Maple: A Sap to Syrup Guide
A Manual for Career and Technical Centers of Vermont

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Shelburne Farms
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Introduction

Maple syrup production is a very important aspect of Vermont life and history. Every year in the early spring people of all ages find their way to the woods to tap trees, collect sap, and participate in the great tradition of producing maple syrup. Vermont is the largest maple syrup producer in the United States and maple is an essential industry from a historical, cultural, agricultural, and economic perspective. As the industry continues to grow, it creates potential employment opportunities for people of all ages, including recent high school graduates.

This manual was developed primarily for use by Vermont Career and Technical Center educators and students. It can be used as a reference as students learn about aspects of sugarbush management and syrup production. Biology, chemistry, math, history, and the culture of maple syrup making can enrich the educational experience as well as provide technical skills for students interested in working in the maple industry. The overall goal of the manual is to create consistency in the sugaring techniques that are taught throughout Vermont and as a guide to prepare students for the Vermont Maple Career Development Event. This manual can also be a valuable resource for anyone interested in sugaring, from the back-yard sugar maker to a new employee joining an established maple syrup producer.

This manual highlights the core principals to training good sugarmakers, both from a production and quality perspective. Key concepts include:

- Tree characteristics (tree size, health, genetics)
- Environmental factors and change (weather, invasive species, climate change)
- Tapping practices (timing of tapping, placement, depth)
- Tubing (installation, repair, cleaning procedures)
- Vacuum (relationship between vacuum and sap yield, vacuum level)

All of these concepts are interrelated and important to syrup production.

Maple identification

If you are going to make **maple syrup** the first thing you need to know is how to identify a maple tree. The easiest way to identify maple trees is before the leaves fall. However, it is still possible to identify maple species even after they have lost their leaves. To do this look at the branching and leaf scar patterns. Leaf scars are where the leaves of the past summer were attached to the branch. The scars are visible after the leaves have fallen. An opposite pattern is where the branches and leaves (or leaf scars if the leaves have already dropped) grow from the branch directly opposite each other, like a "T". Maple, ash, dogwood, and horse chestnut are the only native North American deciduous trees that have opposite branching. All others have alternate branching patterns (Rechlin, 2015). There are many different species of maple including silver maple

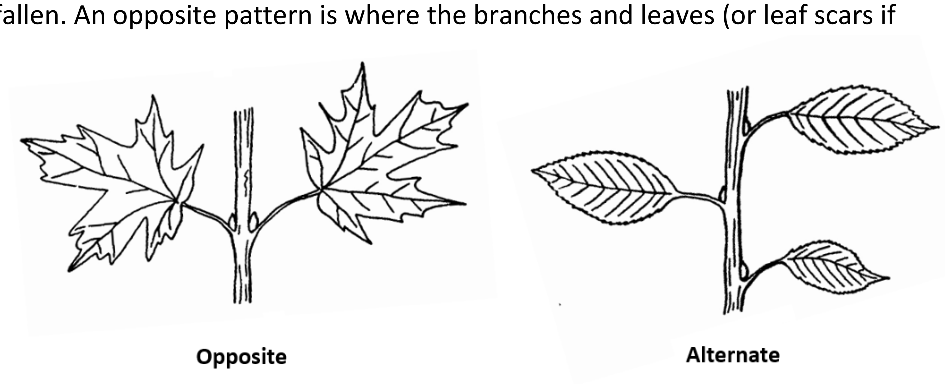

Figure 1 - Opposite vs alternate branching
Plants with opposite branching pattern, like maple, have pairs of buds or leaves at each node. Plants with alternate branching pattern have only one bud or leaf at each node. (Image source Dinnan, 2012)

(*Acer saccharinum*), black maple (*Acer nigrum*), Norway maple (*Acer platanoides*), and box elder (*Acer negundo*). All maples can be tapped, but for the purpose of this manual we will focus on the two maple species that are commercially tapped in Vermont sugar maple (*Acer saccharum*) and red maple (*Acer rubrum*).

Sugar maple (*Acer saccharum*)

Sugar maple leaves are 3-6 inches wide and typically have five palmate (hand-like pattern) lobes. They have smooth **leaf margins** and rounded sinuses (notches). **Terminal buds** are sharply pointed with 6-8 overlapping bud scales. The twigs are somewhat shiny, brown, and slender. The young tree bark is gray and smooth. As the tree matures the back turns gray-brown and develops long irregular, thick vertical plates that curl outward. Flowers appear in the early spring. The fruits are horseshoe-shaped paired winged seeds (called a double **samara**) that mature in the fall (Rechlin, 2015). Sugar maples are the best tree to produce syrup from. They yield the highest volume and sugar concentration of **maple sap**. The average sugar concentration in sap is 2%, but the concentration can vary from tree to tree (Farrell, 2013). Sugar maples are commonly found throughout the Northeast United States, Southeast Canada, and into the upper Midwest US (see Figure 2).

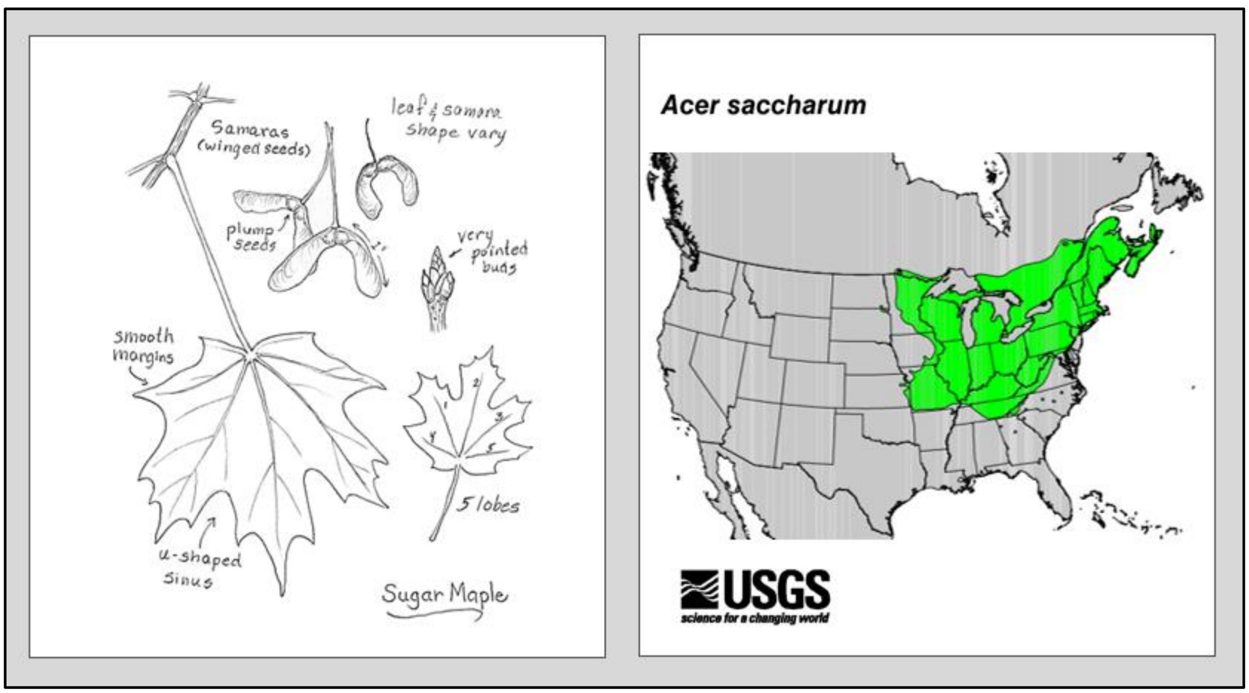

Figure 2 - Sugar maple identification and range
Sugar maple drawing (Image source Boyer-Rechlin, 2015)
Range map (Image source Fryer, 2018)

Red maple (*Acer rubrum*)

Red maple leaves are 2-6 inches wide, have three lobes, shallow v-shaped sinuses, and finely-toothed margins. Mature leaves have whitish undersides. The petioles, buds, new growth, and fall leaves are vibrant red. The buds are much rounder than sugar maples. Young trees have smooth light gray bark. As the tree matures the bark darkens and develops broad scaly plates. Small red flower clusters bloom in early spring. The V-shaped double samaras mature in late spring (Rechlin, 2015). The sap sugar content is generally lower than sugar maples and they also bud out earlier in the spring. Although red maples are not as productive as sugar maples, they have good sap yield per **taphole**, a very respectable sugar content level, and are definitely worth **tapping**. (Farrell, 2013). Red maples have a wider geographic range than sugar maple (see figure 4).

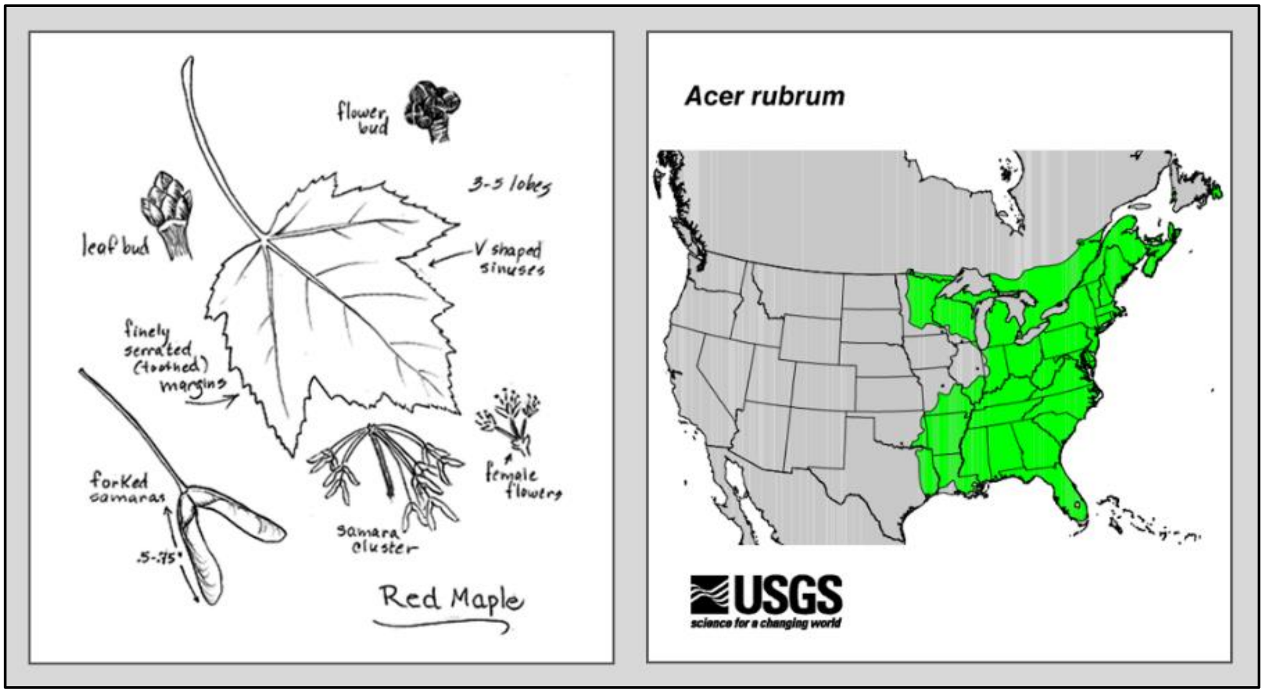

Figure 3 - Red maple identification and range
Red maple drawing (Image source Boyer-Rechlin, 2015)
Range map (Image source Fryer, 2018)

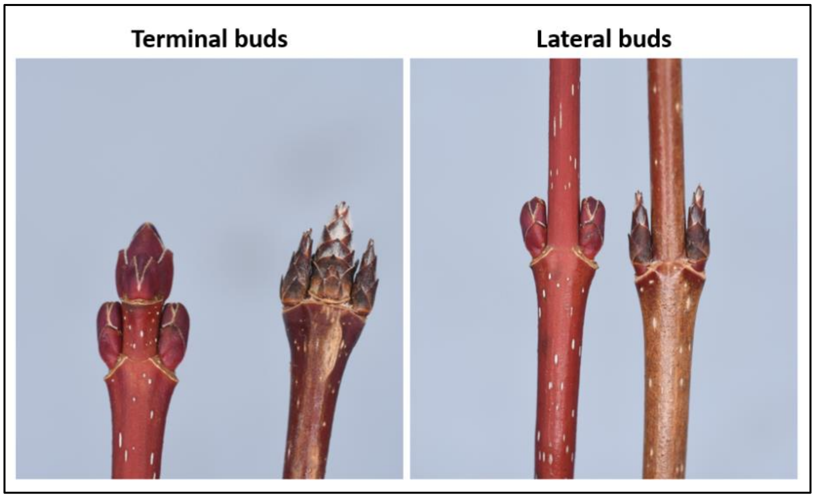

Figure 4 - Red maple and sugar maple bud comparison
Red maple buds are shown on the left and sugar maple buds are shown on the right in each image. (Image source Isselhardt, n.d.)

Table 1 - Characteristics of commercially tapped maple trees
Modified from A Guide to Improving and Maintaining Sugar Bush Health and Productivity.
(Chapeskie, Richardson, Wheeler, Sajan, & Neave 2006)

Species	**Sugar Maple**	**Red Maple**
Leaf	3-6 inches wide; 5-lobed; smooth leaf margins; green upper surface and pale green lower surface.	2-6 inches wide; 3-lobed; V-shaped sinuses, sharply toothed along margin; whiteish color underside.
Bark	Young trees have smooth gray bark; mature bark is gray-brown with long irregular thick vertical plates.	Young trees smooth gray bark; mature bark darkens and has broad scaly plates.
Twig/bud	Slightly shiny, brown, slender, and smooth; sharply pointed terminal bud.	Shiny, reddish, slender; terminal bud red and blunt; odorless if crushed
Fruit	Horseshoe-shaped double-samaras with parallel or slightly divergent wings; 1 inch long; mature in fall.	V-shaped double winged samara; ½ - 1 inch long; mature in spring.
Tree longevity (years)	300	300
Tolerance to flooding	Low	Medium
Shade tolerance	Very tolerant	Tolerant
Response to release	Very high	Very high

Characteristics of maple stands

Species associations

Maple trees are naturally associated with other tree, shrub, and herbaceous plants that require similar site conditions to grow. Together these species form natural communities, "an interacting assemblage of organisms, their physical environment, and the natural processes that affect them" (Thompson & Sorenson, 2000, p. 2). The type and abundance of species that are present in a stand depends on

- Geological history
- Soil properties
- Past natural disturbances
- Characteristics of individual species
- Previous management history

Natural resource professionals have categorized different natural communities to describe a collection of species that are commonly associated with each other, have similar site requirements, and management needs. Sugar maples are predominantly found in two natural communities: (1) rich northern hardwood forests and (2) northern hardwood forests.

Rich Northern Hardwood Forests: Vermont has some of the largest examples of this natural community in the northeast. Sugar maple is abundant in rich northern hardwood forests, which is great for Vermont **sugarmakers**. This natural community occurs in places where lots of nutrients are available for plants. Rich soil and organic matter accumulate from material moving downhill on a slope. At some sites lots of nutrients are available because the bedrock is mineral rich. On lower slopes and **benches**, organic matter and plant nutrients build up over time forming soil that can be compared to compost. These are highly productive forests. Sugar maple is the dominant **canopy** species, but white ash and basswood are common. Other tree species such as butternut, bitternut hickory, yellow birch, hophornbeam, and American beech are often present. There is a lot of variation in the shrub layer. In densely shaded areas the shrub layer can be almost absent, and in sunny open areas shrubs can be abundant. Herbs thrive in this natural community creating carpets of vegetation in the growing season. Many of the herbs are spring ephemerals that flower and fruit in the early spring before the trees leaf out (Thompson & Sorenson, 2000).

Northern Hardwood Forests: This natural community is Vermont's most abundant forest. Northern hardwood forests are broadly defined and have a lot of variation, but some species and characteristics are very common. The soils are loamy, cool, and moist. These forests are found on gentle to steep slopes. American beech, yellow birch, sugar maple, and in some cases red maple are the dominant tree species in the forest canopy. This natural community is often referred to as a Beech-Birch-Maple forest, and for a good reason. Sugar maple *can* be dominant, but it is not the defining species. If you are managing a **sugarbush** in a northern hardwood forest in can be difficult to maintain sugar maple as the dominant species overtime due to competition with beech. White ash, butternut, basswood, hophornbeam, hemlock, red spruce, and other species may also be present. The shrub layer is often composed of hobblebush, shadbush, and striped maple. The herbs on the forest floor are long-lived perennials. Many of the herbaceous plants flower and fruit early in the year before the trees leaf out (Thompson & Sorenson, 2000).

Site factors

Sugar maples can be found on a variety of sites, but there are specific site characteristics in which the species grows best. The moisture, texture, organic content, chemistry of the soil and microclimate all affect how well sugar maples and other species can grow. Sugar maples grow best in moderately well drained soils such as silty sands, loams, sandy loams, fine sands, and silt loams. Sugar maples require well developed humus layer and decomposed litter for proper nutrients. The soil pH ranges from 5.5 to 7.5. Sugar maples are adapted to a range of microclimates. They can be found in cool semi-moist areas, warm southern slopes, and everywhere in-between. Sugar maples are a **shade tolerant** species. They grow slowly in competition with and in the shade of other trees (Chapeskie et al., 2006a). Red maples are often associated with slightly moister soils and can compete on a wider range of sites than sugar maples.

Tree physiology

Photosynthesis

Plants use sunlight, water and air to make sugar. This process is called **photosynthesis**. The sugar in maple sap is the product of photosynthesis that occurred during previous growing seasons and stored for future needs.

In the summer maple trees take in carbon dioxide through tiny holes in the underside of their leaves called stomates. They absorb water through their roots and transport that water to their leaves through the **xylem** vessels in the wood. Maple trees then use the energy from the sunlight to cause a chemical reaction that breaks down the carbon dioxide and water and turns them into sugar and oxygen gas. The sugar is used by the plant and the oxygen is released into the air. Photosynthesis transfers energy from the sun to the plant, in this case a maple tree. In each sugar molecule created there is a little bit of energy from the sun that the plant can either use or store for later (Smithsonian Science Education Center, 2017). Below is the formula for photosynthesis:

CO_2 removed from the atmosphere

O_2 released into the atmosphere

$$6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

Carbon dioxide + Water + Sunlight → Glucose + Water

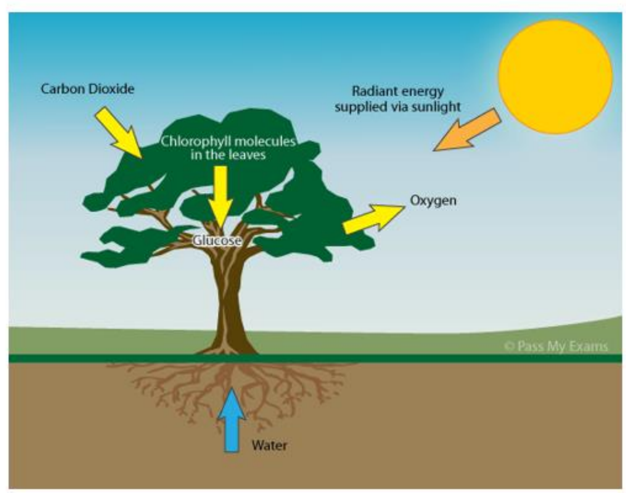

Figure 5 - Photosynthesis
Photosynthesis formula and diagram. (Image adapted from Pass my exams)

Plants move sugars around in the form of sucrose, made up of two glucose molecules. In the fall live cells in the maple trees start storing sugar (sucrose) in the form of starch. This starch serves as an energy source during the winter when the plant is dormant and cannot produce more sugar through photosynthesis. Starch molecules are more compact than sucrose molecules which allows the tree to store more sugar in each cell (Rechlin, 2015). In the spring the tree needs energy to resume growth. As demands for energy increase, the tree converts starch back into sugar. Some of that sugar is dissolved in the sap and that is what is collected during the sugaring season. (Chapeskie, Wilmot, Chabot, & Perkins, 2006).

Understanding maple trees

Why does sap flow in maple trees? And why is sap sweet? To answer these questions, we must start with a basic understanding of tree anatomy and biology:

- **Outer Bark** – Outer most layer of the tree. It provides the tree with protection from the outside world. It helps the tree retain moisture and insulates against cold and heat. It also is a defense mechanism against insects and diseases.
- **Phloem** – Phloem is composed of live cells. They are the pipeline through which energy (sugar and metabolic products) are transported from where it is made in the leaves to where it is used for cell maintenance, growth or storage throughout the tree. The movement of phloem is bidirectional. It can move both up and down the tree.
- **Xylem** – Xylem is another type of transport tissue but is composed primarily of dead cells. Its main function is to transport water and minerals in one direction - up. Xylem transports substances from the roots to stems and leaves. Transport cells in the xylem of maples are called vessels. The xylem vessels are the "pipes" severed by drilling to create a taphole and carry sap.
- **Ray cells** – Ray cells are live cells in the xylem that radiate outward from the center of the tree. They transport sugar from the phloem into other live cells and they store sugar in the form of starch. Ray cells also transport metabolic wastes into the heartwood. They can be thought of as "shuttle carts" moving sugar and wastes throughout the tree.
- **Fibers** – Fibers are the part of the xylem that provide most of the structural support. They are very strong and yet elastic.
- **Vascular cambium** – This is the growing part of the trunk where cells divide annually to produce a new layer of phloem and xylem tissue. The vascular cambium is where growth in the diameter of the tree takes place.

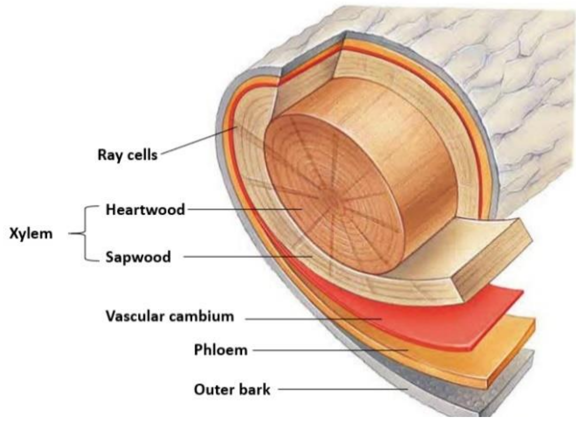

Figure 6 - Anatomy of a tree (Image adapted from Reece, Urry, Cain, Wasserman, Minorsky, Jackson, & Campbell, 2014, p.754).

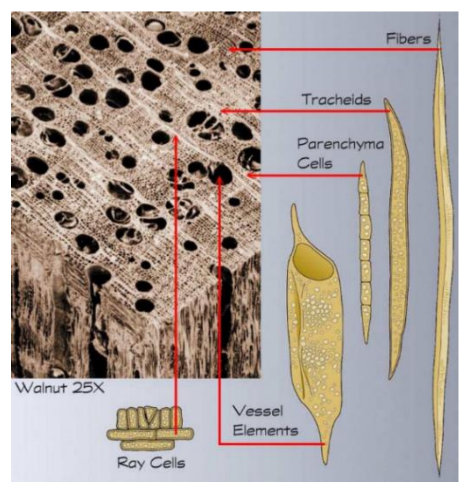

Figure 7 - Xylem in a hardwood tree A cut-away view of the sapwood in a hardwood tree such as sugar maple. Illustrating the vessels surrounded by fibers. (Image source Engler, 2009)

- **Sapwood** – This is light colored wood that acts as the tree's pipeline for water moving up to the leaves. Vessels, rays, and fibers collectively make up sapwood. Sapwood is new wood. In most trees, as newer rings of sapwood are formed, inner cells lose their vitality and turn to heartwood.
- **Heartwood** – This is the dark wood nearest the center of the tree. Its job is to support the tree. Although heartwood cells are dead, they resist decay because of phenolic compounds (poisons) deposited in their cells. When heartwood does decay it results in a hollow tree.
(Arbor Day Foundation, n.d.; Rechlin, 2015).

How do maple trees survive the winter?

