are just a few considerations. The best place to build the sugarhouse depends on a variety of factors including the location of the property and the trees to be tapped and the proximity of these locations to utilities and roads, as well as on significant environmental features of the property, such as topography, soil

[3] While known by a number of various names in different places, we use the term "sugarhouse" to refer to buildings used to produce maple syrup and associated activities.

drainage, and direction of prevailing winds. If the sugarmaker is planning on selling syrup in a retail setting, an attractive facility in a location that is close to a well-maintained road may help increase sales.

Chapters 13 and **14** pertaining to personal and food safety are also valuable resources. Facilities should be constructed with safety, workflow, and food handling in mind. If food manufacturing or retail sales are contemplated, producers should be sure to consult all applicable health and construction codes for such facilities prior to construction.

An oft-heard complaint from producers about their sugarhouses is that they "should've made it bigger." If expansion is even on the distant horizon, think about whether the facility might be made larger initially to accommodate that growth or if it can be built so that expansion/additions can be readily incorporated into the operation as growth occurs.

LOCATION OF SUGARHOUSE

Some basic considerations are necessary whenever a new sugarhouse or upgrades to an existing sugarhouse are planned. A good building site will include good soil and water drainage, good accessibility from an all-weather road, and electrical utilities, space, and air movement in close proximity to the sugarhouse. Some sugarmakers plan on selling their entire crop wholesale or in bulk while others incorporate retail space into their sugarhouse design. The specific location of the sugarbush on the site can be very important. Will sap flow by gravity into the sugarhouse or will it be pumped or trucked? Will the sugarhouse be used for retail sales? If so, it will need to be easily accessible from a paved road and parking space will be needed. If tubing is used, some locations will be far more efficient (operationally and financially) than others. Is there sufficient grade (slope) for tubing? Where is the nearest electrical service access? Now step back and look to see if all aspects of the operation have been considered. When a suitable site has been chosen, stake out the dimensions of the proposed structure. How much earthmoving or drainage pipe/ditch installation will be necessary to minimize the effects of soil moisture? If wood will be used to fuel the evaporator, is there enough room for a wood supply that will last the entire season? Will trucks or tractors with trailers have enough space to turn around and maneuver readily?

DRAINAGE

The soil type and topography of a proposed sugarhouse site are important. If the land is wet some or most of the year, drainage issues will need to be factored into the plans. Wetland areas should be avoided for practical reasons and because of regulatory concerns. Take time to walk the area in late winter and early spring. This will likely be the time of highest ground moisture, but also the time when having access is essential. The earth should be graded away from the base of the sugarhouse. Ditches can be used to direct surface water away from the building. To make efficient use of earthmoving equipment, coordinate these activities with other jobs that need to be accomplished on the site (e.g., foundation excavation, electrical service, culvert installations, or road work).

DESIGN AND CONSTRUCTION

At the heart of every sugarhouse is the evaporator. The size, type, and configuration of evaporator will have significant influence on the design of the sugarhouse. Beginning sugarmakers may be tempted to undersize the sugarhouse. When this occurs, it is not uncommon for the sugarmaker to be faced with the need to expand after only a few years. The need for and costs of future expansion should be anticipated when designing a new sugarhouse. If financial resources permit, build a larger structure than what is presently necessary as expansion within a maple operation is seemingly inevitable.

There are almost as many different sugarhouse designs as there are maple syrup producers working in them. Before any sugarhouse is constructed, it should be designed using drawn plans. An elaborate set of blueprints is not necessary, but a simple, well-drawn diagram will be very helpful (**Figure 12.2**). Working out details on paper can prevent mistakes in construction later on. The basic building should include room for the evaporator with a minimum of 4 feet (1.2 meters) of working space around the evaporator and at least 4 feet (1.2 meters) of room

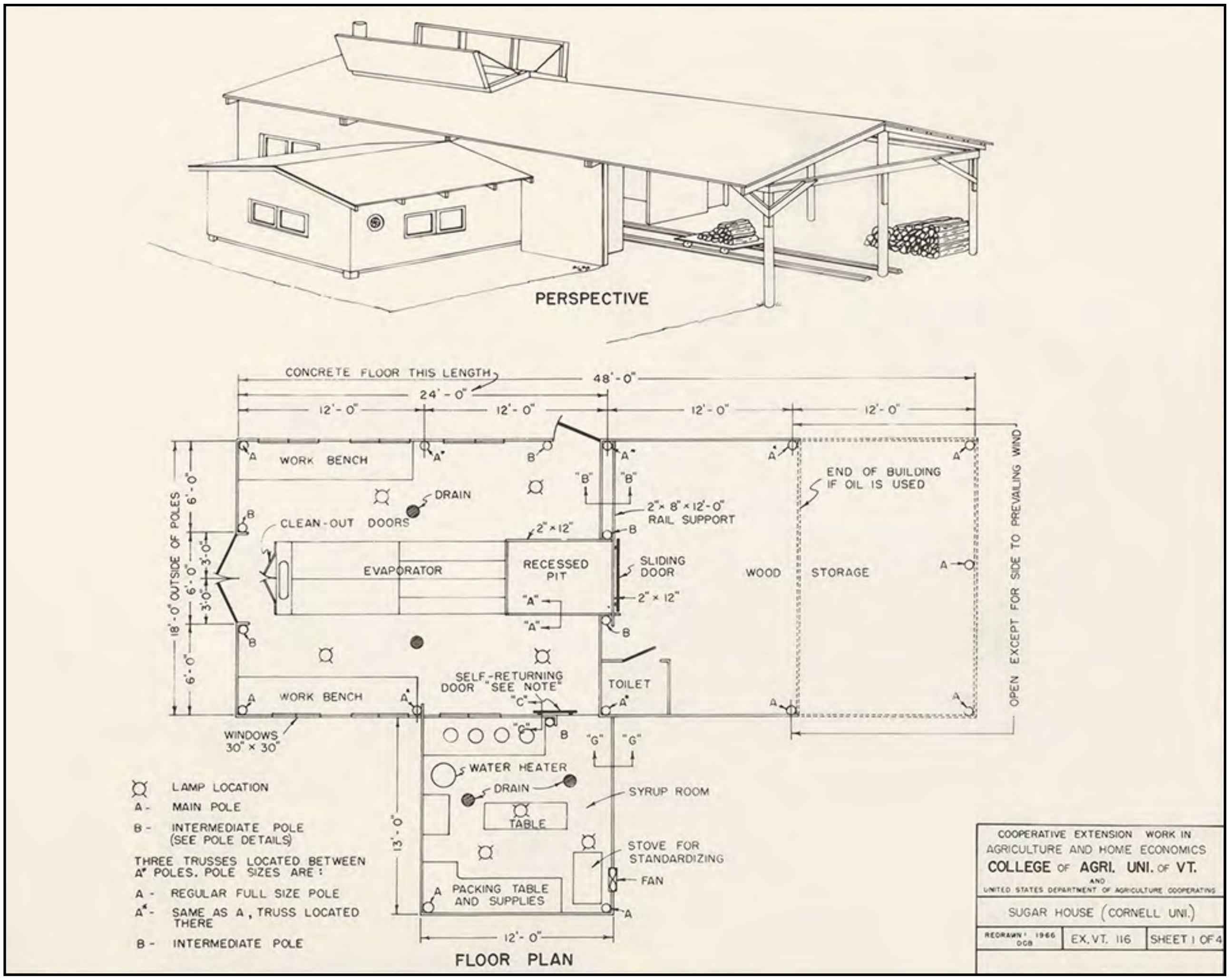

Figure 12.2. An elaborate set of blueprints is not necessary, but a simple, well-drawn diagram will be very helpful as you plan and construct a sugarhouse.

for workbench space. A wood-fired evaporator will need at least 6–10 feet (1.8-3 meters) of space in front to fuel the evaporator.

If a new sugarhouse is being constructed, consider visiting several sugarhouses while they are operating. Visiting other sugarhouses will help make the decision as to what size and type of structure will best meet the needs of the planned operation. There is no substitute for listening to the suggestions and advice of other sugarmakers and learning from their experiences. Ask other sugarhouse owners what works best for them and what they would change in their own design. Always ask "what's wrong" with a design as well as "what's right." Consider using native building materials whenever possible. Buying lumber from your area supports local businesses and will usually be less expensive than purchasing construction lumber from conventional building supply outlets.

The use of pressure-treated, decay-resistant lumber should be minimized. Although effective for delaying rot, some of the chemicals used in the treatment process may pose a risk of contamination to the finished products. This can happen when condensate from the evaporation process finds its way back into the evaporator or other processing operation. However, the use of pressure-treated dimensional lumber is recommended for the foundation sill to minimize decay in this area, thus prolonging the life expectancy of the building.

There are several construction methods from which to choose (**Figure 12.3**). The least expensive

(a)

(b)

(c)

Figure 12.3. Construction methods commonly used when building a sugarhouse include post-frame or pole barn (a), post-and-beam (b), and light frame (c).

is the post-frame construction method also known as pole barn construction. Post-frame involves sinking posts into the ground, then connecting them horizontally with lumber. The poles serve as foundation, bracing, and framework. Excavation is needed for the poles and prepping the site for a concrete slab.

Another type of sugarhouse construction is the traditional light-frame building. This is the most common residential construction method. Frames of "two-by" lumber (2 inches by 4 inches, 2 inches by 6 inches) are built and attached to foundation. This type of construction is more costly than post-frame because it requires more lumber and can be more complicated.

A third type of construction is post-and-beam, also known as timber frame. Post-and-beam makes use of large timbers cut from logs. Vertical posts and horizontal beams are assembled into sections called bents, then raised and attached to a sill beam on a foundation. Timber-frame sugarhouses are typically the most expensive option because their construction often entails hiring a specialized contractor to cut and fit the timbers. Alternatively, producers can assemble and raise the structure themselves using a pre-designed or custom timber frame kit. Timber-frame sugarhouses can be small or large.

Foundations

Ground movement resulting from freezing and thawing of the soil during the winter and early spring can result in significant damage to concrete floors and foundations in some areas of the maple-producing region. This movement, commonly called "frost heaving," can cause concrete to crack, tilt, and/or sink from its original position. If the amount of soil moisture in the ground can be minimized, the effects of frost heaving will be lessened. Soil grading before construction to ensure that water drains away from the sugarhouse will be helpful as well as installing footing drains, especially if soil drainage is not good. Placing the footings for foundation walls below the frost line (this may be 4–5 feet or 1.2–1.5 meters in northern locations) will likewise minimize damage from frost heaving. Insulation of the foundation and the use of other devices such as gutters with downspouts that direct water away from the foundation is also recommended. Consulting a building expert for advice on insulating shallow foundations is another smart way for producers to protect their construction investment.

It is possible to locate small buildings on many well-drained soils without using foundation walls provided the slabs are steel reinforced. Increasing the amount of gravel and adding perforated pipe and curtain drains to control ground and surface moisture will help prevent frost damage to the slab (**Figure 12.4**). If the concrete is not allowed to cure properly or if it is poured when the temperatures

Figure 12.4. Sugarhouses are often built in low-lying areas. Increasing the amount of gravel and adding perforated pipe and curtain drains to control ground and surface moisture will help to prevent frost damage to the foundation.

are below freezing without the addition of calcium chloride, cracks may develop that would not otherwise have occurred. Proper curing delays the drying until the concrete is strong enough to resist shrinkage cracking. Concrete that is moist cured for 7 days is about 50 percent stronger than concrete exposed to dry air for the same period.

Slabs

A 4-inch concrete slab meets the minimum needs of the sugarhouse provided the slab is poured on a properly prepared surface. If vehicles will have access to the sugarhouse, slab thickness should be increased. The slab must be poured on at least 8 inches of well-compacted gravel and reinforced with steel. Never pour a concrete slab on frozen ground. Any area under the slab that will not be filled with concrete (this would include water diversion structures such as drainpipes) should be brought to a uniform level in stages or "lifts." The area around pipes or trenches should be filled with 6 inches of soil at a time and compacted between each lift. Most equipment rental companies have compacting equipment available, and it is worth the cost to use it. If the ground is not compacted the loose soil will settle, leaving the finished slab with air pockets under it. A channel can form and become a route for water. The uneven surface of the slab combined with frozen groundwater can also result in cracking and movement of the slab (**Figure 12.5**).

Figure 12.5. Pouring concrete on an inadequately prepared base can result in cracking.

Construction tubes are available and can be used as a substitute for foundation walls in pole-frame construction; however, attention should be paid to prevent impact from frost heaving. Some type of footing must be used with construction tubes. Plastic forms or "bigfoots" are available and can be used to establish a large footing that can resist the effects of frost heaving. It is important to secure the concrete in the footing to the concrete in the construction tube with reinforcing steel. Metal brackets are available to connect the concrete to the vertical posts.

Floors

Sugarhouse floors should be made of concrete. Some state health departments or other regulatory agencies require a concrete floor for sanitary reasons, and U.S. and Canadian federal food safety regulations require that floors be cleanable. Floors made of dirt, unpainted wood, or other porous material may be difficult or impossible to keep clean and represent an unnecessary risk to the quality of the product. Concrete floor surfaces can be finished many ways. A fine broom finish will provide enough traction while allowing for easy cleanup. Another option is a smooth finish followed by several coats of floor paint containing anti-slip additives. (A concrete floor that is too smooth poses a serious risk of injury from slipping and falling.) A floor that can be cleaned easily will probably be cleaned more often. A clean floor is safer, more attractive to visitors, and less likely to contaminate your syrup.

The entire floor should be graded toward floor drains. A pitch of ⅛ inch per foot is suggested as the minimum grade. Suitable drainage receptacles should be put in place prior to pouring the floor. The most common floor drain is the 4-inch circle drain. It can be difficult to slope an entire floor to a single point. Adding more drains can help. Some sugarmakers prefer a grate drain. The drain can be a single channel running the length of the evaporator or a trench that runs around the perimeter of the evaporator (**Figures 12.1** and **Figure 12.6**). These structures make cleaning around the evaporator easier and represent a larger target toward which to grade the freshly poured concrete. Grates are available commercially in many different shapes, styles, and materials. Particular attention should be given to the outlet of the drain. Water leaving the sugarhouse should not flow directly into a watercourse or otherwise contribute to erosion of the site. Various regulations may specify other requirements for water exiting the sugarhouse.[4]

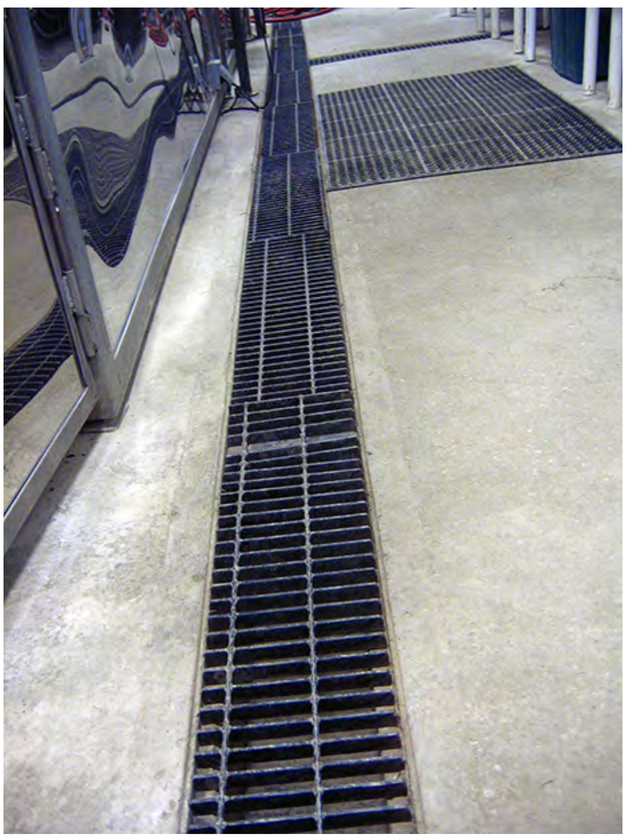

Figure 12.6. Floor drainage in the sugarhouse might include a drain running the length of the evaporator or one running around the perimeter of the evaporator and near areas of heavy water use.

[4] As of the writing of this manual, regulations on maple discharges (permeate as well as RO and evaporator wash and rinse water) are being developed or revised. Consult with local, state/provincial authorities for updated information.

Some evaporator accessories generate a large amount of very hot water. While this is convenient for cleaning, excess hot water will have to be drained away from the building. Hot water run through drains under the building can melt ice in the soil under the building, exacerbating frost heaving problems. Care should be taken when incorporating hot water drainage systems under concrete floors and slabs. Plastic pipe may not withstand large quantities of very hot water and fail upon use, leading to dumping hot water under the floor, exacerbating heaving and other moisture-related issues.

Incorporating a recessed pit in the floor in front of the firebox is a convenient element in a wood-fired operation (**Figure 12.7**). Standing 8–12 inches below the floor will ease back strain when firing the evaporator and make cleaning the ashes from the firebox less arduous. Adding this component to the floor requires some additional engineering but has proven to be worth the extra effort. This pit should also include a drain.

Figure 12.7. Incorporating a recessed pit in the floor in front of the firebox is a convenient feature in a wood-fired operation.

Similarly, including a pit for a releaser and/or entrance lines for buried pipes may be worth considering if grade is an issue with the sap collection system.

Electricity

Most sugarhouses need reliable and adequate power service. Vacuum pumps, reverse osmosis (RO) units, sap transfer pumps, filter presses, blower fans, canning equipment, and lighting all add to the electrical demand of the operation. These needs tend to increase over time as newer equipment is added, so careful consideration should be made of both current and future power needs. Use of electric power reels as well as air hose reels allows flexibility in location of equipment should needs change (**Figure 12.8**).

When power service is interrupted to an operation that relies on electrical equipment, the consequences can be severe. Before new equipment is added to the sugarhouse attention must be paid to the limits of the electrical system. Note that there can be a huge difference between the amperage needed for start-up and what is needed to keep the equipment running once turned on. An electrician should be consulted during the planning process and only qualified electricians should install electrical service in your sugarhouse.

The following questions can help determine the correct size electrical service for each operation:

1. What are the electrical loads and duty cycles of pumps, blowers, and lighting that will be used? What is the start-up load of major equipment (pumps, RO unit)?
2. Is sugarbush expansion expected (adding a vacuum pump or RO unit, for example) and if so, how will it impact Question 1?

(a) (b)

Figure 12.8. Electric reel pull-downs (a) and air hose reels (b) offer flexibility in location of equipment.

3. What is the distance of the sugarhouse to the source of power, and will the lines be buried or aerial?

An example of computation necessary to determine the correct size of the electrical system for four hypothetical sugaring operations is presented in **Table 12.1**. As the size of the operation increases, the amount of power the pumps and equipment need to handle larger volumes of sap also increases. Each successively larger pump in the sample operations doubles in electrical load. Ultimately it will be necessary to select a suitable size amp service to fit the operation.

If a generator is to be used as a power source, the National Electrical Code and voltage drop calculations should be used to determine the appropriate generator size that will be necessary to provide power for the operation. A qualified electrician should be used to properly install a generator. Keep in mind that a gasoline-powered generator will produce exhaust that obviously is not desirable inside the sugarhouse. Be sure to keep generators away from the evaporator, sap tanks, and other food-handling equipment.

Energy is a significant expense in a contemporary maple syrup operation and actions that can be taken to reduce power demands should be undertaken. These include using properly sized pumps for sap collection, transfer of sap from tanks, and operation of filtering and canning equipment. If a sugarhouse is some distance from the electrical utility, power line extension will be an issue. Installing electrical lines can be a very expensive proposition, and the costs should be explored before advancing too far into the design and construction process. The local utility company will have information about line extension requirements and costs.

In some cases, producers will operate their sugarhouses entirely without line power or a generator. This was certainly the case in most sugarhouses not too long ago. If necessary, light can be provided with lanterns, headlamps, or other portable lights. Solar panels with LED lights can be used to provide minimal, but sufficient lighting for operation. Small, battery-operated fans can provide some air for the evaporator. Obviously vacuum pumps and RO machines will not be part of these operations; however, maple production can be accomplished without electricity if necessary.

Walls

Modern evaporators can range in height from 4 to 8 feet (1.2 to 2.4 meters) or more, depending on whether additional equipment such as a steam hood or preheater is being used. A finished total wall height suitable for the evaporator and any accessories is recommended. This height will help prevent the building trusses or collar ties from interfering with the location of the evaporator. Construction costs associated with increasing sidewall height a few feet are not usually large (an extra 5–10 percent generally).

The purpose of exterior siding is to keep wind and weather out of the sugarhouse and not necessarily to insulate the building. Most exterior siding materials are satisfactory, assuming proper installation. Many sugarhouses are sided using rough-sawn lumber installed as board and batten or shiplap siding. These relatively inexpensive materials provide adequate protection and have the traditional "look" of a sugarhouse. In most maple-producing areas, this type of lumber is usually available at local sawmills.

The interior walls of a sugarhouse are exposed to significant changes in temperature and humidity. The often-remote location and seasonal use and location of sugarhouses become a disadvantage when trying to keep the structure free of pests. To comply with basic food safety best practices and regulations, interior wall surfaces should be cleanable and easily wiped or hosed down. They should also be constructed tight enough to prevent rodents from entering. Several materials can be used for covering the walls in a sugarhouse. Plastic milk house paneling, painted shiplap or plywood, and painted metal roofing all provide smooth, cleanable surfaces. While milk house paneling is the most expensive material, its use might be advisable in areas where sanitation is critical, such as in a syrup canning area. Bearing in mind the differences between specifications for surfaces where incidental food contact

TABLE 12.1 Estimated electrical demands for four sample vacuum sugaring operations.[1]

Size	Watts	Equipment	Notes
750 Taps	1,680	1 Hp vacuum pump	*4,755 watts/240 volts = 19.8 amps × 1.25 for continuous duty = 25 amps. Because it is impossible to balance the loads on phase A and B of a 24-amp panel and leave room for an occasional hand tool, the minimum service for the sugarhouse is 40 amps.
	480	¼ Hp transfer pump	
	720	Blower or burner for evaporator	
	840	Blower (small) for Steam-Away®	
	720	⅓ Hp filter press motor	
	315	Lighting for 210 sq. feet	
	4,755	**Total Watts**	
	40	**Amps***	
1,500 Taps	2,400	1½ Hp vacuum pump	**9,480 watts/240 volts = 39.5 × 1.25 for continuous duty = 49.4 amps. This operation would run on 60 amps, but 100 amps is recommended.
	1,200	¾ Hp transfer pump	
	960	Blower or burner for evaporator	
	1,680	Blower (small) for Steam-Away®	
	720	⅓ Hp filter press motor	
	1,920	General outlet circuit	
	600	Lighting for 300 sq. feet	
	9,480	**Total Watts**	
	60	**Amps****	
3,000 Taps	5,520	3 Hp vacuum pump	***25,320/240 volts = 105.5 amps × 1.25 continuous duty = 131.87 amps. With the variables offered by the canning room and the general outlet loads a conservative person could run on a 150-amp service. The larger service will allow for future expansion, and the existing equipment will run cooler.
	8,880	Reverse osmosis unit	
	1,200	¾ Hp transfer pump	
	960	Blower for burner for evaporator	
	1,680	Blower for Steam-Away®	
	720	⅓ Hp filter press motor	
	600	Lighting for 390 sq. foot sugarhouse	
	3,840	Separate canning room lighting and power	
	1,920	General outlet circuit	
	25,320	**Total Watts**	
	150	**Amps*****	
10,000 Taps	12,000	10 Hp vacuum pump	****60,084/240 volts = 250.4 amps × 1.25 continuous duty = 313 amps. A 400-amp service would be the right size for an operation with these loads. The next frame size for service gear is 600 amps.
	28,800	Reverse osmosis unit	
	1,200	¾ Hp transfer pump	
	1,920	Blowers or burners for evaporator (2)	
	1,680	1 Hp blower for Steam-Awayy®	
	720	⅓ Hp filter press motor	
	1,764	Lighting for 1,176 sq. foot sugarhouse	
	5,760	Separate canning room lighting and power	
	3,840	General outlet circuits (2)	
	2,400	¾ Hp electrical releasers	
	60,084	**Total watts**	
	400	**Amps******	

[1] Provided by Donald Schroeder, Master Electrician, Colchester, Vermont.

occurs and those exposed to prolonged contact, producers should take care that all surfaces are suitably constructed for their intended use. This caveat extends to areas within the "splash zone" of sap and syrup, where contaminants could be inadvertently introduced.

Ancillary Structures

In addition to the production floor of the sugarhouse, maple operations often include separate structures dedicated to related functions. These might include a retail sales shop, canning room, barrel shed, and/or woodshed, as well as storage areas for syrup, barrels, and equipment (tractor/ATV). If the sugarhouse is not large enough to accommodate all the desired functions, or can't be easily expanded later, thought should be given to adding one more ancillary buildings. Planning for how water, drainage, sewage, and electrical service might be added to these structures can avoid some common, but serious issues from arising later.

Potable Water[5] and Plumbing

To meet basic food safety best practices and regulations, sugarhouses should be constructed with access to a source of clean, potable running water. Processing equipment should be cleaned after every use. Maple equipment cleaned away from the sugarhouse has the potential for cross-contamination from non-maple materials. On available source of clean water will help with maintaining personal hygiene, washing equipment used in processing and packaging, and keeping the facility as clean as possible. Sugarhouses that do not have running water have successfully used large plastic water coolers to store a day's supply of water or larger tanks periodically filled from a truck to hold a longer-lasting supply.[6] Such tanks should be constructed of food-grade or potable water material and cleaned and sanitized as required.

It is important that the water originates from a high-quality potable source. Untreated water sources (such as a stream or brook) can contain microbiological, chemical, and physical contaminants and is not acceptable for equipment cleaning or handwashing. Regular testing of well water can help minimize the risk of its causing illness or contaminating otherwise good quality syrup. Sugarmakers should check with local county health departments to obtain information about having water tested.

In the rudimentary sugarhouses of the past, plumbing generally either was completely absent or consisted of running water supplied by a nearby spring or from a pipe lying in a nearby brook. For modern sugarhouses, plumbing is often incorporated as part of the construction, at least within the heated sections of the building. Having a potable water supply inside the RO room, canning room, value-added food-preparation areas, and bathrooms is a real game changer in terms of maximizing operational efficiency and keeping equipment clean.

While a heated space will often incorporate plumbing for running water, it is also possible to fashion a suitable alternative in unheated spaces. Circulation pumps or on-demand pumps can be used with potable pipe to produce running water (**Figure 12.9**), as long as the system is drained daily or before the temperatures will fall below freezing. Electric or propane on-demand systems can be installed to supply hot water. If having cold running water is good, having hot running water is amazing.

Figure 12.9. Circulation pumps can be used to deliver water from storage tanks to where it is needed in unheated spaces as long as lines are drained before freezing weather.

[5] Water that is safe to drink.

[6] Some local, state, or provincial regulations permit this, others do not.

BATHROOM FACILITIES

Any sugarhouse that is open to the public should provide bathroom facilities. Some state or provincial health and local zoning requires these facilities. Check with the appropriate county, state, or provincial health departments concerning requirements. Installing bathroom facilities, especially the necessary plumbing, during sugarhouse construction is much less expensive and time-consuming than adding bathrooms to the completed building.

Workspaces and General Storage

Work surfaces that are difficult to clean increase the risk of contaminating syrup or processing equipment. Contaminants can be chemical or biological. Chemical contaminants include cleaning solutions, fuel residues, or pest control materials. Biological contaminants include bacteria, yeasts, molds, and pest urine and droppings. To help reduce possible contamination of either product or equipment, work surfaces should be cleanable, smooth, nonporous, and free of cracks. Stainless steel or food-grade plastic are preferred materials; however, wood surfaces, when properly painted or treated, may also be satisfactory (check local requirements).

Many sugarmakers choose to build vertical shelving to store various supplies. If year-round storage is planned, consider the need to rodent/pest-proof any sugaring supplies. If syrup containers are stored in the sugarhouse keep boxes off the ground and sealed to discourage infestations.

Arranging the sugarhouse to run efficiently can save time and improve your product. Keeping several aspects of the operation visible from one location can advance these goals. In most operations the location of syrup draw-off on the evaporator should be thought of as the focal point that is located centrally. If the operation has several pieces of equipment (vacuum pump, RO unit, mechanical releaser, filter press, etc.) arrange them in a way that allows for a rapid visual check of their status from this position.

Evaporator Fuel Storage

For most sugarmakers fuel storage will involve either building a covered area near the sugarhouse where they can stack firewood or install an oil tank. The amount of fuel storage space needed will depend on how much sap is collected, the sugar content of the sap, the length of the season, and the efficiency of the evaporator. The old rule of thumb of 1 cord of dry hardwood for each 75–100 taps is acceptable for efficient evaporators. An area that is 8 by 16 feet stacked 5 feet high will hold 5 cords of firewood.[7]

Good air circulation is needed for effective drying. Firewood should be protected from rain but not sealed in a tight structure. Split firewood should be air dried for nine months to a year; unsplit for at least one year before use. Try to reduce the number of times firewood must be handled. Many sugarmakers add wood storage onto the end of the sugarhouse nearest to the arch (**Figure 12.10**). This location allows the stacking of wood near the evaporator instead of moving it from a second location. Protection from drifting snow is also recommended.

Sugarmakers have found many inventive ways to transport firewood to the arch including using overhead rails and a carriage that is strong enough to hold a load of wood, installing ground rails that allow pallets of firewood on small carts to be winched toward the arch, stacking wood on pallets and using a small forklift to move wood to the

Figure 12.10. Many sugarmakers add wood storage on to the end of the sugarhouse nearest the arch for easy use.

[7] A cord of wood is a stack of tightly packed wood that occupies 128 cubic feet of volume, often represented as a stack of wood 4 feet high, 8 feet long, and 4 feet deep.

evaporator (**Figure 12.11**), and adding automatic conveyer belts with automatic loading systems.

The price of fuel oil can fluctuate quickly. Some sugarmakers prepay for oil in an attempt to lock in a lower price.[8] For operations that prepurchase fuel oil before the sugaring season begins, larger oil storage facilities will be needed, although producers must take note of requirements and regulations concerning proper fuel storage and the maximum amount of fuel permitted on site. A rule of thumb for determining oil storage requirements is to have 1 gallon (3.8 liters) of storage for each 10 tapholes if fuel delivery during the season is dependable and quick; otherwise plan on 3–5 gallons (11.5–19 liters) per 10 taps. The use of a RO unit or other efficiency-increasing device will change the fuel per tap requirement. Make sure the oil tank can feed by gravity to the burners. Securely position the oil tank on a concrete slab or some other sound footing and locate the tank so that it is readily accessible by delivery trucks. Burying conduit in the sugarhouse's foundation will provide protection for fuel lines. Secondary containment for fuel should be considered, and spill control procedures and supplies be prepared in case of a problem.