In the winter we protect ourselves by putting on lots of warm clothes, but trees don't have the ability to do this. As winter approaches maple trees protect themselves by becoming dormant. One protective method they use is to drop their leaves to prevent desiccation. Live cells and dead cells in maple trees have developed different ways to protect themselves. In live cells, such as phloem and ray cells, some stored sugar remains dissolved in water. Dissolved sugar lowers the freezing point of water. This acts as a natural antifreeze and prevents ice crystals from forming and damaging the living cells. When xylem cells freeze, lots of gas bubbles are produced. This is because as a solution freezes gas bubbles are released. Just think of a tray of ice cubes. When water is placed in the ice cube tray it is clear but when the water freezes the ice looks cloudy, which is caused by small gas bubbles being released as the water freezes.

Sap flow mechanism

Since at least the 1800s scientists have been studying the mechanics of sap flow in dormant maple trees. It is well known that sap flows when temperatures alternate between freezing and thawing, but there is a lot of complexity to why it happens.

When a warm (above freezing) day follows a cold (below freezing period), positive pressure develops in the tree, forcing the sap through the xylem and out the taphole (or wound). During a freezing event, negative pressure in the tree draws water up from the roots. The drawing up of water can be quite rapid. The temperature fluctuations create alternating periods of negative and positive pressure.

- Negative pressure develops when the xylem temperature falls below freezing.
- Positive pressure develops when the temperature rises above freezing.

Fiber cells in the xylem surround the sap-conducting vessels. In maple trees these fiber cells are filled with air, whereas in most other trees they are not. When freezing conditions are present in the late winter/early spring, small ice crystals (frost) begin to form inside each of the air-filled fiber cells similar to how frost will form on the inside of windows of your home on a cold night (Tyree, 1984). The smallest parts of the tree (twigs and fine branches) freeze first followed by larger branches and the main trunk.

When ice crystals do form, the humidity within the fiber cells drops, causing moist air from adjacent vessels to be pulled in. As this moisture is drawn into the fibers, the layer of ice crystals within each fiber becomes thicker and the gas bubble becomes increasingly compressed. The movement of sap into fiber cells pulls water from the vessels. This pull is transmitted throughout the branches and the trunk down to the roots (this occurs because water molecules have a strong tendency to stick together). Strong negative pressure (suction) results throughout the tree. The suction results in water being taken up by the roots (if the soil is not frozen). This process continues until all the sap in the tree is frozen. When maple trees freeze slowly the accumulation of sap in the fiber cells and throughout the tree is greater than if rapid freezing occurs. A slow freeze results in a greater sap yield the next day (Tyree, 1984).

When the temperature rises above freezing and the frozen branches thaw the pressure in the tree transitions quickly from negative to positive. Thawing of the ice in the fiber cells allows the compressed air bubbles to expand and push the sap back into the vessels. Gravity and osmosis also play a role in sap flow. As the temperature rises sap accumulated as ice in branch fiber cells that are located high above the taphole begins to thaw. When this additional sap is returned to the vessels it falls down the tree under gravity. It creates a downward force similar to a standing column of water, with the greatest pressure at the base of the tree. In addition, osmosis (when water moves across a semi-permeable membrane to reach a state of equilibrium) contributes to sap pressure. The movement of water into the fiber cells during the cooling period excludes sucrose (the sugar molecules cannot pass through the fiber cell walls). Once thawed, sucrose in the sap draws water out of the fibers by osmosis. These combined factors can result in positive pressure as high as 40 pounds per square inch near the base of the tree. If there is a taphole or other wound through the bark in the tree, then sap will flow out of the tree as the trunk thaws.

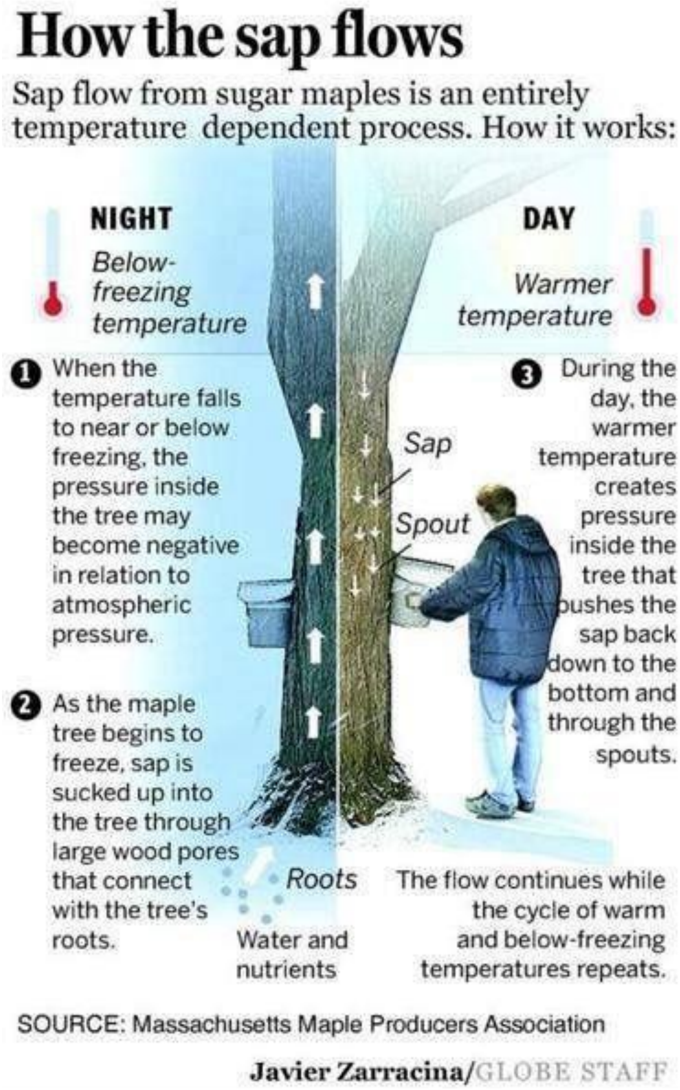

Figure 8 - How sap flows
Graphic image demonstrates what happens in a maple tree during periods when the temperature is above and below freezing. (Image source Zarracina, 2012)

As time passes, the sap pressure begins to lessen. The result is that sap pressure begins to dissipate within a few hours after the thaw begins. Without a new freeze-thaw cycle to restart the process, the pressure inside the tree will eventually subside and equal the pressure outside the tree.

Summary of **sap flow mechanism:**

- As the tree warms ice crystals in the xylem melt and gas bubbles expand. This creates pressure in the tree.
- Warm temperatures stimulate the conversion of starch to sugar and transport the sugar (sucrose) out of the live cells and into the vessels.
- Water is drawn into the vessels and pressure continues to build.
- The build-up of pressure dissolves the gas bubbles. This allows the water molecules to touch each other and thus the xylem transport system is ready for spring.
- Gravity and osmosis play a role in sap flow.
- When the temperatures drop below freezing the tree must respond to protect itself from damage. The pressure drops, ice forms in the xylem cells once again creating gas bubbles, and the negative pressure draws water from the roots (Rechlin, 2015).
- The initial development of pressure is rapid but lasts a relatively short amount of time.
- This process repeats as the tree goes through freeze/thaw cycles, causing sap to flow.

So how long does it take before the flow of sap stops? There is no magic answer. It depends on the length of the previous freeze, how slowly the freeze occurred, the available soil moisture, the size of the tree, and many other attributes. When temperatures remain above freezing, the sap run may last half a day or it may last several days and the flow may be fast or slow (Chapeskie et al., 2006b).

Factors influencing sap flow

Even though scientists have been studying how and why sap flow for as long as they have been tapping trees some aspects of it remain a mystery. Sap flow can be highly variable. Sometimes we think we have the perfect conditions, but the sap barely runs. Other times we look at the weather forecast and think we won't get much sap at all, but to our surprise the sap tanks are overflowing. Some influential factors include: Tree age, size, and health, duration and rate at which the tree froze, atmospheric pressure, soil moisture, crown size, and aspect (Farrell, 2013). There can also be a tremendous difference in temperature within one sugarbush. The temperature at the **sugarhouse** might be quite different than higher up in the property. Lastly, there can be issues with **tubing system** installation that can cause significant ice formations and prevent sap from reaching the collection tank.

Sugarbush management techniques

All plant species in a forest are in direct competition with each other for sunlight, water, and nutrients. Humans manage forests to control and shape the tree size and species composition to get a desired outcome. A sugarbush manager should work to promote a healthy sugarbush that can provide an annual crop of maple sap for multiple generations. Tree growth and size is influenced by tree age, site conditions, seasonal weather patterns, tree health, genetic makeup, and stand density. Management activities that alter stand density can potentially improve sugarbush health and productivity. Factors that influence how to manage a sugarbush include the structure of the sugarbush (size, age, health, inventory), objectives as a land manager, and past management activities (Chapeskie et al., 2006a).

Stand structure

Stand structure is an extremely important characteristic that influences management techniques used in a sugarbush. Stand structures of trees are broadly classified as (1) **even-aged** stand in which the stand of trees is roughly the same age and size or (2) **uneven-aged stand** (multi-age stand) in which the stand of trees has many different ages and sizes. As represented in Figure 11 uneven-aged stands have a very high number of small trees. However, many of these trees will die naturally as they compete with other trees for resources such as light, water, nutrients, and space.

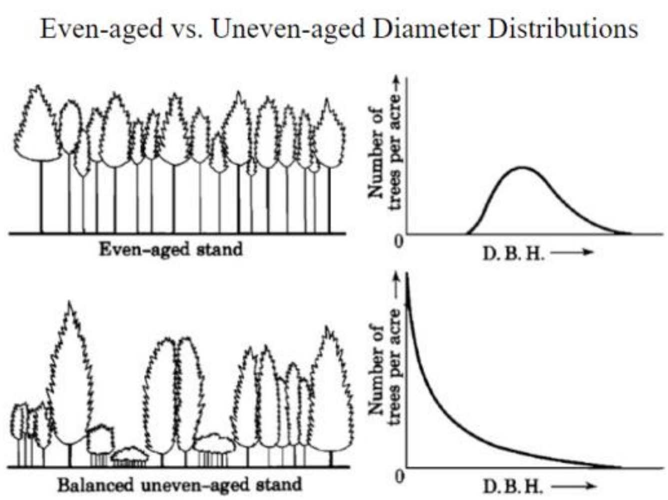

Figure 9 - Structures of even-aged and uneven-aged sugarbush
The structure of an even-aged and uneven-aged sugarbush is very different. This becomes more obvious when the size and number of trees per acre are plotted on a graph.
(Image source Smith, Larson, & Ashton, 1997)

In an uneven-aged sugarbush, the number of taps generally remains constant for many years. In the natural development of this stand new trees grow and replace mature trees as they die or are cut. In some cases, the smaller trees are younger than the larger trees, but not always. In places that were farmed in the 1800's, many of the smaller trees are the same age as the larger trees. The smaller trees are just slower growing and less vigorous. In particular shade tolerant species like sugar maple can live for a long time in a suppressed location in canopy (Heiligmann, R. B., Smallidge, P., Graham, G. W., Chabot, B., 2006). Sometimes when inventorying a stand, you can get a diameter distribution that suggests an uneven-aged structure, but this is actually the result of stratification between different species of trees. Larger sized trees are not always older than smaller sized trees. It takes over a century or more to develop an uneven-aged forest. An uneven-aged stand tends to have fewer taps per acre than a mature even-aged stand but has a steady continuous production level (Chapeskie et al., 2006a).

Even-aged sugarbushes often have more taps per acre when stand conditions have reached mature and tappable stem size. However, if regeneration is not promoted the stand will become less productive as the trees die over time. If there is little regeneration it can take decades before there are enough tapable trees to replace the loss of the mature trees. It will take equally as long for the operation to become productive again (Chapeskie et al., 2006a).

Management plan

It is recommended that sugarbushes have a **management plan** written that details the long-term and short-term objectives for the site. By evaluating a site and writing a management plan, **silviculture** recommendations can be made. These recommendations describe practices that are intended to improve the growth rate, health, species composition, and quality of a site that are aligned with the landowner's objectives. Guidelines for the number, type, and size of trees that should be harvested or left to grow can be determined. These guidelines are called a prescription and give a detailed list of instructions recommended for the sugarbush. The management plan should also include a sugarbush inventory, property description, detailed maps, site history and the number of years the plan is active before the site needs to be reassessed.

The following information should be collected and recorded when conducting an inventory in a sugarbush:

- Tree species – The number of trees of different species, usually expressed as a percentage of **basal area**.
- Tree diameters – Used to generate a diameter distribution showing the number of large and small trees. This information can also be used to determine the total number of tapable trees.
- Tree health – determines if the trees are growing well or declining.
- Number of trees per acre – A measurement of tree density. This paired with diameter distribution can determine if there are too many or too few trees for ideal growth.
- Average tree height of dominant trees – This provides a measure of site quality. Trees grow taller on better sites.
- Regeneration – The current type and abundance of seedlings growing determines the future forest composition.
- Basal Area – This measurement can be used to determine if there are too many or two few trees growing in a sugarbush.
- Site or stand problems – Problems such as invasive species, over browsing, and flooding need to be highlighted because they can impact stand health.
- Unique ecological features – Areas such as rocky outcrops or temporary streams/pools that should be preserved due to their ecological significance.

Stocking conditions

Foresters use the term **stocking** to indicate the number of trees or basal area per acre in a forest stand. Stocking compares the current number of trees or basal area in a stand with the density that produces optimum growth. Stands can be understocked, overstocked, or fully stocked. If a stand is overstocked it has more trees then you want, if it is understocked it has fewer trees then you want, if it is fully stocked it has the desired number of trees (Martin, n.d.). Stocking is an important concept for sugarmakers to understand in order to manage their sugarbush. Stocking charts are used as guidelines to help determine if the sugarbush is overstocked, fully stocked, or understocked. They plot a given stand in relation to pre-established ideal stocking conditions for optimal stand-level growth.

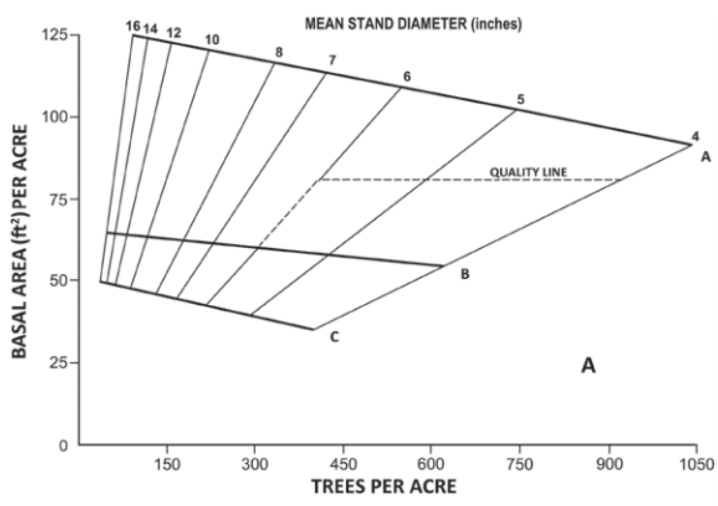

Figure 10 - Stocking chart
Stocking charts are used by foresters to determine if and how much a stand should be thinned. The chart shows a northern hardwood stocking guide. (Image source Leak, Yamasaki, & Holleran, 2014)

To use a stocking chart, locate the basal area estimate on the side of the chart and the number of trees per acre along the bottom of the chart. Find the place on the chart where these points intersect. Stands above the A-line are overstocked; stands below the B-line are understocked; and if the stand falls between the A and B-lines it is fully stocked. The C-line represents the point that will take 10 years to grow to the B-line. These charts help foresters determine how much to thin a stand.

Tree selection

If it is determined that the sugarbush needs to be thinned some of the trees will intentionally be left (**crop trees**) and some of the trees will be harvested (removal trees). Trees that are not designated as crop trees or removal trees will be left for future management activities. When making management decisions it is important to realize that some thinning is very productive and can improve the health of a forest. Too much thinning at one time can be counterproductive and actually harm the forest by causing fine root damage, sunscald, and wind throw.

Crop tree selection – what to leave

Crop trees need to be identified before other trees are marked for removal. A crop tree is a tree that is left in the sugarbush for a specific reason. In most cases, a crop tree is a tree you plan to tap for sap production, but it may also be left for species diversity, wildlife habitat, or future timber value. Land managers strive to have crop trees meet certain characteristics but as always, they need to be flexible when making decisions. Depending on the forest stand some trees that don't meet the perfect crop tree characteristics may need to be left, otherwise too many trees would be removed from the sugarbush. Chapeskie et al. (2006a) recommends looking for the following characteristics when selecting crop trees:

- Select the healthiest maples with no signs of disease, insects, damage, or stress.
- Select trees with good shape that have well defined leaders.
- Select the tallest, single stem maples with the widest deepest crowns.
- Select for u-shaped branch unions.
- Sap sweetness can be used as a factor when choosing between trees that have similar physical characteristics.
- Select trees according to the prescription – this will act as a guide to determine how many trees of each size class should be kept.
- Species that are not maples can be selected as crop trees to increase diversity, act as a buffer, provide additional income, or if a maple isn't available to maintain the recommend stand structure.

Removal tree selection – what to cut

Chapeskie et al. (2006a) recommends considering the following characteristics when selecting removal trees:

- Trees with stem injuries or that show signs of disease or decay.
- Trees with very small crowns.
- Trees with v-shaped branch unions, which increases the likelihood of bark inclusions and points of structural weakness.
- Trees with branches within the tapping zone.
- Trees with poor crown position.
- Trees with lower sap sugar content.
- Over mature maple trees that are still valuable for timber or firewood.
- Hazard trees that pose a danger to people working in the sugarbush.
- Other shade tolerant species, like American beech, if they make up a significant portion of the species composition.

- Select trees according to the prescription – this will act as a guide to determine how many trees of each size class should be removed.

Intermediate cuts

As groups of trees grow, they compete with each other for resources such as sun, water, nutrients, and space. If the trees in a stand are going to reach their full growth potential, some trees in the stand, including maples, need to be periodically removed so that more resources are available for the remaining trees, particularly those with the greatest potential for long-term growth, vigor, and sap production. Foresters use intermediate treatments, such as release treatments and thinning, to improve the growth and quality of the trees left in a stand over time.

Productivity in a sugarbush is diminished by (1) the presence of undesirable trees and (2) overcrowding. During an intermediate cut, more desirable trees such as healthy, fast growing trees with wide crowns and a high sugar content are left and less desirable trees are cut. Thinning treatments are also used to reduce competition in an overcrowded stand and encourage more rapid growth and development of larger crowns in the trees that remain. In a well-managed sugarbush, thinning begins early and continues periodically to maintain tree growth, production, and vigor. In a previously unmanaged stands, intermediate treatments can also increase the tree diameter growth and healthy crown growth (Heiligmann et al., 2006). However, care should be taken to not reduce stand densities too aggressively in these situations to avoid risk of **windthrow** and thinning shock.

Crop tree release

It isn’t enough just to identify a crop tree. It is sometimes necessary to make sure the crop tree has enough room to grow by removing trees with which the crop tree is immediately competing for resources such as space, sunlight, water, and nutrients. The removal of trees directly competing with a crop tree is called “crop tree release” and is the best way to improve the overall health and productivity of a sugarbush. Is it possible to give crop trees too much room to grow? The answer is yes. If crop trees have too much room it can cause damage to the trees, such as **sunscald**, increase the risk of windthrow, and allow too much sun to reach the forest floor (sugar maple can be sensitive to fine root damage from too much sun exposure). Wide spacing can also provide room for unwanted trees and shrubs to grow (Chapeskie et al., 2006a). In a sugarbush it is recommended to release one to two quarters of a given crop tree per thinning. The method attempts to balance optimal growth and mitigating the risks of opening up trees too much. In a non-sugarbush stand it is recommended to release three to four sides of the crop tree. Depending on the long-term goals for crop tree densities, it often only makes sense to release 50-100 crop trees per acre to maintain full stocking conditions and concentrate resources on those individuals that will make up the primary trees tapped in the sugarbush.

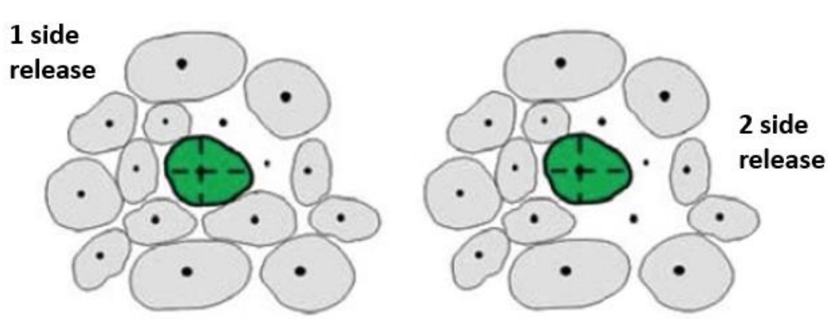

Figure 11 - Crop tree release
A crop tree crown (green) is shown from above the forest canopy. The diagram shows a crop tree release on one and two sides. (Image source Maine Forest Management, 2014)

Crop tree release in even-aged stands

Stands with an average diameter below 4 in:

In a young even-aged stand it is a waste of time and money to release every potential crop tree. These small sapling-sized trees are in a race with each other for resources. When all the trees are sapling-sized it is impossible for a land manager to know which trees will win the race and become future crop trees. By letting nature run its course the most vigorous trees will outcompete the inferior trees. Sometimes it is necessary to increase light on the crowns and release resources below ground. If so, it is recommended to release 100-200 trees per acre to maintain full stocking conditions.

Stands with an average diameter of 4 – 10 inches:

This size stand is often referred to as a polewood stand. If your stand inventory shows that you have an **overstocked** polewood stand with very few tappable trees, the stand would benefit from a thinning. Polewood stands respond to thinnings by dramatically increasing their growth rates, resulting in tappable trees in a shorter period of time. To release crop trees in these stands, identify the best trees, using the crop tree selection criteria, and remove the trees around them that have interfering crowns (Chapeskie et al., 2006a).

Stands with an average diameter of 10 – 15 inches:

This type of stand still responds well to thinning, but often not as well as younger stands. Select the best possible crop trees; the stand should have about 60-85 crop trees per acre. Impacts of thinning should be closely monitored and frequency and intensity of thinning may have to be adjusted depending on how the stand responds (Chapeskie et al., 2006a).

Stands with an average diameter greater than 15 inches:

If your mature stand is overstocked, it is unlikely that a thinning will dramatically increase the growth rate of the trees. However, if the stand has been well managed in the past and is due for another thinning, the remaining trees should respond well. These trees should have large healthy crowns, and thinning will help promote crown and diameter growth. Regardless of past management, most mature stands will benefit from thinning since it promotes maple regeneration and the establishment of a younger generation of trees. If you are concerned that a harvest will dramatically reduce the amount of sap produced in the stand because you will be removing some large tappable trees, thin conservatively and give enough time between harvests for the sugarbush to adjust to the loss of taps. When thinning, focus on the poorest quality trees. Remember that in the long run this management practice will increase the health and growth of the sugarbush which will compensate for the short-term loss of some taps (Chapeskie et al., 2006a). This is also a good stage to evaluate the stand ad consider creating canopy gaps in areas. This will allow regeneration to occur and start the establishment of a new cohort of maple trees where gaps are present.

Crop tree release in uneven-aged stands

An uneven-aged stand requires different management practices because the land manager must consider all diameters of trees when making decisions. Stocking guides are only used for even-aged stands, as they assume a uniform stand condition and desire even age rotation. Uneven-aged stand management is different and is based on “marking guides”. When marking trees for removal focus on what the prescription recommends for each size class. For example, the prescription for the stand that is overstocked in polewood size trees, recommends removing more stems from that size class than from other size classes that are not overstocked. It is just as critical to select and release crop trees in an uneven-aged stand as it is in an even-aged stand. Potential crop trees should be identified in all size classes not just the ones that currently need thinning (Chapeskie et al., 2006a).

Biodiversity

In the past, many forest managers recommended removing all non-maple species as an attempt to maximize the number of taps per acre in a sugarbush. Today we have a much greater understanding of how healthy woodlots function and land managers are realizing the benefits of maintaining a biologically diverse sugarbush. Healthy sugarbushes have a variety of tree species that provide different ecological services and functions such as water filtration, wildlife habitat, natural control of pest species, and much more. Biodiversity can also provide land managers with another source of income from harvesting saw logs or firewood and non-wood products such as mushrooms, ramps, and fiddleheads. Site characteristics and site history dictate current biodiversity levels in a sugarbush, while current management actions will influence future biodiversity of the site. Managing for biodiversity has a variety of ecological and economic benefits. A sugarbush with high biodiversity is more resilient to natural disasters, periods of drought, **invasive species**, and pests. Land managers that maintain between 15% and 25% non-maple species can have a productive and biologically diverse sugarbush as well as meet one of the production standards to be certified as organic maple sap and syrup in Vermont (Chapeskie et al., 2006a; Vermont Organic Farmers LLC, 2016).

Wildlife

Supporting and encouraging wildlife species in a sugarbush provides both ecological and recreational benefits. Recreationally wildlife provides opportunities for hunting, birding, and photography. Additionally, it can be more cost effective to leave low value timber in the woodlot then dragging it out for processing. Four key habitat features are critical to wildlife populations:

- **Cavity trees**: 25% of wildlife living in a sugarbush rely on cavity trees throughout their life. They use cavity trees for hibernating, escaping predators, roosting, and nesting (Chapeskie et al., 2006a).
  Recommendation: Retain an average of two snags and/or cavity trees greater than 10 inches in diameter per acre (Hagenbuch, n.d).
- **Downed-woody material:** Forty five percent of wildlife living in a sugarbush use down-woody material such as logs, stumps, and branches on the forest floor. Uses include feeding sites, cover from predators, and hibernation. When harvesting, some wood material should be left in the sugarbush (Chapeskie et al., 2006a).
  Recommendation: Retain a minimum of 4 logs greater than 10 inches in diameter and 3 ft in length on the forest floor (Hagenbuch, n.d).
- **Mast trees:** Oak, American beech, black cherry, butternut, hickories, and basswood are all important mast (nut, fruits, or edible seed) producing species. Twenty five percent of wildlife living in maple forests eat edible fruits from trees.
  Recommendation: Retain 3-4 good mast producing species per acre. They should have healthy crowns greater than 16 inches in diameter (Chapeskie et al., 2006a).
- **Conifer cover:** Ten percent of wildlife living in maple woodlands use conifer trees for cover. Conifers are especially important for songbird diversity (Chapeskie et al., 2006a).

Figure 12 - Pileated woodpecker utilizing cavity tree (Image source Galipeau, n.d.)

Bird-friendly sugarbush management

Sugarbushes can be managed in very different ways. Some forms of management can result in a maple monoculture with very little or no **understory** growth. Although this approach may increase sap production over the short term and make working conditions in the forest easier, this type of sugarbush does not promote the biodiversity needed to support ecological functions such as wildlife habitat, natural control of forests pests, and resiliency to natural disasters and other stresses. In contrast, sugarbushes managed for biological and structural diversity can produce high sap/syrup yields over the long-term while supporting ecological functions. These sugarbushes also provide habitat for wildlife, such as birds, to forage, find cover, and raise their young.

The Bird-Friendly Maple Project is a partnership between Audubon Vermont, the Vermont Department of Forests, Parks & Recreation, and the Vermont Maple Sugar Makers Association. This project has given maple producers and consumers a way to support and promote sugarbush management that is good for Vermont's birds and forests. The goal is to promote sugarbush management that integrates sap production with high quality breeding habitat for forest songbirds. Managing sugarbushes in this way results in healthy, productive, and sustainable forests for birds and the maple industry (Hagenbuch, n.d).

Steve Hagenbuch, conservation biologist at Audubon Vermont, states that

> Maple sugarbushes provide nesting habitat for a diversity of songbirds. Some of these bird species have more than 1/3 of their global breeding population in the northeastern forest. Others have been exhibiting long-term population declines for over 40 years. Through the planning and implementation of sugarbush management activities that develop a structurally and biologically diverse forest, the maple industry can play a vital role in global bird conservation efforts while simultaneously enhancing the health and sustainability of the sugarbush and promoting and potentially increasing market visibility of pure maple products (Hagenbuch, n.d).

The Bird-Friendly Maple project has created management guidelines, which can be viewed in Appendix A, as a way to recognize sugarbushes that are managing the forest as a functional ecosystem that gives intentional consideration to enhancing bird habitat, promoting species diversity, regeneration, and structural diversity like snags and downed-woody material. Management practices that promote bird habitat support a healthy forest that can produce sap for many years into the future. You can view directions for assessing a sugarbush to see if it meets the Bird-Friendly Maple project criteria in Appendix B. These activities are a fun and engaging way to evaluate your sugarbush. To learn more about participating in the Bird-Friendly Maple project contact Audubon Vermont at vermont@audubon.org.

Problems that affect sugarbush health and regeneration

A variety of insects, diseases, and plants impact sugarbushes. They can impact the health of the forest, impair the ability for maples to regenerate, and be a nuisance to work around (e.g. imagine maintaining **tubing** when the understory is infested with Japanese barberry…ouch!). Sugarmakers and land managers should stay informed on issues associated with pests, diseases, and invasive species in their area. Early detection is vital to minimizing infestations and potential impacts.

Insects and animals

Asian long-horned beetle (*Anoplophora glabripennis*)

Description: Asian Long-horned Beetle (ALB) poses a significant threat to the maple industry. It is an invasive wood-boring insect that feeds on a variety of hardwoods including maple. The beetles are shiny black with white spots on their wing cases and "electric blue" legs. They are approximately 1.5 inches long and have black and white antennae that can be up to twice the length of their body. Eventually ALB kills the tree by girdling it. Since maples are a preferred host tree for ALB, they could cause a devastating impact to the maple industry. ALB is commonly mistaken with the native whitespotted pine sawyer beetle. Some key differences between the two are the whitespotted sawyer has one white dot between the top of its wings. ALB does not have this dot. The whitespotted sawyer's wings are rough and bronzish-black as opposed to the ALB's shiny smooth black wings (Vermont Invasives, (n.d.).

Signs of infestation:

- Round ⅜ to ½ inch exit holes that are at least 1 inch deep in trees beginning in late July.
- Round ½ inch egg laying sites in outer bark.
- Sap oozing from egg-laying sites and exit holes.
- Sawdust (frass) collecting at the base of the tree or on branches.
- Trees with wilted foliage and canopy dieback (New York State Department of Environmental Conservation, n.d.).

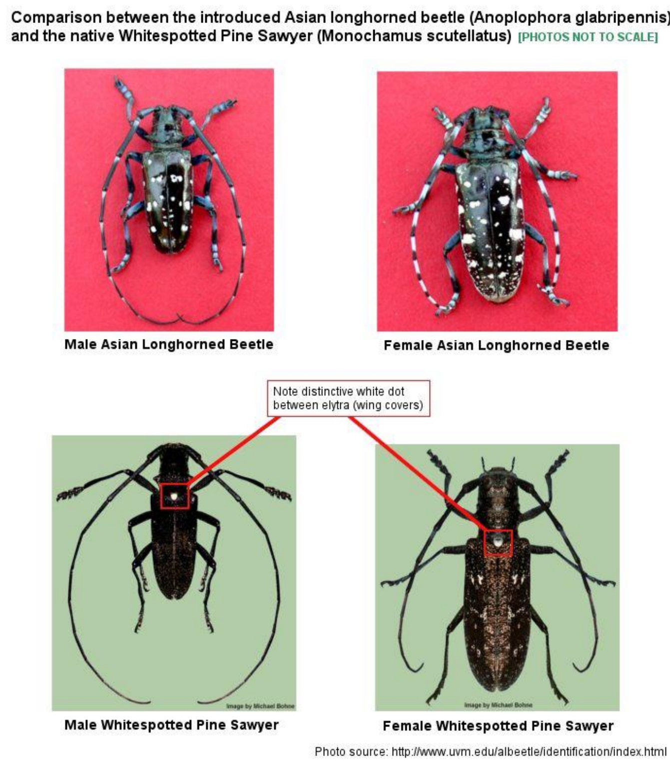

Figure 13 - Comparison between Asian Longhorned Beetle and Whitespotted Pine Sawyer (Image source Vermont Invasives, n.d.)

Management: The best management approach is to become informed about the pest and know the signs of infestation. If you think ALB is present report it immediately by contacting the Vermont Agency of Agriculture or University of Vermont Entomology Research Laboratory.

Emerald ash borer (*Agrilus planipennis*)

Description: Emerald ash borer (EAB) is an invasive beetle that feeds on ash trees. You may be wondering why this pest is included since it doesn't feed on sugar maples? Well, if your sugarbush has a high component of ash, then EAB can greatly impact the structure and composition of your sugarbush. Also, as EAB kills the ash trees there is a risk of the dead ash trees falling and injuring people, other trees, and tubing systems. EAB can kill an ash tree in as little as one or two years. Adults are ¼ to ½ inches long, have a narrow, bullet-shaped, flat back and are metallic green in color with purple and red metallic segments under their wing covers. Some signs of EAB include:

- S-shaped tunnels behind the outer bark
- D-shaped exit holes 1/8" wide on the bark surface
- Bark splitting
- Dead top branches on ash trees

Management: As with all invasive species, early detection is the most important management strategy for your sugarbush as well as the neighboring forests. Understanding the threat and signs of EAB are critical to slowing the spread of this pest. There are currently no ways to control EAB. If your sugarbush is infested with EAB you will likely lose all the ash trees in your woods. This can be taken into consideration when planning future harvests in the sugarbush (Chapeskie et al. 2006a; Vermont Invasives, n.d.). If you think you have seen signs of EAB report it immediately.

Figure 14 - Emerald ash borer
(Image source UMaine News, 2018 (Left) Greiner, 2009 (Right)

Forest tent caterpillar (*Malacosoma disstria*)

Description: Forest tent caterpillar (FTC) is a native insect that can be very destructive and sugar maples are one of their preferred host plants. Caterpillars congregate in large groups. When a tree has been stripped of foliage the caterpillars migrate to other trees in search of food (Isselhardt, 2016). Full grown caterpillars are about two inches long, hairy, bluish-black with white marks along their back (Chapeskie et al., 2006a). FTC outbreaks occur on 10-20-year cycles at the regional level (Isselhardt, 2016). Sugar maples coevolved with FTC so they can withstand defoliating events from time to time. However, if sugar maples are repeatedly defoliated coupled with other stressors, such as drought, long term damage can occur. Once an FTC outbreak occurs it can take several years for natural controls (parasitism, infection, and starvation) to bring the population back to manageable levels (Farrell, 2013).

Management: Since FTC is a native species there are a host of organisms present in the ecosystem that have adapted to control FTC populations. FTC does not feed on red maples so sugarmakers could manage their stand by retaining additional red maples to slow the expansion of future FTC outbreaks. Some producers choose to spray their sugarbush with a natural pesticide (*bacillus thuringiensis* var. *kurstaki*) to kill larvae as they chew on leaves. Doing nothing is also a management option since most trees can survive a few years of defoliation (Isselhardt, 2016). If sugaring areas have experienced many years of repeated defoliation from FTC, the trees should not be tapped because they are already experiencing significant stress and are depleted of resources.

Figure 15 - Defoliation of maple tree caused by forest tent caterpillar
(Image source Isselhardt, n.d.)

Maple leaf cutter (*Paraclemensia acerifoliella*)

Figure 16 - Maple leaf cutter
(Image source Isselhardt, n.d.)

Description: Sugar maple is the preferred host plant of the maple leaf cutter, but it also feeds on red maple, birch, beech, and other hardwoods. Maple leaf cutters make small holes in the leaves starting in June. As summer progresses, infected trees will have holes of various sizes on their leaves. By the end of the summer leaves turn brown and are covered with circular holes and parts of the leaves have skeletonized areas.
Management: Most land managers choose not to actively control maple leaf cutters and let natural factors control the population. This insect defoliates maples late in the season, so unless the population is extremely high for multiple years in a row it will not permanently damage the tree (Hanson and Walker, n.d).

Rodents
Two main species of squirrels are found in Vermont sugarbushes, gray squirrels and red squirrels. They can be a nuisance in a sugarbush, especially if a tubing system is used to transfer sap. Red squirrels are the most common nuisance. They are known for chewing holes in maple tubing and causing leaks. Other rodents such as chipmunks and mice can also cause problems in a sugaring operation by chewing on or making nests in equipment and buildings.
Management: Rodent populations rise and fall related to feed and habitat. Control measures are not very effective. Squirrels are attracted to salt deposited on tubing from human hands and chlorine-based bleach which is used by some producers to clean lines. Produces can avoid adding salt to tubing by wearing gloves when fixing lines. Producers can also avoid using chlorine-based bleach. If they choose to use it the lines should be thoroughly rinsed.

Figure 17 - Squirrel damage
Squirrels can cause significant damage to sugaring equipment especially by chewing on tubing.
(Image source Isselhardt, n.d.)

Invasive worms

Description: Earthworms are not native to the northeast. They were introduced by early settlers who traded soil and plants transported from Europe and Asia. Worms continue to be moved throughout the landscape by disposal of worm bait and movement of horticultural material such as plants and compost. Unfortunately, in forests the worms are a major threat to the ecosystem health. The worms consume the organic top layers of soil (duff). The organic layer includes most of the nutrients available for the plants and is also where many maple seeds germinate. By consuming the organic layer, the worms create soil conditions that are unsuitable for seed germination. Meaning, the canopy trees such as sugar maple and understory species cannot regenerate at the appropriate rate. The worms also create soil conditions that are more suitable for invasive plants.

Not Invaded – Camels Hump, VT **Invaded – Shelburne, VT**

Figure 18 - Invasive worms effect on forest understory (Image source Sullivan et. al., 2018)

Management: Research is currently being conducted on how invasive worms affect forest ecosystems. As of now there are no viable management solutions. However, worm movement can be limited by not dumping horticultural debris or fishing bait on wooded edges or in the forest. Sugarbushes should be monitored for worm presence (Sullivan, Parker, Skinner, & Görres, 2018).

Diseases

Eutypella canker (Eutypella parasitica)

Description: This is a plant disease caused by a fungus and can infect all maple species. The disease looks like a bulge, or canker, around the infected area. The canker appears swollen, callused, and has dead bark attached to it. Most cankers occur between 3 and 12 feet above the ground on the trunk, meaning it is often located in the tapping zone. Small trees are usually girdled and killed by the canker, but large trees can live for many years. The canker often becomes an entry point for other diseases and weakens the tree making it more susceptible to wind breakage (Chapeskie et al., 2006a).

Management: Trees with cankers on the main trunk should be removed and discarded in order to prevent the spread of the canker disease to healthy trees. Cankered branches can be removed by cutting 4-6 inches below the canker. It is best to prune the branches when the weather is dry. When thinning a sugarbush, avoid damaging the trunks of the remaining trees as such damage will render them more susceptible to the fungus (Morrman, 2014).

Figure 19 - Eutypella canker (Image source Haugen, USDA Forest Service, 2018)

Nectria canker (Neonectria galligena)

Description: A fungus causes Nectria canker of branches and stems of over 60 different species of trees and shrubs, including maple. Spores are released and spread by wind and rain splash. New infections occur through open wounds, leaf scars, or branch stubs. Cankers that are one year old are small, discolored areas that appear flattened. As the infection grows, rounded, corky rolls of callus and bark develop a target-like pattern. Nectria canker very rarely girdles stems that are several inches in diameter, but these trees and shrubs are more susceptible to wind breakage.

Management: It is virtually impossible to completely eradicate this disease from a woodlot, but there are some steps that can be taken to lower its impact. Young cankered trees should be removed during thinning operations. Infected branches can be pruned and discarded when the weather is too cold or dry for the fungus to infect pruning wounds (Gillman, 2011).

Figure 20 - Nectria canker
Canker is several years old with patterned callus growth. (Image source Anderson, 2011)

Plants

Common buckthorn (*Rhamnus cathartica*) and Glossy buckthorn (*Frangula alnus*)

Description: Deciduous shrubs that grow up to 20 ft tall. Leaves oval and are one to two inches long. Leaf arrangement is sub-opposite (alternate to nearly opposite). Twig tips have sharp thorns. Both species rapidly grow dense thickets, leaf out earlier and retain their leaves longer than most woody deciduous plants (University of Maine Cooperative Extension, 2001).

Management: Buckthorn does not pose a problem to mature maple trees, but greatly impacts maple regeneration. Buckthorn is much easier to control when it is detected early. Control methods include mechanical removal and herbicide application. If the woodlot is significantly infested, managers should direct energy toward removing buckthorn around regenerating maples until the maple seedlings are at least 10 ft. tall (Chapeskie et al., 2006a).

Figure 21 - Common buckthorn
Leaves are arranged sub-oppositely, oval, with toothed margins, and veins run parallel towards the tip. (Image source Vermont Invasives)

Additional invasive shrubs
Description: Honeysuckle (*Lonicera sp*.), Japanese barberry (*Berberis thunbergii*), and multiflora rose (*Rosa multiflora*) are all invasive shrubs that can threaten the ecological function and viability of a sugarbush.
Management: Control methods for honeysuckle, Japanese barberry, and multiflora rose are very similar. They can be managed mechanically by hand pulling any time of year. They can be controlled chemically by cutting the plant 4 inches above the ground and applying a glyphosate solution to the stump. Or with a low volume foliar spray. Honeysuckle and Japanese barberry can also be controlled by cutting the plants in the fall or winter and wrapping burlap or thick plastic over the stumps (Vermont Invasives, n.d.).

Figure 22 - Invasive Shrubs
Multiflora rose flowers (A), Japanese barberry infestation in fall (B), Honeysuckle flower (C).
(Image source Vermont Invasives)

American beech (*Fagus grandifolia*)
Description: Beech is a native plant species that has thin smooth light gray bark. Its leaves are elliptical in shape with coarse saw-toothed edges. Leaves can remain attached to the trees through the winter (Pennsylvania State University, 2002). It is commonly associated with sugar and red maples in northern hardwood forests. Historically beech did not threaten sugarbushes until it became infested by an exotic insect/disease complex called beech bark disease (BBD). BBD infests beech trees and as the older trees become stressed or die, they send up thousands of root suckers per acre. These suckers make it difficult for sugar maples to regenerate and eventually sugarbushes can be transformed into beech thickets. Forest soils with depleted nutrition as a result of acid precipitation will favor the establishment of beech over sugar maple.

Figure 23 - Beech thicket
BBD mortality results in root suckering or sprouting. In some stands it creates an understory thicket of small-stemmed beech clones.
(Image source McNulty, Castello, & Teale, 2009)

Management: Beech can be mechanically cut, but sprouts will need to be removed with each successive cutting. Trees should originally be cut with high stumps that can be cut a bit lower each time sprouts appear. Cutting should be done in the summer to remove as much biomass and starch reserves as possible. Chemical application can also be used to control beech sprouting. After beech is cut a chemical treatment can be applied to the cut stump (Farrell, 2013).

Tapping

Tapping, the process of drilling a hole in a tree and inserting a **spout**, is the most important activity in sugaring. When tapping you are cutting into xylem, the sap conducting part of the tree. This causes an injury and the tree will respond and heal itself. Sugarmakers need to work with the tree's response system. If done correctly you will have higher yields of valuable sap, and you will be able to tap your trees for multiple generations. If done incorrectly it results in reduced yields, leaks, and the longevity and sustainability of your sugarbush may be shortened. Tapping may seem like a simple practice, but there is a lot to know besides just drilling a hole and putting in a spout.

When to tap

Determining exactly when to tap depends on geographic location and local temperature patterns. If a sugarmaker taps too late they will miss the early sap runs. Sugarmakers typically start tapping in February. However, long-term trends are showing that sap flow is beginning earlier, so if you don't want to miss the first run it is recommended to be ready earlier. Sugarmakers should NOT rely on a calendar to determine when to tap. This can result in missed production.

Producers can predict when to tap by using the following resources:

- Tapping records –Maple seasons are very location specific meaning starting and ending dates for a sugaring season can be dramatically different depending on where a sugarbush is located. Producers should keep their own records of weather and sap flow specific to their location. This is the most valuable information a sugarmaker can record.
- Advice from other producers – New sugarmakers should talk with other local producers to find out when sap flow started and ended in previous years.
- Weather forecasts – Weather forecasts are reliable enough to help producers narrow the window of when they should tap.

Sugarmakers should avoid tapping frozen wood. Tapping frozen wood can lead to cracks around the taphole when the spout is set. Sap will drip from the crack and dribble down the trunk for the entire sugaring season reducing overall sap yields and causing vacuum leaks. Additionally, cracks cause larger wounding around the taphole. It should not be difficult for small producers to avoid tapping frozen wood since tapping can be completed within a few hours or days. They can monitor the 5-day forecast and tap just before the first good run. Large producers with several thousand or more taps must tap earlier than small producers in order to finish before the first good sap run. Temperatures should be closely monitored to avoid tapping when wood is frozen.

Tapable trees

In general, any healthy maple tree larger than 10 to 12 inches in diameter at breast height (4 ½ feet) can be tapped. There is a very strong relationship between tree diameter and syrup yield. Smaller trees produce far less sap than larger trees. "In general, each 1-inch increase in tree diameter results in approximately 2 gallons more sap or 0.67 pounds more syrup" (Isselhardt, Perkins, & van den Berg, 2018, p.38).

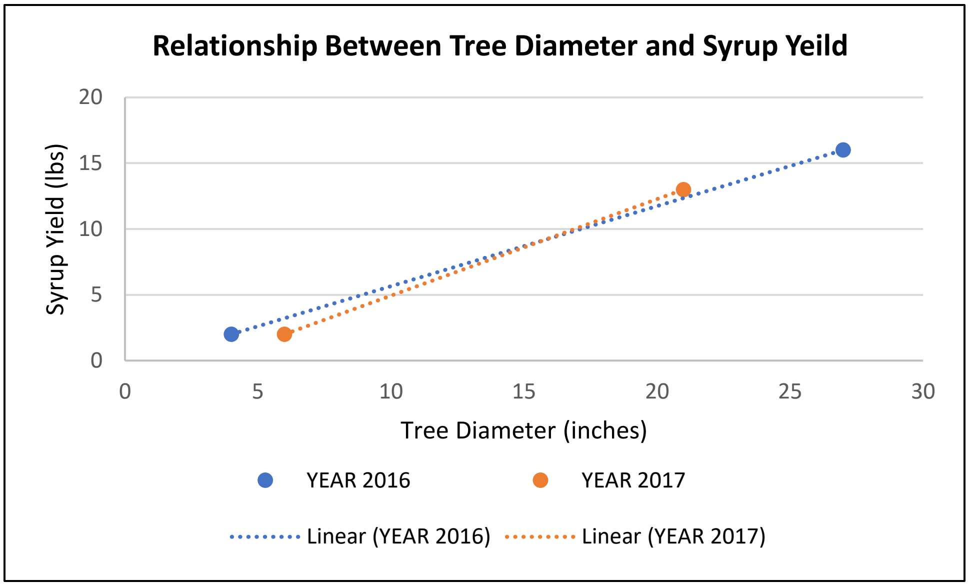

Figure 24 - Relationship between tree diameter and syrup yield (lbs)
For the 2016 and 2017 sap flow seasons in Underhill, Vermont. Best-fit lines are shown by dotted lines. (Image adapted from Isselhardt, Perkins, & van den Berg, 2018)

Maple trees with large crowns or trees known to produce larger sap volumes with higher sugar concentrations are preferred. Trees that are unhealthy, have small crowns, and low vigor should be avoided. Tapholes in healthy trees usually take 1-3 years to completely close. Tapholes in unhealthy trees can take significantly longer. When tapholes take a long time to heal it increases the risk of insect and disease problems, causes increased cambium dieback, and reduces tapping surface on the trunk. Also, sap collected from unhealthy trees may be low in sugar concentration and produce **off-flavored** syrup. When tapping, a sugarmaker's goal is to minimize taphole damage to the tree and minimize microbial contamination of the sap (Chapeskie et al., 2006b).

Tapping Guidelines

To maintain a sustainable long-term sugaring operation that can be tapped for multiple generations it is important to use **tapping guidelines**. These guidelines have been developed to ensure the correct number of taps are placed in a tree and taps are spaced to minimize the chances of tapping into old tapholes or discolored wood. Tapping guidelines use tree diameter to determine how many taps should be placed in a tree. Three different tapping guidelines are outlined in this manual, traditional, conservative, and organic. The organic guidelines outline the maximum number of taps permitted based on tree diameter. Organic producers can use conservative guidelines. When determining how many taps to put in a tree you must consider the health and vigor of the whole tree. Just because a tree is above 18 inches doesn't necessarily mean it should have two taps. When determining how many taps to put in a tree you must balance your desire for maximizing your sap yield this season with maintaining sap yields throughout the life of the sugarbush. It is very important to limit the number of tapholes since every time you drill it removes a portion of the tree where sap can flow in the future. When using a vacuum system there is not a linear relationship between the number of tapholes and the sap yield. This means that a second taphole does not give you double the amount of sap, but it does double the amount of injury to the tree. You can expect to collect 40-50% more sap from adding an additional tap to the tree. As a sugarmaker and forest manager you need to determine if adding an additional tap is worth the injury caused to the tree. If you have a very large healthy tree it may make sense to put in two taps, but if your tree is growing very slowly or showing signs of stress only one tap should be placed even if the tree is above 18 inches **diameter breast height** (DBH) (Farrell, 2013).