Syrup Processing Room

Sugaring operations that plan to sell syrup in retail containers must devote some space to canning their product. Some sugarmakers fill containers in a corner of the sugarhouse; others bring bulk syrup into a residential kitchen for canning. Canning in a home kitchen involves more work and entails the risk of contaminating syrup with non-maple materials.[9] Canning in the same room as the evaporator also exposes the product to the risk of contamination. Locating this function in separate room where syrup can be packed outside the range of the syrup production area is an ideal way to control the quality of syrup entering retail containers. In order to make this room more useful, consider installing a heater, vent fan, smooth light-colored walls that can be easily wiped clean, a stove for canning or making confections, and a water heater. This room can also be designed as a small retail space. Providing a separate entrance from the outside and an attractive display can improve sales.

Figure 12.11. Sugarmakers have found many inventive ways to transport firewood.

Roof

Roofing can be any fireproof material provided that it can handle potential snow loads and is installed correctly. Asphalt shingles are not ideal for use on a sugarhouse. Heavy, potentially damaging loads of snow can build up on them, and they are less durable than metal roofing. Corrugated metal sheets can be easily installed and are designed to shed rain and snow. Standing seam roofs are durable; however, custom-fitted installations are about 25–30 percent more expensive than sheet metal roofing. Regardless of the material chosen, the roof should be carefully installed. Fasteners with a sealing washer for corrugated sheets and properly installed clips for standing seam roofs will prevent leaking or roof damage in the future.

Steam Ventilation

The water vapor generated during boiling must be vented outside to keep the inside of the sugarhouse relatively dry and clean. Water vapor that is allowed to condense inside the sugarhouse will cause water to drip over equipment and supplies in the sugarhouse.

[8] Note that in some areas if a specified amount of fuel is stored onsite a permit or notification to authorities may be required.

[9] If this is planned, check regulations which apply to your operation. It is not permitted in all jurisdictions, or under various food safety regulations which may apply.

This "raining" effect should be avoided as it can cause contamination of syrup, containers, and equipment, as well as create an unpleasant and unsafe workspace. Placing a layer of wood or hard foam insulation under metal roofing can help minimize the condensation. Tightly fitting steam hoods and steam stacks (**Figure 12.12**) are available which direct water vapor out of the sugarhouse. The cost of the steam hood and stack is not insignificant but should be weighed against the potential problems caused by condensation within the sugarhouse.

Several styles of roof ventilators exist, but the traditional sugarhouse cupola remains the most popular (**Figure 12.13**). A cupola allows for sufficient ventilation while providing protection from inclement weather. The opening in the roof above the evaporator should be as long as the evaporator and at least 75 percent as wide. The size of the cupola doors will also impact the ability to vent steam from the sugarhouse. Make cupola doors at least 75 percent as long as the evaporator and a minimum of 24 inches (61 centimeters) high. Cupola doors should be large enough so that on windy days one door can handle all the steam generated from boiling. The doors on a cupola should be made to open and close from the floor using ropes and pulleys. Evaporators with steam hoods and steam stacks can be vented directly through the roof of the sugarhouse, although some sugarmakers prefer to keep the traditional design but reduce the size of the cupola. Provision should be made so the doors of the cupola can be securely locked during the off-season.

FIGURE 12.12. Steam stacks (two rearmost) for venting water vapor from evaporator.

FIGURE 12.13. Cupola with pully system to vent steam from sugarhouse.

Stacks

Wood-fueled evaporators have different stack size requirements than oil-fired evaporators. A rule of thumb for wood-fired evaporators states that the stack should be two to two and one-half times as high as the arch is long. Oil-fired evaporators need only a stack equal to the length of the arch. Added technology and equipment may change the optimal stack height. The stack diameter within each fuel type also depends on the size of the evaporator. Check with the evaporator manufacturer for recommendations about stack diameter and height.

It is possible for live embers to be emitted through the stack to the atmosphere when wood is used as a fuel source for the evaporator. Forced draft systems increase the amount of burning material that is sent through the stack. A spark arrester is essential for preventing release of these potential fire starters (**Figure 12.14**). Spark arresters are constructed of strong metal screen or mesh that is fine enough to catch tiny airborne embers. A spark arrester must not restrict the draft of the stack. The arrester must be sturdy enough to withstand high winds and be fitted with a metal cover for rain protection. Equipment manufacturers have models available for stacks of many different sizes.

Wood-fired arches generate a tremendous amount of heat. Working stack temperatures commonly exceed 500°F (260°C). Care must be taken to

Figure 12.14. A spark arrester is useful in preventing release of these potential fire starters.

avoid exposing combustible material, including the walls of the sugarhouse, to these extreme temperatures. Be sure to provide plenty of open-air space between the back of the stack and any combustible materials. Follow the manufacturer's recommendations regarding installation of the smokestack. A "roof jack" is used to make a watertight seal where the stack comes through the roof. Guy wires should be used to protect the stack from wind damage.

Air

Combustion of wood or oil requires air. This is not such a big deal for traditional sugarhouses, which tended to be fairly "airy," but newer buildings built to current construction standards may not provide enough makeup air for a good draft. Having windows, doors, or an overhead (garage style) door that can be opened is useful in those circumstances. It can also help to provide more of a draft for wood fires and for ventilation of steam through hoods or the cupola.

Some maple equipment requires an air source or air cooling. Pumps and RO machines can generate large amounts of heat and may require adequate ventilation, especially on the hot days near the end of the season. Having windows and/or doors that open nearby can help to provide some cooling capacity. If needed, fans can be used to provide additional air movement.

Other types of equipment such as the Leader Evaporator Co. Steam-Away®, similar steam pans from other companies, and air-injection units all require air. Typically, a fan placed a short distance from the evaporator supplies the air that is piped into these units. It is critical that the air sources be chosen carefully to avoid bringing noxious odors or chemical pollutants into the sugarhouse. Air intakes should avoid areas where gasoline or diesel fumes are present, where animals are housed, or where chemical residues or strong cooking odors are generated. If possible, air should be filtered to remove airborne particles. The optimal approach to cleaning and deodorizing the air that flows into the sugarhouse would be to use a charcoal-impregnated filter. In either case, filters should be changed regularly and in keeping with the filter manufacturer's instructions.

Chemical Storage

The evaporator room, canning area, and food-preparation/sales areas should never be used for chemical or gasoline/oil fuel storage. There are many potentially dangerous cleaning chemicals currently available to the maple industry. Some of these chemicals are concentrated acids, bases, or detergents and should be stored, handled, used, and disposed of with caution. These chemicals should be stored with a readily available Safety Data Sheet (SDS) that covers the proper storage, use, and handling of each product. Contact the equipment dealer or supplier from which the material was purchased or the local Extension agent for additional information. To avoid inadvertent contamination, chemical products must be placed in a secure location that is out of reach of children and visitors and separate from syrup storage areas. Additionally, fuel for gas- or diesel-powered equipment should not be stored in the sugarhouse. The potential for contaminated syrup exists if these materials are used or stored incorrectly.

Sap Storage

Maple sap is highly perishable. Prior to processing, sap should be stored in a cool, clean environment. Tanks should follow food construction guidelines and be made of materials that are suitable for food or potable water storage. Keeping the tanks in a well-lighted, easily accessed location will make it more likely that they're cleaned regularly. Sap tanks should be kept out of direct sunlight to minimize accelerated spoilage due to heating. The north side of the sugarhouse receives the least amount of sun and is therefore a good place to locate sap storage tanks if practical. Sap stored outside the sugarhouse with minimal cover and near roadsides can be exposed to vehicle exhaust, road dust (which contains lead), and other airborne contaminants. Sap tanks need to be covered to avoid contamination but sufficiently ventilated to prevent the sap from heating. Sap tanks located next to a poorly insulated evaporator may be exposed to radiant heat from the arch.

Sugarmakers with buckets should plan on a minimum of 1 gallon (3.8 liters) of sap storage per tap. When tubing is used, plan on 1½ gallons (6.8 liters) of storage per tap for gravity systems and 2 gallons (7.6 liters) of storage per tap for vacuum systems. Refer to **Chapter 6** for a more detailed discussion of sap storage. Extra sap storage will help prevent unnecessary loss during large sap runs or an unplanned rest or equipment failure day. Note that these recommendations describe the minimum requirements under normal operating conditions and do not account for an increased need for storage due to a reduced production rate caused by a broken-down RO machine, non functioning preheater, or inoperative forced draft unit.

If a RO system is employed, three additional tanks may need to be considered. The first is the wash tank for the RO. On some smaller machines the wash tank is integrated into the unit. When the wash tank is separate, it needs to be located relatively close to the RO. The size of the wash tank varies in proportion to the amount of "soap" dictated by the number (and size) of membranes in the RO unit. Typically, the amount of tank storage needed for the cleaning solution is modest, but it is specific to the RO machine. Information can be gotten from the equipment manufacturer or the RO manual.

The second tank required with an RO system is one or more permeate tanks. Permeate is a byproduct of the RO sap separation process and is used to rinse the RO. Requirements for permeate use also depend upon the RO capacity. Permeate tanks typically have at least as much concentration capacity as the RO in gallons per hour. Having more permeate is advantageous in case a double-wash and double-rinse are needed to address a high degree of fouling in the RO. Permeate will remain usable for a reasonable amount of time (weeks) if stored in a covered stainless tank. The amount of time that permeate can be successfully stored in plastic tanks is considerably shorter due to their greater susceptibility microbial growth. Extra storage is desirable, as permeate is very useful for cleaning tanks, the evaporator, and other equipment around the sugarhouse. Keeping some permeate around for a few weeks after the season is over will help make cleanup easier.

The last tank associated with RO processing is the concentrate tank. In most cases, this tank also serves as the feed tank, discussed in more detail below. The only difference is that with RO processing the feed tank is filled with concentrate instead of sap. When used for both these purposes, the tank must be made of high-quality stainless steel to discourage microbial growth, which otherwise occurs very quickly in concentrate.

The location of the evaporator feed tank is particularly important. The outlet from this tank must be located above the inlet on the evaporator in order to provide good flow to the evaporator. If a preheater will be used, the location of inlet must be higher, 18 inches (46 centimeters) or more above the evaporator. The more head pressure from the feed tank, the better the evaporator will function. Optimal functioning often requires putting the feed tank in a loft or second story of the sugarhouse. Even a moderately sized evaporator requires several hundred gallons of sap for continuous operation. The location of all sap tanks must also allow for easy access for cleaning. It should also be remembered that a full sap tank is very heavy, with raw sap weighing 8⅓ pounds (3.78 kilograms) per gallon and concentrate even more dense (depending upon the level of concentration). Depending on the construction of the sugarhouse, extra structural support may be planned for to support the feed tank.

Finished Syrup Storage

If syrup and other finished maple products are to be stored in the sugarhouse, a dedicated storage area is needed. Finished maple products need to be stored in a clean, cool, dry environment with minimal temperature fluctuations and little or no sunlight. The storage area should be of tight enough construction so cleanliness can be easily maintained, and insect or rodent problems kept to a minimum (e.g., concrete floor; tight walls, ceilings, doors). For safety purposes, the storage area should be lockable and located a safe distance from fuel, chemical storage, or any other sources of contamination. If possible, the area should be insulated and air-conditioned. Location and size of the area should be considered carefully, anticipating future expansion, the need to sort inventory within the area, and the potential need for refrigerator or freezer units.

The ability to move pails or drums from the storage outside to a truck for bulk sales or to the canning area for wholesale/retail sales is important. Obviously, the distance and number of steps between locations should be minimized and the floor should be level and free of wet spots. Quick and easy access to storage space for empty barrels is critical and even more essential when full barrels are involved. Moving barrels by hand is both difficult and dangerous. The use of a barrel-cart helps. Using mechanical means to move barrels is far quicker and easier and becomes necessary if barrels are to be stacked. To stack larger totes, a forklift and enough space in which to operate it will be necessary.

If room is available, the producer may also want to consider designing an area where barrels can be cleaned and filled before packaging syrup.

Lighting

Good lighting is essential in an efficient operation. A well-lit sugarhouse allows for effective cleaning of the sugarhouse and production equipment, accurate grading of syrup, and a safe work environment. Sugarhouses with plenty of windows can take advantage of lengthening spring days. Windows do not need to be expensive or complicated units; simple barn sash windows are suitable.

Some form of electrical lighting is necessary for overcast days and during evening hours. All lighting should be shielded with a cover to prevent possible contamination of syrup or other maple products should any bulbs break (**Figure 13.10**). Lighting fixtures are available that include safety covers designed to operate under humid or moist conditions. As a minimum, plan on ½ watt per square foot for fluorescent lighting and 2 watts per square foot for incandescent lighting or a suitable LED equivalent.

Entrances

Consideration should be given to the movement of people, supplies, fuel, and product into and out of the sugarhouse. Doors must provide enough room to move equipment, easily bring in fuel, and make it possible to take syrup out of the sugarhouse (**Figure 12.11**). Doors that are large enough for a vehicle should satisfy these needs. Consider the flow of people in and out of the sugarhouse. If the public is going to be invited to the sugarhouse, plan to have enough space for visitors while not disrupting the operation of the evaporator. Sugarmakers that sell their crop in bulk containers should have a plan for getting the syrup out the door. A full, 40-gallon (152-liter) barrel of syrup weighs 440 pounds (200 kilograms). A loading dock can make moving barrels of syrup easier. A door large enough to drive a vehicle through can facilitate moving large pieces of equipment in and out of the sugarhouse. A concrete apron or ramp leading into the building can help smooth the entry of the vehicle and keep the inside of the building cleaner.

As a critical safety measure in case of fire, a sugarhouse should have at least two operating and accessible doors, one located at each end of the building. These exits must not be blocked when the sugarhouse is occupied.

MAINTENANCE

Careful construction will pay off in reduced maintenance costs. The basic structure of a sugarhouse should require minimal maintenance. Leaks in the roof, walls, or floor should be dealt with before serious damage can occur. Steam and exhaust pipes that are easy to close or remove at the end of the season are essential for limiting the risk of water damage. Keeping the interior clean will have many benefits, including a more attractive workplace and a reduced risk of contaminated syrup.

PEST CONTROL

Rodents are one of the most common pests in the sugarhouse. Droppings and urine from mice can contaminate sap and syrup and pose a health threat to anyone working in the building. Simple preventative measures taken during construction can help avoid infestations. The most obvious is keeping the structure as tight as possible. Take the time during construction to caulk between joints and panels. Setting boards into fresh sealant is much more effective than covering gaps later. Avoid storing food in the sugarhouse.

EXPANSION AND ALTERNATIVE USES

The need for sugarhouse expansion can be the result of access to more taps or the addition of more processing equipment. Careful planning can help reduce the costs of expansion. The foundation for a separate syrup canning room can be poured at the same time as the foundation for the main production area. The cost of the extra concrete and prep work is small compared to the expense involved in building a larger structure from scratch later on. Furthermore, having a foundation in place is an incentive to complete the project.

If changing from a wood- to an oil-burning evaporator is a future possibility, place plastic conduit for fuel lines under the foundation when it is poured. It is also appropriate to consider installing extra drains to allow for the possibility of adding a reverse osmosis machine in the future.

Since sugarhouses are used for such a limited time each year, many producers find alternative uses during the off-season. The alternative may be as simple as using the space for storage or as far-reaching as temporarily putting it to an entirely different use. If this option is contemplated, consideration should be given to how these different uses may affect the space and equipment inside, and how readily the sugarhouse can be put back into an operating condition for the season again when needed.

RECYCLED BUILDING MATERIALS

Using recycled building materials can help reduce construction costs. Generally, the use of old windows, doors, and painted wood should be avoided unless it is certain they can be thoroughly cleaned to eliminate or cover any lead-based paint or other hazardous material that may be present. Used utility poles, railroad ties, or other chemically treated wood should generally not be used in the sugarhouse; additionally, such wood should not be used as fuel for wood-fired evaporators.

ADDITIONAL FEATURES

Sap preheaters such as "piggy back" and Steam-Away® units are filled with many gallons of sap. This additional weight requires support to prevent damage to the back pan and arch. Cables attached to collar ties can be used to relieve stress on the evaporator (**Figure 12.15**). The collar ties should be

Figure 12.15. Cables attached to a beam or collar ties can be used to relieve stress on the evaporator from the weight of a "piggyback," Steam-Away®, or other evaporator accessories.

designed to handle the additional weight. Some sugarmakers have incorporated a system of rails or I-beams and winches to support and lift the back pan. These rails and winches can be attached to a wheeled carriage. This system makes the job of removing evaporator pans and ancillary equipment much safer.

Some maple producers also construct a shelf at eye level that is illuminated by a fluorescent light that can hold a grading kit. The installation of a diffuser screen between the fluorescent light and the grading kit affords a simple setup that provides evenly distributed, consistent light behind the syrup samples, thus facilitating more accurate grading.

CHAPTER 13

Safety in the Sugaring Operation

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CHAPTER CONTENTS

Perkins, T.D., R.B. Heiligmann, M.R. Koelling, and A.K. van den Berg (Editors). 2022. *North American Maple Syrup Producers Manual. Third Edition*. The University of Vermont and the North American Maple Syrup Council, Burlington, Vermont. www.mapleresearch.org/manual/

INTRODUCTION

Safety should be a primary concern in all aspects of the maple syrup operation, from the sugarbush to the sugarhouse and to the processing-packaging facility. Practical means of addressing many personal and environmental safety issues are identified and considered in this chapter; however this work cannot possibly cover all possible sources of injury. A thorough examination of your own operation with respect to equipment safety and protective practices is highly recommended. In addition, **Chapter 12** of this manual addresses the safe and effective design and construction of maple production facilities, while **Chapter 14** deals with specifics of food safety.

While some of the recommendations in this chapter may seem extreme, time and experience have proven them effective in preventing injuries and keeping workers safe. Many farm operators and business owners have learned, sometimes the hard way, that a proactive safety and health program is necessary to reduce injury costs, control insurance rates, provide a healthier work environment, and reduce liability. All of these benefits result in increased operational efficiency and profit potential. These same management principles apply to maple operations, regardless of size.

GENERAL SAFETY CONCERNS AND PRACTICES

Safety and Health Principles

Most injuries have identifiable causes that are either preventable or avoidable. An incident involving an injury normally results from multiple causes, rather than from an isolated situation. Throughout life and in all agricultural operations risk is inherent. Understanding the risks involved in maple production is the key to minimizing injuries. To be human is to err, and individual perceptions of risks are frequently not very accurate. When hazards are identified, human behavior can be changed to reduce risks. Occupational health and safety are largely a function of management, day-to-day decisions, and the consequences of those decisions.

Many jobs within the agricultural industry are among the most dangerous in North America. Agriculture, forestry, and construction are the industries with the highest occupational worker death rates. These industries are regulated by the Occupational Safety and Health Administration (OSHA) in the U.S., and the Canadian Center for Occupational Health and Safety in Canada. Whether or not a maple operation is large enough to fall under the jurisdiction of OSHA or CCOHS, it is the responsibility of producers to manage their business in such a manner that safety standards and practices are observed that will provide for the maximum safety of their family, their employees, and themselves.

There are several steps that can be taken to increase personal safety in the completion of any task. These include the following:

- Identify and eliminate all hazards associated with the job.
- Apply safeguarding technology. This involves the use of guards, shields, or other barriers and keeping them in place and in good repair.
- Use warning signs and continually enforce their message.
- Provide training and instruction for all persons involved with the activity or task, teaching the proper procedures and operation of all machinery and equipment. Test for knowledge and understanding of safe operation before allowing anyone to perform an assigned task.
- Prescribe the use of personal protective equipment (PPE) as appropriate for the task to be completed and the equipment to be operated.

One of the best ways to ensure that these steps are followed is to establish a safety plan comprising an injury prevention program for the maple operation and to assign an individual to carry out requisite procedures. This plan should exist in written form and be kept in a notebook at a convenient location and a copy should be given to each worker. The following items should be part of the injury prevention program:

- Safety and health policy statement (description of the objective or purpose of the plan)
- Safety officer (name of the responsible individual)
- Training for employees (schedule of training sessions and outline of subjects taught)
- Inspection of work areas (frequency of checks and who is responsible)
- Recognition of hazards and corrective measures (what to look for and how to minimize risks)
- Emergency preparedness and procedures (whom to notify, emergency phone numbers)
- Recordkeeping system (for training, hazards identified, corrective measures followed, injuries and treatment with outcome)

A crucial part of any safety plan is hazard control, or the minimization of potential risks and problems. Effective hazard control efforts will not only help reduce or eliminate potential injury, but also reduce potential liability exposure, ensure compliance with regulations, and make employees feel good about working for you. Toward this end, the following should be inspected or reviewed regularly:

- Chemical storage and disposal procedures
- Electrical system
- Equipment guarding and shielding
- Fire extinguishers
- First aid and emergency equipment
- Housekeeping procedures
- Personal protective equipment

The key to an effective hazard control program is to not only identify hazards but also take steps to ensure they are addressed with appropriate corrective actions.

"Telling someone to be safe doesn't go far when we're not setting the proper example ourselves."

Accident or Incident?

By definition, an accident is an event that cannot be prevented. In reality most occupational injuries and illnesses are preventable. In the public health and safety community, the word accident has largely been replaced by the word incident. Reducing the number of incidents requires having a positive attitude toward safety or, stated in another way, making an informed choice at the right time.

A positive attitude begins with the leadership of the business. It must start with the owner, operator, manager, or other team leader and be transferred throughout the operation. Individuals learn by example, and if a proper example is established by following safe operational procedures, employees and family members will quickly develop safe working habits.

Communication

It is important to know the general location of all employees during work hours. If someone is headed into the woods or off to the sugarhouse, they should leave word as to where they are going and at what approximate time they expect to return. Everyone involved in the operation needs to know who is working where, what activities are being conducted, and when workers are in the woods.

"Don't go out alone" is sound advice. From a practical standpoint, however, observing this caveat is sometimes not feasible. When this is the case, the employee should leave a "trail" to make it easy for others to locate him or her if something unforeseen happens. Where cellular service is reliable, location sharing features such as the "Find my" feature in iOS and Android or the Huntstand, OnX Hunt, or similar apps[1] can be used.

Communication is essential in an emergency. Post emergency telephone numbers by each phone

[1] Listings of operating systems and apps are meant to serve as examples, but do not constitute an endorsement or recommendation.

on the property. Cell phones may provide a means of communicating, although in some remote locations there may be a lack of adequate signal. All employees should program emergency numbers into their cell phones. For local communication many producers rely on GRMS or other two-way radio systems. Establishing a base station at the sugarhouse or other continuously staffed location facilitates their use.

Making an Emergency Phone Call

If an emergency arises, remain calm so you can effectively convey the nature of the situation and other relevant information when you summon help. To facilitate reporting an emergency, post critical information beside each landline phone, including the emergency phone number to call (911 or other), the number of the phone being used and the street address, and a clear set of directions to guide emergency crews to the location. Anyone, even a visitor, can then read the information to the dispatcher and ensure that help is on the way. Instruct all employees on procedures to follow in the event of an emergency.

In general, when reporting an emergency, the following information must be conveyed to the dispatcher:

- Your name and the telephone number from which you are calling
- Nature of the problem and what help you need
- How many people are injured
- Age of the injured
- What care is being provided
- Clear directions to the location
- Additional pertinent information about the situation

At the conclusion of the call allow the dispatcher to hang up first.

COMMON SOURCES OF INJURY FOR MAPLE PRODUCERS

There are many possible sources and types of injuries that can occur in maple syrup operations; some common types of injuries that can be avoided by observing recognized safety practices are identified and discussed below.

Lifting and Back Injuries

Lower back pain is one of the most common musculoskeletal problems in North America. A large percentage of North Americans have back pain at some point in their life. Problems with the lower back are a leading cause of Workers Compensation claims, accounting for a large proportion of all work-related injuries. This equates to billions of dollars a year in medical and rehabilitation costs, in addition to the pain, discomfort, and reduced productivity.

Maintaining good physical health, eating a proper diet, and getting appropriate exercise are essential to reducing the potential for injury and the need for medical intervention. Although some individuals who work outdoors may believe they get sufficient exercise, it is important to remember that not all physical activity provides the proper exercise necessary to maintain a strong and healthy back.

Observing proper lifting techniques can be helpful in minimizing problems. Recommendations for correct methods of lifting include the following:

- Establish firm footing, keep your feet apart for a stable base, and point the toes slightly outward.
- Maximize stability when lifting and lowering, by getting a good grip on the object and keeping it close to your body; placing your feet close to the load and lifting slowly and smoothly; and focusing on raising the object by straightening the legs. NEVER use jerking or twisting motions while lifting or carrying anything, no matter how heavy it is.
- Keep the load close; the closer it is to your spine, the less force it exerts on your back. Minimize reaching; even relatively light loads lifted away from the body can create injurious stress levels on the spine. Move objects out of the way to get close to the item to be lifted.
- Bend your knees, not your waist, keeping your back upright. Keep "leverage" in

mind at all times. Don't do more work than necessary. Lifting while bent at the waist means you're bearing not only the weight of the object being lifted but also about one-half the weight of your own body.

- Tighten stomach muscles. Abdominal muscles support the spine when lifting, thereby offsetting the force of the load. Train muscle groups to work together.
- Lift with your legs. Let the stronger leg muscles do the work, not the weaker back muscles.
- Keep the load as light and compact as possible.
- Lift only those loads that can be handled safely. Test the weight of the load before attempting to lift it; if it is unmanageable, get help.
- Do not lift or lower an object with the arms extended.
- Always rotate the body while lifting by moving the feet, rather than twisting or bending the trunk.
- Avoid repetitive lifting; alternate the task with other tasks.
- Use mechanical assistance such as lift tables, hoists, and conveyors whenever possible.
- Maintain flexibility in design and flow of the workplace to accommodate individuals of different sizes, weights, and strengths.

To prevent back injuries when operating motor vehicles, the following precautions should be observed:

- Maintain good seat positioning and use lumbar support.
- Reduce whole-body vibrations by using suspension seats that have appropriate vibration-dampening characteristics.

Falls

Falls are responsible for a large proportion of all workplace injuries. It is a common human characteristic to be in a hurry. Unfortunately, in too many cases the risk of a fall increases with an increasing pace of activity. In agriculture operations falls are commonly associated with mounting or dismounting tractors or other pieces of equipment. The following conditions and actions are likely to increase your chance of falling from a tractor or other equipment:

- Missing the step
- Not using the grab bar
- Not watching what you're doing
- Failing to remove mud, snow, or other debris from the foot tread
- Allowing another individual to ride in the operator's seat alongside the driver; there is only one seat on most farm tractors, and only one person should be on a tractor
- Jumping onto or off moving equipment; this is a common practice during sap gathering

Falls occur in other situations as well. Commonsense advice on addressing these risky situations includes the following recommendations:

- Take care when walking in the woods. During the sap season the forest floor is often icy, snow-covered, wet, and/or muddy, all of which can increase the risk of falling. Running under such conditions further increases that risk.
- Avoid poor housekeeping or messy conditions. Do not leave supplies lying around the sugarhouse or sugarbush. Maintaining an orderly facility and storing supplies and unused equipment in a proper manner will reduce the risk of falling as the result of tripping.
- Maintain a clear walkway around the evaporator and arch. For obvious reasons supplies and/or equipment should not be stored near the evaporator when it is in operation.

Good lighting will help to reduce the likelihood of falls. Steps with railings should be in good repair and kept free of ice, snow, and debris.

Ladder Safety

Ladders are a very common source of falls. Most falls occur as the result of using a ladder that is not in good repair or failing to observe good ladder handling techniques. Be sure to set the ladder on a solid footing. Remember to keep the base of the ladder 1 foot (0.3 meter) away from the building for every 4–5 feet (1.2–1.5 meters) of height. This 4:1 ratio will provide a stable angle that is safe and easy to climb. Individual safety and well-being on a ladder depend on observing commonsense precautions. Among these is having someone steadying the base of the ladder when it is being used.

The National Fire Protection Association (NFPA) provides the following recommendations for ladder use:

- Always wear appropriate footwear and clothing.
- Make sure the ladder you use is in good repair. Inspect ladders for damage and wear. Discard and replace if damaged.
- Use leg muscles, not back or arm muscles, when lifting ladders.
- Make sure that ladders are not raised into electrical wires.
- Check the ladder for proper angle.
- If using an extension ladder, check that hooks are properly seated over the rungs.
- Make sure the ladder is secure at both the top and the bottom before climbing.
- Climb smoothly and rhythmically.
- If a tool is carried in one hand, slide the free hand under the beam of the ladder while making the climb.
- Do not overload the ladder; check the ladder's working load limit.
- Use a fireman's leg lock (**Figure 13.1**) when working from the ladder.
- Ladders should extend a few feet (five rungs) beyond the roof edge to provide both a footing and a handhold for persons stepping on or off the ladder.

Buy and use the right ladder for the job. For a first-story roof, use a ladder that is 16–20 feet (5–6 meters) in length. To ladder a two-story building, select one that is 28–35 feet (8.5–10.7 meters) in length.

Figure 13.1. Always tie into ground ladders with a fireman's leg lock. Leg is wrapped over and around ladder rung.

OTHER IMPORTANT SAFETY CONSIDERATIONS

Staying Rested

Fatigue can pose a major threat to your ability to perform a job in a safe manner. Long hours are a given during the spring boiling season; however, long hours can also contribute to conditions that increase the likelihood of injury. As fatigue increases individuals tend to become careless, take shortcuts, and pay less attention to the job at hand and often make poorer decisions. Because not everyone responds to fatigue in the same way, each individual needs to understand how his or her body reacts to fatigue and should take steps to minimize the effects of fatigue, including rotating job responsibilities as available help and time allow.

Individuals who are well rested are more likely to make safe choices and sound decisions—it is important to recognize when it is time to stop working!

Youth Safety

Hundreds of children are killed, and tens of thousands seriously injured, on farms and ranches in the United States and Canada each year. Unintentional injury can occur when adults and children mistake a youngster's physical size and age for ability and underestimate the hazards and level of risk entailed in agricultural work.

Young people love to help, especially when it involves going out to the sugarhouse, to the woods, or to unusual destinations. As experienced adults who are aware of potential risks, it is our responsibility to ensure that the tasks assigned to youngsters are appropriate for their age and capabilities (**Figure 13.2**). Young people often want to pitch in and tackle jobs that are beyond their abilities. Remember that much of the time they just want to be there and to enjoy the companionship, fun, and excitement. They may have little or no awareness of potential dangers.

In non-agricultural industries there are federal and state/provincial regulations and work standards that indicate appropriate work tasks for both adults and children. In agriculture there are often no such standards, and children may be assigned farm jobs based on the parents' past practices, the need for "extra hands" to get the job done, and preferences of the child and/or parent. The "Agricultural Youth Work Guidelines" were developed under the direction of the National Children's Center for Rural and Agricultural Health and Safety to assist adults in assigning farm jobs to children 7–16 years old living or working on farms. These guidelines are available online.

Figure 13.2. Assign young people responsibilities they can safely and effectively perform, and that are appropriate for their age and maturity.

Liability Insurance

How much liability insurance should the maple producer carry? The answer of course will vary depending on the size, complexity, activity, and nature of the operation. That said, it is important that each operation be insured to cover the risks associated with the business. Coverage adequate for employee activities is a minimum requirement. Specific needs are influenced by a variety of factors, including whether workers are family or paid employees. Additional insurance will be necessary if visitors come to the sugarhouse or sugarbush, even when appropriate precautions (signage, railings, and restraining barriers) are followed. It is recommended that each producer contact their insurance provider and inform them of the specific operation and/or situation. As has been noted, many aspects of a sugaring operation present risks and hazards often unfamiliar to guests and customers. Producers should also consider product liability insurance to provide protection in case someone who purchases their maple products becomes ill or is injured by one of those products.