Table 2 - Traditional tapping guidelines
The number of taps recommended relative to the diameter at breast height (DBH)
(Table modified from the North American Maple Syrup Producers Manual Chapeskie et al., 2006B p. 87)

DBH (in inches)	Number of Taps
10-15	1
15+	2

Table 3 - Conservative tapping guidelines

DBH (in inches)	Number of Taps
12-18	1
18+	2

Table 4 - Organic tapping guidelines
(Table modified from Vermont Organic Farmers LLC & Northeast Organic Farming Association of Vermont, 2016)

DBH (in inches)	Number of Taps
9-15	1
15+	2

Every hole that is drilled into a tree, just like any other injury to the tree, kills a section of its xylem. This results in a stained column of non-conductive wood (Farrell, 2013). So, how does this happen? When you drill a hole in the tree it creates a wound where microbes can enter and invade the tree. Their goal is to grow as fast as they can, which results in the stained dead xylem and decay. However, the tree has a great injury response system. The tree actively works to isolate the invasion of microbes, stop losing sap out of the place of injury (in this case the taphole), and heal the wound as quickly as possible. This healing process takes energy (in the form of sugar). A tree must divert the energy it would have used for growing leaves to heal a wound. Maple trees are very good at stopping the microbes and healing wounds, which is one of the reasons they live for so long. Every time a woodpecker pecks a tree or a branch breaks off in a storm the tree must quickly isolate the injury and stop the microbes in order to survive. The larger the wound the harder it is for the tree to heal. A healthy maple tree has no problem healing a taphole (Rechlin, 2015).

Figure 25 - Taphole scar
The bark was removed from a former sugarbush tree. The dark vertical stained columns show the scar caused by tapholes.
(Image source Isselhardt, 2019)

Tapping equipment

The equipment required for tapping includes: (1) appropriately sized tapping drill bits, (2) drill, (3) clean spouts, (4) tapping hammer

Drills and drill bits

Battery powered drills work well for drilling holes. They are lightweight, and easy to operate. The drill speed should be 1500 RPM. Drill bits need to be specifically made for tapping. They are not the same as drill bits that can be purchased at a hardware store. Bits should be clean, sharp, and the appropriate size for the spouts that will be used. If bits are dull, they are harder to use, create ragged tapholes that can obstruct sap flow, create more surface area in the taphole for microorganism growth, and are more likely to produce oval holes which causes vacuum leaks. When tapping it is good to have a supply of drill bits that are clean and sharp in case your bit becomes dull, contaminated, or is lost. Typically, a bit needs to be replaced after drilling approximately 2,000 taps.

Figure 26 - Drill and bit
Many sugarmakers place a piece of lateral tubing on the drill bit to limit the depth the drill can enter the tree. Some tape their bit in with electrical tape so it doesn't fall out while working in the woods.
(Image source Isselhardt, 2019)

Spouts

Spouts have three purposes: (1) transfer sap from the taphole into a collection container (e.g. **sap bucket**) or tubing, (2) provide support for holding a sap collection container or an attachment point for tubing, and (3) provide a seal to minimize leakage around the taphole. Minimizing leakage is very important for vacuum systems. It will help keep your vacuum pressure high, reduce the risk of contamination of the taphole by microorganisms, and temporarily slow the **taphole closure** process (Chapeskie et al., 2006b). If you are using plastic spouts new spouts should be used every year. This will result in much greater sap yields than using old spouts that have been contaminated with microorganisms. Stainless steel spouts are the only material that can be cleaned and sterilized adequately to use for multiple years (Farrell, 2013).

Figure 27 - Spouts
Examples of different spout styles. Stainless steel (a), black spout (b), clear check-valve spout (c), clear spout (d), stub spout (e), and stub spout with adapter (f).
(Image source Isselhardt, 2019)

Steps for cleaning stainless steel spouts:

- Wash in a detergent solution
- Rinse with clean water
- Soak in dilute bleach solution (3/4 cup bleach to 1 gallon of water)

- Rinse three times with clean water (Rechlin, 2015).

Figure 28 - Cross section of a tapped maple tree
If proper tapping guidelines are followed a tree can be tapped for multiple generations.
(Image source Isselhardt, n.d.)

Sap inside a maple tree is sterile, but once it exits the tree, touches the spout, and enters the tubing system it becomes contaminated with bacteria and yeast. Researchers discovered that in tubing systems sap is sucked back into the tree when temperatures dip below freezing (times of negative pressure). The tree develops a vacuum and up to a pint of sap can be pulled back into the tree from the **dropline**. Sap can also get sucked back into the tree due to simple leaks, when mechanical **releasers** are tripped, and when vacuum systems are turned on and off. This means that when sap is drawn back into the tree it is contaminated. When bacteria from the tubing system returns into the taphole it accelerates the process of the taphole closing. As the taphole closes sap yields continually shrink regardless of weather conditions. Dr. Timothy Perkins at the University of Vermont Proctor Maple Research Center (PMRC) in conjunction with Leader Evaporator Company developed a check-valve spout to prevent sap from getting sucked back into the tree. The check-valve spout prevents sap that leaves the taphole from being pulled back into the tree. Thus, it does not allow contaminated sap from tubing systems to be sucked into the tree during natural freezing and thawing cycles, when mechanical releasers are tripped, when leaks occur, or when **vacuum pumps** are shut off (Leader Evaporator, 2016). In many situations check-valve spouts can greatly increase sap yields. However, the actual boost in yield varies depending on the age and quality of the tubing system, vacuum pump, type of releaser, and date of tapping.

Where to tap

The first step in tapping is to find the right spot on the tree to drill a hole. To get high quality sap and good yields you need to drill into clear white sapwood. You need to avoid defects such as rotten areas on the trunk, old cracks, cavities, or gnarled bark patterns. It is important to avoid old tapholes and the stained columns of dead wood associated with previous tapholes. Tapping into stained wood will result in a significant loss of sap yield, up to 75% (M. Isselhardt, personal communication, February 1, 2019).

When deciding where to tap a tree perform the following steps:

1. Look at the entire tree from crown to ground. Inspect the tree for any obvious signs of tree defects and wounds. This is best done when approaching the tree before you are right next to it.
2. Determine approximately what height you want to drill your hole. When sap is collected in buckets the hole can be drilled at any height as long as it is a convenient for the person emptying the buckets and they are high enough off the ground not to get covered by a late season snowstorm. When using tubing it is most common to drill above the **lateral line**. Lateral lines are small plastic tubing (usually 5/16 inch in diameter) used to collect and transport sap from individual tapholes. Make sure not drill the hole so high that you won’t be able to remove the spout at the end of the season.
3. If trees have been tapped before, locate the previous year’s taphole.
4. Go to the opposite side of the tree from the previous year’s taphole.

5. Inspect the area to see if old tapholes exists. If they do make sure to avoid the old taphole.
6. Make sure that where you plan to drill is free of other defects and injuries.

There is a lot of debate in the maple industry regarding the proper spacing for tapping. Many sources have different guidelines regarding how far to the left or right and above or below a previous taphole to drill a new hole. Unfortunately, there is no magic spacing and no scientific evidence supporting any one recommendation. We do know that the staining column is longer above and below a pervious taphole than it is wide. However, every tree is different and the staining often follows the grain of the wood. The most important thing to do is to look at the whole tree from crown to ground, make sure you are tapping on all sides of the tree, and never drill directly over a previous taphole.

UVM Proctor Maple Research Center has conducted research on drilling below the lateral line. Research has shown that drilling below the line with vacuum creates comparable sap yield as drilling above the lateral line. However, when drilling below the lateral producers should be aware that the tubing is in a location that can be chewed on more easily by rodents, when temperatures lower and sap in the drop line freezes it can cause frost heaving which could push the spout out of the tree, and it is possible for a tap to be covered by snow in a late season storm (M. Isselhardt, personal communication, January 14, 2019).

On older trees that have been tapped for many seasons it can be difficult to find the proper place to tap. Make sure you look carefully. Tapholes should be distributed evenly around the entire tree overtime. When tapping new trees, you can develop a spiral tapping pattern around the tree. To do this drill each new taphole to the side and slightly above or below old tapholes. This is the best way to utilize the entire tapping face of the tree trunk. By moving in a regular direction while tapping in a spiral pattern you avoid re-tapping a previously tapped area before it has enough time to grow new wood over the old taphole (Chapeskie et al., 2006b). If a pattern is developed it is still critical to inspect the whole tree to look for defects. Don't get into the habit of following the pattern and forgetting to take the health of the whole tree into consideration. There may be a situation when the pattern needs to be aborted to drill into healthy clean wood.

Figure 29 - Identifying previous tapholes
A sugarmaker carefully locates the previous tapholes before drilling into the tree.
(Image source Shelburne Farms, n.d.)

Note: Tapholes should not be placed in a straight line around the tree. Never tap only on one side of the tree (such as the south side) even if that side of the tree produces sap runs earlier in the season.

Drilling the hole

Once you pick the place on the tree to put the hole it is time to drill. When drilling the hole, you should perform the following steps:

1. Find good footing.
2. Place your drill perpendicular to the tree.
3. Drill a circular, not oval, hole. If you are using a 5/16 inch spout the hole should be 1.5 inches deep. The hole should be made in a single motion pushing the drill in and pulling it out of the tree. Do not put the drill in the hole multiple times or stop and restart during the drilling process.
4. Examine your shavings. They should be pure white. If the shavings are dark colored you have drilled into a damaged part of the tree (Farrell, 2013; Rechlin, 2015).

Figure 30 - Taphole
Wood shavings from a proper taphole are "clean" and white in color (Image source Isselhardt, 2019)

Notes: Never blow into the taphole to clear shavings, this can contribute to microorganism contamination. If shavings are repeatedly left in the hole your drill is probably dull.

Seating the spout

The final step is to put the spout in the tree. The proper way is to gently tap the spout in the hole. If you tap too hard you can cause the wood and cambium to split, which also causes leaks. The spout can be tapped in with a tapping hammer or small mallet. Larger hammers are harder to control. As you tap you will hear the pitch change to a thumping sound, and you will feel a change in the resistance. That is when you know you are done.

Figure 31 - Properly seated spout
Image source Isselhardt, n.d.)

Figure 32 - Seating the spout
Sugarmaker gently seats the spout with a tapping hammer. (Image source Isselhardt, 2019)

Sap collection

There are two main sap collection systems: (1) buckets (or **sap bags**) hung on individual trees or (2) tubing collection systems that bring sap to a larger tank. When deciding which sap collection system works best for your sugaring operation you must consider the size of the operation, labor supply, equipment and financial resources, **topography**, and desire for profit. Very few large sugaring operations use bucket collection systems because this method is extremely time consuming and labor intensive. Additionally, by attaching a vacuum pump to your tubing system you can double or triple your sap production. However, buckets work just as well today as they did 200 years ago. If you are a hobby sugarmaker and have lots of time and labor available, buckets may not be a bad choice for your operation.

Gravity sap collection

A bucket can be hung on a spout inserted in individual trees. Buckets must be emptied by hand. The sap is transferred to a large collection tank and transported to the sugarhouse. Sugarmakers should always try to collect sap quickly to reduce microbial growth, particularly when temperatures are high.

There are few containers that are actually appropriate for collecting sap. Collection containers must be made of **food-grade** material. Traditional galvanized sap buckets are commonly seen but sap buckets can also be made of aluminum or plastic. If you are using older buckets make sure they do not contain lead in the metal, either in the galvanized coating or in the solder. Each bucket should have a cover to keep out rain, bark, and other debris.

Figure 33 - Image of traditional galvanized sap buckets
(Image source Shelburne Farms, n.d.)

Cleaning buckets

Sap collection containers need to be kept as clean as possible and should be used only for collecting and holding maple sap to reduce microbial growth and off-flavors. At the end of the season buckets should be washed and sanitized by using the following procedure:

- Wash with hot water and detergent
- Thoroughly rinse with water three times to remove detergent
- Optional: wash with diluted bleach solution and thoroughly rinse three times

After washing, buckets should be dried and stored. Prior to use in the spring buckets should be:

- Washed with hot water
- Rinsed with a diluted bleach solution (5-10% solution).
- Thoroughly rinsed three times with hot water to remove all traces of the bleach solution

Sap gathering containers and collection tanks should also be rinsed with water at the end of each use throughout the season to remove the coating of sap. If they are not rinsed microorganisms can grow on the surface of these containers and contaminate sap during the collection process (Chapeskie et al., 2006b).

Tubing

Tubing systems have been recognized as one of the major factors in maintaining the economic viability of the maple industry. The use of tubing was introduced in the 1950s and greatly reduced the amount of labor required for sap collection. The invention of tubing systems also allowed producers to expand and effectively manage large sugarbushes with thousands of taps and minimal labor. Tubing systems allow sap to flow from the tapholes through a network of tubing to the collection tank. Tubing systems have many benefits besides reduced labor. They reduce vehicle traffic that causes soil compaction in the sugarbush, sap can easily be brought through terrain barriers such as ravines and swampy areas, and if a vacuum pump is paired with the tubing system it can substantially increase sap yields (Chapeskie et al., 2006b). The following tubing descriptions and recommendation in this section of the manual assume that the producer will be using a vacuum with the tubing system.

In order to properly use a tubing system a few concepts must be understood and followed

- Tubing should be tight, straight, and slope continuously downhill so gravity can help move sap through the system.
- Tubing systems that are used with vacuum pumps are constructed differently than tubing systems that rely solely on gravity to move sap. The main difference between these systems are the size of the **mainlines** and the number of taps on lateral lines.
- Tubing systems should be as simple and direct as possible.
- Tubing systems should be drained fully and kept clean, so they don’t contaminate sap.
- Tubing systems must be inspected and maintained frequently to prevent leaks and maintain vacuum levels.
- Tubing systems need to be cleaned at the end of each sugaring season and replaced every 10-15 years (Chapeskie et al., 2006b).

Basic tubing terminology

An understanding of common tubing terminology is necessary when designing and working with tubing systems.

- Lateral line – small plastic tubing (usually 5/16 inch in diameter) used to collect and transport sap from individual tapholes. This line runs from tree-to-tree collecting sap from a series of trees.
- Drop line – Short length (24-30”) lateral tubing that connects the spout to the lateral line.
- Main line – ridged pipeline ¾ inch or larger in diameter that carries both sap and vacuum. It is used to collect and transport sap from multiple lateral lines to a common collection tank.
- **Wet-dry conductors**, also known as **dual conductors**: Specially designed mainline systems that have two separate parallel ridged pipes, one to transport sap (wet line) and the other for vacuum transfer (dry line). This can also be called an air-sap conductor (Heiligmann, Koelling, & Perkins, 2006).

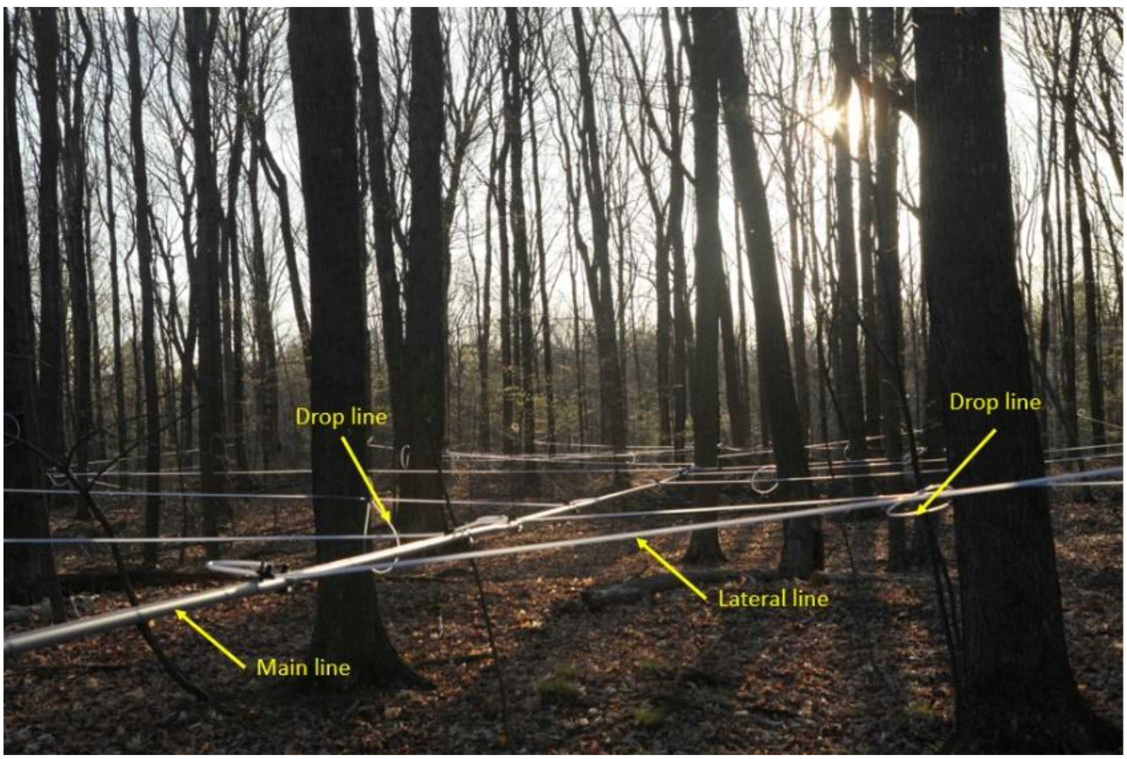

Figure 34 - Tubing terminology
(Image source Webb, n.d.)

Design of tubing systems

A tubing system must be carefully planned before installation begins. Tubing systems are expensive and time consuming to install, but if done correctly can greatly improve a sugaring operation. The tubing system must be specifically designed based on the sugarbush in which it will be installed. The location of the sugarbush, its topography, and the distribution of tapable trees dictate the design of the system (Cornell Maple Program, 2015).

Planning tools

A few planning tools are required to properly design a tubing system.

- An overhead photograph of the property that shows the roads, buildings, and trees.
- Topographical map showing changes in elevation and distinguished features such as valleys and mounds on the property.
- A sugarbush inventory that features individual or groups of maple trees and unique ecological features that should be avoided.

Tubing system layout

There are two main ways to layout out mainlines. The method chosen is primarily based on topography of the sugarbush. The first method is often referred to a herringbone tubing design. The mainlines follow the valleys and the lateral lines feed into both sides of the mainlines. If there are distinct valleys in the sugarbush this pattern often works very well. This design can make regular maintenance more difficult because the producer is constantly ducking or stepping over lines. The second method runs mainlines on a 3 to 5% grade along the contours of the hillsides. All lateral lines are connected to one side of the mainline and run uphill. This method works best for hillsides that don't have much pitch variation. It also makes the system more convenient to walk or ride next to for maintenance. For both systems there should be no more than five taps on each lateral line. This will dictate the distance between the mainlines. For both systems the sugarbush should be broken into manageable blocks based on roads and geographic features such as rock outcrops or bodies of water. Often a combination of the two systems is used (Cornell Maple Program, 2015).

Collection points

It is not always possible to channel sap directly to the sugarhouse so often collection points need to be established. Other possibilities for getting sap to the sugarhouse are remote pumping stations, **sap ladder** (tubing lines that are designed to lift sap from lower to higher elevations) or installing a remote collection tank that can be easily accessed by truck or tractor (Cornell Maple Program, 2015).

Mainline

Figure 35 - View of mainline pitch through sight level
(Image source Isselhardt, 2019)

The location of mainlines must be carefully chosen because they are a permanent part of the tubing system. Location is dependent on topography and distribution of tapable trees. Mainlines often follow the natural surface drainage pattern in the sugarbush. The pitch of a mainline is extremely important because influences the amount of sap yield. Mainlines must be installed on a constant grade, between 2-3% slope without sags. If necessary 4-5% slope is acceptable. A sight level and flagging can be used to establish the correct pitch. Mainlines should be placed across the slope not straight up and down the slope. Wire is needed to support the mainlines (M. Isselhardt, personal communication, February 1, 2019).

Mainline size

When sizing a conductor mainline it is critical that the line can accommodate peak sap flows and allow vacuum transfer. Conductor mainlines need to carry both sap and allow space for air to be removed from the tubing to produce a vacuum. Tubing diameter must be larger for long mainlines with more taps. In general lines should be no more than 1/3 full of sap at any time to efficiently move the sap and air (Chapeskie et al., 2006b).

Table 5 - Recommended number of taps for mainlines of different diameter on different slopes

Mainline Diameter	Percent Slope		
	< 5	5–10	> 10
	Number of Taps		
3/4	< 400	300–500	300–600
1	< 700	400–900	600–1100
1¼	< 1100	900–1400	900–1800
1½	< 1600	1200–2000	1200–2600

Mainline support wire

Mainlines are tied to ridged support wire to prevent sags. Producers commonly use a 12.5-gauge high tensile wire to support mainline tubing. 14-gauge wire is used as side ties to tension the mainline support wire. After the location of the mainlines has been determined the support wire should be installed. There are two methods used to install mainline wire: (1) the wire is made very tight with a fence wire tensioner or (2) the wire is installed loose and pulled tight with side ties. Both methods are often used by sugarmakers. When installing wire, it should first be pulled into the sugarbush on a predetermined path. Both ends of the mainline support wire must be anchored to a tree, post, or ground anchor. The wire can be secured to the anchor using a J-shaped hook or by wrapping the wire around the anchor. If wire is wrapped around a tree it should be encased in a short section of tubing or hose to protect the tree. Wire can be pulled tight with a tensioner, fence jack, or wire puller. The wire should be supported by trees along its path or the wire can be pulled to trees with side ties. The distance between support ties depends on the percent grade. If it is a flat grade supports need to be placed close together, every 10 ft., to prevent sagging. If wire follows a 4 to 5% grade support can be further apart, such as every 40 ft. (Chapeskie et al., 2006b).

Figure 36 - Encasing wire to prevent damage to tree When wire is wrapped around a tree it should be incased in a short section of tubing or hose to prevent the wire from damaging the tree (Image source Isselhardt, n.d.)

Installing mainline tubing

After the wire is up and reasonably tight the mainline tubing can be installed. Tubing should be laid out directly under the support wire. Mainline comes in a large roll. It would be extremely difficult to carry the entire roll in the sugarbush. Instead the free end should be pulled into the woods and the coiled should be unrolled by a helper. Mainline spoolers can also be made or purchased to help unroll the tubing. At the end of the support wire the tubing is plugged or a valve is installed. The mainline is then anchored to the end of the wire. This can be done by using wire mesh tension grips. Next the line is attached to the support wire using wire ties about every 10 ft. The mainline should be pulled tight each time a wire tie is added to avoid sags in the line. At the other end of the wire the tubing is passed through another grip and pulled "hand-tight". Once the mainline is tight additional wire ties should be placed every 1 to 2 feet (Chapeskie et al., 2006b).

Figure 37 - Installation of a mainline
Mainline installation at Shelburne Farms. A wire mesh tension grip is being used to anchor the mainline to the support wire.
(Image source Shelburne Farms, n.d.)

Wet-dry mainline

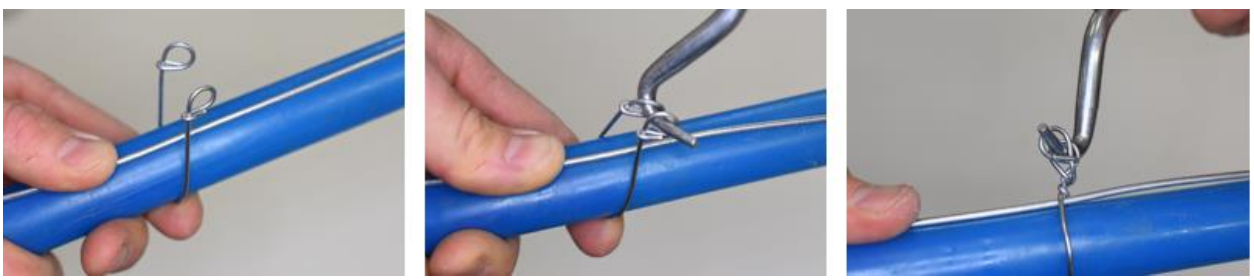

Figure 38 - Connecting support wire to mainline
The mainline is attached to the support wire using wire ties. The wire tie is attached using a manual wire twister.
(Image source Isselhardt, 2019)

Wet-dry line systems, also referred to as sap-air systems, have two parallel rigid mainlines arranged above each other. The lower line carries sap and the upper line transfers vacuum. This system works well when mainlines are very long and where sap from many taps is collected into one conductor line. The wet-dry lines are laid out in the sugarbush. Then single mainlines branch off the dual lines (Chapeskie et al., 2006b). Wet-dry lines are installed the same way as a conductor mainline but require additional hardware and tubing to transfer vacuum and sap where mainlines branch off. This connection is called a manifold or booster. Vacuum gauges and valves can be installed at the manifolds and are helpful to isolate leaks (Cornell Maple Program, 2015). One advantage of wet-dry line systems is that sap can flow through the dry line in the early morning when the wet line is frozen, acting as a backup wet line until the actual wet line thaws (Chapeskie et al., 2006b).

Lateral lines

Lateral lines are used to connect the trees to the mainlines. Most sugarmakers use 5/16-inch diameter tubing. The lateral line is stretched between the mainline and the last tree. Each lateral line should have 5 or fewer taps (with vacuum). The number of taps dictates the length of the lateral line, but generally they are not longer than 150 ft. Droplines at each tree are spliced in after the lateral line is installed. When installing lateral lines run the line from the farthest tree toward the mainline. The line is anchored to the last tree by a loop of tubing that goes around the tree (Chapeskie et al., 2006b). There are many methods used to secure the lateral line at the last tree. One method is to have the tubing wrap around the last tree and then attach a **tubing fitting** that hooks back onto the lateral line (Farrell, 2013).

Figure 39 - Securing lateral line
Lateral lines can be secured to the farthest tree is by looping the lateral around the trunk and attaching a hooked slide fitting on the lateral.
(Image source Shelburne Farms, n.d.)

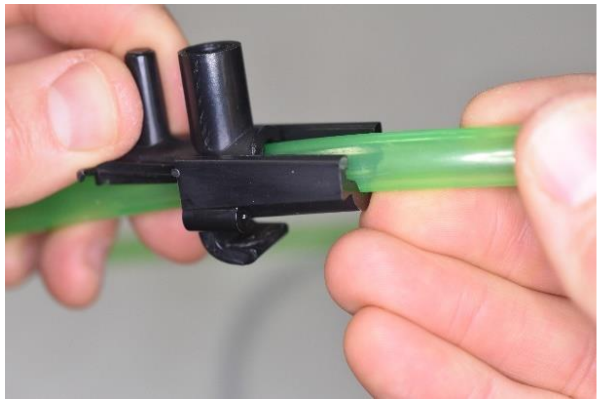

Figure 40 - Hooked slide fitting
(Image source Isselhardt, 2019)

Basic rules for lateral lines

- Lines should be as straight at possible.
- Lines must be suspended between two and five feet above the ground.
- Lines should be tight and run downhill to the mainline.
- Lines should pass against the outside of each tree. This prevents sagging.
-

Connecting fittings to lateral line

There are many different tubing fittings available that can be used on lateral lines. A selection of fittings and associated tools can be viewed in Appendix C Nearly all fittings have barbs or ridges where the tubing is attached. Tubing must be installed over these barbs so the fitting is tight, will not pull off, and will not leak. To install fittings a **tubing tool** is required that can grip the cut ends of the tubing in a small vise and push the tubing onto the fitting when the tool is closed (Chapeskie et al., 2006b).

Figure 41 - Two-handed tubing tool
A two-handed tubing tool being used to install splice in a dropline. (Image source Isselhardt, n.d.)

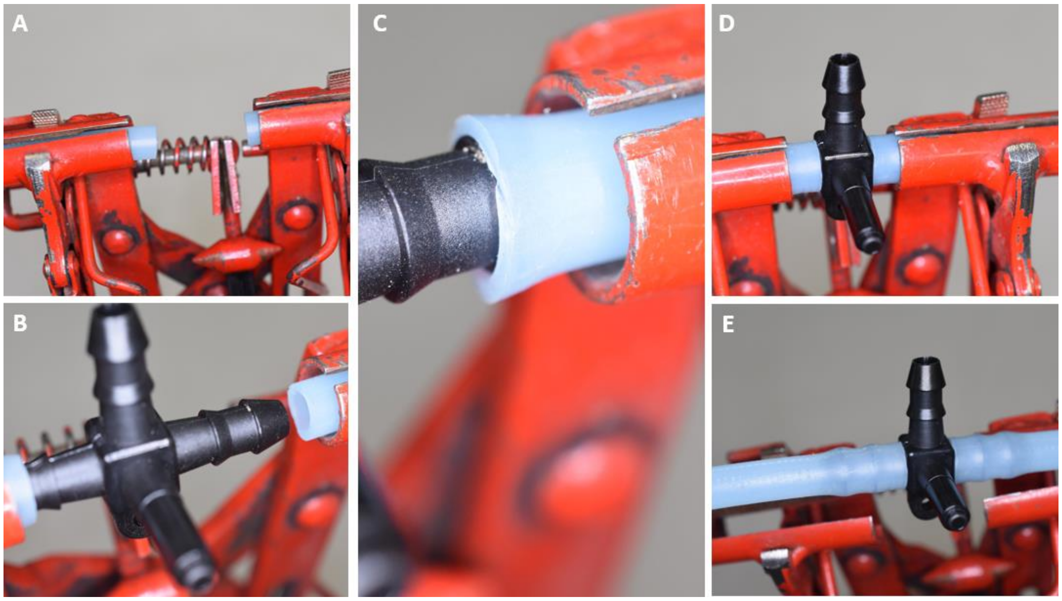

Figure 42 - Connecting fittings to lateral line
Step-by-step image attaching a lateral line tee using a two-handed tubing tool. (Image source Isselhardt, 2019)

Connecting lateral line to mainline

After the lateral lines are in place, they can be connected to the mainlines by installing **saddle manifolds**. Drill a hole in the mainline using an electric drill or a mainline punch, which makes a smoother hole than an electric drill. Drill slowly and do not go through the other side of the mainline tubing. The fitting should be placed directly over the hole and the rubber gasket laid flat on the mainline, this will help prevent vacuum leaks. Some manifolds have plastic ratcheted cuffs that can be closed using pliers. Others are secured with hose clamps or wire ties (Farrell, 2013). A hooked fitting is connected to the saddle with a short loop of tubing. This loop can be used to quickly check sap movement through the lateral line when searching for leaks (Chapeskie et al., 2006b).

Figure 43 - Connection between lateral line and mainline
(Image source Isselhardt, n.d.)

Installing droplines

Once the lateral line is in place the droplines are installed. Droplines connect the lateral line to the spout. Droplines are usually 24” to 30” long so the line can reach the taphole anywhere it is located on the tree. They can be installed with a two-handed tubing tool. This tool makes it easy to maintain tension in the lateral line. The dropline is usually connected to the lateral line with a tee (Chapeskie et al., 2006b). This connection should be placed 4 to 6 inches away from the tree. This avoids rodent damage and makes future replacement easier because the connection is not tight against the tree (Cornell Maple Program, 2015).

Figure 44 - Making a dropline
Using a one-handed tubing tool to make a dropline. (Image source Isselhardt, 2019)

Figure 45 - Dropline
Dropline attached to tree (Image source Wolfe, n.d.)

Using tubing without a vacuum pump

Tubing systems without vacuum pumps have some of the same advantages as tubing systems with vacuum pumps. They can save substantial time and labor compared to collecting sap in buckets or bags. If installed properly a closed tubing system without vacuum can still increase sap yield over tradition bucket or bag systems. **Natural vacuum** develops when sap fills the tubing and the sap in the tube pulls on a taphole. The weight of the sap draws a vacuum within the tubing as the sap and moves towards the mainline. Since air cannot enter the system the movement of sap though the lines create a vacuum at the taphole. Lateral lines should each have 10 to 15 taps and mainlines should be located about 250 ft apart. Lines should be straight, tight, and slope downhill (Chapeskie et al., 2006b).

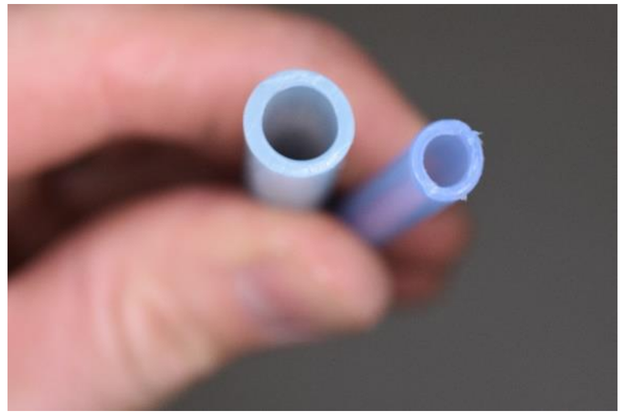

Figure 46 - Visual comparison of 5/16” and 3/16” tubing The larger 5/16” tubing is shown on left and the smaller 3/16” tubing is shown on the right. (Image source Isselhardt, 2019)

3/16 tubing

Tubing with an interior diameter of 3/16” has created new opportunities for producers. This smaller tubing has made it possible to create high natural vacuum in a gravity system. Vacuum is created in 3/16” tubing by gravity pulling the sap downhill and creating a siphon above. The high vacuum causes a sap to constantly flow into the tubing. Since the tubing is small it pushes out the suspended sap. In gravity systems 3/16” tubing outperforms 5/16” systems creating higher natural gravity and higher sap yields. Experiments are being conducted adding vacuum pumps to 3/16” tubing, testing if 3/16” tubing is more effective at moving sap uphill or pulling sap up from taps below the lateral line (Wilmot, 2014). Recent data indicates the potential for reduced sap yield from 3/16” tubing if certain sanitation issues are not addressed. It appears that restrictions and/or blockages can form in lateral lines and around tee fittings thereby impacting flow. Producers can limit the impact by using appropriate cleaning strategies and replacing fittings regularly (M. Isselhardt, personal communication, June 26, 2019).

Facts about 3/16” tubing

- Where there is an elevation change of 15+ feet and at least 6 to 10% slope 3/16” tubing increases sap yield in both gravity and mechanical vacuum systems (Childs, 2015).
- 15 taps are the ideal number for 3/16” gravity systems, but 4-5 taps can produce enough sap to create vacuum (Wilmot, 2014).
- Each inch of vacuum pressure increases at the tap it results in a 5-8% increase in sap yield.
- Taps near the top of the system have better vacuum than taps near the bottom of the system since the vacuum at the tap is directly related to the elevation drop (Childs, 2015).

Checking for leaks

A vacuum tubing system only works properly if it is tight and leak-free. There are three basic ways to locate leaks: (1) watch how the sap moves, (2) listen for leaks, and (3) use vacuum gauges. A gauge on the pump or releaser tells you what the vacuum level is at the bottom of your system. It is a straightforward easy way to tell if the vacuum is at the level it should be. With a wet/dry line system, vacuum gauges should be located at manifolds where mainlines branch off. With a conductor system, you can attach a gauge to a 3 ft piece of tubing that runs up the tree. This is connected to the mainline with a saddle manifold where the vacuum pressure can be checked. If gauges are not located in the sugarbush, valves at each mainline can be closed one at a time and the gauge at the pump or releaser can be checked to see if the problem was isolated (Wilmot, n.d.).

Some sugaring operations often have remote monitoring systems. These systems are available from several equipment manufacturers and work by sending vacuum readings from key points in the sugarbush to digital maps on computers or smart phones. The map displays where the leaks are located so sugarmakers can quickly go directly to the leak and fix it without having to search the entire sugarbush. Installing more sensors will allow for more precise leak detection but will also increase the cost to the producer.

Figure 47 - Air bubbles in tubing
A few slow-moving air bubbles in a lateral line are natural, but if there are lots of air bubbles and the sap is moving quickly there is an air leak somewhere up the line. (Image source Isselhardt, n.d.)

Sometimes the mainline can develop leaks. The mainline can develop leaks where animals peck or bite it and older mainlines can develop cracks. If mainline fittings are not put on correctly or put on with heat (using a propane torch to soften the line) the fitting can leak causing a significant drop in vacuum pressure. Sometimes older mainlines can develop cracks. Most leaks are located on the lateral lines. To locate them you need to watch the sap and listen. Sap movement can be easily observed where the lateral line attaches to the mainline. At this intersection there is a short loop of tubing where sap must move uphill for a short distance. At this loop the sap pools and should move slowly. In a leaking system air from outside the system is pulled into the tubing by the vacuum. This causes sap to look like it is moving rapidly through the tubing. The sap flutters, ripples, or moves back and forth. If you see this on a lateral line you know there is a leak somewhere above that point. Follow the lateral line away from the mainline towards the trees while sliding your hand along the lateral line and feeling for animal chews. At the first drop make a dip in the line so the sap is forced to run uphill. Watch to see if the sap is fluttering, if it is continue moving up the line in search of the leak. When searching for leaks you should also use your ears. Big leaks, like when a tap has fallen out of the tree, make a loud whistle. Small leaks are much quieter. As you search for the leak put your ear near the lateral line at a drop, T, or spout and listen for a soft hiss. If you find a leak in the lateral tubing, splice out the hole and put the tubing back together with a connector fitting. Leaks can also occur at the spouts. This can often be solved by giving a couple of gentle taps with a hammer to reseat the spout (Wilmot, n.d.).

Cleaning tubing

Tubing systems need to be cleaned at the end of the sugaring season to prevent the growth of microorganisms that can contaminate sap in future years. Cleaning removes uncollected sap and microbial growth. Currently there is no industry standard on the best way to clean tubing. One method to clean tubing is with a pressure washing system. Water under high pressure is mixed with air and pumped through the tubing. Only potable water should be used for cleaning the tubing. When cleaning tubing with a pressure washer you should start by first flushing the primary mainline closest to the collection tank, then the secondary mainlines, then the lateral lines (Chapeskie et al., 2006b). A second method is to wash the system from the top down. This can be done with both gravity and vacuum systems. In vacuum system the vacuum is left on during the cleaning process. The sugarmaker carries a container filled with clean hot water and sucks water through each tap as they are removed at the end of the sugaring season. In a gravity system water is injected through each tap. The water is then pulled down through the system by gravity or vacuum (Cornell Maple Program, 2015). A third method is to suck the lines dry under vacuum when pulling the spouts at the end of the season (Farrell, 2013).

Vacuum

Adding a vacuum pump to a tubing system can greatly increase sap production. The University of Vermont Proctor Maple Research Center conducted a study to see how vacuum effects sap yield per taphole. They discovered a strong correlation between the amount of vacuum and the amount of sap collected. In the study sap volume per taphole ranged from 5.0 gallons on one of the gravity (non-vacuum) trees to 32.9 gallons on one of the trees with a vacuum pressure of 25” Hg (Wilmot, Perkins, & van den Berg, 2007).

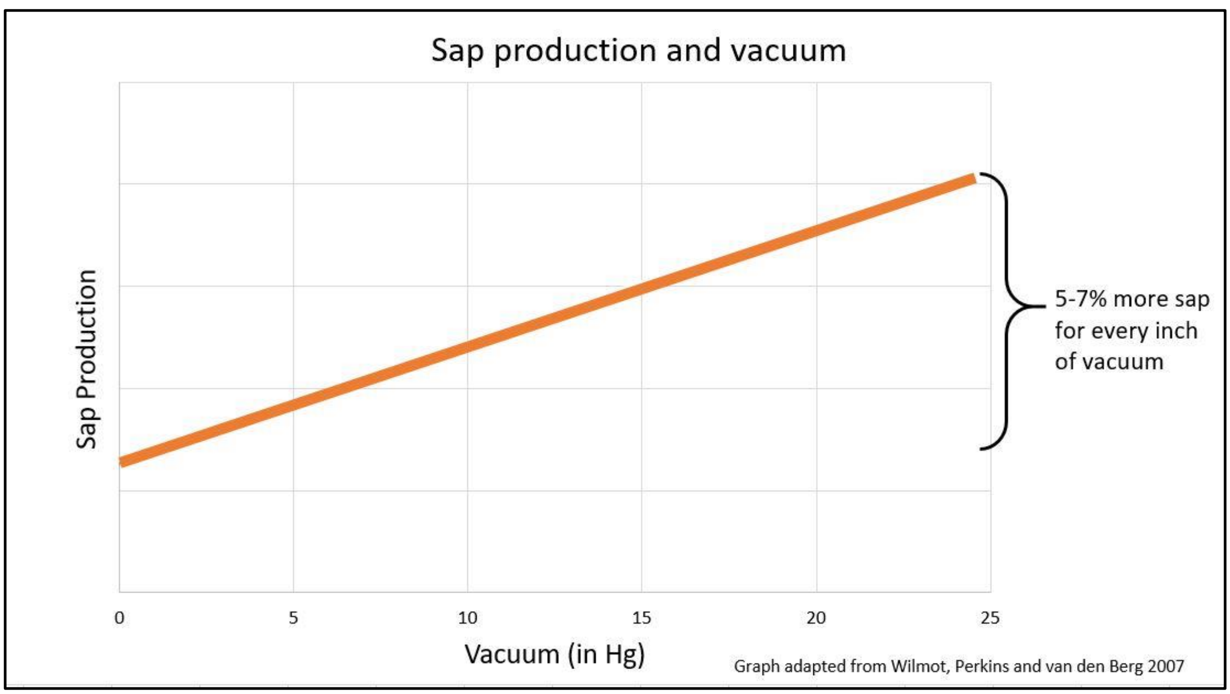

Figure 48 - Relationship between vacuum and sap yield
(Graph adapted from Wilmot, Perkins, & van den Berg, 2007)

Research has shown that a vacuum pump can increase sap yield by 5-7% for every Hg applied to the taphole. The impact of high vacuum sap extraction on the chemistry of sap has revealed no significant impacts to sugar or mineral concentrations. Additionally, the internal staining associated with a trees natural response to tapholes appears to be the same if vacuum or gravity sap collection is used (Wilmot et al. 2007). Gravity systems must rely on a natural freeze thaw cycle to create higher pressure within the tree than outside the tree, which allows sap to flow out of the taphole. When a vacuum pump is attached to a tubing system it removes air from the tubing and the taphole. This creates a difference in pressure between the inside of the tree and the tubing network causing sap to flow from areas of higher pressure within the tree to those of lower pressure near the spout. So even when temperatures are not ideal for sap flow sugarmakers with high vacuum can keep collecting sap (Farrell, 2013). The pump should be turned on anytime during the sugaring season when temperatures begin to rise and the sap is expected to flow. It is recommended to use a pump that can handle being on 24 hours a day 7 days a week. Once the pump is turned on it should not be shut off unless there are going to be many days in a row without the possibility of a thaw. Even then, many producers choose to leave their pumps on because the potential risk of missing a run or the beginning of a run would be costly (M. Isselhardt, personal communication, June 25, 2019).

A vacuum system has a vacuum pump and a mechanically or electrically operated releaser (also called an extractor) which transfers sap from the tubing into a collection chamber and then into a storage tank. The releaser maintains vacuum within the tubing system while this sap transfer is taking place (Chapeskie et al., 2006b). Between the vacuum and releaser is a moisture trap. Its purpose is to trap moisture in the vacuum line and protect the pump in case the releaser fails. Vacuum pumps are designed for air flow, not liquid, and if liquid flows into the pump it can damage it. Some pumps (dry or claw type pumps) are more susceptible to damage from moisture. Many vacuum pumps also have a pressure control valve. This valve allows you to set the vacuum pressure at the level that works well for your system. It allows the right amount of air to enter next to the pump to maintain steady vacuum (Cornell Maple Program, 2015). Many types of vacuum pumps exist including rotary-vane, piston type, and liquid-ring (Chapeskie et al., 2006b).

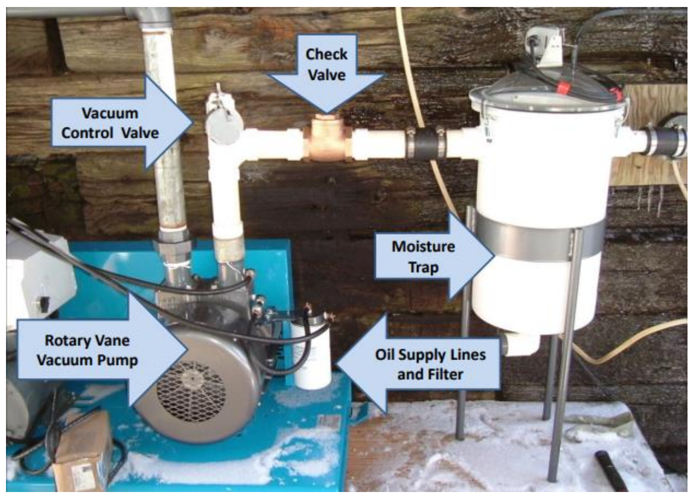

Figure 49 - Components of a vacuum pump
(Image source: Cornell Maple Program, 2015, p.40)

Sap releasers/extractors

A releaser collects sap from the mainlines and directs it to a collection tank without interrupting the vacuum. There are two types of releasers, mechanical and electrical. In a mechanical releaser sap collects in a chamber. When the sap fills the chamber, it triggers a release mechanism allowing the sap to push out through a flap and empty directly into a storage tank. Electric releasers have a liquid pump that removes sap from the collector to a storage tank. When the sap reaches a certain depth, a sensor turns on the liquid pump and the sap is pumped out of the releaser. It is important to have a vacuum gauge at the releaser (mechanical or electric) so you can monitor it and know if the system is operating properly (Cornell Maple Program, 2015).

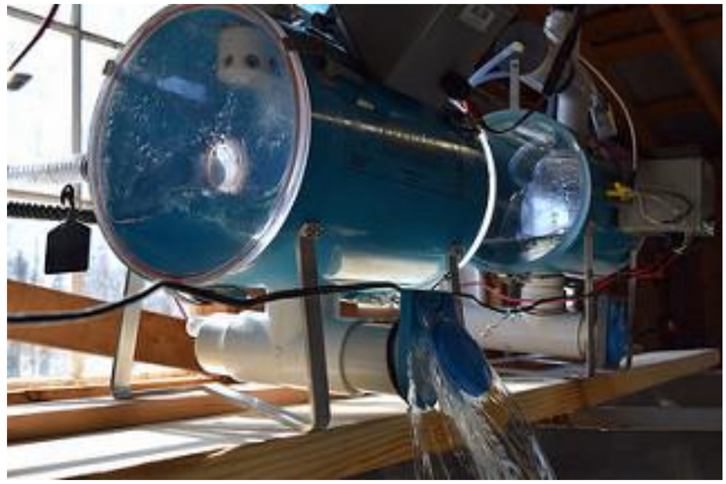

Figure 50 - Sap transferring from releaser to collection tank (Image source UVM Extension, n.d.)

Sap storage

Maple sap is perishable. Therefore, sap storage is an extremely important part of producing quality maple syrup. Storage systems have two main objectives: (1) hold sap until it can be processed and (2) supply a constant flow of sap to the **evaporator**. The proper amount of sap storage entirely depends on your specific operation. It is influenced by the number of taps, how quickly boiling can occur, the capacity of a **reverse osmosis** unit (if one is being used), and the size of your evaporator. It is important to have enough storage capacity to avoid running out of storage space during heavy runs. It is recommended that you have enough storage capacity for two good days of sap flow. On average this amounts to 2 to 3 gallons of sap storage per tap (Chapeskie et al., 2006b).

Careful planning is required when deciding where sap storage tanks should be located. Storage tanks are typically located at the lowest point of the sugarbush. This allows gravity to do the work of filling the tank. However, this is not always practical. If the lowest point is difficult to access or experiences flooding an alternative location should be chosen (Farrell, 2013).

Storage tanks must be constructed of food-grade material so they do not contaminate the sap and can be designed in such a way to allow for easy cleaning. Storage tanks should be placed in cool locations and away from vehicle exhaust, road dust or other potential contaminants. Tanks should not be stored in hot areas such as near the evaporator and sunny locations. When deciding where your tank should be placed it is important to consider ease of cleaning. Each time a tank is emptied it should be cleaned. At the end of the season it should be scrubbed, rinsed with a dilute bleach solution, and then triple rinsed with potable water (Chapeskie et al., 2006b).