SAFETY IN THE SUGARING OPERATION

Install Caution Signs

Caution signs should be installed strategically to safeguard family, workers, and visitors. The hazards identified and the cautions addressed as well as the number of signs required will depend on the character of the operation, but may include falling snow/ice, hot objects, machinery, areas in which access should be limited, and propane or fuel hazards. In operations where visitors are welcome, caution signs need to be more numerous and address hazards normally understood by family and workers but perhaps unfamiliar to visitors. All exits should be clearly marked.

Be Alert to Natural Hazards

While maple producers enjoy the setting and atmosphere associated with the sugarbush and sugarhouse, both places nonetheless do present a variety of hazards that require all who work or visit there to be constantly alert. When working in the woods make it a consistent practice to look up from time to time to identify potential hazards that may be present. For example, the presence of barbed wire along fence lines can be a source of serious injury, whether walking or traveling at high speeds with ATVs or snow machines.

"Widow-makers" or dead, hanging limbs that occur naturally or after major events such as intense summer thunderstorms, heavy snowfalls, or ice storms are especially dangerous on windy days (**Figure 13.3**). It is inadvisable to have anyone working in the sugarbush or woodlot on windy days; leave the woods work for a calmer and less hazardous day. Bent-over trees and saplings can hold a great deal of stored energy. When cutting them, think about where they will land and what kinds of cutting techniques should be followed, as well as what escape path will be followed when the tree is falling. Traveling or walking on deep snow and/or ice is another obvious natural hazard during late winter and early spring.

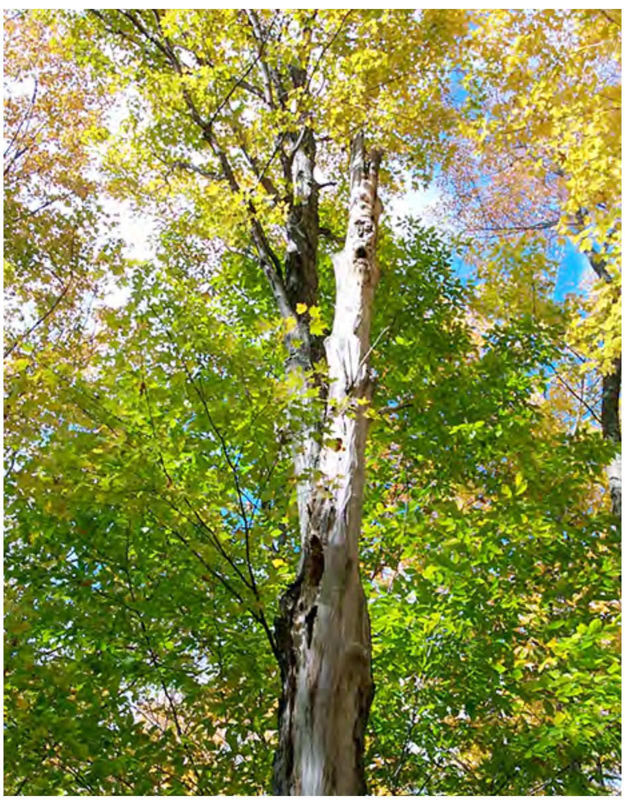

Figure 13.3. Use extreme care when working around "widow-makers," and remove this hazard from the sugarbush as soon as practicable.

Trees are great conductors of electricity—the conductivity of wire used in mainline systems is even greater. In fact, tubing systems are huge antenna out in the woods and will conduct electricity down the line until grounded. Tubing systems should be well grounded before they enter buildings. If a lightning storm is in the vicinity, stay away from the tubing system. Even better, get inside a vehicle, a building, or other form of shelter until the storm has passed.

Dress Properly

Dressing appropriately means using appropriate personal protective equipment (PPE) for the task at hand. In the warmer months, wear long pants and long-sleeved shirts to avoid exposure to brambles, insects, poison ivy, sunburn, and other seasonal hazards. Dress in multiple layers of clothes in cold and windy weather. Steel-toed boots with effective sole and heel grips can help to protect feet. Wear gloves appropriate for the job to be done. A hardhat should be worn when working in areas with overhead hazards, especially in storm-damaged woods. Sunscreen and insect repellent should be used as needed.

Make certain that children who are present in the sugarbush are also appropriately dressed.

Snowshoes

When the depth of snow on the ground exceeds a foot or more, snowshoes can save time and energy, and provide access to otherwise inaccessible areas. However, as with any tool, efficient and safe use requires care and practice. Beyond mastering the use of snowshoes, be careful not to get bogged down in deep, soft snow. The effort to get out can rapidly drain energy from an already tired body resulting in overexertion. In addition to contributing to excess fatigue, this overexertion could result in a heart attack or overheating, followed by rapid cooling in sweaty and wet clothes, leading to hypothermia.

Use extra care when working on slopes. Ice grippers can be very useful when icy, crusty conditions are present. Be especially careful when crossing a stream, as the snow or snow and ice covering may not support your weight. As with most activities in the woods, from a safety perspective, snowshoeing is best done when accompanied by another person.

Machinery Safety

Safe tractor operation begins with trained operators. Even trained operators become tired and may fail to observe safety precautions from time to time. For a maple operation, appropriate training includes familiarization with handling equipment on snow-covered, slippery roads and slopes. It may also include guidelines related to log skidding. Use tractors or other heavy equipment with rollover protective structures (ROPS) (**Figure 13.4**), and always use seatbelts. Remember that most agricultural tractors were not designed as log skidders. Use the right machinery for the job, and remember to keep all guards and shields in place and make certain warning signs and symbols are visible. It is particularly important to make certain that all braking equipment on the tractor is operable and properly maintained.

Figure 13.4. Every tractor and motor vehicle should have a first aid kit. Tractors should always be equipped with a roll-over protective structure.

Trailers or sleds are necessary pieces of equipment in most maple operations. Make certain the hitches are adequate for the job, and if a ball hitch is present, be sure to use the correct size ball. Draw or hitch pins should be safety clipped to prevent them from coming out while in use. Safety chains can prevent a runaway sled or trailer, and trailer brakes provide added control for sap gathering or transport trailers. Do not permit anyone to stand on the tongue or sled runners when the unit is moving. Guardrails or fenders placed around the trailer will help keep legs and feet away from the wheels.

All-Terrain Vehicle (ATV) Safety

ATVs are a common utility vehicle around the sugarbush. When used with caution and operated properly and safely, they are a very handy, versatile piece of equipment. Old three-wheel models should be retired since they have far reduced stability and are considerably more dangerous than four-wheel models. Most ATVs used on the farm or in the sugarbush are designed for operators at least 16 years old. The following guidelines should be observed when they are used:

- Always wear a helmet to reduce the risk of head injuries.
- Wear protective equipment appropriate for the conditions and job being done. This includes boots with heels, and long pants and long-sleeved shirts when working in the woods.
- Require that all new operators be properly trained.
- Always operate the vehicle at a safe speed.
- Do not operate ATVs on paved roads.
- Never drink alcohol while using an ATV!

[2] Isselhardt, M. 2021. Sugarbush Management and Chainsaw Safety. *Maple Syrup Digest*. June. pp. 18–20. https://mapleresearch.org/pub/chainsaw0621/

- ATVs are not designed to carry passengers—do not ride double!
- NEVER allow visitors to use your ATV, no matter how experienced they claim to be. Adults can be as inexperienced as youths.
- Operate ATVs responsibly at all times; don't show off !

Chainsaw Safety[2]

A chainsaw is an essential tool in most maple operations. In fact, most maple producers are so familiar with chainsaws and use them so frequently that it is easy to forget how dangerous this tool can be. Improper use of a chainsaw can result in painful, costly, debilitating, and sometimes fatal injuries. The most common injuries resulting from chainsaw accidents are to the arms and hands or legs.

Anyone using a chainsaw should be properly trained. For most maple producers this means participating in a chainsaw use and maintenance workshop. Simply because someone has used a chainsaw for years does not necessarily mean he or she is using it correctly or safely. It is also recommended that a refresher workshop be completed periodically to resharpen skills, increase sensitivity to safety issues, and become familiar with new techniques. Some basic suggestions regarding the use of chainsaws include the following:

- Properly maintain the chainsaw. A properly running, sharp saw will be easier to use, cause less fatigue, and allow more work to be done in less time in a safe manner.
- Read the owner's manual; become familiar with all features of the saw, and make certain the operator is familiar with how to properly operate the saw before it is used.
- If possible, have a spare saw available. It can be used if the first saw develops problems or becomes bound in a log or tree.
- Always observe safe and effective techniques when starting and using a chainsaw (see below).
- Be alert, and don't use a chainsaw when tired. A high proportion of chainsaw accidents happen when the operator is fatigued.
- Wear protective clothing and use personal protective equipment.
- Don't work alone; when others are present remember to always maintain a safe distance.
- Don't take chances; always work within your own experience, ability, and comfort limits.
- Always remember that the operator's experience, skill, and alertness are the most important factors in chainsaw safety.

CHAINSAW (PPE) Wearing proper clothing and using personal protective equipment (PPE) are two of the most effective safeguards for reducing the possibility of serious injury when using a chainsaw (**Figure 13.5**). Chainsaw operators should include these items when outfitting themselves for work:

- Sturdy, snug-fitting clothing that provides complete freedom of movement.

Figure 13.5. Always wear proper personal protective equipment suitable for the job being performed. Worn or damaged PPE should be promptly retired and replaced.

Loose-fitting clothing, jewelry, or long hair can easily be caught in the moving chain.
- Gloves specifically designed to protect hands from chainsaw injuries.
- Steel-toe, cut-resistant boots with non-slip soles to ensure good footing.
- Approved woodcutter's safety helmet with eye protection, a face screen, and earmuffs. Helmets should be properly fitting, cool, comfortable, and provide protection from falling limbs. The face screen reduces the risk of wood chips or sawdust getting in eyes, nose, and mouth. Earmuffs or ear plugs are essential to reduce potential hearing loss from loud chainsaw noise.
- Safety pants/chaps made of cut-resistant material to reduce the risk or severity of injury in the event of contact with a rotating chain. Safety pants/chaps do NOT prevent penetration by the chain saw but will give the operator protection during reaction time (human reaction time is about 0.75 seconds).

Having a logger's emergency trauma kit attached to your belt and always carrying a cellphone are additional safety precautions that are recommended. A whistle also provides excellent signaling to those nearby in the event of an emergency.

GENERAL RULES FOR SAFE CHAINSAW USE

The following rules are presented as a reminder of some important guidelines for safe chainsaw use.[3]

Before starting the engine, make sure the chain is not contacting anything; always engage chain brake before starting.

- Do not let the saw rest on your leg or knee when starting the engine.
- Do not drop-start the chainsaw; start the saw when it is setting on the ground.
- Never work alone! The minimum necessary standard is to stay within yelling distance of help (a two-tree height separation distance should be maintained between workers).
- Always maintain control by standing securely, holding the saw firmly, and idling the engine between successive cuts.
- Engage the chain brake when taking more than two steps with a running saw.
- Do not work when fatigued.
- Keep saw handles dry, clean, and free from grease or oil and fuel mixtures.
- Be sure the body is clear of the natural path the saw will follow when the cut is complete.
- Never straddle a log to make a cut.
- Always shut off the engine before setting it down, even when retreating from a falling tree.
- Carry the saw with the engine stopped, the guide bar and chain pointing behind you, and the muffler held away from your body.
- Make sure the saw is off and the chain has stopped before making any adjustments or repairs.
- Do not run the saw indoors.
- Wait until the engine has cooled before refueling it. Do not smoke during fueling.
- Check the air filter, chain tension, and nuts, bolts, and screws for tightness each time the saw is fueled.
- Make sure you know which way a tree will fall before you start cutting it down.
- Always plan an escape route before cutting the tree.

Kickback is one of the greatest hazards when using a chainsaw. It occurs when the upper quadrant of the bar nose contacts a solid object or is pinched. The force produced from the moving chain throws the saw rapidly and sometimes uncontrollably up and back toward the operator. This very violent and sudden motion can result in severe injury to the operator. Kickback may occur when the nose of the guide bar is pinched unexpectedly, contacts harder material in the wood (e.g., knots, metal), or is incorrectly used to begin a plunge or boring cut. It

[3] The list is not intended to be all-inclusive and is not adequate instruction to prepare someone to operate a chainsaw.

may also occur when cutting limbs off the main tree trunk. The risk of kickback is increased by

- an abrupt change in wood character (e.g., hitting a knot);
- running the chain too slowly;
- twisting the saw in the cut so the chain binds or grabs;
- using a dull or loose chain;
- having a loose grip on the saw or cutting with only one hand;
- not paying attention to movements of the saw when cutting.

Kickback can be prevented or controlled with a few steps and precautions. These do not eliminate the risk of kickback completely but will reduce the likelihood of significant kickback occurring.

- Always hold the saw firmly with a both hands and keep the left arm as straight as possible.
- Use a firm grip with the thumbs and fingers encircling the chainsaw handles.
- Use a well-balanced saw equipped with a chain brake, an anti-kickback chain, a throttle interlock, and a hand guard. A well-balanced saw is more comfortable when operated and is easy to control and handle under all conditions, including when kickback occurs.
- When activated the chain brake will stop the chain within a fraction of a second. This can mean the difference between a speed of 45 mph and 0 mph if the chain actually contacts the body. It is recommended that older model saws without a chain brake be replaced with new saws equipped with a chain brake.
- An anti-kickback chain reduces the forces on the chain that cause kickback. Replace worn chains with anti-kickback safety chains to reduce kickback.
- Make certain the correct tension of the chain is maintained and that the chain has been sharpened following instructions of the manufacturer.
- A throttle interlock prevents the throttle from accidentally advancing or inadvertently moving by automatically returning the throttle and chain to idle when the trigger button is released.
- The hand guard keeps the left hand from slipping forward into the chain.
- Check the chain brake frequently to ensure it is working properly.
- Do not rely exclusively upon safety devices; practice safety techniques when using the saw.
- During operation do not let the nose (kickback or danger zone) of the guide bar contact other objects such as a log, branch, the ground, or other obstruction.
- Watch for branches or small saplings that could snag the chain. The area in the vicinity of the chainsaw bar should be free from branches or small saplings before felling, limbing, or bucking.
- Avoid cutting brush or shrubbery.
- Do not cut with the upper quarter of the bar tip.
- Maintain a high saw speed when entering, cutting, and exiting wood.
- Keep the chain sharp and the saw well maintained.
- Do not overreach. Do not cut at a distance away from the body that requires relinquishing a safe grip on the saw.
- Do not cut above mid-chest height—the saw will be too close to the face and more difficult to control.
- Use only replacement chains and bars specified by the manufacturer of the saw.

Power Drills

Modern battery-powered drills are a huge improvement over gasoline tapping machines; however despite the increased level of safety, drills can still be dangerous. Tapping bits are sharp and present a danger if you should fall. While the motors are small, they have a great deal of torque. The primary recommendations for safe use are listed below:

- Use a sharp tapping bit.
- Make sure that no loose clothing will get tangled in the drill.
- Take a stable position prior to starting the drill.
- Use a fluid in/out movement with the drill at full speed.
- Place the drill back in its holster or clip before inserting the spout into the taphole and when moving from one tree to the next.

INJURIES AND FIRST AID

First aid training pays off. Everyone should take a class in basic first aid and cardiopulmonary resuscitation (CPR). Refresher courses should be taken to maintain skills. Even Emergency Medical Technicians (EMTs) are required to complete ongoing training and be recertified every 2 years.

First Aid Kit

Well-stocked first aid kits should be placed in convenient locations around the home, farm, and sugarhouse. Having one back at the house when someone is severely injured at the sugarhouse or in the woods will not be a great deal of help. Also, every tractor, ATV, and motor vehicle should have a first aid kit (**Figure 13.4**).

A first aid kit for the sugarhouse should include these basic supplies:

- Band-Aids
- Bandages and dressings
- CPR mask
- Cravats (triangular bandage)—for bandaging or making a sling
- Rubber gloves
- Splinting materials
- Sterile burn sheets

Hearing Protection

Hearing loss is a common condition in many agricultural operations and has been called the silent epidemic. Noise-induced hearing loss affects many individuals. Loss of hearing is a slow process and usually increases gradually until the time it is recognized as a significant problem. Some early warnings signs include a ringing in the ears that doesn't go away; feeling a sense of confusion in large, loud groups; or constantly having to ask people to repeat themselves. Consult with a physician if any of these symptoms are experienced. Always use personal protective equipment (PPE) such as earmuffs or ear plugs. Wearing PPE must become a habit and be required of all workers, especially children. There are many sources of excessive noise in a sugaring operation, including electric motors, vacuum pumps, tractors, snowmobiles, all-terrain vehicles (ATVs), and chainsaws.

Eye Protection

Eye injuries can cause pain, cost time and money, and even result in the loss of sight. Even a slight impairment in vision is a tremendous price to pay for a moment of carelessness. Wear proper eye protection (goggles, face screens, safety glasses) when potential eye injury hazards are likely and remember to always use common sense. Common types and causes of eye injury in maple producers include the following:

- Blunt injuries to the eye from flying objects such as when splitting wood or from hitting foreign objects while walking, especially in poorly lit areas
- Burns from flying sparks when firing the arch
- Injuries from welding, both hot materials and dangerous bright arcs or flames
- Chemical burns from being splashed by cleaning products

Protective eyewear should be durable, reasonably comfortable, and fit snugly without interfering with head movement or vision of the wearer (**Figure 13.5** and **Figure 13.6**). It should be easily cleaned, capable of being disinfected, and maintained in a clean condition and in good repair. Store eyewear in

Figure 13.6. Appropriate hearing protection should be worn whenever working around excessive noise; eye protection should be worn whenever there is potential for eye injury.

clean, dust-proof containers. To shield eyes from flying particles and objects, wear industrial-rated glasses or sunglasses, or flexible or cushion-fitting ventilated plastic goggles that fit over ordinary eyeglasses. Adding side shields increases protection. Always wear splash goggles when handling and using chemicals (e.g., pan cleaners), and never wear contact lenses when handling chemicals. Full-face shields are another option for eye protection and can be worn comfortably. Maple producers should also wear appropriate welding goggles to protect the eyes from intense light and sparks during metal repair operations.

Basic eye protection for those who wear glasses or sunglasses is a necessity. Wearing ordinary glasses or sunglasses offers little or no protection from serious hazards; they may even splinter or shatter on impact. Individuals who wear glasses should wear a face shield, goggles, or safety glasses with protective lenses. All safety glasses should be of industrial quality with flame-resistant frames.

Everyone working in the sugaring operation should become familiar with first aid treatment for eye injuries. The appropriate actions will depend on the type of injury. The suggestions listed below address some of the most common types of eye injuries:

- For small foreign objects in the eye, let natural tears wash out the object. Do not rub.
- Consult a physician if natural tearing does not remove the object. Do not remove any object that has penetrated the eye but stabilize the person and transport to a physician.
- For blows to the eye, apply cold compresses for 15 minutes and again each hour as needed to reduce pain and swelling. Consult a physician if the blow was hard enough to cause discoloration as internal damage may have occurred.
- For cuts and punctures to the eye, do nothing to the eye but bandage it lightly and consult a physician immediately.
- For chemical burns to the eye, irrigate the eye with fresh water or sterile saline for at least 15 minutes (**Figure 13.7**). Do not put any substance in the eye to "counteract" the chemical. Consult a physician immediately and have available the label or container of the chemical involved.

Figure 13.7. Portable eye wash station suitable for heated spaces (RO room) can be placed in the sugarhouse where chemicals are used.

Burns

Burns are one of the most frequent occurring injuries in the sugarhouse. Among the most common of these injuries are burns on the hands from reaching over the front pan with a scoop or opening a stem hood door and burns on the face from opening the steam hood door and looking in. Producers should be aware that steam hoods are under a slight positive pressure when the damper is partially closed, resulting in steam rushing out when the hood doors are opened.

Immediate first aid treatment for burns is critically important. Some suggestions include the following:

- Cool all burns quickly to minimize the severity of the damage to tissue that lies under the skin.
- One of the best steps is to immerse the burned part immediately in cold water. In the sugarhouse cold sap works just as well. Snow is also often readily available to cool a burn.
- Keep the affected areas cool for 10–15 minutes.
- After cooling, cover the skin with a dry, sterile dressing and bandage loosely.
- Whenever there is any question as to the severity of the burn, the victim should be seen by a physician.
- A physician should see individuals who suffer burns to the head, face, or chest as soon as possible. Severe burns in these areas increase the risk of serious injury to the respiratory system.
- At no time should ointments, salves, or butter be applied to any burn; these do not aid in the healing process and may increase opportunity for infection of the wound.

A pair of welding or fireplace gloves used when refueling the arch will reduce the likelihood of burns to fingers and hands.

Cold Temperature Injuries

Injury from cold temperature is a very distinct possibility when working outdoors during the winter. Before going outside during wet or stormy conditions, make certain to dress warmly, as becoming both cold and wet increases the risk for cold temperature injury. Minimize exposed areas of the body as injuries from cold temperatures are more likely on uncovered areas such as hands, ears, and face.

Windchill is an important concept to understand in cold weather. It is the temperature that people (not trees) feel in cold temperatures due to wind increasing the rate of heat loss from exposed skin (**Table 13.1**). Wind draws heat away from the body faster, making it feel colder. In general, windchill is a more important factor to consider when going outside than temperature alone. When windchill temperatures are in the high-risk category, producers should dress very warmly and limit the time outside. When windchill falls into the very high risk or below, outdoor activities should be stopped or restricted only to brief periods.

Hypothermia, or low body temperature, can be a life-threatening condition. Hypothermia occurs when the body loses heat faster than it can be maintained, thereby resulting in the body's core temperature dropping below normal. Normal body temperature is at or near 98.6°F (37°C); when the core body temperature drops below 95°F (35°C), hypothermia develops. Most commonly hypothermia occurs after prolonged exposure to freezing or near freezing temperatures. Because hypothermia may develop slowly, often the victim may not realize it is happening. If the cooling process is not reversed death may occur. Symptoms of hypothermia include uncontrollable shivering, bluish tint to skin, poor coordination, slowing pace in walking or other activities, increasing numbness, and loss of dexterity. In severe cases, the victim may have a dazed or confused look, be very drowsy, suffer from slurred and slow speech and be slow to respond to questions, have dilated pupils, experience hallucinations, have a decreased attention span, and display changes in personality.

Appropriate treatment for hypothermia victims depends on the specifics of the situation; some basic strategies are listed here:

- If the person is unable to communicate or is no longer shivering, immediately call for

TABLE 13.1 Wind chill index, exposure risk, and what to do to prevent injury.[1]

Wind Chill °F (°C)	Exposure Risk	Health Concerns	What to Do
32 to 15 (0 to –9)	**Low**	Slight increase in discomfort.	Dress warmly. Stay dry.
14 to –17 (–10 to –27)	**Moderate**	Uncomfortable. Risk of hypothermia and frostbite if outside for long periods without adequate protection.	Dress in layers of warm clothing, with an outer layer that is wind-resistant. Wear a hat, mittens or insulated gloves, a scarf, and insulated, waterproof footwear. Stay dry. Keep active.
–18 to –38 (–28 to –39)	**High** exposed skin can freeze in 10–30 minutes	High risk of frostbite—check face and extremities for numbness or whiteness. High risk of hypothermia if outside for long periods without adequate clothing or shelter from wind and cold.	Dress in layers of warm clothing, with an outer layer that is wind-resistant. Cover exposed skin. Wear a hat, mittens or insulated gloves, a scarf, neck tube or face mask, and insulated, waterproof footwear. Stay dry. Keep active.
–40 to –53 (–40 to –47)	**Very high** exposed skin can freeze in 5–10 minutes	Very high risk of frostbite: Check face and extremities for numbness or whiteness. Very high risk of hypothermia if outside for long periods without adequate clothing or shelter from wind and cold.	Dress in layers of warm clothing, with an outer layer that is wind-resistant. Cover all exposed skin. Wear a hat, mittens or insulated gloves, a scarf, neck tube or face mask, and insulated, waterproof footwear. Stay dry. Keep active.
–54 to –65 (–48 to –54)	**Severe** exposed skin can freeze in 2–5 minutes	Severe risk of frostbite: Check face and extremities frequently for numbness or whiteness. Severe risk of hypothermia if outside for long periods without adequate clothing or shelter from wind and cold.	Be careful. Dress very warmly in layers of clothing, with an outer layer that is wind-resistant. Cover all exposed skin. Wear a hat, mittens or insulated gloves, a scarf, neck tube or face mask, and insulated, waterproof footwear. Be ready to cut short or cancel outdoor activities. Stay dry. Keep active.
below –66 (below –55)	**Extreme** exposed skin freezes in under 2 minutes	**DANGER!** Outdoor conditions are hazardous.	Stay indoors.

[1] Adapted from Environment Canada, https://www.canada.ca/content/dam/eccc/migration/main/meteo-weather/80b0f2af-9697-4bee-ab17-d401ebba5b4b/windchill_poster_en.pdf

an ambulance to transport the person to an emergency department.

- Seek professional treatment as soon as possible even if signs of hypothermia are no longer evident. Serious health problems or death can arise even from mild cases of hypothermia.
- Get the victim into a shelter or area that can be heated slowly. Do not set the victim too close to a fire or heat source; a slow warmup is better.
- If in an open area, block the victim from wind with a sleeping bag, tree limbs, or other suitable object. If no shelter or heat source is available, fit as many people as you can in as small an area as possible to allow their body heat to warm the victim's environment.

- Encourage movement of the victim, but do not make movements for him or her.
- If conscious and alert, the victim should slowly drink warm (approximately 110°F/43°C), sugary liquids like hot chocolate; otherwise, warm bouillon or warm water will suffice. Do not give the victim alcoholic beverages.
- Wrap the victim in warm blankets or sleeping bags. If using people to warm a victim, remove wet clothes as they draw heat from the body. The warmer (person aiding the victim) and the victim should be unclothed (underwear may be left on), as body-to-body contact is needed to start warming the victim. Each warmer should exercise vigorously before and after contact with the victim to maintain his or her own body temperature. The warmers should rotate every 30 minutes to allow them time to get their body temperature up to normal.
- Keep the victim's head level with body, with slight elevation of legs and feet.

Victims of hypothermia should not be left alone. Ice, rubbing, alcohol, and hot or caffeinated beverages should not be used. Smoking reduces blood circulation. Only necessary medications should be administered.

Frostbite is a common cold weather injury. It is also one of the most serious because affected tissues are actually frozen and can be irreparably damaged. Areas most likely to be affected by frostbite include the ears, nose, cheeks, feet, fingers, and toes. Learn to recognize the following early symptoms in affected areas: tingling (pins-and-needles) or loss of sensation, tissue that feels cold and hard to the touch, blisters on the skin, white or pale, waxy appearance, and/or absence of pain in affected area.

Treatment guidelines for frostbite include the following:

- Move victim indoors or to a sheltered, preferably warm location.
- Get medical attention as soon as possible.
- Never rub the affected areas as it causes damage to frozen tissue.
- Warm affected area slowly.
- Avoid placing direct heat on affected areas.
- Immerse frozen parts in warm water or wrap in a warm compress (100°F/38°C) for 20–30 minutes. Do not let the victim control water temperature or heat source as he or she may be unable to feel how hot it is and may suffer burns as a result.
- Keep affected area elevated.
- Wrap area in warm blankets once pink or reddish color returns.
- Do not let affected area be exposed to the cold again.
- Serving a warm beverage is good, but not alcoholic beverages.

The severity of frostbite increases with the depth of the frozen tissue. Deep frostbite is the freezing of tissue, blood vessels, veins, muscles, tendons, nerves, and even bones. Any frozen tissue or organ can suffer irreversible damage in a short time or lead to further complications including infection, blood clots, and gangrene. Victims of frostbite are often more susceptible to future frostbite injury.

SAFETY AT THE SUGARHOUSE

Sap Storage

Make sure that the sap storage tank framing is structurally sound and strong enough to support the weight of the tank(s) when filled with sap. Sap weighs approximately 8⅓ pounds per gallon and concentrated sap weighs more with increasing sugar concentration. Before any tank is filled it should be inspected to ensure the tank framing support is sufficiently strong enough to handle the weight of the tank and its contents when filled. If changes are made in tank capacity or fill level (e.g., more taps are added to the system so the tank can be expected to hold more sap), re-evaluate the tank framing to ensure that it is adequate. If unsure, contact a carpenter or structural contractor for an on-site analysis of the current design, materials, and workmanship.

If tanks are very large, provisions should be made for a means of egress to prevent drowning, especially if children are present.

Fuel Safety—Wood

Wood is the traditional fuel for the sugarhouse. Wood should be carefully stacked in the woodshed to ensure that the stack is stable and not likely to fall. Children should not be allowed to play on or around the wood pile. When wood is used during the sugaring season, remove wood from the top down, rather than from the face of the pile. This will ensure the pile does not become top-heavy. Sparks are always a threat when burning wood; care must be taken, especially late in the season after the snow has melted, to safeguard against sparks that may ignite dry combustibles, leaves, stored wood, and other tinder. Windy conditions can increase the danger from sparks. There is also an increased chance of backdraft when the fire doors of the arch are opened, blowing hot embers out onto the sugarhouse floor. Keeping paper, wood, and other combustible materials picked up can prevent a potential fire, especially around the front of the arch. Prior to the beginning of the season, consider hiring an independent inspector to conduct a thorough check of the arch, stack, and all joints to be sure that they are in safe operating condition. If holes, perforated metal, or rusted and weak areas are found, replace the defective sections with new equipment.

Maple producers have developed various forms of spark arresters to be attached to the top of the smokestack (**Figure 13.8**). Wood fires can create large numbers of sparks, especially if resinous softwoods are used for fuel. A spark arrester will minimize the danger of sparks being emitted from the smokestack. Spark arresters are particularly valuable during the latter part of the season when the snow cover is gone.

Fuel Safety—Oil/Propane/Natural Gas

Oil burners should be inspected and, if necessary, adjusted before the season begins. Likewise, during operation they should be serviced regularly and maintained as required. Do not disable any safety devices that have been designed and built into the unit as they serve a vital purpose, namely, to protect the operator and the facility. Inspect all fuel lines, fittings and connections, and valves to be sure the system is ready for the maple season. Remember to uncap the stack prior to firing the burners as a buildup of stack pressure will not only affect performance of the burner but could also contribute to a safety problem. If the burner does not ignite after one or two attempts, stop and wait at least five minutes before attempting again. If the unit still does not ignite, shut off the power to the burner and call for repair service. The fuel oil tanks should be located in an area separate from the evaporator room and away from the parking area, but accessible to the delivery truck. A fuel containment system with a capacity equal to that of the tank should be constructed to capture any spilled oil in the event of a tank rupture or leak. A concrete structure surrounding the fuel tank is a suitable option.

Figure 13.8. A spark arrester on top of smokestack will help reduce the chance of accidental fires.