Evaporator

Maple syrup not just concentrated sap that has had a lot of water removed. Sap can be concentrated in many ways, but there is only one way to make syrup and that is to boil the sap. Boiling concentrates the sugar in the sap through evaporation and it also provides heat for complex chemical reactions between **flavor** and color precursors naturally present in maple sap. This is what creates the distinct color and flavor of maple syrup (Rechlin, 2015). Evaporators (even efficient modern models) are relatively inefficient

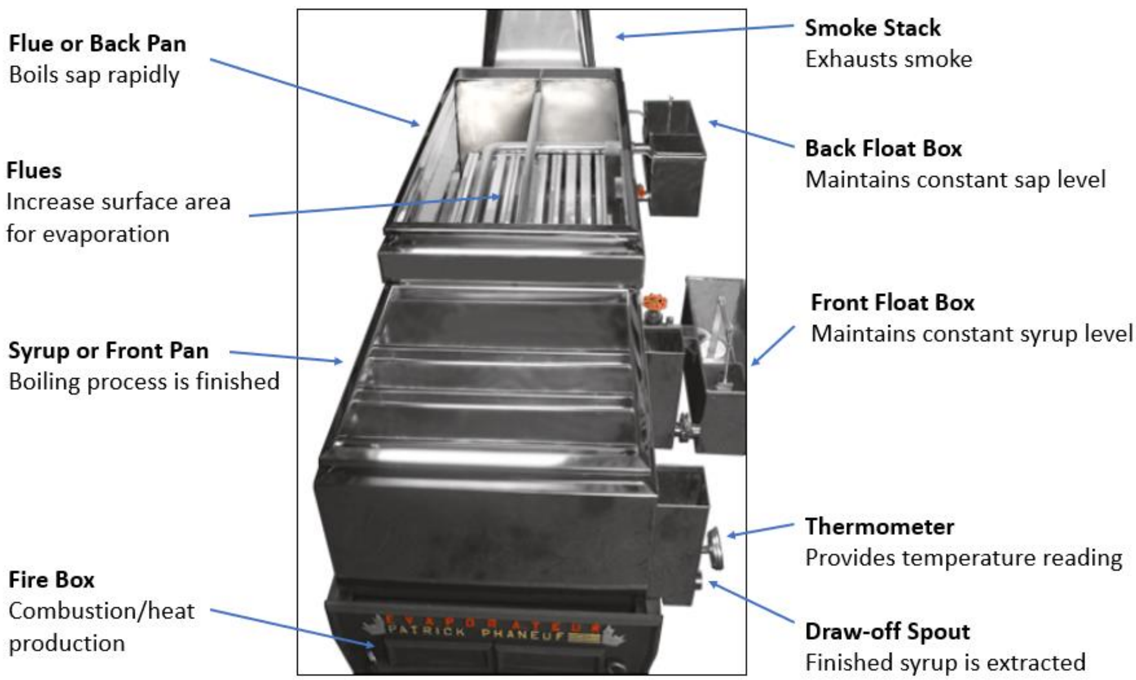

Figure 51 - Evaporator
Diagram depicting parts of an evaporator. (Image adapted from Townshend, n.d.)

Evaporators have a pan or pans that sit over an arch that contains heat. The heat fuel source can be in the form of wood, oil, natural gas, propane, or wood chips. This heat brings sap to a boil, evaporating the water and fueling the chemical reactions that develop flavor and color (Rechlin, 2015). Evaporators are designed to have a continuous flow of sap. Sap enters the evaporator through a valve or float box that helps regulate the liquid level. The sugar maker decides at what depth the evaporator should be run and adjusts the float accordingly. The deeper the depth the slower the evaporator will process sap. Boiling at a shallow depth increases the risk of burning pans.

Modern evaporators have four distinct parts: (1) the **arch** (also called a firebox), (2) the heat source, (3) the (also called the **flue** pan), and (4) the **front pan** (also called the syrup pan). Dividers are built into the pans to create channels that direct the flow of sap through the evaporator. Sap is forced to follow a winding path from the point of entry to the outlet. This prevents fresh sap from mixing with partially processed sap and creates a sugar concentration **gradient** throughout the pans (Stowe, Cook, Perkins, & Heiligmann, 2006).

The flue or back pan

The Flue is where the majority of the water is evaporated. It has deep fluted channels that increase the surface area and thus increases the rate of boil. Flue pans have a float box that controls the amount of sap entering the pan. Flue pans sit on the arch behind the syrup pan. There are two types of flue pans (1) **drop flue** and (2) **raised flue**.

Drop flue – The sap pan has flues that run lengthwise. Flues are below the level of the top of the arch. Heat runs directly between the flues on its way out the smokestack. Drop flues have one float box that controls the level of sap in both the flue and the syrup pans. Flue ends are closed which can allow **sugar sand** (also known as **niter**) to become trapped. For a more detailed description of sugar sand see page 50.

Raised flue – The sap pan has flues that are above the top of the arch. The sap level is several inches higher than the liquid in the syrup pan. A raised flue has two float boxes, one to control the level of the sap in the flue pan and a second to control the flow of sap from the flue pan to the syrup pan. Flue ends are open allowing sap to move out of the flue ends and helps minimize collection of sugar sand (Stowe et al., 2006).

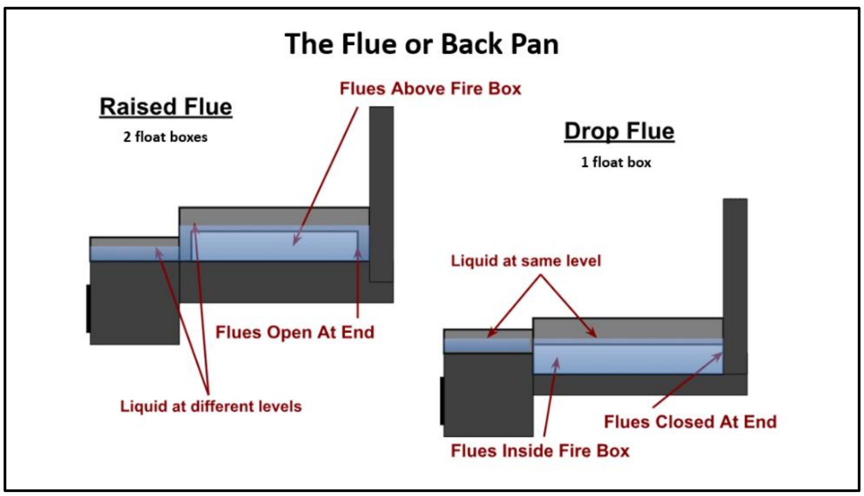

Figure 52 - Styles of flue pans
Evaporator diagram shows two styles of flue pans, a raised flue and a drop flue.
(Image adapted from Townshend, n.d.)

The syrup pan or front pan

Syrup pans have flat bottoms and dividers built into the pan to channel the boiling sap as it increases in concentration. There are two types of syrup pans (1) **reverse flow** and (2) **cross flow**.

Reverse flow – channels are oriented front-to-back. These pans have two draw-off valves, one on each side. This feature was developed to reduce sugar sand build up. Sugar sand is produced anywhere in the evaporator during the boiling process, but the greatest amount of sugar sand accumulates in the syrup pan channel nearest the draw-off because this is where the sugar concentration is the highest. By reversing the flow in the syrup pan and drawing off from alternating sides it reduces the accumulation of sugar sand and extends the time a pan can be used before it needs to be cleaned.

Cross flow – channels are oriented side-to-side. In this design the syrup pan is two separate pans that are connected by pipes. These pans can be rotated frequently so a clean pan can be switched for a sugar sand coated pan (Stowe et al., 2006).

The gradient

When the evaporator is first started there is no concentration gradient. All the liquid in the pans have the same sugar concentration. As the liquid heats and water is evaporated from the sap the sugar concentration, and thus the **density**, increases. As boiling occurs and the level of the sap within the evaporator drops, more sap is drawn into the flue pan through a float valve. This raw sap or RO **concentrate** will keep the sap near the inlet at roughly the same concentration. The partially boiled liquid (also known as sweet) further away from the inlet does not have the same chance to be diluted and therefore becomes more concentrated. As the gradient develops the sweet located near the draw-off spout of the syrup pan is the most concentrated and has been in the pan the longest (Stowe et al., 2006).

When the evaporator is shut down the remaining liquid cools and mixes together causing the concentration gradient to disappear. At the end of a boiling session sugarmakers save some “sweet” (sap from the front pan that has been boiled and is almost at the syrup stage) to pour back into the front pan the next time the evaporator is started. This helps establish the proper gradient (Rechlin, 2015).

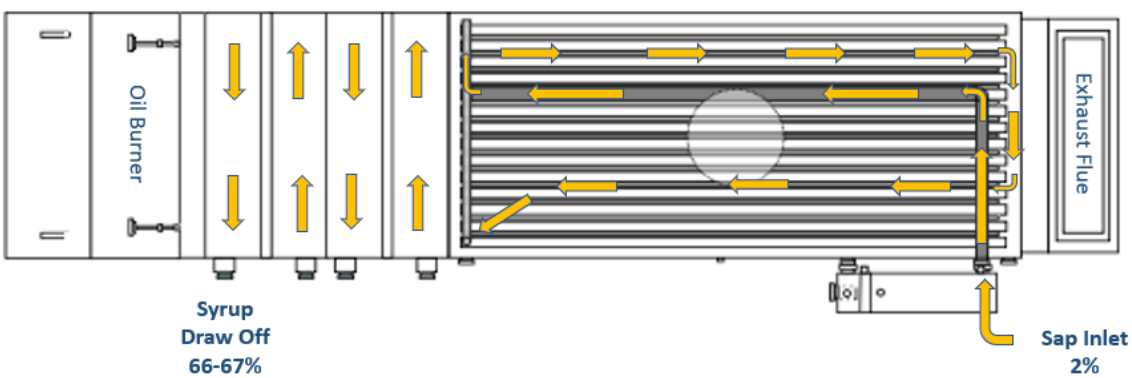

Figure 53 - Diagram of sugar concentration gradient in evaporator
Image shows flow of sap through the evaporator channels as a concentration gradient develops. Sugar concentration is reported at the sap inlet and syrup draw off.
(Modified Image source North American Syrup Producers Manual p.130)

Reverse osmosis

Membrane concentration of sap, commonly referred to as Reverse osmosis (RO) has greatly changed the sugaring industry over the past 30 years. RO machines allow sugarmakers to separate a large amount of water from sap before boiling. A RO unit pumps sap through a membrane to remove most of the water molecules, thus concentrating the sap. This is a very efficient process that greatly reduces the amount of time and fuel a sugarmaker needs to make maple syrup. Sugarmakers can reduce their boiling time by 75 to 85% (Farrell, 2013).

A RO works by using a high-pressure pump to force sap against a semi-permeable membrane. Water molecules are small enough to make it through the tiny pores in the membrane (0.0001 micron for a typical membrane) and come out of the RO as **permeate**. The sugar molecules, minerals, and other biological organisms in the sap are too large to fit through the pores of the membrane and come out the RO as concentrate. When the pressure is turned up more water is forced through the membrane and the sugar and minerals become even more concentrated (Farrell, 2013). High **brix** RO units can concentrate the sugar content from 2% to 40%. The ability to concentrate sugar content has led to greater use of red maple in addition to sugar maple. Other advantages of RO technology are that it reduces the holding time for unprocessed sap and shortens the time during which sap is processed at high temperatures, this results in higher quality syrup (Stowe et al., 2006). The permeate byproduct is essentially pure water and is extremely useful. Producers that us a RO should have a separate storage tank for permeate. Since permeate lacks minerals it is the best product for cleaning the RO, evaporator pan, and other equipment.

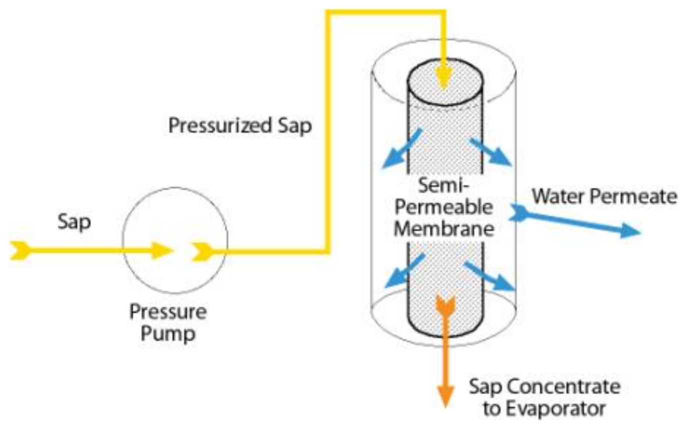

Figure 54 - Reverse osmosis semi-permeable membrane
Simplified diagram of how pressurized sap is run through a semi-permeable membrane to separate a large amount of water from sap. (Image source USDA, 2016)

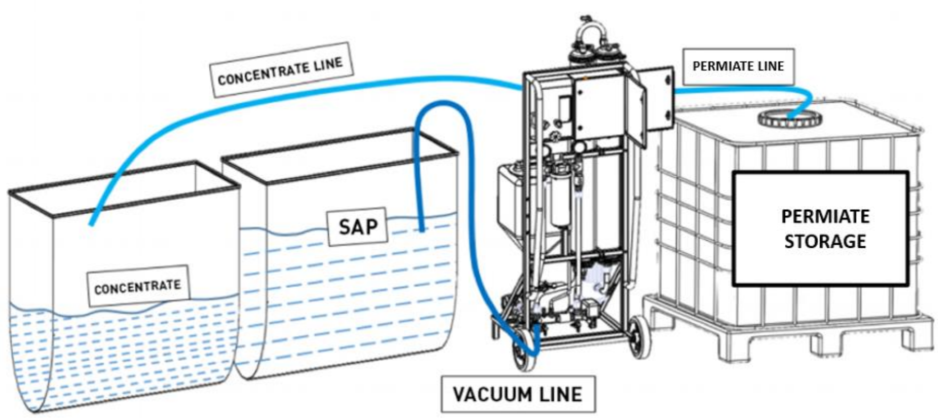

Figure 55 - Reverse osmosis machine
Diagram demonstrating reverse osmosis machine and storage tank system. (Image source CDL, 2018)

Operating the evaporator

Before "firing up" and operating the evaporator there are several systems that must be checked to make sure the evaporator will function properly. There are details specific to the equipment/system that has been installed in a sugarhouse, but the general principals are similar. Below is list of things that should be checked prior to and while operating the evaporator:

- Level the evaporator – The evaporator pans must be level before adding sap. If they are not the sap will be uneven and the pan could be burned
- Sap supply to evaporator – Make sure the sap quantity is sufficient to maintain the proper sap level in the evaporator at full boil and the **feed line** is functioning properly
- **Flooding the evaporator** – If the evaporator has not been used recently make sure it is clean of dirt, dust, and other debris. Flood the pans with sap until the bottom of each pan is covered with 1 inch of sap (the exact depth will vary depending on the type of evaporator and if a RO machine is used).
- Firing the evaporator – When the proper level of sap is in the pans heat can be applied. The way to properly start the evaporator depends on the type of fuel you are using
- Boiling – When the sap begins to boil and water evaporators a sugarmaker must monitor the level of sap in the evaporator. Float levels should be monitored and adjusted when necessary to maintain the proper sap level (Stowe et al., 2006).

Foam

As sap boils in the evaporator it can produce a considerable amount of foam. It is important to minimize this foam. If there is too much foam it can bubble over the sides of the evaporator, interfere with the concentration gradient between the channels in the pans, burn the pan if all the sap turns to foam, and insulate the boiling sap thus preventing the steam from escaping. Keeping all the equipment as clean as possible will help reduce the amount of foam, but foam is something that every sugarmaker must learn to manage. Sugarmakers can use **defoamers** sold by maple equipment companies or various oils. The most common defoamer is called Atmos 300K and is very effective at managing foam in a maple evaporator. If the operation is certified organic the defoamer needs to be a certified organic vegetable oil such as safflower oil or sunflower oil that will not impart an off-flavor to the syrup. Organic defoamers do not work as well as conventional defoamers. When using an organic defoamer the sugarmaker must be careful about where and when they are adding the defoamer because it can impact the syrup flavor. Dr. Abby van den Berg at Proctor Maple Research center is currently working on a project to develop an effective organic defoamer. Sugarmakers need to make sure they don't use a defoamer such as peanut oil that could cause an allergic reaction to the consumer. Regardless of what type of defoamer is chosen it must be used correctly. A very small amount of defoamer should be used and it needs to be applied frequently. Sugarmakers should put in a couple of drops at regular intervals to keep the foam in control. Some large evaporators have automatic defoamers (Farrell, 2013).

Sugar sand or niter

As sap boils and the sugars become concentrated so does the minerals found in sap. Chemical reactions occur in the liquid sap that cause the minerals to form a solid, the solid is called the precipitate. The minerals that precipitate out of solution as the sap gets concentrated is called sugar sand or niter. Niter needs to be cleaned from the pan on a regular basis. If the niter is not cleaned it can form a thick layer on the bottom of the pan and create off-flavor syrup or even burn the pan. Some front pans have two points of entry and exist so the sugarmaker can switch sides when the niter starts to build up. Other operations have multiple front pans so when niter starts to build up that front pan can be switched out for a clean one (Farrell, 2013).

Figure 56 - Niter
Image of niter that will build up on the bottom of the pan if not cleaned regularly (Image source Isselhardt, 2019)

Drawing off

Finished syrup has minimum of 66% sugar and measures 66 to 66.9°Brix with a **hydrometer**.

Sap becomes syrup 7.1°F above the boiling point of water. This is not as simple as it sounds because the boiling point of water changes depending on location and can even change throughout the day due to changes in weather patterns and atmospheric pressure. The right temperature to draw-off can range from 215 to 220°F depending on elevation and barometric pressure (Farrell, 2013). Sugarmakers determine when to draw-off syrup based on temperature and then check the syrup using a hydrometer (Rechlin, 2015).

Figure 57 - Drawing off finished syrup from the evaporator (Image source UVM Extension, n.d.)

Hydrometer

A hydrometer is a specially made glass tube with a weighted bottom and has a calibrated scale (Brix or Baume) (Marckres, Heiligmann, & Koelling, 2006). A hydrometer measures the density, of syrup. The **Brix scale** measures the percent of sugar in a pure sugar solution. The **Baume scale** represents the percentage in a salt solution. Density is temperature dependent. When a liquid is heated the molecules absorb energy which causes them to move faster. Fast moving molecules bounce off each other and take up more space. As a result, hot liquids are less dense than cold liquids because colder molecules move slower. IT IS CRITICAL TO MEASURE THE TEMPERATURE OF THE SYRUP RIGHT BEFORE FLOATING THE HYDROMETER. NOT KNOWING THE SYRUP TEMPERATURE WILL LEAD TO SYRUP THAT IS OUT OF GRADE AND COULD SPOIL OR PRODUCE SUGAR CRYSTALS.

Syrup hydrometers have two red lines to indicate the density of finished syrup. The first red line is the **hot test** (211°F) the second red line is the **cold test** (60°F) (Rechlin, 2015).

Hydrometers are calibrated to provide a reading when the syrup is at specific temperatures. However, when you measure the sugar content of syrup it can be much hotter or colder than the hydrometer calibration. When the hydrometer is placed in hot syrup it will provide a lower than actual brix reading because the syrup is less dense. If you open a barrel of cold syrup (below 60°F) the hydrometer will provide a higher apparent brix reading. To solve this problem table 6 is used by sugarmakers to determine the actual **syrup density** based on the hydrometer reading and current temperature of the syrup. To use the table all a sugarmaker needs to do is take the hydrometer and temperature reading at the same time and view the conversion chart to get the actual brix or baume of the syrup (Farrell, 2013). If the reading is higher than the number on the table, the syrup is "heavy" and needs to be diluted. If the number is lower than the number on the table, the syrup is "light" and needs to be boiled longer.

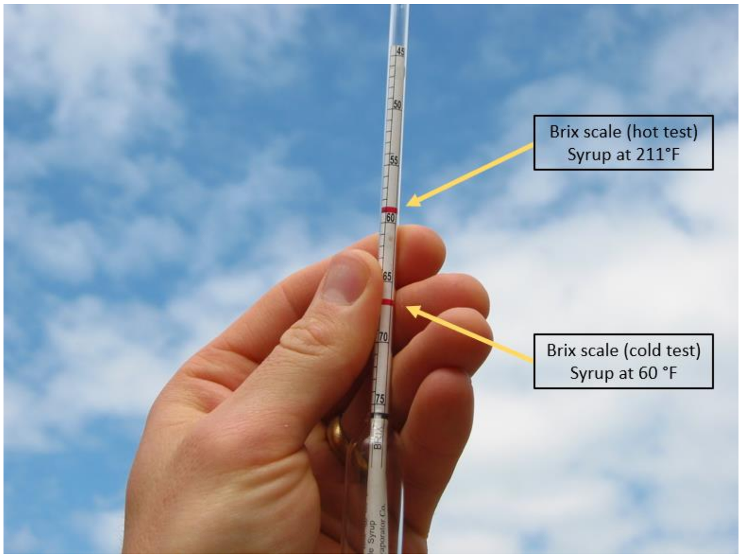

Figure 58 – Hydrometer
Hydrometer showing the red lines that represent the hot test and cold test. (Image source UVM Isselhardt, n.d.)

Table 6 - Temperature conversion chart for maple syrup

209° F	Baume 32.00	Brix 59.0
202° F	Baume 32.25	Brix 59.6
193° F	Baume 32.50	Brix 60.0
185° F	Baume 32.75	Brix 60.4
176° F	Baume 33.00	Brix 60.9
167° F	Baume 33.25	Brix 61.4
158° F	Baume 33.50	Brix 61.8
149° F	Baume 33.75	Brix 62.3
140° F	Baume 34.00	Brix 62.8
130° F	Baume 34.25	Brix 63.3
120° F	Baume 34.50	Brix 63.8
110° F	Baume 34.75	Brix 64.3
100° F	Baume 35.00	Brix 64.8
90° F	Baume 35.25	Brix 65.4
80° F	Baume 35.50	Brix 65.9
70° F	Baume 35.75	Brix 66.4
60° F	Baume 36.00	Brix 66.9
50° F	Baume 36.25	Brix 67.4

Example: If the syrup temperature is 202°F and the hydrometer floats at 59.6 Brix or 32.25 Baume the syrup is the correct density.

How to use a hydrometer

- Heat hydrometer cup with hot syrup before using it to take a hydrometer reading.
- Fill the hydrometer cup with syrup 1-2 inches from the top.
- Place hydrometer cup on level surface.
- Slowly lower the hydrometer into the syrup until it is floating on its own. Note: Do not drop the hydrometer into the syrup, it is fragile and can shatter.
- Take a temperature reading at the same time as the hydrometer reading.
- Read the hydrometer once it has stopped bobbing.
- At 211°F use the top red line (hot test). If the syrup is even with the top red line the density is correct. If the syrup is below the red line it is “heavy” and needs to be diluted. If the syrup is above the line it is “light” and needs to be boiled longer.
- At 60°F use the bottom red line (cold test).
- If a reading is taken at any other temperature use the conversion chart to determine the correct brix or baume reading (CDL, n.d.).

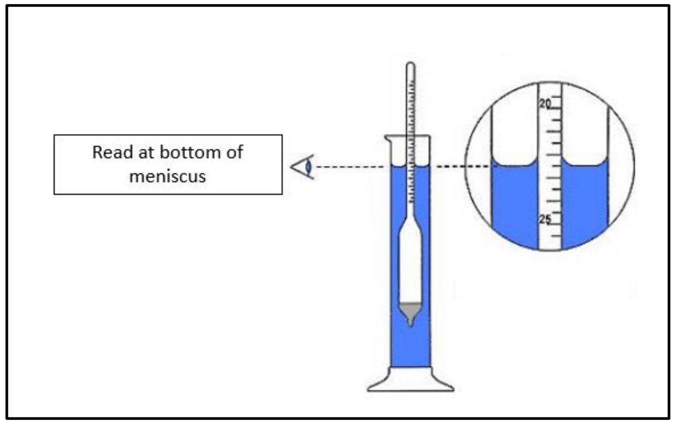

Figure 59 - Reading a hydrometer
The hydrometer should be read at the bottom of the syrup meniscus. (Image source CDL, n.d.)

Syrup at 66°Brix (or 66.9°Brix in Vermont) is not only the legal limit, but when syrup is stable. If the brix level is higher the syrup will form sugar crystals. If it is lower the syrup can mold.

Figure 60 - Using a hydrometer
Placing hydrometer in a hydrometer cup to test the density and determine if it is syrup.
(Image source Shelburne Farms, n.d.)

Refractometer

A **refractometer** is another tool that can be used to measure the density of syrup or sap. It works by measuring the refractive index of a solution, which is related to the amount of dissolved solids (in this case primarily sugar) in a solution. The solutes cause light to scatter. The greater the amount of solutes present the more scattering that occurs. Refractometers should not be used to measure syrup density right off of the evaporator or **filter press** because it can give an inaccurate reading if the syrup is too hot, the instrument is too cold, or the two are significantly different. Refractometers must be calibrated with distilled water or similar if accurate readings are to be obtained.

How to use an optical refractometer:

- Place a drop of sap or syrup on the small window at the end of the refractometer
- Hold the eyepiece up to your eye
- Read the density of the solution. It is indicated by a dark shadow appearing against a background scale.

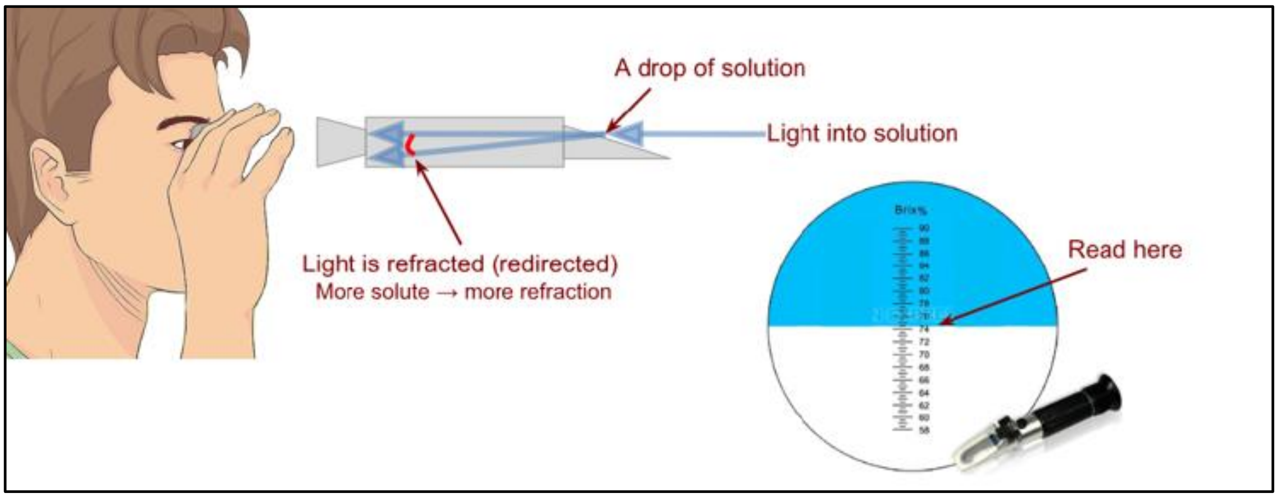

Figure 61 - Reading a refractometer
Demonstration of how light is a refracted and how to read a refractometer.
(Image adapted from Townshend, n.d.)

Filtering syrup

When syrup is removed from the evaporator some niter or sugar sand is suspended in the syrup. Niter is made of calcium and magnesium salts of malic acid. The salts form during the evaporation process. Niter can vary in appearance from a dark oily substance to a light fine-grained material that looks like beach sand, hence the name sugar sand. Niter can make the syrup look cloudy, darker in color, have a gritty texture, and cause off-flavors. If syrup is sold the suspended particles, niter, must be removed to meet the mandatory legal syrup grading requirements. Niter can be removed by filtering finished syrup with a **gravity filter** or a pressure filter (Marckres et al., 2006). Filtering works best when the finished syrup is very hot, so it should occur right after it comes out of the evaporator (Farrell, 2013).

Gravity filters

Figure 62 - Flat gravity filter
(Image source Shelburne Farms, n.d.)

As the name implies gravity filters use the natural force of gravity to move finished syrup through a wool or synthetic felt material that removes the suspended particles. As hot syrup passes through the filter the suspended particles are removed and collect on the filter. Gravity filtration is slow because as the material collects on the filter it reduces the flow of syrup and can eventually clog the filter. Filters can be washed and reused. Gravity filters are used by many small-scale sugarmakers. Cone filters and flat filters are the most common gravity filtering systems.

Caring for gravity filters:

- Sugar sand should be carefully scraped from used filters.
- Hot water should be sprayed from the syrup side to the sugar sand side.
- After all the sugar sand is removed the filter should be allowed to air dry.
- Filters should not be twisted because it can break some of the fibers.
- New filters should be rinsed multiple times with clean, hot water before use. When the rinse water no longer contains suds or chemical taste the filters are ready for use. If they are not rinsed, they may create off-flavored syrup.
- Do not clean with chlorine bleach or detergents.
- Make absolutely sure the filters are dry before storage or mold can grow and damage syrup flavor
- In the off-season filters should be stored in a clean dry place that is protected from rodents and insects (Marckres et al., 2006).

Pressure filters

In pressure filter systems syrup is forced through a filtering medium under pressure from a pump. The filtering medium is filter paper or cloth used with **diatomaceous earth**, commonly called DE or filter aid. It is very important to use food-grade DE that is meant for filtering syrup. Pressure filters are much faster than gravity filters. There are two types of pressure filters, a filter press (also called a plate filter) and a canister filter.

Filter press – A filter press is composed of a filter press frame, end plates, filter plates, a pump, and a pressure gauge. There are two types of filter plates, frame plates (or cake) and backer plates (or waffle). Frame plates have an open area in the center where DE collects. Backer plates are solid with a waffle texture. Some backer plates are now made with stainless steel screens. When the press is put together the frame plates and backer plates alternate dividing the press into a multiple filter compartment. Filter paper is placed between each filter plate and acts as a barrier to hold the DE in the frame plates.
How a filter press works:

- Diatomaceous earth is mixed into hot syrup and then pumped into the press.
- Syrup flows into the press. Diatomaceous earth “cakes” are formed in the frame plates.
- Syrup flows through the diatomaceous earth cakes and the adjacent filter papers. Suspended particles and DE in the syrup are removed gradually increasing the size of the cakes.

- Syrup flows into the adjacent backer plates and exits the compartments through the holes in the plates (Marckres et al., 2006).

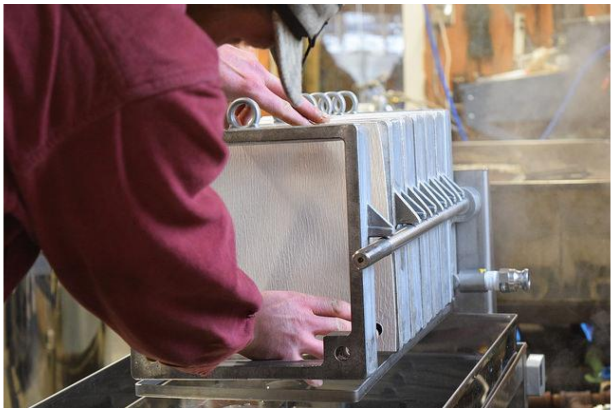

Figure 64 - Components of a plate filter press
The components of a plate filter press include the filter press frame, end plates, filter paper, backer plates, and frame plates. Many of these components are visible in the photograph as a sugarmaker puts the filter press together in preparation of filtering a batch of syrup.

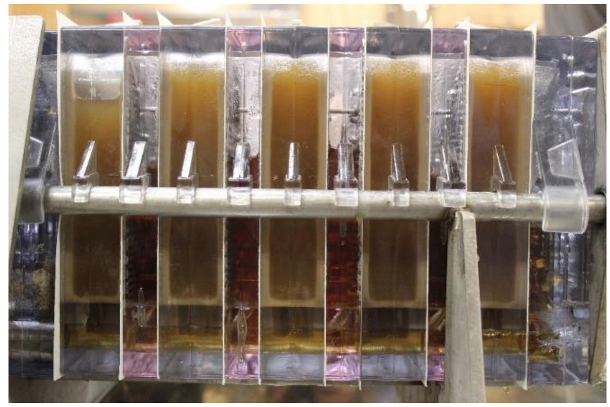

Figure 63 - Clear filter press
When a filter press is constructed from clear material it is easy to view the filter compartments and the filtering DE "cakes" that form in the frame plates. (Image source Shelburne Farms, n.d.)

Shutting down evaporator

At the end of a boiling session when it is time to shut down the evaporator it is important not to damage the pans. Residual heat is maintained in the arch of wood or oil-fired evaporators even after the evaporator is "shut down." If the sap level is too low, the pan can burn. To prevent potential damage 3 to 5 inches of sap should remain in the pans when the heat source is removed. If the sugarmaker does not have enough sap the pans can be flooded with mineral free water or permeate to prevent the pan from burning (Stowe et al., 2006).

Cleaning evaporator

The evaporator needs to be cleaned at the beginning of the sugaring season, usually during the season, and at the end of the season. At the beginning of the season before sap enters the pans the evaporator needs to be washed out or water can be boiled in the evaporator. This removes dust, dirt, bugs, etc. that have collected in the evaporator during the off-season. The evaporator will need to be cleaned during the season between runs to prevent/remove build-up of niter, remove soot that has accumulated on the underside of the pans (more common in wood-fired evaporators), or prevent old sap from spoiling fresh sap if there has been a long stretch between boiling sessions. Niter build up in the front pan requires the most attention. It is best to clean niter frequently to avoid thick deposits.

How to clean niter from pans:

- If niter build up is moderate boil permeate or water in the pans to loosen the niter. Scrub remaining niter with a stiff nylon brush, Teflon pad, or similar equipment. Do not use steel wool, wire brushes, or other cleaning equipment that can scratch the surface of the pan.
- For thicker niter build up some producers use a dilute water vinegar solution. Bring the solution to a boil and let it sit in the pan for 12 to 24 hours. Scrub the remaining niter with the equipment described above.

- For thick niter deposits acid chemical cleaners can be used on the pans. Chemical cleaners specific for maple equipment is sold by equipment dealers. When using chemical cleaners follow the recommendations for mixing and safety guidelines. Add the specified amount of acid to water to make a diluted solution. Warm the solution in the pan to 140°F to 160°F. Let the solution sit in the pan. Follow the label recommendations to determine how long the solution should sit. Scrub the sides and bottom of the pan as needed. When the evaporator is clean drain the acid solution and rinse the pan several times with mineral free water such as permeate. A baking soda should be used as the first rinse to neutralize the acid solution (Stowe et al., 2006). Most concentrated acid pan cleaners contain large amounts of phosphorous so producers should try to limit the amount of acid used for cleaning.

Vermont sugar house certification program

The Vermont Maple Sugar Makers' Association is working on enhancing the voluntary sugarhouse certification program that was originally developed 4 years ago in partnership with the Vermont Agency of Agriculture, Food and Markets. This certification examines sugarhouse operations for food safety measures. Even though pure maple syrup is considered a low risk food, it still has the potential to be contaminated during the production process. Enrolling in the sugar house certification program and/or developing a food safety plan can maintain high-quality production and reduce risk. The VMSMA sugarhouse certification program uses a scoring sheet to evaluate equipment and procedures used when producing maple syrup such as sanitation practices, buildings, containers, filters, food allergens, food contact materials, etc. A sample of the sugaring operations certificate score sheet can be viewed in Appendix D. ***An updated scoresheet is currently being developed and the scoresheet in Appendix D is no longer applicable. Unfortunately, the new one is not yet finalized.*** The scoresheet is intended to help sugarmakers evaluate practices and highlight activities that can be done to ensure maple syrup meets high standards for food safety.

Jones Rule of 86…or is it 88.2?

The “**Jones Rule of 86**” was developed so sugarmakers could figure out how much sap is required to produce a gallon of syrup. It is a simple formula where 86 is divided by the sugar content in the sap to get the number of gallons of sap needed to make one gallon of syrup.

Revised rule

The Rule of 86 was developed many years ago before sugarmakers used calculators and smartphones. At that time the legal standard for syrup was 65.5° brix. Today the legal minimum for syrup in Vermont is 66.9° brix in most other states it is 66° brix. To get the required higher sugar concentration more water must be boiled off, meaning the Rule of 86 is no longer accurate. This rule was also developed when everyone boiled raw sap. Today many producers boil sap that has been concentrated through reverse osmosis machines. The original Rule of 86 underestimates production of syrup for concentrate. For syrup that is produced at 66.9° brix you should use the Rule of 88.2 and for syrup produced at 66° brix you should use the Rule of 87.1.

The Rule of 88.2

$$\text{Gallons of sap to make one gallon of syrup} = \frac{88.2}{\text{Sugar content}}$$

It can also be written as S = 88.2 ÷ X
"S" is the number of gallons of sap needed to make 1 gallon of syrup
"X" is the sugar content (percent sugar in the sap measure as °Brix)
88.2 is a mathematical constant that represents the percent of solids (mostly sucrose) that are in a gallon of syrup.

The number of gallons of water that must be evaporated from sap to get 1 gallon of syrup can be calculated by subtracting 1 from the above equation
W = (88.2 ÷ sugar content) – 1
"W" is the amount of water being boiled off to produce 1 gallon of syrup

Examples:
1) Sap is found to have a 2.5% sugar content. How much sap is required to make 1 gallon of syrup? How much water will be boiled off to produce 1 gallon of syrup?
S = 88.2 ÷ 2.5 → S = 35.3 gallons
W = (88.2 ÷ 2.5) – 1 → W = 35.3 – 1 → W = 34.3 gallons

2) Sap is found to have 1.8% concentration. How much sap is required to make 5 gallons of syrup?
S = 88.2 ÷ 1.8 → S = 49 gallons of sap to make 1 gallon of syrup
49 X 5 → = 245 gallons of sap

3) If you have 5000 gallons of 2.1% sap, how much syrup would that make?
S = 88.2 ÷ 2.1 → S = 42 gallons of sap to make 1 gallon of syrup
5000 ÷ 42 = 119 gallons of syrup

Syrup grading

Vermont adopted the harmonized grading system for pure maple syrup after more than 10 years of discussion, review and refinement. If syrup meets the standard in the four basics (color, **clarity**, density and flavor) it can be labeled as grade A pure maple syrup.

Within the label of Grade A pure maple syrup four maple grades exist: (1) golden color with a delicate taste, (2) amber color with a rich taste, (3) dark color with a robust taste, and (4) very dark color with a strong taste.

Figure 65 - Maple syrup grades
Image demonstrates the four different maple syrup grades. Golden/delicate has a light transmittance of 100-75%, amber/rich is 4.9-50%, dark/robust is 49.9-35%, and very dark/dark is less than 25%. (Image source Isselhardt, n.d.)

Maple **syrup grades** as described by the Vermont Maple Sugar Makers' Association:

- Golden with delicate taste – Light, golden color with a mild, delicate taste. Excellent as table syrup or over ice cream or yogurt.
- Amber with rich taste – A light amber color and full-bodied flavor, this class of syrup is the product of choice for consumers who desire the classic maple syrup flavor.
- Dark with robust taste – A dark amber color with a more pronounced maple flavor, this class will satisfy those consumers who desire the strong flavors of what has been known as Grade B.
- Very dark with strong taste – Nearly black, this syrup has a strong flavor that translates well to cooking, where the maple flavor will carry through to the finished dish.

Maple syrup must meet strict standards and is graded on four characteristics, color, clarity, density, and flavor. A maple grading flow chart produced for the Vermont Farm Show is located in Appendix E and can be used as a guide to help grade syrup

Color – Color is one of the most distinguishable characteristics of maple syrup. Color grading should be done only after density and clarity are correct. A known set of standards determines color grade, either a comparator kit or a spectrophotometer which measures the percent of light that passes through syrup. When using a comparator kit, the grade of syrup in question is determined by comparing its color to a set of standard color grades. Colored standards are the darkest color a particular syrup sample can be and still be in that grade. So, a syrup sample must be as light or lighter than the low end of the color grade in which it falls. Not whichever grade it appears closest to. When color grading, use the syrup sample container provided with the kit. Move the syrup in question next to each standard to determine what grade the syrup sample is. There are two types of comparator grading kits, **permanent comparators** which contain glass or plastic colored plates as the color standards, and **temporary comparators** that have glycerin solutions in bottles as color standards. The colored plates in permanent kits do not fade. The color of the solution in temporary kits does fade over time. Temporary kits need to be checked or replaced annually. When not in use temporary kits should be covered and stored in a cool dark location. Temperature impacts color grade so syrup should be graded when it is room temperature. Syrup color will darken over time, which is why it is very important that the syrup is as light or lighter than the color grade it falls in (Marckres et al., 2006).

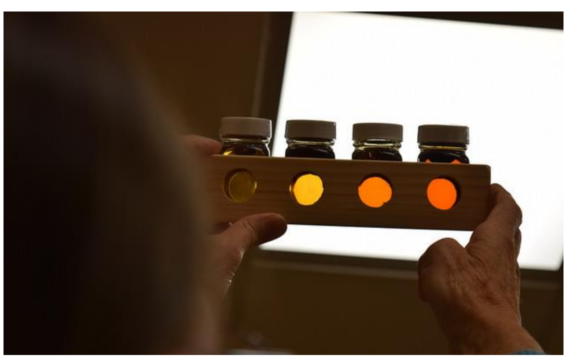

Figure 66 - When using comparator kits make sure you are in an area that well illuminated with direct, natural light. (Image source Isselhardt, n.d.)

Figure 67 - Impact of using an old temporary grading kit The color of the glycerin solution in temporary grading kits can fade over time. In this photograph the sample from 2014 is significantly lighter than the sample from 2018. Using an old temporary grading kit can cause a sugarmaker to incorrectly grade their syrup. (Image source Isselhardt, 2018)

Clarity – Clarity refers to how clear the syrup is. As discussed previously in the manual a small amount of minerals is naturally found in sap. As sap concentrated into syrup during boiling the minerals are also concentrated and become suspended. Suspended solids make syrup cloudy and must be filtered out and have no air bubbles before syrup is packaged for consumer purchase. If syrup is cloudy it can influence the perceived color grade of the syrup. When grading, clarity is determined visually (Marckres et al., 2006). The style of filtering can influence the clarity of maple syrup. Syrup that has been filtered with DE will usually have a more sparkling appearance compared to syrup filtered through cloth. However, cloth filtering (if done correctly) will produce acceptable levels of syrup clarity.

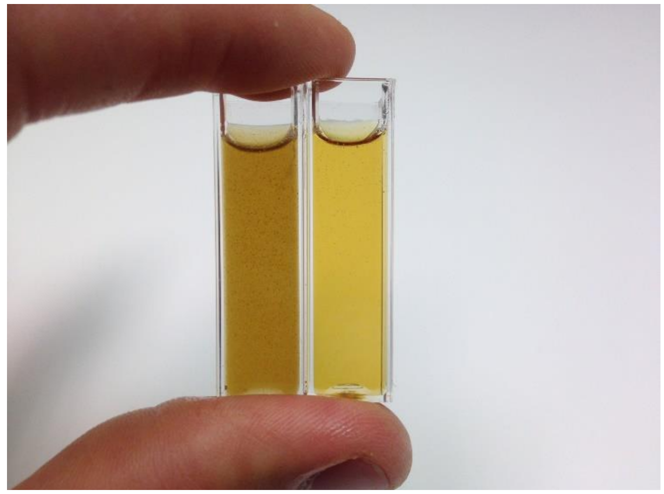

Figure 68 - Filtered vs. unfiltered syrup
Unfiltered syrup (L) has suspended solids in it that gives a cloudy appearance. Filtered syrup (R) does not have suspended solids. (Image source Isselhardt, n.d.)

Density – All maple syrup that is sold must meet the legal minimum and maximum density standards of the state or province where it is sold. In Vermont syrup must be between 66.9° and 68.9° Brix. (Vermont Sugar Makers' Association, n.d.) Density is measured with a hydrometer or refractometer.

Figure 69 - Grading maple flavor
The only way to grade maple flavor is by tasting it. Sugarmakers taste syrup from a variety of producers to fine tune their pallet. (Image source Shelburne Farms, n.d.)

Flavor – Flavor must be evaluated by tasting. It is the most subjective characteristic of maple grading and there is no quantitative or qualitative method for maple producers to describe the flavor… you must taste it! Syrups cannot have any objectionable flavors, known as off-flavors, or odors. Sugarmakers should take the time to taste both good and undesirable syrup flavors from other producers to develop their pallet and recognition of each grade and off- flavor.

Off-flavors

Maple syrup has a unique flavor that can be altered or destroyed by several undesirable or off-flavors. Most off-flavors are caused by a mistake made by the sugarmaker during stages of collection, processing, or storing. Luckily these mistakes can be identified and avoided in the future. A few off-flavors are the result of natural processes which the sugarmaker has no control over. Below is modified list of commonly occurring off-flavors that can be encountered. A complete list can be found in the *North American Maple Syrup Producers Manual.*

- **Buddy** – At the end of the sugaring season when temperature warms the buds of the trees begin to swell the sap, and thus the syrup, takes on chocolaty flavor often described as tasting like a Tootsie Roll. Often a chocolate odor is associated with buddy syrup. The flavor can also range from butterscotch to strong bitter. This syrup can be sold as commercial grade but should never be bottled as one of the four standard syrup grades.
- **Burnt niter** – If niter build up is not frequently removed from the evaporator pans it can burn onto the pans and cause off-flavor syrup. Niter can cause a bitter, strong caramel, or burned flavor. It may also cause a slight fizzy effect on the tongue.
- **Chemical** – When using reverse osmosis machines, the membranes need to be cleaned with a chemical wash throughout the season. If a producer does not properly wash and rinse the RO after a chemical wash cycle it will alter the taste of the next batch of syrup produced. Chemical flavors can also be caused by soap or bleach that is not rinsed completely from equipment. The syrup will take on a soap or bleach flavor and can be hazardous to the consumer.
- **Chlorine** – If equipment, such as tubing, is washed with chlorine and not properly rinsed a residue will remain. This will affect the syrup imparting a medicinal or bathroom cleaner smell and salty taste. Chlorine residues in sap can also damage RO membranes.
- **Defoamer** – If too much of any type of defoamer or a small amount of foul-tasting defoamer is used it will create an off-flavor syrup. Flavor can be waxy, oily, greasy, or rancid depending on the type of defoamer used.
- **Detergent/soap** – Most equipment can be properly cleaned with hot water, but some sugarmakers use detergent or soap for cleaning. If it is not rinsed properly it can destroy the maple flavor and cause syrup to taste like soap. It may even make the consumer nauseous.
- **Earthy** – If dead, decaying, or dark colored wood is tapped it can give the syrup an "earthy" or rotten wood flavor.
- **Fermented** – If the density of syrup is not high enough or if syrup is not hot-packed properly into clean containers bacteria, yeast, and mold can form. This creates a fruity and/or alcoholic flavor and odor.
- **Filters** – Using brand-new filters that have not been rinsed with hot water or old filters that have not been cleaned/stored properly can ruin syrup. New filters can cause a chemical flavor and old filters can cause moldy or defoamer flavors.
- **Metabolism** – This is a natural process that can occur during the sugaring season. It is associated with warm weather during the maple season causing chemical changes in the sap. Unfortunately, there is nothing a sugarmaker can do to prevent it. Metabolism flavors are rare and described as woody, popcorn, peanut butter, chocolate, or cardboard.
- **Metallic** – If syrup is packaged in metal containers for a long time or if the containers are low quality (rusty or have cracked epoxy) the syrup can take on a tinny flavor.

Figure 70 - UVM Extension off-flavor syrup reference kit UVM Extension has developed off-flavor syrup reference kits of three natural off flavors that can occur. UVM Extension provides a syrup grading seminar in which sugarmakers can learn details about grading and better refine their pallets through tasting good and off-flavored syrup samples. (Image source Isselhardt, n.d.)