High-Pressure Steam

Evaporators that use steam as a heat source present their own set of safety concerns. Unlike other systems, there are no open flames, and the fuel and stack are well away from the boiling pans. Despite these seeming advantages, the potential of steam boilers to cause severe burns is even greater than that of other evaporators due to the very high temperature of the steam; therefore a thorough understanding of their management is crucial. It is essential that anyone using high-pressure steam thoroughly master the principles and practice of using this method and to know and adhere to the rules, regulations, and safety requirements appropriate for their locale. In most areas where maple syrup is produced, steam boilers must be inspected periodically by the proper authorities. In some areas, a license must be held to operate a steam boiler to fuel an evaporator. Steam-powered systems are in a class entirely their own and are generally used in larger operations. A thorough understanding of these systems is required for their safe operation but is beyond the scope of this manual.[4]

Carbon Monoxide

All types of fires produce carbon monoxide, an invisible, odorless, deadly gas. Carbon monoxide poisoning is a danger anytime there is fire or combustion, whether it is from wood, oil, gas, or anything else that will burn. To detect carbon monoxide levels in buildings, detectors are commonly installed about as frequently as are smoke detectors. The construction of new, tighter sugarhouses has increased the possibility of high carbon monoxide levels in the work area. Owners of such facilities should consider incorporating a supplemental air source for combustion into their design. In newer structures producers should consider installing carbon monoxide detectors, particularly in any building with sleeping quarters. Smoke detectors should also be installed.

Fire Safety

The sugarhouse and all vehicles used in sugaring operation should have fire extinguishers. A fire extinguisher is the first and often only line of defense in the event of a fire. Generally, unless the fire can be stopped within a very short time, the first step is to call for help. After that, if trained in the proper procedures, decide whether an attempt can be made to extinguish the fire either with water from a hose (if the sugarhouse is so equipped), with buckets or sap or water, or with an extinguisher. While saving the structure and equipment might seem important at the time, keep in mind that these can always be replaced, lives cannot.

There are many different types and sizes of portable fire extinguishers. To meet minimum safety requirements, an ABC type dry chemical extinguisher of at least 10-pound (4-kilogram) size should be placed in service near the entrance to the sugarhouse.

Fires are categorized by type:

Class A fires include most common combustibles (e.g., trash, wood, paper, clothing).
Class B fires are flammable liquids, oils, and grease.
Class C fires are all energized electrical fires.

Three commonly available portable fire extinguishers include the following:

- **Dry chemical extinguishers** are among the most commonly used portable fire extinguishers. Multi-purpose dry chemical agents themselves are nontoxic and are generally considered safe to use. However, when released the cloud of chemicals may reduce visibility and can create respiratory problems for some. Many dry chemical agents corrode metals, although this is a secondary concern in the event of a fire. It may be advisable to have an alternative type of extinguisher available (e.g., carbon dioxide) in the sugarhouse for use with fires of different origins. An ABC dry chemical extinguisher is acceptable for all types of fires. If only one type of fire extinguisher is installed it should be an ABC dry chemical extinguisher.

[4] Producers wishing to investigate high-pressure steam evaporation should consult Chapeskie, D. 2003. Use of High-Pressure Steam in the Production of Maple Products. Ontario Ministry of Agriculture, Food and Rural Affairs. Factsheet. AGDEX 383/737. 10 pp.

- **Carbon dioxide extinguishers** contain a liquefied gas ready for release at any time. Small dry ice crystals or carbon dioxide "snow" usually accompany the gaseous discharge. When released the carbon dioxide (CO_2) gas displaces available oxygen and smothers the fire. The dry ice crystals also lower the temperature of the fuel. Carbon dioxide produces no vapor-suppressing film on the surface of the fuel, so re-ignition is always a possibility. Carbon dioxide extinguishers are acceptable for all types of fires.
- **Stored-pressure water extinguishers,** also called air-pressurized water (APW) extinguishers, are useful for small Class A fires. Water-type extinguishers should be protected from temperatures lower than 40°F (4°C) common in unheated sugarhouses. Freeze protection may be provided by adding antifreeze to the water or by storing in a heated area. Pressurized water extinguishers should be used for Class A fires only. Never use a water extinguisher on Class B fires as rapid spreading of the fire could occur if the burning liquid is dispersed. Likewise, these extinguishers should not be used on electrical fires as the danger of electrocution could result from water contacting an energized electrical system.

Extinguishers should be inspected frequently to verify that they are fully charged and operable. If so equipped, the needle on the pressure gauge should be within the "green" zone. Hoses should be kept free of obstructions (debris, mice, insects, etc.). Extinguishers should be placed in strategic locations that are clearly visible throughout the facility—typically this is near exit doors. Installing bright red and white "Fire Extinguisher" signs will help identify the location of each extinguisher.

Everyone who works in the sugarhouse should be trained in the proper operation of the extinguisher. The following four-step procedure, known as the P.A.S.S. system, should be used.

- **P**ull the pin.
- **A**im at the base of the fire, stand about 8 feet (2–3 meters) back.
- **S**queeze the handle.
- **S**weep from side to side until no trace of fire remains.

When in doubt, don't take chances. After the fire has been extinguished it is advisable to contact the local fire department to come and check out the situation. In too many instances, producers who thought a fire that had been extinguished left the facility only to return later to a burned-down sugarhouse.

A fire blanket is handy for sugarhouses without a good source of water.

Electrical Safety

The human body was not designed to tolerate contact with electrical current without significant harm. In fact, under certain conditions an electrical shock of less than $\frac{1}{10}$ amp can be fatal. Proper grounding of all electrical services and equipment is absolutely necessary for personal safety and the safety of your business investment. Grounding also eliminates the dangers of ground-fault hazards.

The electrical service should be installed and maintained by a qualified electrician. While many maple producers believe they can adequately wire a sugarhouse or pumping facility, it is always recommended that a competent electrician inspect the completed installation. It is also advisable to perform an electrical service check regularly. The following questions that should be addressed when completing the inspection:

- Has it been 10 or more years since the service was installed?
- Have significant changes been made in electrical usage or consumption that has increased the load on the system since the installation was completed?
- Do the lights dim when certain equipment is turned on?
- Do motors run "hot"?
- Are circuit breaker ground fault switches tripping regularly, or do fuses blow frequently?

- Was the original system installed or since modified by someone other than a qualified electrician?

If the answer to any of these questions is yes, it is recommended that a certified electrician inspect the service and make any needed modifications.

Ground fault circuit interrupters or GFCIs (**Figure 13.9**) should be used to protect all circuits in the sugarhouse. A ground fault occurs when electric current in a circuit travels outside its intended path. If a person's body provides a path to ground for the stray current, serious injury or even death may occur. Ground faults often result from damaged electrical wiring or water getting into electrical equipment. These are both situations that could occur in a sugarhouse. A ground fault circuit interrupter is an inexpensive electrical device that constantly monitors electricity flowing in a circuit and trips or shuts off the current if the electricity to an electrical device differs even slightly from that returning. The primary purpose of the ground fault circuit interrupter is to protect individuals from electrical shock, burns, or electrocution.

(a)

(b)

Figure 13.9. Permanently installed (a) or portable (b) ground fault circuit interrupters (GFCI) should be used to protect all circuits in the sugarhouse.

The advantage of using GFCIs is that they detect even those amounts of electricity too small to trip a fuse or circuit breaker. Three types of UL listed GFCIs are readily available:

- Wall Receptacle GFCI—Replaces the standard wall outlet currently installed.
- Circuit Breaker GFCI—In buildings equipped with circuit breakers, this type of GFCI may be installed directly in the panel.
- Portable GFCI—This unit requires no special knowledge or equipment to install. It can be plugged into a regular grounded outlet, and the electrical appliances are plugged into the GFCI outlet.

Because a GFCI detects ground faults, it can also prevent some electrical fires and reduce the severity of others by interrupting the flow of electrical current. GFCIs should be tested monthly; a "TEST" button is present on the unit to allow testing. The GFCI should disconnect the power to that outlet. Pressing the "RESET" button reconnects the power. If the GFCI does not disconnect the power, it should be checked by a qualified electrician and may need to be replaced.

Ground fault circuit interrupters should be installed and used anywhere moisture may be present, or where portable electric tools may be plugged into the circuit and used on damp ground or under damp conditions—in other words, in just about every location in the sugarhouse. Moisture-proof covers should be installed over receptacles that have the potential of becoming wet.

Lighting

Good lighting is essential to safe and efficient operations. Lighting needs should be carefully determined before fixtures are purchased and installed. A well-illuminated sugarhouse will increase the efficiency of the many operations that occur there. Important areas that need illumination include pathways to and around the sugarhouse, the pump room, the sap storage area, the room where the reverse osmosis unit is located, over the evaporator, and in the woodshed. Covered, shatter-proof bulbs/fixtures should be installed wherever there is possible contact with sap or syrup (**Figure 13.10**). A combination of multiple types of bulbs may be necessary as some are more appropriate for different applications and locations. Spotlights can provide valuable additional point lighting when directed at the syrup draw-off, filtering, or canning area.

Floors and Drains

Sugarhouse floors should be finished to provide an easily cleanable, non-slippery surface. Provision should also be made for floor drains to handle water, sap, and other liquids that result from condensation, spillage, and cleaning. Several of the features and desirable characteristics of sugarhouse floors and drains are discussed in **Chapter 12**.

Traffic Flow

Traffic pattern and flow in the sugarhouse can be a major concern, especially in sugarhouses that are open to visitors. When the sugarhouse is occupied with several individuals, the risk of injury to both workers and visitors is increased. Care must be taken to ensure that injuries resulting from falling or burns do not occur. Railings, walkways, or barriers may be a practical means of allowing visitors to observe boiling and other activities while maintaining a safe distance from equipment. This may be especially important if large groups including tourists, school children, or others can be expected to visit the operation. Most visitors to the sugarhouse will not be familiar with sap collection, evaporation, and other processing operations, or the risks associated with these activities.

Figure 13.10. All lights in areas where sap is stored or syrup is processed should be shielded to prevent breakage and glass entering the product.

Avoiding Spills

Remove the handles from unused valves to avoid an accidental opening that could cause spilling of both hot and valuable contents. By the same token, make operations easier and safer by putting handles on pans, buckets, or other containers used for dumping sap or pouring hot syrup.

Water Supply

Whenever possible sugarhouses should be constructed in locations where a dependable source of clean, running water is present. Processing equipment must be cleaned with potable water after every use. A dependable source of clean, potable water is essential for personal hygiene, washing, processing, and packaging and for keeping the facility as clean as possible. An adequate pressurized source of running water can also be very helpful in the event of a fire.

Sugarhouses that do not have running water sometimes use water tanks to store potable water for use in cleaning. When this is done, the tanks should be made from food-grade material and should be cleaned and sanitized regularly. In many sugarhouses relatively clean, and sometimes hot depending on the source, water is produced from equipment such as preheaters, a Steam-Away®, piggy back pan, or reverse osmosis unit. However, it must be emphasized that water from these sources is not always potable due to contamination from microorganisms, dirt and debris, or non–food-grade materials.

It is important that water in the sugarhouse be of high quality and potable (suitable for human consumption). Untreated water sources, such as a well or spring, can contain microbiological, chemical, and physical contaminants. Regular testing of untreated water for potential impurities can help prevent individuals from becoming sick or tainting otherwise good quality syrup. Sugarmakers should check with local county health departments to obtain information about water testing.

CLEANING EQUIPMENT SAFELY

Several of the commercial cleaners used to remove sugar sand (niter) from tubing, reverse osmosis machines, and other items used in maple production are defined as Hazardous Materials (HazMat) in both the United States and Canada, and great care should be taken in their storage and use. To use these products in a safe and environmentally friendly manner, it is important that the user read, understand, and follow the information and directions provided on the labels (**Figure 13.11**). Some of these chemicals are extremely incompatible in terms of use and storage. Never use cleaners that do not have adequate instructions. Obtain, read, and understand the Safety Data Sheet (SDS) provided for each product. The SDS contains essential safety and handling information including chemical composition, identification of degree or type of risk or danger, first aid information, and recommendations for safe use, transport, storage, and disposal. Labels should remain with the cleaner so they can be referenced as needed. One copy of the SDS should remain in the storage cabinet or on file for reference, and one copy should be posted in a visible location in the sugarhouse. In the event of an emergency, the information contained in the SDS could be critical to providing helpful information to emergency personnel, the physician, or poison center.

Figure 13.11. To use cleaners and other chemicals safely and in an environmentally friendly manner, it is important to read, understand, and follow the information and directions provided on the labels.

Observe these precautions when using cleaners:

- Buy only the amount of cleaning materials that will be used in the current season. Avoid storing cleaners from one season to the next, as this may constitute an unnecessary hazard.
- Use the exact amount as directed on the label.
- Drain empty cleaner containers for 30 seconds before rinsing.
- Triple-rinse each empty container. A triple rinse requires the container be rinsed and thoroughly drained, and then rinsed and thoroughly drained two more times.
- Dispose of empty containers in accordance with the label and local recycling regulations.
- Use recommended personal protective equipment (PPE) identified on the label such as goggles, a face-shield, protective gloves, an apron, and boots.
- Store all chemicals and their SDS in a secure (locked), dry storage facility according to manufacturer's recommendations. This location should be separate from the evaporation room, away from fuel storage areas, and inaccessible to animals and visitors.

Do not contaminate local water supplies or the local environment when disposing of cleaning solutions and rinse water by dumping them into a stream, "over the bank," or out the back door. Always follow the printed disposal instructions found on the label and consult local environmental regulators if there are questions. Be aware that any pollution of local water supplies can affect water sources used for drinking and other purposes.

PROCESSING AND PACKAGING AREAS

High temperatures can be a potential hazard in the sugarhouse, packaging room, and candy kitchen. Exercise particular care when working around finishing or reheating units, or when handling open containers of hot syrup. When bulk quantities are handled in this area, use of equipment (**Figure 13.12**) and safe lifting practices need to be enforced so that the likelihood of back injuries, slips, or falls is minimized. In the warehouse area, stack barrels and other supplies carefully to reduce the likelihood of falling. Caution should be exercised any time motorized vehicles are used to transfer supplies throughout the storage facility. Motorized vehicles should be equipped with backup alarms and operated only by workers who have received proper training in their use.

VISITORS

Inviting visitors or guests into your woods or sugarhouse is accompanied by an increased liability for their safety and well-being. The use of barriers, clearly delineated travelways, and other facility modifications to minimize the risk of injury to visitors is discussed elsewhere in this chapter. In addition to following the suggestions already presented, producers should provide groups that are planning to visit their maple facility with some practical awareness training. Information should be provided to potential visitors, including school administrators, teachers, and other group leaders, about preparing students, parents, and others for a fun, educational, and safe experience. The information and advice provided should include a brief discussion of expected behavior (particularly important with younger visitors and their chaperones), potential hazards, areas of restricted access, and recommended dress (warm clothing and boots if going into the sugarbush), as well as what not to wear (such as nylon jackets that may be affected by high temperatures, sandals, etc.). In addition to this information, each group visit to your facility should begin with a welcome that includes an orientation about what group members will see, what to expect during their visit, and how to pose questions.

Figure 13.12. Use mechanical aids such as this barrel lift on a tractor to move heavy loads and prevent back injuries.

CHAPTER 14
Food Safety for Maple Production

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CHAPTER CONTENTS

INTRODUCTION

Producing safe, high-quality food is never an accident. It takes unequivocal commitment to food safety, keen awareness of the potential hazards associated with your product, and proactive implementation of effective risk reduction strategies. All food producers, including maple producers, have an obligation to protect public health and comply with all applicable regulations. Depending on the characteristics of the maple operation, the products it

Perkins, T.D., R.B. Heiligmann, M.R. Koelling, and A.K. van den Berg (Editors). 2022. *North American Maple Syrup Producers Manual. Third Edition*. The University of Vermont and the North American Maple Syrup Council, Burlington, Vermont. www.mapleresearch.org/manual/

produces, where it is located, and where and to whom it sells its products, the operation may be required to follow a diverse array of food safety regulations (federal, state/provincial, local). Maple producers might also need to meet additional food safety requirements specified by a certifying agency, syrup packer, or food retailer.[1] However, the general food safety practices outlined in this chapter should be followed in every maple operation.

FOOD SAFETY HAZARDS

The first step in the safe production of any food is the identification of potential hazards. Food safety hazards typically fall into one of three categories: biological, chemical, or physical. Contamination from one of these sources during maple product production can occur at any stage, from sap collection to final syrup packing and storage, and could cause mild to severe foodborne illnesses and result in discomfort, hospitalization, and possibly death.

Biological Hazards

Biological hazards that may cause illness include bacteria, viruses, parasites, molds (fungi), and yeasts that occur naturally in the air, water, and soil. Biological contamination can be introduced by contact with people, animals, or contaminated surfaces (**Figure 14.1**).

Figure 14.1. Mold in maple syrup. When this happens, syrup should be discarded.

[1] The general food safety practices described in this chapter are not a substitute for knowing and understanding the applicable rules and regulations within a maple producer's jurisdiction.

Some important concepts about microbial contamination:

- Microbes, such as viruses, molds, and bacteria, are the most frequent cause of foodborne illnesses.
- Water activity (a_w) is a measure of water in food products that is not bound to food molecules. The lower the water activity of a food, the less water is available for microbial growth. Thus, controlling water activity is a way to prevent and control microbial growth in foods. The water activity level of 66°Brix syrup is approximately 0.85. Most pathogenic bacteria will not grow at water activity levels below 0.91. Most molds and yeast found in maple syrup will not grow at water activity levels below 0.85, except a few xerophilic ("dry-loving") molds which will grow at levels as low as 0.70.
- Some types of pathogenic bacteria, such as *Escherichia coli* O157:H7, *Salmonella*, *Listeria monocytogenes*, *Staphylococcus aureus*, *Clostridium*, and *Campylobacter* can cause serious foodborne illnesses. These bacteria are problematic because they do not always cause noticeable changes in food. These have not been found in maple syrup as they normally cannot survive the high temperatures of production and packing or the water activity level of maple syrup that meets regulatory requirements (66°Brix).
- Spoilage bacteria such as *Pseudomonas*, *Leuconostoc*, *Bacillus*, and *Enterobacter aerogenes* can occur in maple sap can cause changes in its composition and adversely affect the flavor, color, and texture of syrup.
- Several species of mold within each of the *Acremonium*, *Eurotium*, *Penicillium*, and *Wallemia* genera have been identified in maple syrup and can cause off-flavors, ropiness, gastrointestinal distress, and allergic reactions in people with mold allergies.

- Another specific potential food hazard associated with the xerophilic molds (molds that survive in low water activity food products) found in syrup is from the byproducts of their metabolism, such as mycotoxins, that may be present in contaminated syrup. A mycotoxin is a toxic secondary metabolite produced by some fungal species. Mycotoxins cannot be filtered out or destroyed by heating. Unlike molds, mycotoxins aren't characterized as allergens. They are naturally occurring toxins that people are more less sensitive to depending on factors like age and immune status. Frequent exposure to trace doses of certain mycotoxins can cause long-term health effects rather than anaphylactic shock. Research on mycotoxin occurrence in maple syrup is preliminary and the risk posed is still being assessed.
- Syrup contaminated with any microbe, including mold and yeast, is considered adulterated and cannot be sold for human consumption (or used in the production of another product). The once widely accepted practice of skimming mold off the top of syrup, reboiling, and filtering falls short of a reliable decontamination strategy and is no longer an acceptable practice. Even after the removal of visible mold, mycotoxins and mold spores may remain in the syrup, posing the threat of negative health effects and future mold growth. The common food safety adage applies: When in doubt, throw it out.

PREVENTING BIOLOGICAL HAZARDS IN MAPLE PRODUCTION There are numerous best practices maple producers can adopt to prevent biological hazards. Some basic actions that can be taken by maple producers to help prevent biological hazards include the following:

- Boiling to a minimum density of 66°Brix (35.6°Baume). The water activity level of syrup at this density will limit the growth of many microorganisms.
- Packing syrup at the minimum recommended temperature (180°F/82°C) with appropriate procedures. Note that *all* syrup in the container must be at this temperature until the container is sealed.
- Completely filling drums for bulk storage with hot syrup at the minimum temperature and sealing immediately. Tipping the drum slightly exposes all interior surfaces to microbe-killing hot syrup and will reveal any leaks in the cap seal. As the hot syrup cools, it will contract, leaving an anaerobic (oxygen-free) space hostile to microbial growth. The minimum temperature must be maintained in all syrup in the barrel throughout the filling process.
- Bottling syrup at the minimum packing temperature in clean, unused, uncontaminated retail-size containers that are filled to the proper level, and capped immediately and inverted to heat the container neck and the inside of the cap. As with bulk containers, this practice optimizes storage conditions by creating an anaerobic space hostile to microbial growth inside the bottle.
- Avoiding cold packing of syrup unless refrigeration is guaranteed.
- Eliminating overtemperature packing of syrup. Caution should be exercised to prevent the release of niter at these higher temperatures (see **Chapter 8**).
- Preheating small glass containers to maximize spore reduction and help minimize microbial contamination. When filling containers whose volume of glass is large relative to the volume of syrup it will hold, this step will maintain the minimum syrup temperature required to ensure safe packaging (see **Chapter 8**).
- Maintaining cleanliness throughout the production and packaging operation.
- Storing finished products at low temperatures, ideally by refrigerating or freezing to discourage microbial growth.

- Boiling sap or concentrate to a finished product as soon as possible after collection. Sap is extremely perishable and, depending on the temperature, can spoil in as little time as a few hours. Fungi can rapidly colonize and ferment sap at temperatures above 40°F (4.4°C).

Chemical Hazards

Using only food-grade products intended for maple production and properly storing, handling, and using these products will reduce potential exposure to chemical hazards. The major chemical hazards include lead, processing aids such as defoamers and diatomaceous earth, lubricants, evaporator and RO cleaning chemicals, water treatment chemicals, pest control products, and food allergens.

PREVENTING CHEMICAL HAZARDS IN MAPLE PRODUCTION **Lead.** Lead is a significant risk to consumer health. Prenatally, in infancy, and during early childhood, consumption of very small quantities of lead can irreversibly damage developing brains and nervous systems. In adults, studies suggest low levels of exposure over time may damage the heart, kidneys, and brain.

Sap and syrup are both slightly acidic. When these liquids come in contact with lead-bearing equipment, they can dissolve the lead, thus introducing lead particles into maple syrup products (**Figure 14.2**). Lead can be found in lead-soldered, galvanized, terneplate and English tin–coated equipment, brass and bronze pump components and fittings, copper, and some non–food-grade plastics.[2] Some solder or fittings labeled as "lead-free" can also contain small quantities of lead. Lead-containing equipment is not acceptable for use at any stage of the maple sap collection or syrup production cycle. Syrup produced with equipment that contains lead is not acceptable for sale or consumption, and any equipment or component that contains lead should be removed. Regular testing of finished syrup is recommended to ensure lead is not present. Best practices dictate that syrup found to contain elevated lead levels be destroyed, not diluted with another syrup.

Figure 14.2. Older lead-soldered and galvanized equipment can leach significant quantities of lead into maple sap and syrup.

Defoamers. Using a dairy or an egg product to control foam is no longer an acceptable practice due to the allergen risk in susceptible populations. In addition, defoamers should not contain other high-risk allergens including wheat, peanuts, soybeans, tree nuts, fish, or crustacean shellfish. Such defoaming agents are not only hazardous, but also may become rancid and cause off-flavors. Only commercial food-grade defoamers should be used, with best practices employed to prevent rancidity and off-flavors (see **Chapter 7**). Certified organic producers must use only those defoamers permitted by the certifying agency.

Diatomaceous earth. Diatomaceous earth (D.E.) is used to improve the efficiency of filtering maple syrup. Only food-grade D.E. should be used. Other types of D.E., such as those for swimming pool filtration, may contain lead or other heavy metals and contaminants that if added to syrup would pose a chemical hazard. To ensure a food-grade product is used, producers should request a product specification sheet from their vendor to confirm the product is acceptable for use in food. D.E. should be stored in an airtight, food-grade container when not in use to prevent it from absorbing moisture and odors, or developing mold growth, leading to contamination and off-flavors in syrup.

[2] Wilmot, T.R. and T.D. Perkins. 2006. *Keeping Lead Out of Maple Syrup: A Guide to the Use of Sap Collecting and Syrup Making Equipment.* University of Vermont, Agricultural Experiment Station Miscellaneous Publication, Burlington, Vermont (Reprinted from 2000). 4pp. https://mapleresearch.org/pub/leadout/

Lubricants. Only food-grade materials may be used to lubricate equipment parts and, when required, should be applied sparingly. Food-grade lubricants are clearly labeled and are available through equipment dealers.

Cleaning and Sanitizing Chemicals. Chemical cleaner residues can create off-flavors and lead to hazardous food contamination. Products used for cleaning and sanitizing in the maple industry must be approved for use in food-processing environments, and for the material being treated. A universal best practice when using cleaning and sanitizing chemicals in food production is to strictly follow label directions. At a minimum, surfaces should be triple-rinsed thoroughly with warm, potable water following application. It must be noted that many chemicals used in maple production—such as evaporator pan cleaners and RO wash chemicals—require specific procedures to ensure residues are fully removed. For example, eliminating residues from an RO unit following a chemical wash cycle generally requires rinsing the unit with 40 times its empty residual volume. Note also that when cleaning evaporator pans, chemical residues can be trapped in any residual niter on the pans—no amount of rinsing is adequate until the pans are completely free of residual niter (see **Chapter 7**). Always follow label instructions and equipment manufacturer recommendations for the specific equipment and cleaner being used. Wash and rinse water should be safely neutralized and disposed of as dictated by federal, state, provincial and local regulations. Store chemicals in their original, labeled containers and in a secure location away from the food production and finishing areas.

Allergens. Management of food allergens is a critical component of food safety, and the prevention of allergen cross-contact is required by U.S. and Canadian federal food regulations. U.S. food safety regulations list 8 common food allergens: milk, egg, fish, crustacean shellfish (crab, lobster, or shrimp), tree nuts, wheat, peanuts, and soybeans. Health Canada has identified 12 allergenic foods of concern: crustaceans and mollusks, eggs, gluten, milk, mustard, peanuts, fish, sesame, soy, sulfites, tree nuts, wheat and triticale. Food legislation in the European Union lists 14 food allergens: cereals containing gluten (e.g., wheat, barley, rye), crustaceans (prawns, lobster, crabs, and crayfish), eggs, fish, peanuts, soybeans, milk, tree nuts, celery, mustard, sesame, sulfur dioxide, lupin, and mollusks.

Preventing allergen contamination begins with awareness and identification of potential sources of contamination and cross-contact—from obvious sources like nuts used in the production of value-added products to those that can easily escape attention, such as items in an employee's lunch. Once identified, the next step is the use of allergen protocols to avoid accidental contact or cross-contact with the listed allergen-producing foods. The basic food safety practices outlined in the "Current Good Manufacturing Practices and Preventive Controls" section are designed to prevent allergen contamination through direct or cross-contact and comprise measures such as production scheduling, washing, rinsing, and sanitizing equipment and utensils; washing hands and changing gloves after working with foods; and designating separate equipment and work areas to use when preparing such foods. Note that additional labeling, such as advisory "May contain" labeling for value-added products containing food allergens, is also required to alert customers of potential allergen cross-contact. Consult the applicable regulation for more detailed guidance on requirements and procedures for allergen labeling and cross-contact prevention.

Food-Grade Materials and Equipment. Equipment and any surface or component that will contact sap, syrup, or materials used in the production of syrup and maple products (e.g., water, D.E.) used throughout the maple operation must be constructed of food-grade materials that are non-toxic, suitable for the intended use, non-absorbent, inert, durable to withstand repeated cleaning and sanitizing (if needed to prevent food contamination), smooth, corrosion resistant, cleanable, non-breakable, and properly maintained. Using non–food-grade equipment or materials that do not meet these requirements may introduce chemical contamination and off-flavors. Tubing, fittings, storage containers, or other equipment that has been previously used with hazardous substances or non-food substances are not safe for use.

Understanding the properties of food-grade plastics is important for their proper use. Plastics can vary widely in composition and physical properties. For instance, exposing certain plastics to high temperatures, sanitizers, and UV radiation may degrade their performance and may even cause harmful substances to leach from their constituents into food. Be sure that plastics are used for their intended purpose and check with the manufacturer for safety specifications for high temperature applications. This precaution is particularly important for preventing contamination from plastic pipes and hoses used in high-heat applications in the sugarhouse.

Physical Hazards

Physical hazards are substances not normally found in food that can cause physical injury to the person consuming the food. Common physical hazards include glass shards, wood splinters, metal shavings, pieces of packaging, small stones, insect parts, hair, and jewelry. These types of extraneous materials can result in choking, cuts, damage to the teeth, or mouth, or internal injuries.

Basic practices for preventing the introduction of physical hazards from the production environment into maple products include properly maintaining and calibrating equipment; shielding light fixtures (**Figure 14.3**), windows, and other potential sources of hazardous material and debris; using hair coverings; and removing jewelry. Because even food-grade D.E. constitutes a physical hazard, producers should likewise carefully maintain and operate filtering units to ensure no particles enter the finished syrup. Managing syrup containers to prevent contamination or damage during storage and prior to filling, both retail and bulk, is also key to protecting maple consumers from the risk of physical injury. Additional practices to prevent physical hazards are outlined in the "Current Good Manufacturing Practices and Preventive Controls" section.

Figure 14.3. Light fixtures in facilities producing or packaging maple syrup should be properly shielded to prevent accidental contamination of syrup if bulbs are broken.

Other Issues

WASTEWATER DISCHARGE There are increasing levels of concern in some states and provinces about known point source discharges from maple operations. Some states look at this issue during an inspection and some do not. Areas of concern are the discharge points of the RO unit and wash water, the septic system in facilities that have restrooms, and the evaporator. Check with your state or provincial association to determine whether the Department/Agency of Agriculture and/or Department of Environmental Protection has jurisdiction over maple production and to determine which regulations may apply to your operation. In some cases, local Departments of Health may have additional requirements for maple processing facilities; those that make value-added products are particularly likely to be subject to more extensive regulations.

SUGARHOUSE AESTHETICS It is important to keep in mind that visitors to your sugaring operation will judge your product based upon the appearance of your site and facilities. Studies over the years have shown that consumers taste with their eyes and nose as well as their mouth. If elements of your operation look dirty or smell bad, customers will assume that the food product you make is dirty as well. It is critical that your operation be kept to high visual and aromatic standards for visitors. If the facility includes an area where product samples are offered, it must be kept clean and tidy and project an image of cleanliness, high quality, and value.

FOOD SAFETY REGULATIONS

The primary regulations governing food safety in maple operations are the federal regulations detailed in the United States Food Safety Modernization Act (FSMA) and in Canada's Safe Food for Canadians Regulations (SFCR). Both are based on principles established by the Codex Alimentarius *Recommended International Code of Practice—General Principles of Food Hygiene* and are considered by both countries to be equivalent to each other. Furthermore, different states and provinces and localities may have additional safety regulations or requirements for food production beyond those specified by the United States and Canadian federal governments. It is the responsibility of each producer to know the food safety rules and regulations mandated by the governments within their respective country, state or province, and locality and to implement and comply with all applicable food safety procedures and practices when producing maple products.

Federal Food Safety Regulations

This section describes general information about the federal food safety regulations in the U.S.A. and Canada. The regulations described in this section are current as of the time of publication of this manual. However, it is important to note that both FSMA and SFCR are frequently updated with revisions to existing rules and the addition of new regulations. Consult the FSMA and SFCR websites frequently to check for updates and changes and to obtain more detailed information on the regulations.

UNITED STATES—FOOD SAFETY MODERNIZATION ACT (FSMA) Food safety regulations have been a part of the greater food industry in the United States since the administration of President Abraham Lincoln. In 1862, legislation created the United States Department of Agriculture (USDA). The early regulations were the states' responsibilities to implement, but with increased movement of food across state lines, the Interstate Commerce Act of 1887 was passed to expand the federal regulations to ensure all citizens were protected by the same standards of food safety. The first major food safety regulation was the Federal Food, Drug, and Cosmetic Act of 1938. Subsequently, there were very few changes in federal food regulations until the passage of the 2002 Public Health Security and Bioterrorism Preparedness and Response Act. The Food Safety Modernization Act (FSMA), under the authority of the United States Department of Health and Human Services—Food and Drug Agency (FDA), was signed into law on January 4, 2011. The new FSMA regulations were prompted by rising cases of foodborne illness in the early 2000s. The intention of FSMA is to ensure a safe U.S. food supply by focusing on preventing food contamination.

There are two major components of FSMA: **Current Good Manufacturing Practices (CGMPs)** and **Hazard Analysis and Risk-Based Preventive Controls (HARPC)**.

CGMPs. CGMPs are essential food safety practices applicable to all food production facilities, aimed at ensuring food is manufactured, processed, packaged, and stored in a manner that ensures it is safe, wholesome, and sanitary. These practices are described in more detail in the "Current Good Manufacturing Practices and Preventive Controls" section.

HARPC. HARPC is a further step in implementing food safety practices to achieve the same goal as the CGMP standards, and has many additional requirements, including a written food safety plan, hazard analyses, and the implementation of preventative controls, all overseen by a "qualified individual."[3]

In general, all U.S. maple operations required to register (see below) must comply with the CGMPs. Small or very small businesses (those with fewer than 500 employees or that average less than $1 million per year in sales during the previous 3-year period) that are engaged in the production of low-risk foods on farms, including maple syrup, candy, and cream, are known as "qualified facilities" and are typically exempt from HARPC portion of FSMA. However, every operation is unique, and it is advisable to consult with the state FDA office or

[3] A qualified individual is someone who has successfully completed certain training in the development and application of risk-based preventive controls or is otherwise qualified through job experience to develop and apply a food safety system.

guidance documents available online to determine which regulations apply to your operation.

Registration and Inspections under FSMA. FSMA currently requires food facilities to register online every 2 years on even years. Once registered, operations that fail to reregister on the next even year must repeat the full registration process and register as a new applicant. It is important to keep your registration updated. In general, at present, operations that sell less than half of their crop directly to consumers at the location in which it was produced, that focus solely on sap collection, or that produce only enough syrup for self-consumption are not required to register. All others must register. There are numerous online resources available to assist in determining if an operation is required to register. It is recommended maple producers use these and/or consult with their individual state FDA office or Department or Agency of Agriculture to confirm if registration is required. Some states are implementing a registration and/or licensing process. This is an additional level of protection for producers and aids in the implementation of the numerous FSMA regulations. As more states develop their own requirements for FSMA compliance, it is each producer's responsibility to adhere to these state requirements.

During the registration process, if your operation is a "qualified facility"—a small or very small business (fewer than 500 employees or one that sells less than $1 million per year [3-year average]) engaged in the production of low-risk foods on a farm, including maple syrup, candy, and cream—you will be required to submit an attestation that your operation does indeed meet the financial requirements, and is either (1) addressing identified hazards through preventive controls and monitoring the preventive controls, or (2) complying with an applicable non-federal food safety law (such as state food safety laws) and notifying consumers of the name and complete business address of the facility where the food was manufactured or processed. Qualified facilities must also keep records to support the attestations made on the form. Qualified facilities are exempt from the HARPC portion of FSMA but are still required to adhere to CGMPs. For more guidance and information on this consult your local FDA office or online resources.

Maple operation inspections will occur under the FMSA regulations. The inspection may be conducted by an FDA inspector or, in some states, an official from the state's Department or Agency of Agriculture acting on behalf of the FDA. There is no definitive list of FDA inspection requirements. In general, any inspection will focus on the adherence to the guidelines of the CGMPs (and HARPC, if the operation is not exempt from this portion of FSMA).

There are guides available online that can assist U.S. producers in determining whether they need to register and if their operations meet the "qualified facility" definition.[4]

CANADA—SAFE FOODS FOR CANADIANS REGULATIONS (SFCR) Canada has a long history of creating food rules, guides, and nutritional information resources. The first Canadian food safety measure became law in 1875 via the Act to Prevent the Adulteration of Food, Drink, and Drugs. This initial food safety law has been revised periodically to ensure the safety of consumers. The Safe Food for Canadians Regulations (SFCR) was passed in 2012 to consolidate and modernize regulations under several existing acts to strengthen food traceability, to make food as safe as possible for all Canadians, and to provide better protection from food safety risks. Although requirements for certain food commodities were phased in, all requirements for maple products came fully into force on January 15, 2019. Other than certain SFCR traceability, labeling, and advertising provisions that apply to intra provincially traded foods, the SFCR does not apply to maple producers who trade solely within their home province.

Licensing. Under the SFCR, Canadian food producers must be licensed to manufacture, process, treat, preserve, grade, package, or label food for human consumption (including ingredients) that

[4] https://www.fda.gov/files/food/published/Questions-and-Answers-Regarding-Food-Facility-Registration-%28Seventh-Edition%29.pdf

are to be exported or sent or conveyed from one province to another.

Traceability and Labeling. License holders are required to prepare and keep documents that contain trace back and trace forward information. In addition, license holders must attach a label to their product that include its common name; a product lot code or unique identifier; and the name and principal location of their business.

Like FSMA in the U.S., the SFCR consists of two main components. In the Canadian legislation, these complementary components are designated **Preventative Controls** and **Preventative Control Plan** and are largely analogous and generally considered equivalent to the CGMPs and HARPC components of FSMA.

Preventive Controls. Preventive Controls are policies, procedures, and practices that control the operational conditions within a food establishment and promote favorable environmental conditions for the production of safe food. They are described in more detail in the "Current Good Manufacturing Practices and Preventive Controls" section. By preventing or reducing food safety hazards to an acceptable level, they reduce the likelihood of contaminated food entering the Canadian market. All producers licensed under the SFCR are required to implement Preventive Controls.

Preventive Control Plan (PCP). In addition to Preventive Controls, licensed Canadian maple producers with average annual food sales of $100,000 or more, or those who require an export certificate, must prepare, keep, and maintain a Preventive Control Plan (PCP). The PCP must address food safety hazards, control measures, and evidence of their effectiveness, as well as demonstrate compliance with consumer protection and market fairness requirements in areas such as packaging, labeling, grades, and standards of identity.

Inspections under SFCR Regulations. Canadian producers licensed under SFCR are regulated by the Canadian Food Inspection Agency (CFIA). Among its responsibilities are formulating regulations for food industries and, to ensure compliance, employing an advanced, fully integrated inspection system across all food commodities. Inspection frequency is based on the level of risk determined by three factors: the degree of inherent risk posed by the food being produced, the risk mitigation measures undertaken by the producer, and the producer's compliance history.

IMPLEMENTING FOOD SAFETY IN MAPLE OPERATIONS

Consumers value foods that are viewed as safe, pure, natural, and free from contaminants. All food safety programs have the same overall goal of ensuring that foods are free from biological, chemical, and physical hazards and are safe for human consumption. They are designed to identify potential hazards before they occur and to implement control measures to eliminate or reduce the likelihood of their occurrence. Creating and implementing a food safety program in every maple operation is the key to ensuring that these conditions are met and ultimately that the maple industry and maple products retain the pure, safe, and low-risk image they currently enjoy. The Current Good Manufacturing Practices (CGMPs) under FSMA and Preventative Controls under SFCR are the foundation of a food safety program.

Current Good Manufacturing Practices and Preventive Controls

CGMPs (FSMA) and Preventative Controls (SFCR) are risk-based preventive controls that reduce the risk of foodborne illness. They are general so each food industry can adapt the regulatory requirements to meets its specific needs. The purpose of both is to prevent the introduction of contamination into the food product. The CGMPs and Preventative Controls apply to the following areas:

1. The day-to-day operational activities of personnel in the manufacturing environment that promote the production and distribution of safe food. These activities include food handler hygiene, cleaning and sanitizing, water safety, chemical use, pest control, equipment maintenance, food and ingredient handling practices, and shipping, receiving, storage, and recall procedures.

2. The environment in which the food is produced. This area of concern includes equipment design, construction, and installation and the design and construction of both the interior and exterior of the food-producing facility and the surrounding property.

U.S. maple operations required to register under FSMA, and Canadian operations licensed under SFCR, are required to follow CGMPs and Preventative Controls, respectively. However, all maple operations, regardless of legal requirements, should be following these best practices for food safety.

Although structured differently, the CGMPs and Preventative Controls each include practices and procedures in the categories detailed below. The basic components of each are described here, particularly as they apply to maple production; however, producers must refer to the original documents to ensure full compliance. It is the responsibility of the maple producer to develop, implement, and maintain the policies, procedures, and records required for each CGMP or Preventive Control. Together with the best practices described in previous sections on Biological, Chemical, and Physical Hazard Prevention, these activities are the fundamental steps to producing maple products safely.

Third-Party Certification. The voluntary Sugarhouse Certification Program of the Vermont Maple Sugar Makers Association (VMSMA) is designed around the practices and procedures required for maple operations to implement the CGMPs (and thus the Preventative Controls of the Safe Food for Canadians regulations). The certification checklist and resources of this program, including educational information and templates for required recordkeeping and development of standard operating procedures, are an excellent starting place for maple operations to implement the CGMPs/Preventative Controls, and overall food safety programs and are available from the VMSMA.

PERSONNEL ***Training.*** All personnel, including temporary and full-time paid employees and unpaid volunteers, must have experience and training on the basic principles of food hygiene and safety (including personal health and hygiene), and the operation's comprehensive food safety program. This training must be documented. It can be provided by the operation itself or by food safety training courses sponsored by outside agencies. Each operation must have a designated person responsible for establishing and overseeing the food safety program and for overseeing and documenting the training of employees.

Cleanliness and Disease Control. Personal hygiene plays a major role in the production of safe food. To protect products from contamination and allergen-cross contact, all personnel must observe the following precautions and directives:

- Smoking, chewing gum, eating, drinking, and storing of personal items are not permitted in any areas where food is produced, packaged, or handled or where food-contact utensils or equipment is cleaned.
- Clean clothing suitable for preventing contamination and allergen cross-contact is required in all food handling areas, including appropriate footwear, hairnets, and head and/or facial hair coverings. Jewelry or other unsecured objects that might fall into food (e.g., pens in shirt pockets) must be removed. Hand jewelry that cannot be removed (e.g., wedding bands) must be covered. Gloves should be changed anytime they become soiled.
- Adequate personal cleanliness must be maintained.
- Hand-washing stations and potable water must be available to all personnel. Water for hand washing must be potable. Proper hand-washing practices must be followed: Wash hands in warm soapy water for 20 seconds, and wipe dry with disposable paper towels. This procedure is required after using the toilet, eating, or smoking, sneezing, or touching garbage containers or other dirty surfaces or allergens as well as before donning gloves or entering food production areas.

- Sick personnel must not be allowed in production or finishing areas.
- A first-aid station should be in a designated location away from the food-processing area. Personnel with open cuts or abrasions must never handle food or be exposed to food contact surfaces. Personnel with hand wounds must cover them with impermeable bandages or with gloves if planning to enter food production areas.

SUGARHOUSE AND GROUNDS. In general, the sugarhouse and surrounding grounds must be designed, constructed, and maintained in a way to prevent contamination and allergen cross-contamination and facilitate the safe production of food. To that end, the facility should meet the following requirements:

Sugarhouse

- Floors, walls, and ceilings should be durable, non-porous, and cleanable. Sugarhouse walls, floors and overhead areas should be cleaned both pre- and post-season and as often as needed during the season.
- Buildings should be well ventilated to prevent condensate from dripping onto any production or packaging areas.
- Buildings should be secure, structurally sound, and tight enough to prevent pests from entering.
- Indoor lighting should be protected by guards/shields or break-proof bulbs to prevent broken glass from contaminating food.
- Windows near food production and packaging areas must be shatterproof or protected to prevent contamination by broken glass.
- Adequate light and ventilation are required, with appropriate screening and safety covers to prevent food contamination.
- Buildings must be designed and constructed in a way that minimizes the potential for contamination of and allergen cross-contact with food-contact surfaces. Recommended practices include separating operational activities as needed in time or space and restricting the flow of people and products from "dirty" to "clean" areas. Packing activities that require a high level of cleanliness or contact with a food allergen should be physically and/or operationally separated from the evaporator/production area.
- Visitor access to production and finishing areas should be restricted to those accompanied by sugarhouse personnel, and visitor logs maintained.
- Outdoor bulk storage (sap tanks, drums, etc.) must be adequately protected against contamination, by appropriate means, including container covers and other preventive pest control measures, such as eliminating pest harborages in the surrounding area.
- A secure storage area away from the production area must be designated for any chemical supplies, and chemicals stored appropriately according to chemical compatibility.
- Non-food contact tools and any other non–food-grade materials should be kept in a designated area away from production and packing activities.

Grounds

- The grounds around the sugarhouse must be well maintained to deter the sheltering of pests. This means removing litter and waste, clearing overgrowth, and storing unused equipment and pallets far enough away from the building to discourage pest harborage and travel. A 10-foot gravel perimeter and 30-foot vegetation-free area around the sugarhouse will deter pest infestations.
- Grounds, roads, and waste management, equipment storage, and drainage areas should be maintained to prevent food contamination or attraction of pests. A separate area for managing waste can help reduce the risk of attracting pests.

- Outside lighting located away from the sugarhouse, rather than near doors, will help discourage entry of pests such as rodents and insects.
- Pest control on the grounds (not in the food production area) of a facility must be done following all applicable regulations governing pesticide use (local, state/provincial) and requirements for certification programs (organic, etc.) and should be done only by certified professionals.

SANITARY OPERATIONS ***General maintenance.*** The sugarhouse, its fixtures, and all other physical facilities of the operation must be maintained in clean and sanitary condition and in good repair.

Pests and pets. Both pests and pets present an opportunity for contamination in the sugarhouse and/or packing room. Both are a source of hair and fecal pathogens. Pets are not permitted in production or packaging areas of the sugaring operation (except for service animals). The sugarhouse and packing areas must be free of pest harborage sites and litter and garbage that will encourage pest infestation. Pests are less likely to invade an operation that is tight, clean, uncluttered, and dry. Openings or cracks in the exterior of the building or physical facilities should be sealed to discourage entry. Any interior openings between walls or ceilings should also be sealed to inhibit pest movement through the building.

The general strategy for rodent control is to employ exclusion measures to prevent their entry into the sugarhouse or packaging areas. Traps or glue boards positioned along rodent travel areas can be used to monitor for breaches of exclusion (**Figure 14.4**) and to reduce populations. Given the risk of contamination of food contact surfaces and maple products, pesticides and poison bait must ***never*** be used inside the sugarhouse.

Cleaning and Sanitizing. All food-contact surfaces, including utensils and food-contact surfaces of equipment, must be cleaned and sanitized as frequently as necessary to prevent food contamination and allergen cross-contact.

Figure 14.4. Cleanliness, exclusion, and traps should be used to reduce rodent presence in and around production, storage, and packaging facilities.

Cleaning

Cleaning is the removal of dirt or unwanted material from a surface by manual, mechanical, and/or chemical methods. Both food-contact and non-food contact surfaces should be cleaned as frequently as necessary to prevent contamination or allergen cross-contact. Because they are organic, fresh sap and syrup residues are easily removed from food-contact surfaces with warm water. However, if not removed immediately, eliminating these residues may require higher water temperatures, longer wash times, and the use of additional mechanical action (e.g., scrubbing, additional water turbulence).

Chemical cleaning agents for maple production equipment, like evaporator pan cleaners, can make the equipment cleaning process easier. However, using chemicals in a maple production environment presents challenges. Chemical residues can introduce off-flavors in maple syrup even at very low concentrations and can be toxic if ingested. Before using any chemical product, consider non-chemical alternatives such as potable warm water or steam. When using chemical cleaners, use only those that are approved for use in the maple industry and always follow label directions. Following use, triple rinse thoroughly with warm, potable water, or follow the specific rinsing instructions noted for the chemical and equipment (such as RO wash cycles). Safely neutralize (if necessary) and dispose of the wash and rinse water as outlined in the label directions and according to local regulations.

Sanitizing

Sanitizing involves applying heat or chemicals to a clean surface to reduce disease-causing microorganisms to a level considered safe for public health.[5] Not all surfaces (e.g., porous surfaces such as wood or tubing) can be sanitized. Sanitizing is required following cleaning of any surface that food touches to prevent microbial contamination. Note that sanitizing does not kill mold spores or eliminate mycotoxins that may be present as the result fungal contamination.

If sanitizing is required following cleaning, producers have several options. Use only sanitizers approved for food contact and for the material with which it is being used and closely follow the instructions on the label. Sanitizers are pesticides and must be registered with the Environmental Protection Agency (EPA) in the U.S. and Health Canada in Canada. Because of the low cost and ready availability, household bleach (5.25 percent sodium hypochlorite) is a widely used sanitizer. Use only a non-scented, surfactant free, food-safe product (labeled as "germicidal bleach") with an EPA (U.S.) or DIN (Canada) registration number. Other chemical sanitizers approved for food-contact surfaces include peroxyacetic acid compounds and hydrogen peroxide, as well as quaternary ammonium compounds. The use of some sanitizers, including bleach, may be prohibited by organic certification agencies. Note that all chlorine, peroxyacetic acid and quaternary ammonium compound sanitizers can corrode metal surfaces. To effectively reduce harmful pathogens, a sanitizer must be used according to label directions and must be in direct contact with a clean surface for the length of time required by the sanitizer at that concentration. To avoid chemical contamination, triple rinse treated equipment or utensils with potable water thoroughly after the use of any chemical sanitizer. To sanitize a work surface, first clean it with food-grade detergent and rinse thoroughly; then mist the entire surface with sanitizing solution from a spray bottle. Allow the surface to air dry or rinse as directed by the label.

When mixing any chemical sanitizer, use only potable water, prepare the correct concentration in an area with good ventilation, and use a fresh solution daily or more often if the solution becomes dirty or diluted. Check the concentration with a test strip.

Chemical contamination, as well as off-flavors in maple products, may result if there is incomplete rinsing of cleaner and/or sanitizer residues. Using chemicals at concentrations that exceed recommended levels may adulterate food products and can cause serious health risks to consumers. Reading label directions and reviewing the Safety Data Sheets (SDS) for a product clarifies what personal protective equipment (PPE), such as eye protection, aprons, and gloves, is needed during the cleaning and sanitizing process. All cleaning and sanitizing chemicals must be stored in their original, labeled containers in a secure location away from food production or packaging areas.

Avoid mixing different sanitizing chemicals together. Combining chemicals that are incompatible with each other can result dangerous reactions.

Cleaning and Sanitizing Recordkeeping

Keep a cleaning log when equipment is cleaned and sanitized. If chemicals are used, the type used and its concentration should also be recorded. A log helps keep food safety a priority in an operation and serves as documentation of the operator's food safety practices.

Other. Single-use items (like cups for tasting or paper towels) and any portable equipment and utensils (scoops, filter press plates, etc.) must be

[5] *Cleaning* removes dirt, dust, and germs from surfaces, and generally involves the use water and soap/detergent to physically clean surfaces and objects. *Disinfecting* uses chemicals to kill germs on surfaces and objects. Bleach and alcohol are common disinfectants. Sanitizing results in lowering the number of germs to a safe level and is accomplished by either cleaning, disinfecting, or both. *Sterilization* is a process that removes, kills, or deactivates all forms of life and other biological agents, and is rarely achieved outside medical or research settings.

stored and handled in a way that prevents contamination and allergen cross-contact.

SANITARY FACILITIES AND CONTROLS ***Water Quality.*** Only a potable (drinkable and tested for bacterial contamination) water source should be used during production of maple products. Cleaning and sanitizing solutions used on food-contact surfaces must be prepared only with potable water. Food-contact surface rinse water must also be potable. Non-potable water may be contaminated with pathogenic bacteria, fungi, viruses, or protozoa. Depending on the location of the source, it may also be contaminated with fertilizer runoff, pesticide residues, road salt, or heavy metals. Note that permeate does not always meet standards for potability.

Water from all sources, including municipal water, should be tested regularly, at minimum, annually before the maple production season. Test result records should be retained. Water should always be tested at the point of end use because water may become contaminated between the source and the producer's facility. Directions for collection are included with the sample bottle supplied by the testing agency and must be carefully followed.

Toilet and Hand-Washing Facilities. Toilet and hand-washing facilities must be readily accessible and adequately designed, operated, and maintained to avoid product contamination.

Plumbing. Plumbing in the operation must be able to provide adequate quantities of water and to transport sewage and liquid waste away from the facility and must be constructed to prevent cross-connection between wastewater discharges and potable water supply.

Rubbish. Litter within the production and packing areas must be managed in a way to reduce odor and prevent pests and food contamination. Lids on waste containers and daily emptying are simple solutions for maple operations.

EQUIPMENT AND UTENSILS ***Food-Grade Material.*** All equipment components and fittings and all utensils and surfaces that will have contact with sap, concentrate, syrup, or materials that will be used during the production of syrup (water, D.E., etc.) must be constructed of food-grade material. In addition, the material must conform to the following criteria:

- Appropriate for intended use; suitable for the activity being conducted and the environment (temperature, sunlight, pH, etc.) in which the activity is taking place
- Non-toxic; surfaces and coatings free of lead solder, lead, and/or lead-containing alloys or other toxic components likely to contaminate food
- Non-absorbent to ensure contaminants such as chemical residues, and mold spores aren't trapped/absorbed/transferred to sap or syrup
- Smooth; surfaces free from pitting, cracks, crevices, open seams, holes, corrosion, loose scale, peeling paint, etc.
- Inert; will not chemically react with, or leach into maple products, will not react with cleaning chemicals, etc.
- Cleanable (and able to be sanitized, if necessary, to prevent the contamination of food); will not harbor bacteria or cleaning and/or sanitizing chemicals
- Durable; able to withstand repeated cleaning and sanitizing without surface degradation or contamination of food
- Corrosion resistant for intended use
- Non-breakable; will not create a physical hazard

Equipment. All equipment used in any part of the production process (processing, packaging, storage, etc.), including tanks, evaporator, RO unit, and canning equipment must be kept in the proper condition as specified below:

- Cleaned immediately after each use
- Constructed and maintained to ensure effective cleaning over its lifetime
- Constructed of materials that are compatible with products, the production environment, and any required cleaning and sanitizing chemicals

- Accessible for inspection, maintenance, and cleaning/sanitation
- Self-draining to ensure no standing liquids or product can serve as a starting point for the spread of microorganisms
- Free of hollow areas or sealed to prevent entry of moisture, food materials, or organic matter
- Free of cracks, corrosion, recesses, open seams, gaps, etc. that could become microbial harborages
- Safe during operation, so that it doesn't contribute to unsanitary conditions or growth of microorganisms
- Cleanable to prevent contamination and cross-contamination (e.g., enclosures, control buttons, switches)
- Validated for regulatory compliance by records of established cleaning and sanitation procedures
- Free of lead, damage, and rust (**Figure 14.5**)
- Kept in good repair and maintained following the manufacturer's recommended procedures and schedules
- Maintained as necessary to prevent physical hazards (e.g., metal shavings) and/or eliminate niches for microbial growth
- Able to be dismantled, inspected, repaired, washed, rinsed, and dried at the beginning and end of the season; when not in use equipment should be stored clean in a dry, clean environment, covered with impenetrable (plastic) material, or otherwise maintained according to manufacturer's specifications
- Kept clean and free of contaminants if it is a source of compressed air or air used in production or packing (air injection units, steam pans, filter presses, etc.)
- Calibrated and maintained as appropriate and necessary to ensure accuracy if used to monitor operating conditions (e.g., hydrometers, thermometers, and refractometers); see **Chapter 8**.

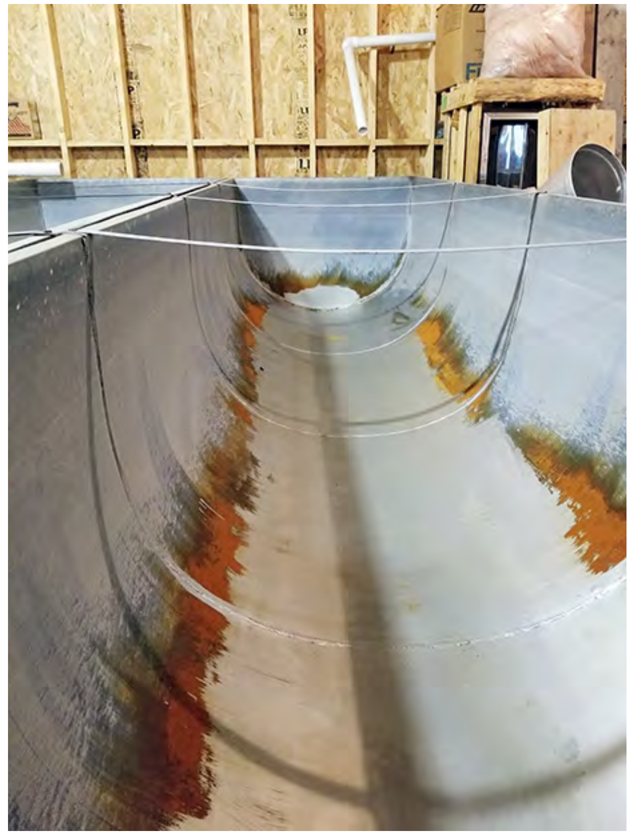


Figure 14.5. Equipment used for sap collection and storage and for syrup production and storage should be clean, lead-free, and undamaged. This tank is unsuitable and should be retired.

PROCESSES AND CONTROLS In general, steps must be taken to ensure that all processes and procedures in production, handling, packaging, and storage are conducted in accordance with sound sanitation principles and do not contribute to allergen cross-contact or to contamination from any source. Following the guidance in the other CGMPs/Preventative Controls is the first step toward achieving this outcome. It is also useful to develop written standard operating procedures for all activities from evaporator and RO start-up and shutdown, filtering, and canning to annual sugarhouse opening and shutdown.

PACKAGING, HANDLING, AND STORAGE PRACTICES In general, finished food products must be handled in a way that prevents damage and/or contamination during handling, packaging, shipping, receiving, or storage. Only clean, new, unused food-grade containers should be used for retail packaging; these should be inspected before use. Boxes of unused containers should be kept sealed to prevent dust, pests, or foreign material from entering the unused containers. Retail containers or other supplies received in damaged packaging should not be accepted as they may be contaminated. Inverting containers or blowing clean, filtered air into them to remove any unwanted foreign material immediately prior to filling is a good hazard prevention practice. Bulk storage containers should be made of food-grade material and cleaned and inspected for rust, debris, etc. before filling. Storage areas for processing and packing materials and for storage of finished products should be clean, dry, and odor-free and maintained in a way that prevents contamination from external sources. See **Chapter 8** for other retail and bulk packaging and storage best practices.

TRACEABILITY Finished products must be properly coded (**Figure 14.6**) and labeled with the product (maple syrup) and a unique identifier in case of recall. Each barrel should be assigned a date and tracking code, and any syrup packed for purchase must also be incorporated into the tracking system. Documentation must be kept that affords the ability to trace products back to the batch, as well as forward to purchaser (bulk buyer, retail customer, etc.).

Figure 14.6. Packaged syrup and other maple products should always bear a batch code to allow tracing and a recall if necessary.

DOCUMENTATION Recordkeeping is a critical part of following CGMPs and Preventive Controls and of any successful food safety program. Records help document safe and sanitary procedures and can be used to determine where a potential problem might arise in food safety or operational activities. To maximize their value, records must be accurate, complete, timely, consistent, and understandable.

Records should be kept of the following and any other usual procedures conducted in the process of making maple syrup and maple products:

- Sugarhouse policies and standard procedures
- Equipment purchases, calibration, maintenance, and repairs
- Cleaning/sanitizing, training, and pest control activities
- Water test results
- Batch and lot data
- Buyer contact list, source of incoming products, and the destination of outgoing products to enable two-way traceability
- Licenses and certifications
- Visitor information
- Safety Data Sheets (SDSs)

Effective records will have the name of the equipment or procedure being documented, the date that the record was checked or monitored, the frequency of monitoring (hourly, daily, weekly, etc.) the actual results of what was checked or monitored, and a place to write in any corrective actions taken. Records will have a place for the person conducting the inspection to sign or initial, confirming that conditions were adequate or, if not adequate, that corrections were made. Organizing this in a checklist format will make recordkeeping efficient and streamlined. Keeping records in a three-ring notebook in a central location makes it easy to access and keep updated records.

HARPC and PCP

There will be maple operations required to follow the Hazard Analysis and Risk-Based Preventive Controls (HARPC) and Preventative Control Plan (PCP) portions of FSMA and SFCR. A detailed discussion of the provisions of these regulations is beyond the scope of this chapter. Numerous resources exist online to assist producers in determining if these regulations apply to their operations, and in developing and implementing procedures necessary to meet their requirements. Both the FDA and CFIA have created tools to assist in implementing HARPC and PCP that can be accessed on their respective websites.

Other Food Safety Certification Programs

Some retail or wholesale outlets or bulk buyers may require additional independent third-party certification to Global Food Safety Initiative (GFSI) benchmarked programs, such as Safe Quality Foods (SQF) and British Retail Consortium (BRC). While adherence to GFSI programs is voluntary, certification is increasingly a condition for doing business with many retailers and wholesalers. Though many provisions will be similar, third-party certification does not replace requirements of FSMA or SFCR.

Food Safety Resources for Maple Producers

There are numerous resources available online to assist maple producers in understanding food safety regulation as well as how to develop and implement the required best food safety practices. In addition to information on the FSMA and SFCR websites, information specific to maple production is available from the University of New Hampshire and University of Maine Cooperative Extension Programs, including food safety plan templates, tools to determine which regulations are applicable to an operation, and guidance on best food safety practices like preventing allergen contamination and cleaning and sanitizing. Producers are strongly encouraged to consult these resources when launching a maple business, when making changes to products, and as a period review.

The responsibility for product safety and the continued use of best practices and adherence to applicable regulations rests with each maple production operation. Developing a supportive and proactive attitude toward food safety makes the job of being a food producer easier and helps ensure the safety of consumers and the good reputation of the entire maple industry.

(A. PERKINS)

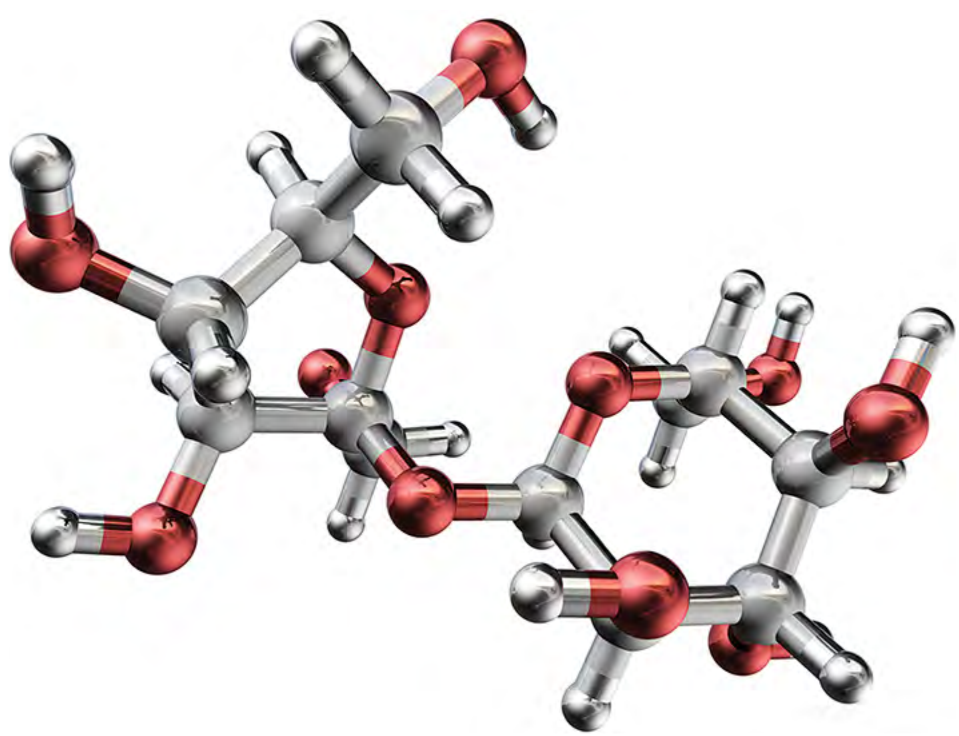
APPENDIX

Chemistry of Maple Sap, Syrup, and Sugar

Technical data sheets generously provided courtesy of:
Producteurs et productrices acéricoles du Québec
Longueuil, Quebec, Canada

@erableduquebec
@maplefromcanada

https://maplefromcanada.ca/
https://ppaq.ca/en/



Sucrose, a disaccharide, is the dominant sugar in maple sap with a chemical formula of $C_{12}H_{22}O_{11}$ and a molar mass of 342.3 g/mol. When acted upon by microbes, this large molecule is cleaved in two, producing glucose and fructose, also known as "invert" sugars, which play a large role in the formation of color and flavor during processing into maple syrup and are critical in crystallization properties of value-added maple products.

Perkins, T.D., R.B. Heiligmann, M.R. Koelling, and A.K. van den Berg (Editors). 2022. *North American Maple Syrup Producers Manual. Third Edition*. The University of Vermont and the North American Maple Syrup Council, Burlington, Vermont. www.mapleresearch.org/manual/

MAPLE WATER OF QUÉBEC
IN BULK

Technical Description

04/2018

TECHNICAL DESCRIPTION	
Product	Pure maple sap harvested from sugar maple trees as they naturally flow in spring. Sterilized using UHT processing.
Advantages	100% natural and authentic product, harvested exclusively from Canadian maple groves. No preservatives added. Nothing has been added or removed.
Environment	Ecological and renewable source. The maple industry helps protect Québec's forests.
Certifications NAPSI CERTIFIED Natural Authentic Pure Sterile Integral	NAPSI-certified (Natural, Authentic, Pure, Sterile and Integral). Pure maple sap. May be certified organic. To be confirmed for each producer. The NAPSI logo is registered for certification mark registration in Canada, the United-States, the United Kingdom and Japan. The logo may only be used by businesses that sign a licensing agreement according to the terms established by the Federation of Quebec Maple Syrup Producers, and under the condition of adherence to the certification standard and the design standards. This logo may be used only for maple water in containers of no more than five (5) kilograms or no more than (5) litres. It may in no way appear on maple water in bulk containers. Bulk maple water must be labelled, with no logo, only as follows: PRODUCT IN NAPSI-CERTIFIED PROCESSING STAGE.
Origin	Quebec, Canada.
Declaration in the list of ingredients	Maple water or maple sap.
Production codes	Provided by the processor.
GMO	None.
Pesticides	No pesticide residue. Maple production does not require the use of products such as antibiotics, antiparasitics, pesticides, herbicides, plant-growth regulators, etc. As a result, the risk of finding traces of these substances is practically zero, according to the recommendations in effect in Quebec.
Allergens	None added at the maple grove.

COMPOSITION	
Ingredients	Maple water (or maple sap).
Brix	1.7 to 3.0 °Bx
pH	6.60 to 7.50

SPECIFICATIONS	
Organoleptic properties	Clear and translucent appearance, like pure water, sometimes with a very slight amber tint. Slightly sweet with a subtle maple flavour. Free of foreign flavours or odours. Sediment of natural components of the maple tree may be present.
Sweetness	0.04 (sucrose = 1) 0.06 (glucose = 1)

maple FROM QUÉBEC

Fédération des producteurs acéricoles du Québec

/ 1

Analysis

DETAILED PHYSICOCHEMICAL ANALYSES	Median	Number of samples	Minimum	Maximum	Method
Total solids (%)	2.56	18	1.70	2.97	AOAC, 100 °C
Water activity	0.98	15	0.98	0.99	AW meter
Dextrose equivalent	BQL*	6	BQL*	BQL*	Titrimetry
Invert sugar (%)	BQL*		BQL*	BQL*	Calculations
Transmittance at 560 nm (%)	98.6	6	97.4	99.7	Spectrophotometer
Density (g/ml)					Densimeter
20-21 °C	1.01	6	1.006	1.01	
4 °C	1.01	6	1.01	1.01	
Viscosity (cP)					Brookfield viscometer
20-21 °C	0.82	6	0.81	0.84	SC4-18, 100 rpm
4 °C	0.80	6	0.78	0.81	SC4-18, 100 rpm

*BQL = Below Quantifiable Limit

MICROBIOLOGICAL ANALYSES AFTER 48 MONTHS
COMMERCIAL STERILITY

MICROBIOLOGY	Result	Method
Yeasts (CFU/ml)	<1	MFHPB-22
Molds (CFU/ml)	<1	MFHPB-22
Aerobic spore-forming bacteria (CFU/ml)	<1	MFLP-44
Aerobic mesophilic bacteria (CFU/ml)	<1	MFHPB-18
Anaerobic spore-forming bacteria (CFU/ml)	<1	MFLP-44
Anaerobic mesophilic bacteria (CFU/ml)	<1	MFHPB-18
Pseudomonas aeruginosa (CFU/ml)	<1	ILMA-017
Bacillus cereus (CFU/ml)	<2.5	MFLP-42
Clostridium spp (CFU/ml)	Not detected	MFHPB-23

Nutritional Values

NUTRIENTS	Typical values for 100 ml (100 g)				
CARBOHYDRATES	**Average**	**Number of observations**	**Minimum**	**Maximum**	**Method**
Sucrose (g)	2.23	430	0.69	3.56	HPLC-RI
Glucose (g)	0.006	400	BQL*	0.027	HPLC-RI
Fructose (g)	0.006	405	BQL*	0.023	HPLC-RI
Total sugar (g)	2.29	411	0.78	3.67	HPLC-RI
Complex carbohydrates (g)	0.049	413	BQL*	0.127	HPLC-RI
Total carbohydrates	**2.34 g**				

MINERALS	**Average**	**Number of observations**	**Minimum**	**Maximum**	**Method**
Aluminum (mg)	BQL*	414	BQL*	BQL*	ICP-MS
Calcium (mg)	4.19	396	BQL*	11.28	ICP-MS
Copper (mg)	0.09	389	BQL*	0.43	ICP-MS
Iron (mg)	0.32	385	BQL*	1.61	ICP-MS
Magnesium (mg)	0.74	405	0.01	2.11	ICP-MS
Manganese (mg)	0.22	407	BQL*	0.78	ICP-MS
Potassium (mg)	5.59	407	BQL*	17	ICP-MS
Sodium (mg)	BQL*	402	BQL*	BQL*	ICP-MS
Zinc (mg)	0.13	388	BQL*	0.65	ICP-MS
Total minerals	**11.28 mg**				

VITAMINS	Not detected	HPLC-DAD

AMINO ACIDS	**Average**	**Number of observations**	**Minimum**	**Maximum**	**Method**
Total amino acids	**2.05 mg**				HPLC-FL

*BQL = Below Quantifiable Limit

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Nutritional Values (*cont'd.*)

NUTRIENTS	Typical values for 100 ml (100 g)				
ORGANIC ACIDS	**Average**	**Number of observations**	**Minimum**	**Maximum**	**Method**
Malic (mg)	24.17	398	1.79	48.69	HPLC-UV
Citric (mg)	1.78	121	0.89	3.09	HPLC-UV
Fumaric (mg)	0.24	378	BQL*	0.71	HPLC-UV
Lactic (mg)	BQL*	263	BQL*	BQL*	HPLC-UV
Acetic (mg)	0.83	347	0.07	1.33	HPLC-UV
Gluconic (mg)	1.00	295	BQL*	3.4	HPLC-UV
Pyruvic (mg)	0.41	386	BQL*	1.67	HPLC-UV
Succinic (mg)	0.92	381	BQL*	1.83	HPLC-UV
Total organic acids	**29.35 mg**				

ANTIOXIDANT	Average	Number of observations	Minimum	Maximum	Method
Antioxidant capacity	**12 µmol TE**	3	5.4	15.6	ORAC

POLYPHENOLS	Average	Number of observations	Minimum	Maximum	Method
More than 25 phenolic compounds	**0.96 mg**	318	0.33	2.22	Folin-Ciocalteu and UFLC-MS/MS

PHYTOHORMONES	Average	Number of observations	Minimum	Maximum	Method
Abscisic acid ABA (µg)	0.38	87	0.08	1.70	UPLC/ESI-MS/MS
Phaseic acid PA (µg)	3.29	87	0.87	10.34	UPLC/ESI-MS/MS
ABA metabolites (µg)	1.58	87	0.30	5.81	UPLC/ESI-MS/MS
Total phytohormones	**5.25 µg**				

ENERGY VALUE	Average	Number of observations	Minimum	Maximum	Method
	9.36 kcal				calculations

*BQL = Below Quantifiable Limit

Nutrition Facts Tables (generic)

CANADA

GENERAL INFORMATION

Nutrition Facts tables may change depending on use:

- Industry: Nutrition Facts table for 100 ml

Format must be confirmed for your packaging. Consult with a specialist.

These tables are presented for information purposes only.

The values presented in the Nutrition Facts Table are averages.

MAPLE WATER 100 ml

Nutrition Facts / Valeur nutritive
pour 100 ml / Per 100 ml

Calories 10	% valeur quotidienne* / % Daily Value*
Lipides / Fat 0 g	0 %
saturés / Saturated 0 g + trans / Trans 0 g	0 %
Glucides / Carbohydrate 2 g	
Fibres / Fibre 0 g	0 %
Sucres / Sugars 2 g	2 %
Protéines / Protein 0 g	
Cholestérol / Cholesterol 0 mg	
Sodium 0 mg	0 %
Potassium 10 mg	0 %
Calcium 0 mg	0 %
Fer / Iron 0,3 mg	2 %
Zinc 0,1 mg	1 %
Cuivre / Copper 0,09 mg	10 %
Manganèse / Manganese 0,225 mg	10 %

* 5% ou moins c'est **peu**. 15% ou plus c'est **beaucoup**
* 5% or less is **a little**. 15% or more is **a lot**

Nutrition Facts / Valeur nutritive
pour 100 ml / Per 100 ml

Calories 10	% valeur quotidienne* / % Daily Value*
Lipides / Fat 0 g	0 %
Glucides / Carbohydrate 2 g	
Sucres / Sugars 2 g	2 %
Protéines / Protein 0 g	
Potassium 10 mg	0 %
Fer / Iron 0,3 mg	2 %
Cuivre / Copper 0,09 mg	10 %
Manganèse / Manganese 0,225 mg	10 %

Source négligeable de lipides saturés, lipides trans, cholestérol, sodium, fibres et calcium.

Not a significant source of saturated fat, trans fat, cholesterol, sodium, fibre or calcium.

* 5% ou moins c'est **peu**. 15% ou plus c'est **beaucoup**
* 5% or less is **a little**. 15% or more is **a lot**

Fédération des producteurs acéricoles du Québec

Potential Claims in Canada for Pure Maple Water

(In accordance with new Health Canada standards)

• Nutrient content claims are based on rounded values as per the new Food and Drug Regulations, Article B.01.401 (1.2) "The percentage of the daily value for a mineral nutrient shown in the nutrition facts table for a prepackaged product in accordance with subsection (1) shall be established on the basis of the amount, by weight, of the mineral nutrient per serving of stated size for the product, rounded off in the applicable manner set out in column 4 of the table to this section."

• It is important to note that claims vary according to the serving size in the Nutrition Facts Table.

VITAMINS AND MINERALS

	Stated Serving Size of 100 ml*		Vitamin and Mineral Claims
Copper	0.09 mg	10 %	Source of copper
Manganese	0.225 mg	10 %	Source of manganese

POLYPHENOLS

Only quantitative claims are allowed (as in the table below), and only outside the Nutrition Facts tables. Note that using words such as "contains" is not allowed.

Packaging format	Quantitative claims
100 ml	0.96 mg polyphenols per serving of 100 ml*

**The data presented in theses tables correspond to average value.*

Fédération des producteurs acéricoles du Québec

Potential Claims in Canada for Pure Maple Water (*cont'd.*)

CLAIMS REGARDING COMPOSITION, QUALITY, QUANTITY AND ORIGIN		
No added sugar	Yes, but only if a general note is added	The text must not imply that other maple waters may contain added sugar. The claim must be accompanied by a note stating that the quality attributed to this maple water does not apply to the food in question alone, but to all foods of the same category. <u>General note:</u> Ex.: "Maple products do not contain added sugar" or "Like all maple products, contains no added sugar," etc.
100% pure and natural*	Yes	
Naturally sweet	Yes	
100% pure	Yes	
No preservatives/ additives/ parabens	Yes, but only if a general note is added	The text must not imply that other maple waters may contain preservatives, additives or other added substances. The claim must be accompanied by a note stating that the quality attributed to this maple water does not apply to the food in question alone, but to all foods of the same category. <u>General notes:</u> Ex.: "Maple products do not contain preservatives" or "Preservative-free, like all maple products," etc. And "Maple products do not contain additives" or "Additive-free, like all maple products," etc. And "Maple products do not contain parabens" or "Paraben-free, like all maple products," etc.
No added flavours	Yes, but only if a general note is added	The text must not imply that other maple waters may contain added flavours. The claim must be accompanied by a note stating that the quality attributed to this maple water does not apply to the food in question alone, but to all foods of the same category. <u>General note:</u> Ex.: "Maple products do not contain added flavours" or "Like all maple products, contains no added flavours," etc.
Subtle maple flavour	Yes	
Hydrate naturally	Yes	
Refreshing	Yes	
Thirst-quenching	Yes	
Organic	To be confirmed	Claim is possible if the standard is met. Contact the authorities responsible for this certification.
Halal/kosher	To be confirmed	Claim is possible if the standards are met. Contact the authorities responsible for these certifications.

*Notes regarding the use of the claim "Natural"

- *A natural food or ingredient is not expected to contain, or to ever have contained, an added mineral nutrient, added vitamin, artificial flavouring agent or food additive.*
- *Furthermore, in order for a food or ingredient to be called "natural," it must not have any constituent or fraction thereof removed or significantly changed, except the removal of water.*
- *The new CFIA guidelines state that "a natural food or ingredient of a food must have been produced through the ordinary course of nature without the interference or influence of humans."*

Packaging - Varies by Manufacturer

Tote in 200 L or 1 000 L.

Storage and Shelf Life

18 months at room temperature. Potential for sedimentation of maple water's natural compounds.

Freezing

Possible. Potential sedimentation of the natural components of maple water.

Potential Uses

Can be used as is or can replace water or certain juices or liquids in food preparations such as: flavoured waters, functional beverages, sports drinks and thirst-quenchers, smoothies, broths, soups, poaching liquids, etc.

NAPSI Standard

The purpose of this mark is to certify that the maple water is:

- **N**atural: sourced exclusively from trees of the genus ACER;
- **A**uthentic: harvested in Canada and controlled from production to marketing;
- **P**ure: free of any chemical preservatives;
- **S**terile: free of any living microorganisms;
- **I**ntegral: unrefined, thus preserving the integrity of its constitution.

All according to specifications that must be followed at every step along the production chain.

Copyright

The information contained in this sheet is provided for information purposes only and is the result of generic analyses of maple water conducted by external laboratories based on current knowledge. However, it is important to remember that the product may vary depending on numerous factors, conditions and harvests. This sheet is a practical guide and as such shall not, in any case, be considered a legal opinion on the matter, and the Federation of Quebec Maple Syrup Producers makes no commitment in this regard. You are strongly advised to consult a lawyer for a legal opinion regarding labelling rules. Although the information contained in this sheet was obtained from reliable sources and the Federation of Quebec Maple Syrup Producers has every reason to believe it accurate, its accuracy and completeness are not guaranteed and it is intentionally presented in a summarized, generalized manner. The Federation of Quebec Maple Syrup Producers makes no guarantee or representation either explicit or implicit regarding the accuracy, integrity or usefulness of this sheet, and disclaims all liability resulting from its use or the information contained herein. Anyone who chooses to use this sheet in any way whatsoever, to rely on it or to make a decision based on its contents assumes full responsibility for such choice. It is important to remember that claims and statements must be based on facts and must not be false, misleading, deceptive or likely to create an erroneous impression, as required in paragraph 5(1) of Canada's *Food and Drugs Act* and article 7 of the *Consumer Packaging and Labelling Act*.

MAPLE SYRUP OF QUÈBEC

Technical description

04/2018

TECHNICAL DESCRIPTION	
Product	Syrup obtained by concentrating 100% natural raw sap, or "maple water." Extraction of maple sap, concentration by osmosis and boiling to a sugar density of 66 °Brix.
Advantages	100% pure product, harvested exclusively from Canadian forests. No added preservatives. Natural product and from renewable sources. Maple industry means Quebec and Canadian forests are protected.
Potential certifications	Organic. Kosher. To be confirmed by each producer.
Origin	Quebec, Canada.
Declaration in the list of ingredients	Maple syrup.
Codes	Provided by the processor.
Compliance	Meets the requirements of the Règlement sur les aliments [Food regulations] (P-29, r. 1) administered by the Ministry of Agriculture, Fisheries and Food of Quebec; the Règlement des producteurs acéricoles sur les normes de qualité et le classement [Maple Syrup producer regulations on quality standards and classification] (chapter M-35.1, r. 18) administered by the Federation of Quebec Maple Syrup Producers; and the Maple Products Regulations (C.R.C., c.289) administered by the Canadian Food Inspection Agency.
Commercial sterility	Yes, by heat treatment (canning).
GMOs	None.
Pesticides	No pesticide residue Maple syrup production does not require the use of products such as antibiotics, antiparasitics, pesticides, herbicides, growth promoters or similar. The risk of finding residues of these substances in maple syrup is therefore practically zero, in line with the recommendations in force in Quebec.
Allergens	None added at the sugar bush.
Colour classes	According to regulations in force, maple syrup colour classes are determined by the degree of light transmission at a wavelength of 560 nm according to the following scale: Golden, Delicate Taste (between 100 and 75%*); Amber, Rich Taste (between 74.9 and 50%); Dark, Robust Taste (between 49.9 and 25%); Very Dark, Stong Taste (between 24.9 and 0%). The analysis is made using a spectrophotometer and is a common optical technique used in maple syrup production. * The percentages refer to the syrup as light transmission.

COMPOSITION	
Ingredients	Maple syrup.
Brix	66.0 to 68.9 °Brix
pH	5.5 to 8.0

SPECIFICATIONS	
Organoleptic properties	Syrupy liquid ranging in colour from light to dark depending on its class. Has a characteristic maple flavour and taste. Free of foreign flavours or odours.
Sweetness	0.6 (sucrose = 1) 0.91 (glucose = 1)

maple FROM QUÉBEC

Fédération des producteurs acéricoles du Québec

Analysis

DETAILED PHYSICOCHEMICAL ANALYSIS	Average	Number of samples	Minimum	Maximum	Method
Total solids (%)	66.8	21	66.4	68.9	AOAC, vacuum, 70 °C
Soluble solids (° Brix)	66.6	21	66.2	67.3	Refractometer
Water activity	0.848	21	0.841	0.855	AW meter
Dextrose equivalent	2	21	0	14	Titrimetry
Transmittance at 560 nm (%)	55.46	612	2.85	87.80	Spectrophotometer
Colour classes					
Golden, Delicate Taste (≥75%)	79.82	81	75.10	87.80	
Amber, Rich Taste (<75% and ≥50%)	61.73	318	50.05	74.85	
Dark, Robust Taste (<50% and ≥25%)	40.85	176	25.30	49.90	
Very Dark, Strong Taste (<25%)	17.75	37	2.85	24.80	
Density (g/ml)					
25 °C	1.33	21	1.32	1.33	Densimeter
4 °C	1.34	21	1.33	1.35	Densimeter
-20 °C	1.35	21	1.35	1.35	Densimeter
Viscosity (Cp)					Brookfield viscometer
25 °C	135	21	120	182	SC4-31, 60 rpm
4 °C	618	21	519	880	SC4-31, 12 rpm
-20 °C	3,668	21	2,909	5,409	SC4-31, 3 rpm

MICROBIOLOGICAL ANALYSIS AFTER 18 MONTHS
COMMERCIAL STERILITY

MICROBIOLOGY	Result	Analysis method
Yeasts (CFU/g)	<5	MFHPB-22
Molds (CFU/g)	<5	MFHPB-22
Aerobic mesophilic bacteria (CFU/g)	<150	MFHPB-18
Pseudomonas aeruginosa (CFU/g)	<10	ILMA-017
Bacillus cereus (CFU/g)	<25	MFLP-42
Total coliforms (CFU/g)	<10	MFHPB-34
Clostridium spp (CFU/g)	Not detected	ILMA-61/MFHPB-23
Staphylococcus aureus (CFU/g)	<10	MFLP-21

Fédération des producteurs acéricoles du Québec

Nutritional Values

NUTRIENTS	Typical values for 100 g (75 ml)				
CARBOHYDRATES	Average	Number of observations	Minimum	Maximum	Method
Sucrose (g)	64.18	491	60.75	67.67	HPLC-RI
Glucose (g)	0.11	458	BQL*	0.39	HPLC-RI
Fructose (g)	0.14	581	BQL*	0.67	HPLC-RI
Total sugar (g)	65.89	497	62.47	69.04	HPLC-RI
Complex sugars (g)	1.35	471	0.467	2.27	HPLC-RI
Total carbohydrates	**67.24 g**				
MINERALS	Average	Number of observations	Minimum	Maximum	Method
Aluminum (mg)	0.48	446	BQL*	2.88	ICP-MS
Calcium (mg)	78.53	1112	11.32	166.0	ICP-MS
Copper (mg)	0.19	424	BQL*	0.99	ICP-MS
Iron (mg)	0.44	453	BQL*	2.16	ICP-MS
Magnesium (mg)	20.22	1151	1.02	37.98	ICP-MS
Manganese (mg)	2.05	1159	0.03	6.0	ICP-MS
Potassium (mg)	240.42	586	97.31	396.03	ICP-MS
Selenium (mg)	BQL*	391	BQL*	BQL*	ICP-MS
Sodium (mg)	1.44	511	BQL*	9	ICP-MS
Zinc (mg)	0.44	1058	BQL*	1.21	ICP-MS
Total minerals	**344.21 mg**				
VITAMINS	Average	Number of observations	Minimum	Maximum	Method
Niacin (mg)	0.21	551	BQL*	0.56	HPLC-DAD
Riboflavin (mg)	0.44	532	0.03	1.25	HPLC-DAD
Thiamin (mg)	0.07	90	0.02	0.60	HPLC-DAD
Total vitamins	**0.72 mg**				
AMINO ACIDS	Average	Number of observations	Minimum	Maximum	Method
Arginine + Threonine (mg)	45.15	496	BQL*	93.21	HPLC-FL
Leucine (mg)	1.67	472	BQL*	7.30	HPLC-FL
Proline (mg)	44.61	474	10.38	81.05	HPLC-FL
Histidine (mg)	0.83	472	BQL*	2.37	HPLC-FL
Total amino acids	**92.26 mg**				

* BQL = Below Quantifiable Limit

Fédération des producteurs acéricoles du Québec

Nutritional Values *(cont'd.)*

NUTRIENTS	Typical values for 100 g (75 ml)				
ORGANIC ACIDS	**Average**	**Number of observations**	**Minimum**	**Maximum**	**Method**
Acetic (mg)	25.41	451	3.68	56.15	HPLC-UV
Citric (mg)	26.16	106	11.57	46.57	HPLC-UV
Fumaric (mg)	6.03	443	1.44	18.04	HPLC-UV
Gluconic (mg)	10.80	397	BQL*	30.01	HPLC-UV
Lactic (mg)	10.45	470	BQL*	25.35	HPLC-UV
Malic (mg)	459.93	489	172.33	768.41	HPLC-UV
Oxalic (mg)	1.07	325	BQL*	2.72	HPLC-UV
Pyruvic (mg)	15.12	494	BQL*	56.48	HPLC-UV
Quinic (mg)	7.46	316	BQL*	20.73	HPLC-UV
Shikimic (mg)	BQL*	312	BQL*	BQL*	HPLC-UV
Succinic (mg)	18.03	458	4.44	39.44	HPLC-UV
Tartaric (mg)	BQL*	257	BQL*	0.16	HPLC-UV
Total organic acids	**580.46 mg**				

ANTIOXIDANT Antioxidant capacity	**Average**	**Number of observations**	**Minimum**	**Maximum**	**Method**
All classes combined	**590.89 µmol TE**	45	312	1,566	ORAC
Colour classes					
Golden, Delicate Taste (≥75%) (µmol TE)	391	9	312	472	ORAC
Amber, Rich Taste (<75% et ≥50%) (µmol TE)	469	23	317	756	ORAC
Dark, Robust Taste (<50% et ≥25%) (µmol TE)	750	8	620	915	ORAC
Very Dark, Strong Taste (<25%) (µmol TE)	1,260	5	796	1,566	ORAC

* BQL = Below Quantifiable Limit

Fédération des producteurs acéricoles du Québec

Nutritional Values *(cont'd.)*

NUTRIENTS	Typical values for 100 g (75 ml)				
POLYPHENOLS 67 phenolic compounds counted to date	**Average**	**Number of observations**	**Minimum**	**Maximum**	**Method**
All classes combined	**97.7 mg**	481	34.0	212.4	Folin-Ciocalteu and UFLC-MS/MS
Colour classes					
Golden, Delicate Taste (≥75%) (mg)	64.5	60	34.0	173.3	Folin-Ciocalteu and UFLC-MS/MS
Amber, Rich Taste (<75% et ≥50%) (mg)	87.8	253	40.8	199.1	Folin-Ciocalteu and UFLC-MS/MS
Dark, Robust Taste (<50% et ≥25%) (mg)	118.3	135	48.8	212.4	Folin-Ciocalteu and UFLC-MS/MS
Very Dark, Strong Taste (<25%) (mg)	150.7	33	71.0	210.9	Folin-Ciocalteu and UFLC-MS/MS

PHYTOHORMONES	Average	Number of observations	Minimum	Maximum	Method
Abscisic acid ABA (μg)	16.64	88	2.15	84.51	UPLC/ESI-MS/MS
Phaseic acid PA (μg)	183.33	88	64.22	786.33	UPLC/ESI-MS/MS
Other phytohormones (μg)	95.26	88	51.87	164.14	UPLC/ESI-MS/MS
Total phytohormones	**295.23 μg**				

ENERGY VALUE	Average	Number of observations	Minimum	Maximum	Method
	268.96 kcal				Calculations

Nutrition Facts Tables

CANADA

GENERAL INFORMATION

Nutrition Facts tables may change depending on use:

- If the product is for industrial use, packagers must use the Nutrition Facts table for 100 g
- If the product is for consumers, packagers must use the Nutrition Facts table for 80 g

These tables are presented for information purposes only.
Format must be confirmed for your packaging.

Consult a specialist to ensure compliance with Food and Drug Regulations (c.r.c., c.870).

MAPLE SYRUP 100 g

Nutrition Facts / Valeur nutritive
pour 100 g
Per 100 g

Calories 270	% valeur quotidienne* / % Daily Value*
Lipides / Fat 0 g	0 %
saturés / Saturated 0 g + trans / Trans 0 g	0 %
Glucides / Carbohydrate 67 g	
Fibres / Fibre 0 g	0 %
Sucres / Sugars 66 g	66 %
Protéines / Protein 0 g	
Cholestérol / Cholesterol 0 mg	
Sodium 0 mg	0 %
Potassium 250 mg	5 %
Calcium 75 mg	6 %
Fer / Iron 0,4 mg	2 %
Thiamine 0,075 mg	6 %
Riboflavine / Riboflavin 0,45 mg	35 %
Niacine / Niacin 0,2 mg	1 %
Magnésium / Magnesium 20 mg	5 %
Zinc 0,4 mg	4 %
Cuivre / Copper 0,19 mg	21 %
Manganèse / Manganese 2,05 mg	89 %

* 5% ou moins c'est **peu**. 15% ou plus c'est **beaucoup**
* 5% or less is **a little**. 15% or more is **a lot**

Nutrition Facts / Valeur nutritive
pour 100 g
Per 100 g

Calories 270	% valeur quotidienne* / % Daily Value*
Lipides / Fat 0 g	0 %
Glucides / Carbohydrate 67 g	
Sucres / Sugars 66 g	66 %
Protéines / Protein 0 g	
Potassium 250 mg	5 %
Calcium 75 mg	6 %
Fer / Iron 0,4 mg	2 %
Riboflavine / Riboflavin 0,45 mg	35 %
Cuivre / Copper 0,19 mg	21 %
Manganèse / Manganese 2,05 mg	89 %

Source négligeable de lipides saturés, lipides trans, cholestérol, sodium et fibres.
Not a significant source of saturated fat, trans fat, cholesterol, sodium or fibre.
* 5% ou moins c'est **peu**. 15% ou plus c'est **beaucoup**
* 5% or less is **a little**. 15% or more is **a lot**

MAPLE SYRUP 80 g

Nutrition Facts / Valeur nutritive
pour 1/4 tasse (60 ml)
Per 1/4 cup (60 ml)

Calories 220	% valeur quotidienne* / % Daily Value*
Lipides / Fat 0 g	0 %
saturés / Saturated 0 g + trans / Trans 0 g	0 %
Glucides / Carbohydrate 54 g	
Fibres / Fibre 0 g	0 %
Sucres / Sugars 53 g	53 %
Protéines / Protein 0 g	
Cholestérol / Cholesterol 0 mg	
Sodium 0 mg	0 %
Potassium 200 mg	4 %
Calcium 75 mg	6 %
Fer / Iron 0,4 mg	2 %
Thiamine 0,05 mg	4 %
Riboflavine / Riboflavin 0,35 mg	27 %
Niacine / Niacin 0,2 mg	1 %
Magnésium / Magnesium 15 mg	4 %
Zinc 0,3 mg	3 %
Cuivre / Copper 0,15 mg	17 %
Manganèse / Manganese 1,65 mg	72 %

* 5% ou moins c'est **peu**. 15% ou plus c'est **beaucoup**
* 5% or less is **a little**. 15% or more is **a lot**

Nutrition Facts / Valeur nutritive
pour 1/4 tasse (60 ml)
Per 1/4 cup (60 ml)

Calories 220	% valeur quotidienne* / % Daily Value*
Lipides / Fat 0 g	0 %
Glucides / Carbohydrate 54 g	
Sucres / Sugars 53 g	53 %
Protéines / Protein 0 g	
Potassium 200 mg	4 %
Calcium 75 mg	6 %
Fer / Iron 0,4 mg	2 %
Riboflavine / Riboflavin 0,35 mg	27 %
Cuivre / Copper 0,15 mg	17 %
Manganèse / Manganese 1,65 mg	72 %

Source négligeable de lipides saturés, lipides trans, cholestérol, sodium et fibres.
Not a significant source of saturated fat, trans fat, cholesterol, sodium or fibre.
* 5% ou moins c'est **peu**. 15% ou plus c'est **beaucoup**
* 5% or less is **a little**. 15% or more is **a lot**

Fédération des producteurs acéricoles du Québec

Potential Claims in Canada

(In accordance with new Health Canada standards)

- Nutrient content claims are based on rounded values as per the new Food and Drug Regulations, Article B.01.401 (1.2) "The percentage of the daily value for a mineral nutrient shown in the nutrition facts table for a prepackaged product in accordance with subsection (1) shall be established on the basis of the amount, by weight, of the mineral nutrient per serving of stated size for the product, rounded off in the applicable manner set out in column 4 of the table to this section."

- Claims are based on the sizes of reference. As such, the reference amount for any syrup, including maple syrup, must be 60 ml.

Legende:
RA: Reference Amount
MM: Metric Measurement
HM: Home Measurement

Products Category	Reference Amount (RA)	A. Criteria to determine the serving of stated size for multiple serving prepackaged products	B. Units for expressing the serving of stated size for multiple serving prepackaged products HM (MM)
Syrups used as toppings, such as pancake syrups, maple syrup, fruit syrups, and ice cream sundae syrups	60 ml	• MM: RA • HM: 4 tablesppons or 1/4 cup	4 tbsp (60 ml) 1/4 cup (60 ml)

Source: Food and Drug Regulations

VITAMINS AND MINERALS

	Content by Reference Amount and Stated Size of 60 ml (80 g)*		Vitamin and Mineral Claims
Calcium	75 mg	6%	Source of calcium
Riboflavin	0.35 mg	27%	Excellent source of riboflavin
Copper	0.15 mg	17%	Good source of copper
Manganese	1.65 mg	72%	Excellent source of manganese

INDUSTRY SHEET

GRANULATED MAPLE SUGAR

Technical Description

04/2018

TECHNICAL DESCRIPTION	
Product	Sugar obtained by concentrating 100% natural raw sap, or "maple water." Extraction of maple sap, concentration by osmosis and boiling to a sugar density of 66 °Brix.
Advantages	100% pure product, harvested exclusively from Canadian forests. No added preservatives. Natural product and from renewable sources. Maple industry means Quebec and Canadian forests are protected.
Potential Certifications	Organic. Kosher. As confirmed by each individual producer.
Origin	Quebec, Canada.
Declaration in the list of ingredients	Maple Sugar.
Codes	Provided by processor.
Compliance	Meets the requirements of the Règlement sur les aliments [Food regulations] (P-29, r. 1) administered by the Ministry of Agriculture, Fisheries and Food of Quebec; the Règlement des producteurs acéricoles sur les normes de qualité et le classement [Maple Syrup producer regulations on quality standards and classification] (chapter M-35.1, r. 18) administered by the Federation of Quebec Maple Syrup Producers; and the Maple Products Regulations (C.R.C., c.289) administered by the Canadian Food Inspection Agency.
Commercial sterility	Yes, drying method.
GMOs	None.
Pesticides	No pesticide residue Maple syrup production does not require the use of products such as antibiotics, antiparasitics, pesticides, herbicides, growth promoters or similar. The risk of finding residues of these substances in maple sugar is therefore practically zero, in line with the recommendations in force in Quebec.
Allergens	None added at the sugar bush.

COMPOSITION	
Ingredients	Maple sugar.
Brix	66.0 to 68.9 °Brix
pH	5.5 to 8.0

SPECIFICATIONS		
Organoleptic Properties	Granulated sugar with more-or-less fine or coarse crystals depending on the sugar category. Crystals melt in the mouth. Colour varies from light to dark. Sweet taste and characteristic maple scent with a note of caramelized sugar (toffee).	
Density	Apparent density: Min. 625 g/L Compacted density: Max. 740 g/L	
Aw	0.34	
Particle Size	Fine sugar 88.5%: < 250 microns (< mesh 60) 11.5%: 420 < 250 microns (mesh 40 < 60)	Sugar with more-or-less fine crystals 59%: < 250 microns (< mesh 60) 34%: 420 < 250 microns (mesh 40 < 60) 7%: > 840 microns (> mesh 20)

Fédération des producteurs acéricoles du Québec

Analysis

MICROBIOLOGICAL ANALYSIS AFTER 12 MONTHS COMMERCIAL STERILITY		
MICROBIOLOGY	**Results**	**Method**
Yeasts (CFU/g)	<5	MFHPB-22
Molds (CFU/g)	<5	MFHPB-22
Aerobic mesophilic bacteria (CFU/g)	<5	MFHPB-18
Anaerobic mesophilic bacteria (CFU/g)	<5	MFHPB-18
Total coliform count (CFU/g)	<10	MFHPB-34
Pseudomonas aeruginosa (CFU/g)	<10	ILMA-017
Bacillus cereus (CFU/g)	<25	MFLP-42
E. Coli (CFU/g)	<10	MFHPB-34
Clostridium spp. (CFU/g)	Not detected	ILMA-61
Staphylococcus aureus (CFU/g)	<10	MFLP-21
Salmonella (CFU/g)	Not detected	MFHPB-20

Nutritional Values

NUTRIENTS	Typical Values per 100 g				
CARBOHYDRATES	**Average**	**Number of Observations**	**Minimum**	**Maximum**	**Method**
Sucrose (g)	94.78	22	91.08	97.50	HPLC-RI
Glucose (g)	0.35	22	0.23	0.55	HPLC-RI
Fructose (g)	0.19	22	0.12	0.28	HPLC-RI
Total Sugar (g)	95.33	22	91.56	98.22	HPLC-RI
Complex Sugars (g)	1.55	22	1.23	2.25	HPLC-RI
Total carbohydrates	**96.88 g**				

FATS	**Average**	**Number of Observations**	**Minimum**	**Maximum**	**Method**
Saturated (g)	BQL*	23	BQL*	BQL*	HPLC-RI
Trans (g)	BQL*	23	BQL*	BQL*	HPLC-RI
Omega-3 (g)	BQL*	23	BQL*	BQL*	HPLC-RI
Omega-6 (g)	BQL*	23	BQL*	0.01	HPLC-RI
Monounsaturated (g)	BQL*	23	BQL*	0.03	HPLC-RI
Polyunsaturated (g)	BQL*	23	BQL*	0.03	HPLC-RI
Cholesterol (mg)	BQL*	23	BQL*	BQL*	HPLC-RI

* BQL = Below Quantifiable Limit

Nutritional Values *(cont'd.)*

NUTRIENTS	Typical Values per 100 g				
MINERALS	**Average**	**Number of Observations**	**Minimum**	**Maximum**	**Method**
Aluminium (mg)	0.04	22	BQL*	0.1	HPLC-RI
Calcium (mg)	155.3	22	141	175	HPLC-RI
Copper (mg)	0.025	22	0.02	0.04	HPLC-RI
Iron (mg)	0.099	20	0.05	0.18	HPLC-RI
Magnesium (mg)	32.56	23	26.4	45.5	HPLC-RI
Manganese (mg)	4.034	21	2.62	6.19	HPLC-RI
Potassium (mg)	338.5	21	313.1	364	HPLC-RI
Sodium (mg)	0.73	23	0.54	0.91	HPLC-RI
Zinc (mg)	1.535	23	0.93	2.69	HPLC-RI
Phosphate (mg)	0.84	21	0.62	1.08	HPLC-RI
Total minerals	**533.66 mg**				

VITAMINS	**Average**	**Number of Observations**	**Minimum**	**Maximum**	**Method**
Thiamin (B1) (mg)	0.03	23	BQL*	0.07	HPLC-RI
Riboflavin (B2) (mg)	BQL*	22	BQL*	BQL*	HPLC-RI
Niacin (B3) (mg)	0.18	22	0.14	0.23	HPLC-RI
Total vitamins	**0.21 mg**				

AMINO ACIDS	**Average**	**Number of Observations**	**Minimum**	**Maximum**	**Method**
Total amino acids	**4.1 mg**	2	2.62	5.58	HPLC-RI

* BQL = Below Quantifiable Limit

Nutritional Values *(cont'd.)*

NUTRIENTS	Typical Values per 100 g				
ORGANIC ACIDS	**Average**	**Number of Observations**	**Minimum**	**Maximum**	**Method**
Oxalic (mg)	1.71	21	1.07	2.73	HPLC-RI
Tartaric (mg)	BQL*	0	BQL*	BQL*	HPLC-RI
Quinic (mg)	BQL*	0	BQL*	BQL*	HPLC-RI
Pyruvic (mg)	5.24	20	4.52	7.48	HPLC-RI
Malic (mg)	694.25	20	662.25	744.57	HPLC-RI
Shikimic (mg)	0.84	23	0.39	1.49	HPLC-RI
Lactic (mg)	23.37	19	15.2	30.65	HPLC-RI
Acetic (mg)	91.86	22	57.61	123.69	HPLC-RI
Fumaric (mg)	12.11	22	8.64	16.79	HPLC-RI
Succinic (mg)	118.56	22	94.65	144.35	HPLC-RI
Citric (mg)	6.27	20	5.88	6.62	HPLC-RI
Total organic acids	**954.21 mg**				

ANTIOXIDANT	**Average**	**Number of Observations**	**Minimum**	**Maximum**	**Method**
Antioxidant strength	**1618 µmol TE**	22	1403	1818	ORAC

POLYPHENOLS	**Average**	**Number of Observations**	**Minimum**	**Maximum**	**Method**
67 phenolic compounds counted to date	**0.3 mg**	22	0.3 mg	0.33 mg	UFLC-MS/MS (isolated lignans)

PHYTOHORMONES	**Average**	**Number of Observations**	**Minimum**	**Maximum**	**Method**
Abscisic acid ABA (µg)	8.7	22	6.35	11.05	UPLC/ESI-MS/MS
Phaseic acid PA (µg)	128.75	22	109.69	155.06	UPLC/ESI-MS/MS
Other phytohormones (µg)	72.83	22	59.47	81.77	UPLC/ESI-MS/MS
Total phytohormones	**210.28 µg**				

ENERGY VALUE	**Average**	**Number of Observations**	**Minimum**	**Maximum**	**Method**
	394.09 kcal				Calculations

* BQL = Below Quantifiable Limit

Fédération des producteurs acéricoles du Québec

Nutrition Facts Tables (generic)

CANADA

GENERAL INFORMATION

Nutrition Facts tables may change depending on use:

- If the product is for industrial use, packagers must use the Nutrition Facts table for 100 g.
- If the product is for consumers, packagers must use the Nutrition Facts table for 3 g.

These tables are presented for information purposes only.
Format must be confirmed for your packaging.
Consult a specialist to ensure compliance with Food and Drug Regulations (c.r.c., c. 870).

MAPLE SUGAR 100 g

Nutrition Facts / Valeur nutritive
pour 100 g
Per 100 g

Calories 390	% valeur quotidienne* / % Daily Value*
Lipides / Fat 0 g	0 %
saturés / Saturated 0 g + trans / Trans 0 g	0 %
Glucides / Carbohydrate 98 g	
Fibres / Fibre 0 g	0 %
Sucres / Sugars 98 g	98 %
Protéines / Protein 0 g	
Cholestérol / Cholesterol 0 mg	
Sodium 0 mg	0 %
Potassium 350 mg	7 %
Calcium 150 mg	12 %
Fer / Iron 0 mg	0 %
Manganèse / Manganese 4,05 mg	176 %

* 5% ou moins c'est **peu**. 15% ou plus c'est **beaucoup**
* 5% or less is **a little**. 15% or more is **a lot**

Nutrition Facts / Valeur nutritive
pour 100 g
Per 100 g

Calories 390	% valeur quotidienne* / % Daily Value*
Lipides / Fat 0 g	0 %
Glucides / Carbohydrate 98 g	
Sucres / Sugars 98 g	98 %
Protéines / Protein 0 g	
Potassium 350 mg	7 %
Calcium 150 mg	12 %
Manganèse / Manganese 4,05 mg	176 %

Source négligeable de lipides saturés, lipides trans, cholestérol, sodium, fibres et fer.
Not a significant source of saturated fat, trans fat, cholesterol, sodium, fibre or iron.
* 5% ou moins c'est **peu**. 15% ou plus c'est **beaucoup**
* 5% or less is **a little**. 15% or more is **a lot**

MAPLE SUGAR 3 g

Nutrition Facts / Valeur nutritive
pour 1 c. à thé (3 g)
Per 1 tsp (3 g)

Calories 10	% valeur quotidienne* / % Daily Value*
Lipides / Fat 0 g	0 %
saturés / Saturated 0 g + trans / Trans 0 g	0 %
Glucides / Carbohydrate 3 g	
Fibres / Fibre 0 g	0 %
Sucres / Sugars 3 g	3 %
Protéines / Protein 0 g	
Cholestérol / Cholesterol 0 mg	
Sodium 0 mg	0 %
Potassium 10 mg	0 %
Calcium 0 mg	0 %
Fer / Iron 0 mg	0 %
Manganèse / Manganese 0,125 mg	5 %

* 5% ou moins c'est **peu**. 15% ou plus c'est **beaucoup**
* 5% or less is **a little**. 15% or more is **a lot**

Nutrition Facts / Valeur nutritive
pour 1 c. à thé (3 g)
Per 1 tsp (3 g)

Calories 10	% valeur quotidienne* / % Daily Value*
Lipides / Fat 0 g	0 %
Glucides / Carbohydrate 3 g	
Sucres / Sugars 3 g	3 %
Protéines / Protein 0 g	
Potassium 10 mg	0 %
Manganèse / Manganese 0,125 mg	5 %

Source négligeable de lipides saturés, lipides trans, cholestérol, sodium, fibres, calcium et fer.
Not a significant source of saturated fat, trans fat, cholesterol, sodium, fibre, calcium or iron.
* 5% ou moins c'est **peu**. 15% ou plus c'est **beaucoup**
* 5% or less is **a little**. 15% or more is **a lot**

Potential Claims in Canada

(In accordance with new Health Canada standards)

• Nutrient content claims are based on rounded values as per the new Food and Drug Regulations, Article B.01.401 (1.2) "The percentage of the daily value for a mineral nutrient shown in the nutrition facts table for a prepackaged product in accordance with subsection (1) shall be established on the basis of the amount, by weight, of the mineral nutrient per serving of stated size for the product, rounded off in the applicable manner set out in column 4 of the table to this section."

• Claims are based on reference quantities. All reference quantities of sugar, including maple sugar, are 4 g.

Legende:
RA: Reference Amount
MM: Metric Measurement
HM: Home Measurement

Product Category	Reference Amount (RA)	A. Criteria to determine the serving of stated size for multiple serving prepackaged products	B. Units for expressing the serving of stated size for multiple serving prepackaged products HM (MM)
Sugars, except those in another section of Column 1	4 g	• MM: RA • HM: number of teaspoons or packets with a weight in grams closest to RA	1 tsp. or packet(s) (4 g)

Source: Food and Drug Regulations

MINERALS

	Content by Reference Amount and Stated Size of 1 tsp. (3 g) *		**Claims for Minerals**
Manganese	0.125 mg	5%	Source of manganese

Packaging

As per packager.

Storage and Shelf Life

Room temperature. More than 5 years in airtight container. Keep dry.

Copyright

The information contained in this sheet is provided for information purposes only and is the result of generic analyses of maple syrup conducted by external laboratories based on current knowledge. However, it is important to remember that the product may vary depending on numerous factors, conditions and harvests. This sheet is a practical guide and as such shall not, in any case, be considered a legal opinion on the matter, and the Federation of Quebec Maple Syrup Producers makes no commitment in this regard. You are strongly advised to consult a lawyer for a legal opinion regarding labelling rules. Although the information contained in this sheet was obtained from reliable sources and the Federation of Quebec Maple Syrup Producers has every reason to believe it accurate, its accuracy and completeness are not guaranteed and it is intentionally presented in a summarized, generalized manner. The Federation of Quebec Maple Syrup Producers makes no guarantee or representation either explicit or implicit regarding the accuracy, integrity or usefulness of this sheet, and disclaims all liability resulting from its use or the information contained herein. Anyone who chooses to use this sheet in any way whatsoever, to rely on it or to make a decision based on its contents assumes full responsibility for such choice. It is important to remember that claims and statements must be based on facts and must not be false, misleading, deceptive or likely to create an erroneous impression, as required in paragraph 5(1) of Canada's Food and Drugs Act and article 7 of the Consumer Packaging and Labelling Act.

GLOSSARY

age structure Variation in tree age or the proportion of trees in one or more age-classes within a stand. An even-aged stand varies in tree age by less than 20 percent and typically is caused by a single large-scale canopy disturbance resulting in nearly simultaneous seedling establishment. An uneven-aged stand has at least three distinct age-classes, and generally results from ongoing small-scale canopy disturbances.

Acer The genus name of maple trees, which belong to the botanical family Aceraceae, and which are characterized by having leaves and branches in opposite arrangement along the stem and a double samara fruit.

additive solution Solution with a high invert sugar level added to amend syrup when the level of invert sugars in syrup is too low to make the desired confection.

adulteration The accidental or deliberate addition of substances; substitution of less expensive, but similarly tasting ingredients; the addition of non-declared substances; contamination by filth or pesticides; the presence of naturally occurring toxic materials; and contamination by microorganisms.

advertising The paid presentation of information in a public medium to attract favorable attention to a product or business.

air injection device Evaporator accessory that forces filtered air through a series of small holes in stainless-steel tubes lowered into the pans (either the flue pan or syrup pan or both), generally used to produce lighter-colored syrup.

allegation A mathematical tool used to find the ratio in which two or more ingredients of a known density, color, or flavor must be mixed to produce a mixture with the desired qualities.

angle gauge Tool used to estimate basal area per acre or hectare.

apron test Traditional method for determining whether the desired density of syrup had been achieved. A square-ended dipper was inserted into the syrup and held up to allow the syrup to "apron-off" in a sheet. Syrup was "finished" when the apron formed had the right shape and other characteristics.

arch Frame structure supporting the evaporator pans and enclosing the firebox (wood fired evaporator) or other heat sources, e.g., oil burners, gas burners.

automatic draw-off Electrically operated, temperature sensing valve assembly that automatically opens to allow finished or near-finished syrup to be removed from the evaporator. The temperatures at which the valve opens and closes can be set by the evaporator operator. Found in simple on/off or modulated (variable size opening) versions.

back pan (flue pan or **sap pan)** Pan located towards the rear of the evaporator where sap enters and is concentrated prior to moving into the front (syrup) pan. Back pans typically have a number of deep channels that increase the heat transfer surface area. *See also* **raised flue**, **drop flue**, and **tube-style flue**.

backflow The movement of sap backward (toward the taphole) in a tubing system caused by suction during freezing or by changes in pressure caused by (especially mechanical) releasers tripping. Excessive backflow results in movement of microbes into the taphole resulting in more rapid taphole drying.

bare-root seedlings Relatively small seedlings, commonly less than 3 or 4 years old, that are lifted from a nursery bed and shipped without soil around the roots.

basal area (stand) The basal area of a stand is the sum of the basal area of trees per unit land area (acre or hectare).

basal area (stem) Cross-sectional area of a tree's trunk determined 4½ feet (1.37 meters) above ground. Usually expressed on a tree, stand, or area (acre or hectare) basis.

basal area increment (BAI) The annual increase in basal area of a tree. More accurately reflects tree growth than the annual change in diameter.

batch processing Evaporation method in which syrup is made by periodically adding sap to the kettle, pan, or other evaporating container. Usually performed on a smaller scale. *See* **continuous flow evaporator.**

batching The undesirable occurrence when excessively large amounts of syrup are produced at one time at the drawoff rather than a steady stream or periodic smaller amounts. Often occurs more frequently with the first drawoff of a boil or shortly after reversing flow.

Baume scale Scale used to determine the density of maple syrup; this scale relates the density of syrup to a salt concentration of the same density.

bedrock Solid rock underlying a soil or loose overlying material.

biodiversity The variety of different, typically native, species of trees, shrubs, herbs, insects, fungi, and other organisms important to the ecological functioning of the forest or woodland. Biodiversity includes both the number of different species and the abundance of each species necessary to fulfill its ecological role.

blow test Traditional method for determining whether the desired density of syrup had been achieved. A loop of wire was inserted into hot syrup and a gentle breath was blown against the syrup. Syrup was "finished" when a "certain puff" of breath blew the syrup off the loop.

branch collar Swollen area (usually) around the base of a tree branch which anatomically is part of the trunk rather than the branch.

Brix The sugar content of a solution (sap, concentrate, syrup, permeate) expressed as a percentage by weight. One degree Brix (°Brix) is equal to 1 gram of sucrose in 100 grams of solution.

Brix scale Scale used to express the concentration of an aqueous sucrose solution; 1 degree Brix equals 1 gram of sucrose in 100 milliliters of water. Because the primary solid in maple syrup is typically sugar (and predominantly sucrose), the Brix scale is commonly used to express the density of maple syrup.

browning Color (and flavor) development in a sugar solution caused by caramelization and Maillard reactions.

BTU (British Thermal Unit) Amount of heat required to raise 1 pound of water 1° F.

buddy Off-flavor (and odor) in maple syrup ranging from chocolaty to butterscotch to strongly bitter. Typically found near the end of the sap flow season.

buffer pH A measure of a soil's resistance to pH change, as when lime is added. Also referred to as lime test index.

callus tissue Woody tissue produced by the cambium that develops around and over the outer edge of a taphole to eventually cover the opening.

cambium The growth layer of the tree producing new cells during the growing season that become part of the phloem (to the outside of the stem) and part of the xylem (to the inside of the stem). Cambial growth increases the tree diameter and closes over tapholes and other wounds.

canister pressure filter (canister filter press) Filtration device that utilizes a pump to push maple syrup (or occasionally sap) through a tubular device consisting of an inner perforated container, filter cloth, and diatomaceous earth to remove suspended particulate material.

canker (disease) Dead area on a branch or main trunk. Over time, some cankers become visible as swellings or deformations when callus tissue has begun to grow over the canker.

canopy The aggregate of the crowns of trees. The canopy is often differentiated into sections that receive direct sunlight (upper canopy) and those that receive primarily diffuse or indirect sunlight (lower canopy).

caramelization Browning of sugars that occurs during heating, which affects color and flavor development. *See also* **Maillard reactions**.

carbon monoxide Colorless, odorless, poisonous gas (CO) formed by burning wood, petroleum products, or any organic fuel with an insufficient supply of oxygen. Its presence can cause asphyxiation and death by interfering with the body's ability to absorb oxygen.

cation exchange capacity (CEC) Measure of the ability of the soil to retain positively charged ions (termed cations) such as hydrogen, calcium, magnesium, potassium, and aluminum. An important soil characteristic since many plant nutrients occur in the soil in cation form.

CCOHS Canadian Centre for Occupational Health and Safety.

ceramic insulation Insulation made from ceramic fibers, commonly used between the sap and syrup pans, and between pans and the arch wall.

CFM Cubic feet per minute—a measure of air flow or pump capacity to move air in a tubing system.

chaps Personal protective equipment worn when operating a chainsaw that reduce the risk or severity of injury to the legs.

chasing the sweet Use of water, preferably mineral-free (permeate or condensate) to force some the last of the partially concentrated sap (or "sweet") out of the evaporator.

clarity Component of maple syrup grading guidelines expressing the transparency or translucence of syrup; freedom from haze or cloudiness caused by suspended solids.

clearcutting Removal of all of the trees in a stand above a small minimum diameter (e.g., 2 inches or 5 centimeters) at one time.

compartmentalization (walling off) The natural healing process within wood tissues in which the tree prevents the spread of disease-causing organisms by building physical and chemical barriers (walls) within the affected zone. This process results in the formation of zones of discoloration consisting of nonconductive wood.

concentrate Sap that has passed through a reverse osmosis unit which has an enriched sap sugar content. *See* **permeate**.

condensate Relatively pure water that has condensed into a collecting vessel, such as the water that collects in the drip pan below a preheater or hood.

conifers Cone-bearing woody trees such as pines, spruces, and firs.

continuous flow evaporator Evaporator designed so maple sap enters at one end of the evaporator and syrup is removed at the opposite end in a reasonably continuous semi-automatic fashion. Flow is normally controlled by a series of floats or valves.

cord A stack of wood occupying 128 cubic feet (3.62 cubic meters) of volume, often represented as a pile of wood 4 feet high, 8 feet long, and 4 feet deep (1.22 meters high, 2.44 meters long, and 1.22 meters deep).

crop trees Trees identified in a forest stand that are to be retained and favored to be vigorous because they contribute to ownership objectives.

crop tree management Activities conducted to encourage the growth and vigor of individual crop trees to allow maximum production. Differs from other types of forest management in that the focus is on the individual tree rather than a stand.

cross flow pans Syrup pans, set on the front portion of the arch, usually with compartments through which the sap moves from side to side rather than back to front. They are intended to be rotated and cleaned frequently as a way to control niter accumulation.

crown class The position of a tree's crown relative to its neighbors. Trees taller than surrounding trees are termed "dominant." Those that are about the same height positioned in the upper canopy are "co-dominant." Trees slightly below the upper canopy but with some direct sun exposure are "intermediate," while those below the canopy are "suppressed."

crown, tree Part of a tree bearing live branches and leaves. which fulfills the energy requirements of the tree via photosynthesis. *See also* **canopy**.

crowning Preparation of a road surface so that it is higher in the middle (as viewed in cross-section) than on either outside edge.

crystal coating Coating molded candy with a moisture-resistant shell made from crystalline sucrose to prevent drying out.

culvert Structure to move water from one side of a road to the other without the water flowing on the road surface. Can be either open or closed at the top.

cupola Opening located on top of the sugarhouse, usually directly above the evaporator, through which water vapor from boiling sap is exhausted from the sugarhouse.

dbh *See* **diameter breast height**.

defoamer Substance periodically added to the evaporator in very small amounts to reduce foaming.

density, syrup The concentration, often expressed as a percentage, of solids in pure maple syrup. Generally considered equivalent to Brix scale but may also be presented in the Baume scale.

density, tree The number of trees per unit of land area (acre or hectare).

diameter breast height (dbh) Diameter of a tree measured 4½ feet (1.37 meters) from the ground. Measured on the uphill side if on sloping ground. Can be calculated by dividing the circumference by 3.14 (pi).

diatomaceous earth (D.E.) Naturally-occurring silica product used to facilitate and increase the efficiency of pressure filtering of maple syrup to remove suspended particulate material (sugar sand). *Also known* as **filter aid**.

dolomite (dolomitic limestone) Calcium magnesium carbonate, often used to increase soil pH where additional magnesium is desired.

double samara *See* **samara**.

draw-off The point at which syrup is removed from a continuous flow evaporator. May be manually or automatically controlled.

draw-off partition Final partition or channel in the front (syrup) pan from which finished or nearly finished syrup is removed.

draw-off rate The amount of syrup drawn-off from an evaporator within a unit of time. *See also* **feed rate**, **evaporation rate**, **processing rate**.

drop flue pans Back pans constructed with flues extending below the rail of the supporting arch.

dropline Relatively short length of 3⁄16- or 5⁄16-inch tubing used to connect an individual spout to a lateral tubing line via a tee-fitting.

dual conductor (wet-dry conductor) Mainline installation system in which two separate lines are installed to maximize the transfer of vacuum (dry line) to lateral lines and the movement of sap (wet line) to the collection unit.

dump unit *See* **releaser**.

evaporator A device designed to efficiently process maple sap into maple syrup by evaporation though boiling. Consists of an assemblage of several individual components, principally including a sap or flue pan, syrup or front pan, arch, firebox, floats and other devices such as draw-off units.

evaporation rate The total amount of liquid boiled off within a unit of time. *See also* **draw-off rate**, **feed rate**, and **processing rate**.

even-aged stand A grouping of trees in an area that is primarily composed of a single age category where the difference in age between the oldest and youngest trees in the main canopy is less than 20 percent of the total age of the stand at maturity. Even-aged stands can have a range of diameters and include large and small trees.

exotic, species Plant (or animal) introduced into an area from another country or geographic region. Not native to the region.

extractor *See* **releaser**.

FDA United States Food and Drug Administration.

feed line Conducting line from feed tank that supplies sap to the evaporator.

feed rate The rate at which sap enters the evaporator through a float box, valve or other flow regulator device.

feed tank Sap storage tank from which sap flows to the evaporator.

felt-hat filter Cone-shaped syrup filter made of wool or synthetic material.

filter aid (filter aide) *See* **diatomaceous earth**.

filter press *See* **canister pressure filter** and **plate pressure filter**.

filtrate *See* **permeate**.

filtration system Process, using either a gravity or pressure filtration system to remove suspended sediments from finished maple syrup.

finished syrup Maple sap that has been processed (boiled) until a sugar concentration of at least 66.0°Brix has been achieved (66.9°Brix in Vermont and New Hampshire).

finishing pan Separate pan into which syrup slightly light in density (typically between 45° and 60°Brix) is further evaporated to reach finished density. Used principally to achieve better density control and to facilitate grading and filtering.

firebrick Brick capable of tolerating high temperatures that is used to line the inside of a wood-burning arch.

firing Starting and maintaining a fire in the arch of an evaporator.

fixed costs Those costs that do not change as a function of the amount of sap and/or syrup produced.

flat filter Wool or synthetic fabric filter placed over a metal screen through which hot finished syrup is passed to remove suspended sediments.

flat-bottom pan Evaporator pan without flues or other similar features on the bottom of the pan. *See:* **front pan**.

flavor Component of maple syrup grades that recognizes the unique taste associated with pure maple syrup.

flooding the rig Filling an empty evaporator with sap to the proper depth. Typically done in preparing evaporator for start-up.

flue Metal channel in the bottom of the sap pan designed to increase the surface of the pan, thereby increasing the heat input and shortening the processing time.

flue pan *See* **back pan**.

food-grade Materials that have been determined to be safe for use in the manufacture of food products.

forced draft unit Blower assembly unit that forces additional air into the firebox of a wood fired evaporator to increase the rate of burning and thus the amount of heat produced.

front pan (syrup pan) Pan or set of pans, usually further divided into partitions into which partially evaporated sap flows from the back pan, and is further boiled until being drawn off.

fructose *See* **invert sugar**.

gathering pail Bucket or similar container used to carry sap from individual buckets or bags to a gathering tank.

gathering tank Container used to transport sap collected from individual buckets to a larger sap storage tank, usually located near the sugarhouse.

Geographic Information System (GIS) Computer application used to store, view, and analyze geographic (spatial) information, especially mapped information.

GFCI (Ground Fault Circuit Interrupter) Device providing protection against electric shock and electrocution in situations where ground is compromised or electrical leakage occurs.

girdling Removal of bark and outer sapwood in a complete circle around the trunk of a tree with the intention of killing the tree.

GIS *See* **Geographic Information System**.

Global Positioning System (GPS) A geographic positioning system that utilizes signals from satellites to identify a specific location on the ground.

glucose *See* **invert sugar**.

grade *See* **Syrup Grade**.

gradient Increasing sugar concentration of sap within an evaporator as measured from the sap or concentrate inlet in the sap pan to the draw-off point in the syrup pan.

grading The process of assigning syrup to a particular class based upon attributes of density, clarity, color and flavor. *See* **Syrup Grading**.

grading kit Collection of colored glass or colored solutions used as a visual guideline in determining the grade of finished maple syrup.

grading standard Set of guidelines used to evaluate and determine the grade of finished syrup. Specific grading terminology is variable throughout the maple producing region.

gravity filter Method of syrup filtration that relies on gravity to move syrup through a filtering medium.

Ground Fault Circuit Interrupter *See* **GFCI**.

group selection Cutting of trees in small groups throughout the stand. Not uncommonly the width of the openings produced by such harvesting average about twice the height of the dominant trees.

hardwood Broad-leaf deciduous trees such as maples, oaks, hickories, and others.

HazMat Hazardous materials.

heartwood Innermost, dark-appearing wood that is no longer involved in sap transport.

high-vacuum Generally referring to vacuum in a maple tubing system better than 25 inches Hg.

hood Structure, usually made of metal, placed over the evaporator to facilitate the movement of water vapor out of the sugarhouse.

hot pack Process of filling and otherwise packaging maple syrup in containers when the temperature of the syrup is maintained at 180°F or higher.

hot test Determining the density of a sample of hot syrup from the evaporator. Hot testing is commonly done with a hydrometer.

hydrometer Glass measuring device containing a weighted bottom and a calibrated scale (Brix or Baume) which when floated in syrup indicates the density of the syrup.

hypothermia Dangerous condition resulting when a person's core body temperature drops below 95°F (35°C) after prolonged exposure to freeing or near freezing temperatures.

hydrotherm Specially designed hydrometer that has a liquid thermometer built into it that automatically locates the point on the hydrometer (the top of the thermometer liquid column) for measuring standard density syrup.

increment borer Instrument used to obtain a small-diameter core of the cross-section of a tree to determine age and growth rate.

indicator plants: Plants whose presence in an area suggest a particular environmental condition (e.g., soil pH, soil moisture, elevation).

individual tree selection Cutting of individual trees throughout the forest stand.

in-sloping, road Preparing a road surface along a hill so that it slopes inward toward the uphill side, most commonly to a ditch.

intermediate cut A cut done in a forest stand to improve the growth and quality of trees that remain after the cut (referred to as the residual trees or the residual stand).

invert sugar Six carbon sugars, glucose (dextrose) and fructose (levulose), which are structurally different, but which both have the chemical formula $C_6H_{12}O_6$. Invert sugars are produced by the breakdown (hydrolysis) of sucrose, commonly by the action of microorganisms. The name *invert* comes from the fact that a solution of invert sugars rotates (inverts) the plane of polarized light passed through the solution.

kickback Dangerous situation resulting from incorrect chainsaw use that occurs when the upper portion of the bar nose contacts a solid object or is pinched, resulting in the saw being forced rapidly and sometimes uncontrollably up and back toward the operator.

lateral buds Buds located along the sides of a branch.

lateral line Smaller tubing lines running from tree to tree, usually 3⁄16- or 5⁄16-inch in diameter used to collect and transport sap from individual tapholes (droplines) to mainlines.

lenticel An area of cells on the surface of a twig through which gases pass. Lenticels on twigs are often seen as small rounded or near-rounded areas, somewhat different in color from the surrounding bark.

lime Calcium carbonate or other calcium containing material used to increase soil pH.

lobe Distinct projection or division related to the shape of a leaf, as in the five lobes that define the characteristic shape of a sugar maple leaf.

macronutrients Nutrients required by maples (and other plants) in large quantities, including hydrogen, carbon, oxygen, nitrogen, potassium, calcium, magnesium, phosphorus, and sulfur.

Maillard reactions Chemical reactions between amino acids and sugars that affect color and flavor development in many food products including maple syrup. *See also* **caramelization**.

mainline Larger diameter plastic tubing used to collect and transport sap from several lateral tubing lines to a common collection tank.

mainline installation tool Tool used to attach fittings such as manifold units, connectors, etc. to mainline tubing.

management plan Planned set of activities designed to improve the maple resource for the purpose of producing sap. Management activities may include planting, thinning, selected individual tree harvest, and other activities.

manifold A device or section of pipe connecting a spur mainline to a wet-dry conductor mainline tubing system.

Manitoba maple Boxelder.

maple butter *See* **maple cream**.

maple candy Molded maple candy made by evaporating additional water from maple syrup until the temperature of the liquid is 32°–34°F (18°–19°C) above the boiling temperature of water, followed by processing and molding. Unlike maple fondant (nougat), the sugar crystals in maple candy can be felt or sensed on the tongue.

maple confection A sweet, maple flavored food product made from maple syrup, such as maple candy, maple sugar, and maple cream.

maple cream (maple crème or maple butter or maple spread) Semi-solid spread made by evaporating additional water from maple syrup until the temperature of the liquid is 22°–24°F (12°–13°C) above the boiling temperature of water and processing.

maple fondant A nougat or fudge-like confection made by evaporating water from maple syrup until the temperature of the liquid is 27°–29°F (15°–16°C) above the boiling temperature of water and processing as described. Maple fondant is smoother in texture than molded maple candy; sugar crystals should be so small as to not be detectable when fondant is eaten.

maple nougat *See* **maple fondant**.

maple sap Sugar (primarily sucrose) containing liquid collected from maple trees during the dormant season from which pure maple syrup is produced.

maple spread *See* **maple cream**.

maple sugar Specifically, a solid (sugar cakes or blocks) or granular sugar made by further evaporating water from maple syrup and processing. More generally, used to refer to all or most of the confections made from maple syrup that have a definite crystalline structure including soft sugar, hard sugar, block sugar, molded sugar, and granulated sugar.

maple syrup Produced exclusively by the concentration and heating of maple sap or the solution/dilution of a maple product in potable water with a minimum of 66.0 percent and maximum of 68.9 percent soluble solids.

maple taffy Non-crystallized, taffy-like form of maple sugar made by evaporating additional water from maple syrup until the temperature of the liquid is 23°–26°F (13°–14°C) above the boiling temperature of water and processing.

margin, leaf Peripheral border or edge of a leaf, as in "red maple leaves commonly have small teeth along their margin."

market research Efforts undertaken to determine the needs and wants of customers and how these needs can be satisfied most effectively.

market segment Group of consumers with common characteristics that separate them from other groups.

marketing Activities carried out by a business to promote and sell products and or services.

membrane A cartridge fitting into an RO machine which uses pressure to remove water from sap while preserving sugar, minerals, and other sap constituents.

microbes (microorganisms) Bacteria, fungi, yeasts, algae, and/or molds. Involved in hastening taphole drying and spoilage of sap and syrup.

micronutrients Nutrients required by maples (and other plants) in very small quantities, including iron, boron, manganese, copper, zinc, molybdenum, and chlorine.

MSDS *See* **Safety Data Sheets**.

natural vacuum Vacuum that develops in a nonvented tubing system as a result of sap moving through the lateral and mainlines. More commonly found in 3⁄16-inch tubing systems but can also develop in 5⁄16-inch tubing systems under the proper conditions.

niche market Market in which a particular segment is targeted; also a market in which marketing activities focus on a specific role or function of a product.

niter or nitre *See* **sugar sand** and **scale**.

nonconductive wood (NCW) *See* **zone of discoloration**.

off-flavored A flavor or odor defect not normally found in maple syrup. Off-flavored syrup does not meet the standard for Grade A maple syrup.

organic certification Credentials earned from a third-party organization that a maple operation complies with a specified set of guidelines and regulations to ensure that no chemicals or inorganic products are used in the sugarbush or sugarhouse and aimed at fostering sustainability.

open taphole A taphole made the previous year that has not yet closed.

orthophotograph Photograph (viz. an aerial photograph) in which displacements or distortions caused by tilt, relief, or perspective (e.g., camera location) have been removed.

OSHA United States Occupational Safety and Health Administration.

out-sloping, road Preparing a road surface along a hill so that it slopes outward toward the downhill side.

paraformaldehyde pellet (PFA) Aspirin-sized tablet containing a small amount of paraformaldehyde that was formerly used in tapholes to prevent microbial growth. Its use in maple production is prohibited in both the U.S. and Canada.

permanent glass comparator Grading kit that contains colored glass standards representing the minimum color associated with various grades of maple syrup; the glass color in each standard will not fade, hence the name permanent. Used as a guide when grading maple syrup.

permeate Water removed from sap by a reverse osmosis machine, often stored and used for cleaning. *See also* **concentrate**.

petiole The stalk or stem of a leaf.

pH A measure of the relative acidity or alkalinity of a soil, with 7.0 being neutral, lower than 7.0 being acidic, and higher than 7.0 being alkaline.

pig Metal pan portion of a maple candy making machine that holds hot syrup.

piggy back Evaporator accessory that sits over the flue pan and uses heat energy in the water vapor from the evaporator to heat and remove water from sap before it enters the flue pan.

pinnately compound Describes the structure of a leaf composed of several leaflets (individual leaf blades), with the leaflets arranged along the sides of the petiole and often at the terminal. Ash, black walnut, hickory, and boxelder are among the species having pinnately compound leaves.

plate pressure filter (plate filter press) Filtration device utilizing a pump to force maple syrup through a series of plates and filter papers or pads along with diatomaceous earth to remove suspended particulate material.

pole Commonly, a standing tree between 3 and 9 inches dbh.

PPE (Personal Protective Equipment) Safety equipment or apparel worn to reduce the risk of injury.

prefilter (sap) A cloth or paper cartridge used to reduce biological material before RO processing. Normally removes material down to 5 microns.

prefilter (syrup) Thin paper or synthetic filter placed on top of a flat or cone filter and through which maple syrup is passed to remove suspended particulate material.

preheater Heat transfer piping unit that captures some of the heat produced by boiling sap to increase the temperature of sap before it enters the evaporator flue pan.

prescription Treatments or manipulations designed to regulate the behavior of trees and the ecology and dynamics of forest stands.

pressure filter *See* **plate pressure filter** and **canister pressure filter**.

prism Tool used to optically estimate basal area.

processing rate (RO) The amount of raw sap an RO can process within a given amount of time at a specified sap temperature and concentration.

processing rate (evaporator) The sum of evaporation rate and draw-off rate. Should be functionally equivalent of the evaporator feed rate.

promotion Efforts undertaken to communicate information about a product and to persuade consumers to purchase.

pruning Removal of some competing branch leaders and all or a portion of a tree's side branches.

PTO (Power Take Off) Rotating shaft at the rear of most tractors designed to transmit power to an attached piece of equipment.

pubescence Refers to hairs on the surface of a leaf.

publicity The non-purchased presentation of favorable information about a business or product.

raised flue pans Back pans constructed with bottom flush with the rails of the supporting arch, with flues extending upward.

reaming Redrilling a taphole that had been made earlier in the season in an attempt to stimulate additional sap flow in the late-season. Most often unsustainable in the long-term from a wounding perspective and thus not a recommended practice. *See also* **retapping**.

refractometer Instrument used to measure the density of sap or syrup by determining the refractive index (the bending of light passing through the solution).

regulator box Small compartment on the side of one or more evaporator pans containing a float or electronically operated valve to control the depth and flow of sap within the evaporator system. May be either attached to the pans or separate but connected via pipes.

rejection rate The proportion of water that can be removed from sap by a membrane or group of membranes. For example, most individual membranes have a maximum rejection rate around 80%, meaning it is capable of removing 80% of the water from the sap.

release A treatment designed to free young trees from undesirable, usually overtopping, competing vegetation.

releaser (extractor, dump-unit) Device used to transfer (release) sap collected with a vacuum equipped tubing system without reducing (breaking) the vacuum in the system.

reproduction harvest (cut) Cutting done in a sugarbush or other woodland to encourage the establishment and growth of new maple trees or other species.

residual trees or residual stand Trees remaining after an intermediate cut.

resilience The ability of a tree to recover from stresses, as opposed to vulnerability, the likelihood that a tree will suffer the severe impacts of a stressor. Vigorous trees are more resilient to stressors.

retapping The generally unsustainable practice of making a new taphole during the mid-to-late sap flow season in an attempt to obtain additional sap because of taphole drying or contamination of the original taphole. *See also* **reaming**.

reverse flow pans Syrup pans, commonly with three or more partitions running front to back, that are designed to allow syrup to be drawn-off from either side so that the flow can be periodically reversed as a means of controlling the build-up niter.

reverse osmosis (RO) Process in which the sugar concentration of maple sap is increased prior to boiling by forcing the sap, under pressure, through a semipermeable membrane. The pores in the membrane are large enough to permit water molecules to pass through, but too small to allow the passage of sugar and other large molecules. In the maple industry, the term *reverse osmosis* is commonly used to refer to any type of membrane separation process, including true reverse osmosis and nanofiltration. *See also* **permeate** and **concentrate**.

reversing flow (switching sides) The process of altering the flow of liquid in the syrup pan to loosen niter/scale and allow evaporator operation to continue for a period of time. Reversing flow is also possible in some flue pans.

RO *See* **reverse osmosis**.

roadside trees Maple trees growing alongside a road. Usually the sap sugar content of such trees is greater than for trees growing in a sugarbush due to the presence of larger crowns and thus more leaf area.

rock candy Large sucrose crystals made by heating maple syrup to 8°F (4.4°C) above the boiling point of water and allowing it to sit unagitated for a considerable length of time at room temperature.

root collar Location along the stem of a tree where the anatomy changes from that of the aerial stem to that of the root, commonly identified externally by a change in the color and texture of the bark.

ROPS (Roll Over Protective Structures) Devices installed on tractors and other open vehicles to protect the operator in the event the vehicle rolls over.

ropy (stringy) Defect resulting from microbial contamination of sap in which syrup exhibits a thick, viscous, texture and may stretch out in a sticky filament when pouring is stopped. When extreme, can behave like jelly and/or feel rubbery in mouth.

Rule of 86 (Jone's Rule of 86) Guideline used by maple producers to determine how much sap of a known sugar content will be required to produce a gallon of syrup. This has been updated to conform to higher syrup density standards and higher levels of concentration used currently.

saddle fitting (mainline entrance) Mainline fitting that does not require cutting of the mainline to connect lateral tubing lines to the mainline. The fitting is installed into a hole made using a drill or mainline cutting tool.

Safety Data Sheets (SDS) Detailed information on chemicals including such topics as chemical composition; safe handling, storage, and disposal; human and environmental risks; and emergency first aid care.

samara Winged fruit. The fruit of maple trees is a double samara, joined at the seed end to form a "U" or "V" shape.

sanitation Term generally used to describe the level of cleanliness of the spout and dropline. Better sanitation is associated with significantly higher sap yields due to reduced rates of taphole drying.

sap Watery liquid obtained from tapholes in maple trees that is composed mainly of water, with a small percentage of sucrose and other lesser compounds.

sap bag Plastic bag and frame used with a spout to collect maple sap.

sap bucket Container usually made of galvanized metal, aluminum, or plastic that is placed on the spout and used to collect sap from individual tapholes.

sap flow mechanism Physical-biological process by which maple stems are alternately under negative pressure (resulting in soil water uptake) and positive pressure (resulting in sap exudation) during the dormant season in response to temperature changes.

sap ladder Arrangement of tubing lines designed to lift sap from a lower to higher elevation (usually driven by vacuum in the mainlines) to facilitate sap collection and movement in a plastic tubing sap collection system.

sap pan *See* **back pan**.

sap preheater Piping device usually suspended under a hood over the flue pan designed to raise the temperature of sap entering the evaporator.

sap run Term describing the period of time, usually measured in terms of a day or fraction thereof, when sap flows as a result of favorable temperature conditions.

sap season Period of time in late-winter to early spring when sap flow can be expected following favorable temperature changes.

sap storage tank Tank or container used to store sap following collection but before it is processed.

sapling Commonly, a tree larger than 4½ feet tall and less than 3 inches in diameter.

sapwood The outer, lighter portion of the wood in a tree trunk, at least some of which is involved in the conduction of sap. The opposite of heartwood, **stained wood**, or **non-conductive wood**.

sawtimber trees Trees, commonly with diameters greater than 10 inches and of appropriate quality, from which lumber can be produced.

scale Niter material adhering to evaporator surfaces. *See also* **sugar sand**.

scoop A uniquely shaped ladle used by some maple producers to skim foam from the top of sap in the evaporator, and by some sugarmakers to perform the apron test.

scorch (scorching, burning) Burning of syrup (and perhaps) pans caused by overheating, typically when liquid levels are low, pans are uneven, or pans have heavy **niter** deposits. Syrup that has been scorched is generally not suitable for Grade A Classification.

secondary products Any of the several products that are produced by using maple syrup as the starting product for the manufacture of maple sugar, maple candies, maple crème, and other maple confections.

seeding Addition of a small quantity of the finished product to a new batch of maple cream or other confection to induce the formation of crystals.

seedling Commonly, a tree less than 4½ feet tall, that develops from seed rather than a stump sprout.

selection harvest Trees removed from a woodland singly or in small groups to create gaps for young maples or other species to grow.

settling Gravity filtration method for removing suspended particles from finished maple syrup by simply allowing the suspended materials to settle to the bottom of the storage container followed by decanting.

shade tolerant The relative ability of some tree species to regenerate and survive under the shade of other trees and shrubs.

shelterwood harvest Cutting of trees in a stand in a series of two or three cuts that gradually open the forest, creating an environment that encourages the establishment of more shade tolerant species like maple.

silviculture The cultivation and management of groups of trees (*silvi* is Latin for "tree") via the control of the establishment, growth, mixture of species, and number, size, and quality of stems. Analogous to agriculture.

single tree selection See individual tree selection.

small pore filter Mechanical filter unit that forces maple sap through a series of filters to remove microbial organisms.

soap, RO A strong alkaline material, typically sodium hydroxide, used to clean organic material from RO membranes.

soil type Classification given to soil that defines its characteristics, including profile (e.g., texture, structure, color, drainage), and the climate and type of vegetation under which it developed.

spile *See* **spout**.

spout Device placed in a taphole to channel sap into an attached collection container or tubing.

spout adapter A type of spout designed to be used in conjunction with and attach to a stub-spout. Facilitates easy annual spout replacement.

stack burn Condition that may develop when freshly packaged containers of hot maple syrup are stored close together so the containers do not cool rapidly; usually results in syrup darkening.

stain *See* **zone of discoloration**.

stand structure Distribution of tree sizes/ages within a stand (viz. even-aged stands versus uneven-aged stands).

stand, forest Contiguous group of trees of at least several acres or hectares similar enough in age/size, species composition, soil type, topography, use history, and tree health to be treated as a uniform area for purposes of management prescriptions.

star ladder Arrangement of ⁵⁄₁₆-inch tubing and fittings designed to lift sap from one level to another. *See* **sap ladder**.

steam hood Enclosed structure over the evaporator to direct water vapor from the evaporator out of the sugarhouse.

Steam-Away® or steam pan Evaporator accessory unit that sits tightly over the flue pan and uses the heat in water vapor to heat and remove water from sap before it enters the flue pan.

stem pressure The development of a positive pressure (above that of air pressure) in the tree stem upon thawing after a freeze period as a result of gravity and osmotic forces.

stipules Leafy structure attached to the twig at the base of the leaf petiole. Stipules commonly occur in pairs.

stocking, stand Expression of the amount of tree growth present on an area as compared to what is considered optimum, as in "the sugarbush is 70 percent stocked."

straight-through spout A simple type of spout consisting of a single straight segment with one end going in the tree and the other end connecting to tubing.

stub-spout or stubby Fitting connecting to a dropline that facilitates attachment to a spout adapter.

sucrose The principal dissolved sugar in maple sap, $C_{12}H_{22}O_{11}$, and the primary sugar in maple syrup.

sugar camp Traditionally, the site, often literally a camp in the woods, where sap was collected and processed into syrup.

sugar sand (niter, nitre) Substance that precipitates during the evaporation process. Composed primarily of minerals and organic acids. *See also* **scale**.

sugarbush Woodland or other group of maple trees tapped for maple sap.

sugarhouse Building used to house the evaporator and other equipment necessary for the production and processing of maple syrup including filtering and packaging.

sugaring (syruping, sapping) Process of collecting maple sap and converting it into maple syrup; sometimes used to as a reference for the business and/or season of producing maple syrup.

sugaring season Period of time in the spring when sap is collected and maple syrup and other maple products are produced.

sugarmaker (syrup maker) Individual who makes maple syrup.

sugar-on-snow Confection made by pouring maple syrup heated to 22°–27°F (12°–15°C) above the boiling point of water directly onto snow or crushed ice.

sunscald Localized injury or death, of a portion of a tree's trunk due to sudden exposure of the area to intense sunlight and increased temperatures, most commonly during the winter.

switching sides *See* **reversing flow**.

syrup density Component of grading referring to the concentration of solids, mostly sugars, in maple syrup. Finished syrup has a standard density (minimum) of 66.0°Brix except in Vermont and New Hampshire where it is 66.9°Brix.

syrup grade Designation or class assigned to pure maple syrup based on several attributes, including color, clarity, density and flavor. Grade A syrup must have a minimum of 66.0 percent and not more than 68.9 percent soluble solids by weight, be of uniform color, have good flavor and odor associated with the color class, be free of off-flavors and objectionable odors, not be cloudy or turbid or contain sediment or foreign material, and have no defect that affects its flavor, odor, appearance, edibility, or quality.

syrup grading Process and/or act of assigning one of the recognized standard grades or classes to finished syrup.

syrup pan *See* **front pan**.

taphole Hole (typically $\frac{5}{16}$-inch or $\frac{7}{16}$-inch diameter) drilled a few inches deep into the trunk of a maple tree from which sap is collected.

taphole closure Process through which a taphole closes over during the growing season via the growth of callus tissue following removal of the spout.

taphole drying The late-season reduction or cessation of sap flow from tapholes. Usually, tapholes become progressively less productive over the season due to the presence of microbial growth and the associated tree wound response.

tapping Process of drilling of a taphole into the trunk of a maple tree for the purpose of collecting maple sap to produce maple syrup.

tapping guidelines Recommended number of tapholes for maple trees of differing diameters and conditions, based on research and industry experience.

tapping zone The area between the lowest and highest point on the stem where the taphole can placed and extending around the full circumference of the tree. If on tubing, the area in which tapping can be accessed by the dropline.

target market A group of similar consumers (a market segment) to which marketing activities are directed.

temporary grading kit Tool used as a guide to grade finished maple syrup which utilizes differently colored glycerine solutions as the base color for individual grades of syrup. Temporary refers to the fact that the colors in the various solutions will change over time, thus necessitating periodic replacement of old kits with a new kit.

terminal bud Bud at the end or tip of a branch.

terneplate Sheets of iron or steel coated with an alloy commonly containing three parts lead to one part tin.

topographic map Map showing elevations and landforms, usually by means of contour lines and colors.

tube-style flue Back pans constructed with heat exchange pipes that are submerged within the liquid in the pan.

tubing Flexible, plastic (usually $\frac{3}{16}$- or $\frac{5}{16}$-inch) tubes used as drop lines and lateral lines to channel sap from a taphole to a common collection container or mainline.

tubing fittings Any of several different types of adapters used to connect both small and larger plastic tubing lines to accommodate sap collection and movement. Examples include spouts, tees, connectors, manifolds, end-rings, etc.

tubing manifold (saddle, mainline entrance) Mainline fitting to which individual lateral sap collection lines are attached.

tubing system Network of mainlines, lateral lines, appropriate fittings, vacuum pumps, collection tanks, releaser units, and other equipment as appropriate established for the purposes of collecting sap from maple trees.

tubing tool Tool used to cut and connect fittings to $\frac{3}{16}$- or $\frac{5}{16}$-inch tubing.

ultraviolet light (UV light) A device producing high-intensity, short wavelength (antimicrobial) light used to kill microorganisms in maple sap, thereby maintaining high sap quality.

uneven-aged stand Stand containing trees of many ages and sizes occupying the same area, with the larger trees forming the upper canopy while the smaller trees are present in a progression of sizes below and/or among the larger trees.

vacuum Pressure below standard air pressure in a tubing system created by a pump. Typically expressed in inches Hg (inches mercury) with the negative sign implied.

vacuum filter Filtration device that utilizes a vacuum to pull maple syrup through filtration media (paper and/or cloth) to remove suspended particulate material.

vacuum pump Pump used to create a negative pressure that is transferred via a tubing network to individual tapholes.

vacuum system A tubing system equipped with a vacuum pump used to collect sap from maple trees.

vacuum transfer Effective movement of air from the tubing system to the pump.

value-added product Secondary products produced from pure maple syrup such as maple sugar, maple crème, maple candies, etc.

variable costs Costs associated with production of a particular product that are subject to change, depending on quantity produced.

veneer tree A tree that is free of defect or injury, usually representing 2 to 5 percent (at most) of the largest trees in an average woodlot. Trees tapped for maple production are not suitable as veneer.

vessel elements Specialized elongated vertically-oriented cells in the vascular tissue of hardwood trees through which the majority of sap is conducted.

vigor The ability of the tree to sustain normal function and to grow new wood each year. Often expressed as a percentage of sapwood or relative to leaf area. Vigor reflects the remaining energy available for stem wood after the requirements of higher-priority tree functions (e.g., twig elongation) are satisfied. Vigor is often considered synonymous with tree health.

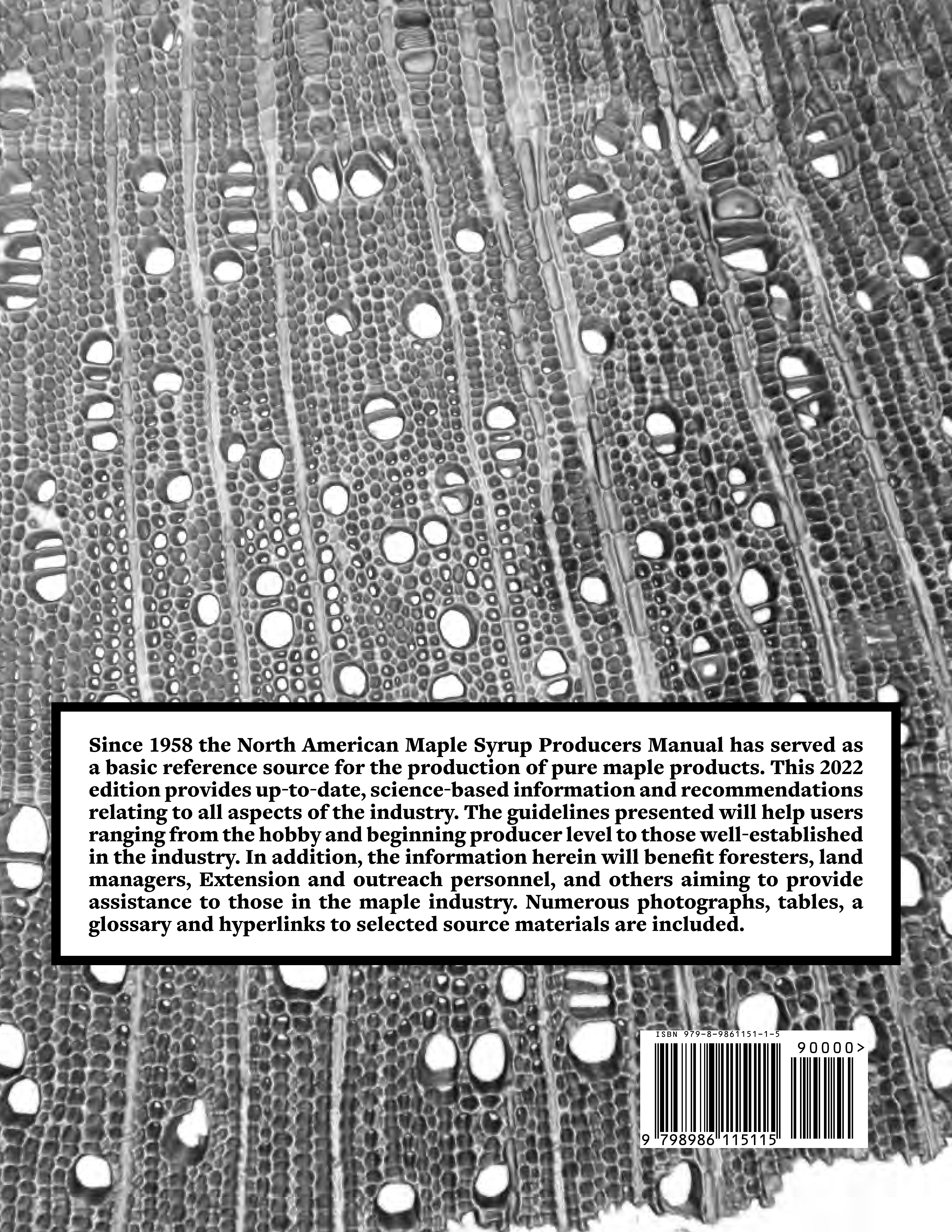
viscosity Characteristic of syrup that expresses its resistance to flow.

wet-dry conductors (dual-conductors) Tubing mainline system utilizing two separate lines, the bottom line transports sap to the collection tank (wet line) and the upper line (dry line) permits better air (vacuum) transfer from the woods.

woods trees Maple trees growing in a woodlot or sugarbush typically with small, compact crowns due to competition with neighboring trees; distinguished from open-grown or roadside trees.

xylem The vascular woody tissue in trees found inside the bark that conducts water and dissolved nutrients from roots to the crown. Maple producers tap into the xylem to collect sap. See **sapwood**.

zone of discoloration (stain) Narrow band of discolored, nonconductive wood that develops above and below a taphole or other wound in the sapwood.



Since 1958 the North American Maple Syrup Producers Manual has served as a basic reference source for the production of pure maple products. This 2022 edition provides up-to-date, science-based information and recommendations relating to all aspects of the industry. The guidelines presented will help users ranging from the hobby and beginning producer level to those well-established in the industry. In addition, the information herein will benefit foresters, land managers, Extension and outreach personnel, and others aiming to provide assistance to those in the maple industry. Numerous photographs, tables, a glossary and hyperlinks to selected source materials are included.

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