- **Musty/moldy** – Sometimes a “dirty sock” or moldy odor and flavor can develop. This happens if moldy filters are used or if mold is present in the syrup due to improper density or bottling.
- **Plastic** – When non-food-grade plastic buckets are used to collect, store, or transport sap or syrup a plastic flavor can develop. This same flavor is also caused by bottling syrup in plastic containers that are not rated for hot syrup.
- **Sour** – Acids can form in syrup when bacteria is present and interacts with sugars. This gives the syrup a sour flavor. Bottling syrup quickly at the appropriate temperature can kill microorganisms that cause the sour flavor (Marckres, & Heiligmann, 2006).

Bottling syrup

When maple syrup is the correct density and has been graded it is ready to be packed. Syrup must be packed when it is hot to prevent the growth mold, yeast, or bacteria. Syrup can be packed directly into small containers for retail sale or larger drums for bulk storage. Bulk containers can be sold at wholesale or used to fill retail orders throughout the year. Retail containers come in various sizes and materials such as plastic, glass, or ceramic (Marckres et al., 2006).

Figure 71 - Syrup canner
This syrup canner has an adjustable sensor probe that causes the canner to automatically stop releasing syrup when the bottle is filled to the proper level. (Image source Shelburne Farms, n.d.)

Bottling syrup for retail:

- Reheat and refilter syrup before bottling if it has been stored in a bulk container. Heat syrup to 180°F for plastic bottles or 190°F for glass bottles.
- Re-check the grade of syrup before it is bottled. A barrel that was graded amber in March will not necessarily still amber after being stored in a barrel for months and then reheated.
- Re-check the density of the syrup after it is heated and if necessary, adjust. In Vermont packaged syrup in containers less than 5 gallons must be 66.9 Brix. Bulk syrup may be stored at 66 Brix.
- Fill bottles with syrup. Screw the cap on tightly so the bottle is sealed. Lay bottle on its side. This will provide an induction seal on the cap, sanitize the top of the bottle, and provide a check to make sure the cap is properly on and does not leak (Farrell, 2013). If the bottle is not sealed correctly mold can grow in the syrup.
- Bottles can be stored at room temperature. They do not need to be refrigerated.
- All packaged syrup offered for sale MUST include name/address of producer and a lot code or other batch identifying mark that allows for traceability.

Record keeping

Sugarmakers should keep detailed records throughout the sugaring season. This information can help a sugarmaker plan activities in future seasons and troubleshoot problems. Examples of information that some producers record include:

- Date tapped
- Amount of time spent tapping; weather conditions
- Date of first run
- Sugar content of sap
- Sap condition (clear/cloudy)
- Sap flow (gallons per hour or per day)
- Hours boiled
- Gallons of sap boiled
- Gallons of syrup produced
- Date, grade, and amount for each batch of syrup
- Amount of fuel used (e.g. cords of wood, gallons of fuel oil, etc.)
- Vacuum level
- Frequency of switching sides of front pan for draw off
- Amount and type of defoamer used
- Amount of filter aid used
- List of problems encountered and the solutions
- Detailed records on bottling (production batches, what barrel(s) were used, number and size of bottles used, etc.) (Stowe et al., 2006).

Sample record sheets for boiling, vacuum readings, and barrel records are located in Appendix F.

Value-added products

There are a variety of **value-added** products that can be made from maple syrup. These are secondary products that are made by processing pure maple syrup, such as maple cream, candy, and sugar. Value-added products are a great way to the increase profits margins of a sugaring operation.

Maple cream candy and sugar are traditional value-added products, although there are many other products that can be made. To make these products, syrup is boiled to a higher temperature thereby removing additional water. Evaporation increases the concentration of sugar in the syrup creating more dissolved sugar in the solution than can be held at room temperature. As the syrup cools, the excess sugar crystalizes. For value-added products the concentrated syrup is agitated after different cooling periods. Each product has specifications for what temperature the syrup is boiled at, how long it is allowed to cool, and when and how much to agitate.

Invert sugars

Value-added products need to be made with syrup that has the proper **invert sugar** levels. Invert sugars are created when sucrose, the primary sugar in sap, is converted into glucose and fructose through microbial contamination in sap before it is boiled. These invert sugars impact how syrup behaves when it is processed into candy, cream, or sugar. A small amount of invert sugar provides the right maple flavor and texture. Too little causes invert sugar causes the product to be grainy, but too much can prevent the syrup from forming small crystals. In general, light-colored syrups made early in the season have lower invert sugar levels than dark syrups made late in the season. The syrup grade can act as a guide in selecting syrup for making value-added products, but grade alone is not enough to indicate precisely what the invert sugar levels are (McCrumm, Koelling, & Heiligmann, 2006). Michael Farrell, former director of the Uihlein Forest at Cornell University and author of *The Sugarmaker's Companion* recommends the following procedure to test the invert sugar content in syrup:

- Make a 1:10 dilution of maple syrup and water using a gram scale.
- Place a small paper cup on the scale and then "zero" it out.
- Add 10 grams of syrup to the cup and then 90 grams of water until the scale reads 100 grams, mix well.
- Have a basic glucose meter, commonly used by diabetics to measure blood sugar levels, that provides a numerical output of mg/dL for whole blood readings.
- Insert the glucose meter test strip into the 10% syrup solution and place it on the meter.
- Whatever the reading is multiply it by 0.02 in order to determine the percentage of invert sugar
- Once you know the invert sugar content you can decide if the syrup is suitable for the desired value-added product (Farrell, 2013 p. 199).

Example:
The glucose meter reads 50
50 x 0.02 = 1
The invert sugar content is 1%

Maple cream

Maple cream is smooth and creamy spread that has a delicious maple flavor. It is a great topping for toast, muffins, fruit, or anything really anything you want to spread it on. A gallon of maple syrup will produce about 7 ½ pounds of maple cream

How to make maple cream:

- Use syrup that contains less than 4% invert sugar. Syrup that contains from 0.5 to 2% invert sugar will make a fine-textured cream. Golden/delicate or amber/rich syrup recommended.
- Boil maple syrup to 22° to 24°F above the boiling point of water. Syrup that contains 2 to 4% invert sugar should be heated to 25°F.
- Skim off the froth that forms on the surface of the boiling syrup.
- Rapidly cool the syrup to about 75°F or below. When sufficiently cooled the surface of the syrup is slightly firm to the touch. Make sure the cooling syrup is kept completely still.
- Slowly stir the chilled syrup under room temperature conditions. Stirring can be done by hand or in a mechanical mixer. Stir continuously until creaming is complete. Very small sugar crystals should form giving the product a consistency similar to peanut butter.
- Freshly made cream can be packed immediately
- Maple cream should be stored in the refrigerator if it will be used in the next two months. For long term storage is should be stored in the freezer (McCrumm et al., 2006).

Molded sugar candy (soft sugar candy)

Molded sugar candy is a very popular value-added product. Pieces are often molded into a variety of shapes, although maple leaf shaped mold is commonly used. The crystals in molded sugar candy are larger than in maple cream and can be felt on the consumers tongue, but crystals should not be large enough to have a sandy or gritty texture. One gallon of maple syrup can make approximately 7 ½ pounds of molded sugar candy. Candy can be made by hand or with a commercial candy machine.

How to make molded sugar candy

- The ideal invert sugar level for molded sugar candy is 1%, but it can be made from syrup with a level between 0.5 and 1.5%. Golden/delicate or amber/rich syrup recommended.

- Heat syrup to 32° to 34° above the boiling point of water.
- Cool the syrup before stirring. Syrup that is stirred at temperatures around 200°F will produce harder candy. Syrup stirred at temperatures between 190°F and 175° will produce medium hard candy. Syrup stirred at temperatures less than 170°F will produce softer candy. Syrup cooled to lower temperatures will form finer sugar crystals.
- Stir syrup by hand or with a commercial maple sugar machine. Stirring will only take a few minutes. Stirring is complete when the solution becomes light in color, thicker, and creamy.
- While the sugar is soft pour it into molds.
- Place molds on a rack to cool. The molded sugar candy should set up in 10 to 30 minutes.
- Candies can be removed from the molds after 30 minutes to one hour. Candies should be placed on a wire racks for 24 hours before packaging.
- Candy can be stored in a cool dry place (Childs, 2007).

Figure 72 - Maple candy
Maple candy being made with a commercial candy machine. (Image source Isselhardt, n.d.)

Lollipops

It is hard to turn down a maple lollipop. The smooth glass-like non-crystalline hard candy with a strong maple flavor is often enjoyed by consumers. Typically, recipes for maple lollipops include the addition of corn syrup or invert sugar to get the combination of sugars to prevent crystallization and produce hard candy. There are many different recipes to produce maple lollipops, below is one example.

How to make maple lollipops:

- Prepare lollipop molds by greasing them and placing a lollipop stick in each mold.
- Mix 1/3 maple syrup (amber/rich or golden/delicate syrup is recommended), 1/3 light corn syrup, and 1/3 white sugar. Bring the syrup and corn syrup to a boil before adding the white sugar.
- If the solution begins to foam add a drop or two of anti-foam
- Boil the solution to 295°F.
- Transfer the hot solution into a glass measuring cup or other pouring device that can be used to pour the solution into the molds.
- When the temperature is 250°F pour the solution into the molds.
- Let the lollipops cool and harden then remove from molds and package (Childs, n.d.).

Figure 73 - Maple lollipops
Maple lollipops being made by students at Missisquoi Valley Union High School.
(Image source Wolfe, 2019)

Organic certification

Many sugarmakers are realizing the potential profit and ecological benefits of producing certified organic maple syrup. The Northeast Organic Farming Association of VT (NOFA-VT) certifies just over 200 operators which amounts to 59,000 acres of sugarbushes (Moore & Walke, 2019). Producers get a premium price for sap that is certified organic. To be certified, producers must follow specific guidelines and regulations while managing the forest, tapping the trees, processing syrup, and equipment used. Below is a brief summary of the requirements to become a certified organic maple syrup producer:

- Producers are not allowed to use conventional pesticides, fertilizers made with synthetic ingredients, or herbicides.
- Producers must have a written forest management plan that describes how diversity, wildlife habitat, and forest regeneration will be promoted and maintained in the sugarbush. The Vermont Department of Forests, Parks and Recreation partners with Vermont Organic Farmers (VOF) to evaluate and certify sugarbush plans to ensure that they meet VOF standards and that they align with Use Value Appraisal standards.
- Producers can only put a limited number of taps per tree (one tap for trees 9-15" DBH and two taps for trees above 15" DBH)
- All containers and materials used to hold sap and process it into syrup must be food-grade and lead free.
- Organic producers are required to use certified organic defoamers such as safflower oil or sunflower oil that will not impart an off-flavor to the syrup.
- Independent auditor (third-party auditor) must inspect the sugaring operation once a year. They perform a physical inspection and look at paperwork and maple syrup production records.
- The sugaring production must be certified by an organic certification body such as the Northeast Organic Farming Association.

Marketing and business planning

The marketing and business planning section of this manual was primarily written by Mark Cannella, UVM Extension Associate Professor: Farm Business Management Specialist, and amended by Lynn Wolfe.

If you have made it this far in the manual you clearly love thinking about and making maple products. However, it is absolutely crucial that you spend a significant amount of time planning and researching what your production costs will be, how you are going to get customers to buy your products, and how you plan on generating profit.

Start-up cost

Establishing a new maple enterprise requires significant **capital investments**. Capital investments are the initial costs required to start a sugaring operation. These investments include real estate purchase, land improvements (roads, culverts, etc.), building construction, tubing system installation, sap collection equipment and syrup processing equipment. Capital investments are expected last and be used for at least several years or more. For example, a vacuum pump that is purchased during the start-up phase would be expected to last at least 7-10 years. Constructed buildings are often expected to last 20-30 years or more before they require significant maintenance, repairs, or replacement.
Modern maple enterprises have approximately $45 per tap invested in equipment, buildings, and improvements. This represents the purchase price off all the capital investments needed to operate the business but not the value of real estate.

Start-up benchmarks: capital investments estimate

- All investments, equipment, and improvements (not including forest land): ~$45 per tap
    - Maple tubing system installation: ~ $15 per tap for materials and installation
      *This tubing system benchmark is part of the $45 "all investment" benchmark above.
- Land purchase: (~55 taps per acre, 1 acre ~$800 per acre*): $15 per tap
  *Forest land purchase prices can vary widely based on property features, location and the number of acres in the parcel.
    - *Tap lease: the leasing of maple taps is not considered a capital investment since the tenant does not take ownership of the trees or property. Rental costs to access taps are considered an annual operating cost (see the operating cost section below)

Table 7 - Capital start-up costs
An estimate of the capital start-up costs required for a 2,500 tap maple syrup business.

Capital Start Up Sample: 2,500 Taps	
Item	**Cost**
Tubing System	$37,500
Sugarhouse	$25,000
Evaporator	$18,000
Vacuum Pumps	$5,000
Woods Equipment	$3,000
Reverse Osmosis	$12,500
Canning Unit	$1,250
Filter Press	$2,000
Small Tools	$1,000
Transfer Pumps	$1,000
Sap Tanks	$7,500
Total	**$113,750**
*This is a sample for teaching purposes. Each start-up budget must be researched, and each budget will vary based a number of factors.	

Sales

Developing a sales forecast is an essential step in business planning. The term **gross sales** is used to measure the sale of business products over a single year before accounting for any costs. For an existing business, gross sales can be observed through accounting records and reports. For planning purposes, a sales forecast is developed by multiplying the expected volume of the crop by the market price. When multiple products are sold, or multiple prices are received a sales forecast will have more categories.

Table 8 - Sales forecast for a 2,500 tap maple syrup business
In this example the business produces a crop yield of 0.35 gallons per tap for a total of 875 gallons. The business sells 75% of the crop as bulk syrup in barrels and 25% of the crop directly to consumers at a roadside stand and through special events.

Sales Forecast for 2,500 tap maple syrup business		
Products	**Sales**	**Notes**
Bulk Syrup	$15,709	75% of 875 gallons = 656 gallons 656 gallons x $2.15 per pound bulk price 1 gallon = 11.138 lbs 7,306 lbs x $2.15 per pound = $15,709
Retail	$16,425	25% of 875 gallons = 219 gallons 219 gallons x $75 per gallon average (this average price is a mix of gallons ($55 per gallon), quarts ($20 each) and pints ($12)
Gross Sales	$32,134	

Operating costs

The **operating costs** of a business refer to the annual costs is takes to produce a crop. These costs are generally re-occurring each year. Operating costs do not include the initial outlay for capital purchases. During the business planning process, a maple business owner will develop a budget forecast to plan for the annual operating expenses of the business. An owner that has been making maple sap or syrup for more than one year, can also use accounting records from a recent calendar year to analyze the costs of production to run the business.
Below is a sample of variable costs and fixed costs in a basic maple budget

Variable costs

- Freight, trucking, shipping
- Evaporator Fuel
- Gasoline, fuel, and oil
- Labor
- Marketing – advertisement
- Packaging and containers
- Repairs and maintenance
- Supplies purchased
- Utilities – electricity

Fixed costs

- Insurance (other than health insurance)
- Real estate taxes
- Rent or lease
- Subscription, dues, registrations
- Education – professional

Maple marketing and prices

When marketing maple it is important to concentrate of 5 marketing concepts: price, product, place, people, and promotion. These are known as the 5 P's of marketing.

Price: Establishing the right price is important to sales and profitability. The first step to analyze if this particular business is a "price maker" or "price taker". Price makers are able to provide a unique product or experience that is different enough from competitors that it is able to set its own prices. Price takers, on the other hand, will receive the current market price at the time of sale. This is relevant for bulk producers that will be told what the market price is at the time of sale. Setting prices tend to follow four general methods:

- Competitive pricing: observing how similar products are priced in the marketplace and matching those prices
- Signal pricing: observing how similar products are priced and then making an intentional choice to set prices higher or lower than the similar products based on additional features that may or not be present.
- Cost-based pricing: tracking the full cost of production to produce a good and basing prices on that
- Penetration pricing or skimming: Penetration pricing refers to setting low prices in order to introduce a new product to the marketplace and generate initial awareness. Price skimming occurs when a new and unique product enters the market where no similar products exist. High prices can be charged until competition develops and eventually pulls down the price.

Product: This describes the goods or services that are being sold, including both physical and emotional attributes. For maple syrup this includes features like flavor, color, density and grade. A product can also be described by the form or size it is sold in. A one-gallon container may appeal to different customers and require a different marketing strategy than ½ pint containers. The description of a product can also include less tangible characteristics like a "family farm" brand.

Place: This refers to the physical place a good is sold or to the distribution channel that a good travels through to reach the final customer. Place also includes the logistics of placing an order and the delivery of goods.

There are 3 general types of market or distribution channels:

- Direct to consumer: goods sold direct to consumer indicate a direct transaction between the producer and the end consumer. It may occur via a direct sale in person at a maple open house event and it could also occur via online sales where the consumer orders the product directly from the business.
- Wholesale: this generally refers to a "business to business" transaction where a product is sold to a grocery store, restaurant , or other retailer that will resell the product to the final consumer. Wholesale orders often reflect standard case sizes and individual units are often priced lower than a direct to consumer price for the same unit size.
- Commodity/bulk maple: the sale of a bulk product in a large unit size to a processor that will combine products from multiple sources.

People: Who is the target audience for your products? People can refer to current customers and future target customers. A target market profile can be developed to describe the ideal customer. A profile can consider shopping habits, geographic location, the amount purchased and their product preferences. For existing customers, a business marketing plan can include ways to get feedback from these customers. This can include feedback on the specific product, and it should also include their customer service experience from interacting with business employees at some point from making a purchase decision to after then have used the product.

Promotion: Communication and promotion is essential to making people aware of your products and motivating them to make a purchase. A promotion plan must first include the appropriate message that is intended to be communicated. A plan will clarify the features of the product, the producer and the brand are you seeking to convey. The promotion plan then needs to consider the actual methods to share that message. Promotion materials include logos, labels, point of sale materials, advertisements, websites, social media activity and much more.

Modern markets

Canada is a market leader in maple syrup and maple products. Canada produces 70% of the global syrup supply. The global maple price is heavily influenced by Canada and Quebec Maple Syrup Producers (PPAQ). PPAQ has established a market leadership position through 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 a maple syrup marketing agency.

The United States produces the other 30% of global maple syrup supply. Syrup is produced in several states. The largest producing maple states are Vermont, Maine and New York. Other maple producing states include New Hampshire, Pennsylvania, Ohio, Minnesota, Michigan, Wisconsin, and Massachusetts.

Bulk price ranges

Bulk syrup prices vary over time, but generally they range from \$2.00 - \$3.00 per pound. (1 gallon = 11.138 pounds). In 2019 the bulk prices were estimated to be approximately \$2.10 per pound.
In 2019: bulk prices estimated to be approximately \$2.10 per pound. Different prices are paid for different grades of syrup and there are premium prices paid based on other factors such as certified organic maple syrup.

2019 bulk maple syrup prices for Butternut Mountain Farm, set on 4/19/19

grade	base price	organic premium	volume delivered (A)	volume picked up (A)	barrel premium	notes
golden/delicate	\$ 2.15	\$ 0.15	\$ 0.10	\$ 0.08	\$ 0.03	B
amber/rich	\$ 2.15	\$ 0.15	\$ 0.10	\$ 0.08	\$ 0.03	B
dark/robust	\$ 2.15	\$ 0.15	\$ 0.10	\$ 0.08	\$ 0.03	B
very dark/strong	\$ 2.15	\$ 0.15	\$ 0.10	\$ 0.08	\$ 0.03	C
processing	\$ 1.40	\$ 0.15	\$ 0.10	\$ 0.08	\$ 0.03	D
substandard	\$ 0.60	\$ -	\$ 0.02	\$ -	\$ 0.03	E

A - 35,000 pounds of syrup minimum to qualify for volume and/or delivery premiums
B - table grade with no off flavors
C - good flavor, may have very mild off flavors
D - filtered, metabolism, buddy, sour and off flavors
E - unfiltered, ropey, severe off flavors and defects (ex. strong bud, strong sour)

Figure 74 - Bulk maple syrup prices
Example of bulk maple syrup prices for Butternut Mountain Farm. (Source Butternut Mountain Farm, 2019)

Retail price spreads
Maple businesses produce, package, promote and price maple syrup in a variety of ways. Different prices are set based on container size and type (example glass containers vs plastic containers).

Table 9 - Retail maple syrup prices
A sample of approximate retail maple syrup prices in standard plastic jugs.

Product	Price
Gallon	$55
Half-Gallon	$30
Quart	$20
Pint	$12
Half-Pint	$8

Changing climate

Many people are concerned about the potential impact **climate** change could have on sugaring operations. Will the tapping season change? Will there be more frequent severe storms? Will there be a shift in the range and distribution of sugar maples? It is true that our climate is changing. We will have to adapt our sugarbush management and sap collection techniques to keep pace with our changing climate to ensure a sustainable sugaring industry. Below are some factors that may be influenced by climate change and suggestions on how sugarmakers can adapt to these changes.

Seasonal dynamics

Historically sugaring season fell sometime between late February and late March. Now that winter temperatures are increasing it is not uncommon to have perfect sugaring conditions in January and early February. Dr. Tim Perkins, Director of the University of Vermont Proctor Maple Research Center looked at long term tapping records throughout the Northeast and found that sugaring season has started about a week earlier and ended 10 days earlier over the past 40-50 years. The season in moving earlier and warmer temperatures in March could reduce yields (Farrell, 2013). With winters predicted to become milder and shorter we may experience a shorter number of days with freezing temperatures resulting in decreased sap production. This will likely affect southern production areas more than northern production areas (Chapeskie et al. 2006a).

Extreme weather events

Climate experts suggest that we will see an increase in storm severity and frequency. Storms with high winds or heavy ice accumulation will significantly impact sugarbushes infrastructure in terms of roads and could damage trees in the sugarbush (Chapeskie et al. 2006a).

Pests and diseases

Insects and diseases thrive in warm conditions. An increase in temperatures could increase the problems associated with pests and diseases. The distribution and range of southern pest species could shift into maple sugaring production areas and pose new threats to northern hardwood forests (Chapeskie et al. 2006a).

Distribution

Climate change is predicted to impact forest composition, distribution, and health. Climate change will alter current patterns of precipitation and hydrology. This will mostly likely cause drier summer conditions, increase soil temperature, increase risk of drought, and alter nutrient availability in rich northern hardwood forests and northern hardwood forest systems. This could have a significant impact on sugarbushes. It is predicted that habitat suitability, defined as the ability of a habitat to support a population, will decline for some canopy species in these natural communities, including sugar maples. These impacts will vary within a landscape. North-facing sugarbushes on deep soils are less likely to be impacted relative to other landscape positions and settings. In impacted areas the habitat is projected to be more suitable for some southern tree species such as white oak, yellow poplar, and sassafras (Janowiak, et. al., 2018).

Figure 75 - Snow covering high elevation in early spring
Forests at higher elevations experience sugaring conditions later into spring than at lower elevations. (Image source UVM Extension, n.d.)

Climate change should be taken seriously, and it is a significant concern for sugarmakers, however there is hope. These natural communities are widespread across Vermont and occur on a variety of soils and landforms. Forests at higher elevations or located farther north are expected to experience less change, meaning it is likely that conditions will still support sugarbushes located in these areas. It is also possible that sites that are currently too wet or cold to support sugarbushes may be suitable in the future. Red maples are not as sensitive as sugar maples and red maple distribution might actually increase with climate change (Janowiak et. al., 2018). As such, sugarmakers may want to considering tapping more red maples in the future.

It is also important to understand that although conditions may become more suitable for a species, such as oak, it doesn’t mean that the forest composition will automatically transform. There needs to be a seed source present for a species to become dominant in a forest. Additionally, habitat suitability does not take into consideration how forest management activities can alter forest composition. Informed land managers and sugarmakers who understand the possible impacts of climate change will have an opportunity to alter forest management techniques and develop new sugaring technology to keep pace with a changing climate and continue producing maple syrup.

How sugarmakers can adapt

Luckily with knowledge gained through scientific research and technological advancements we can improve some sugaring practices and adapt to overcome some challenges associated with unfavorable and unpredictable weather patterns.

- Tap when conditions are favorable, even if that means tapping earlier than the traditional tapping timeline.

- Put in new sterile spouts every year. They produce better sap yields than used spouts that are contaminated with bacteria, yeast, and mold spores.
- Regularly replace droplines.
- Select trees with resistant crown forms. This will reduce damage in extreme weather events, such as ice storms.
- Apply stand tending treatments to maintain vigor of sugar maple.

With these simple practices you can take advantage of early season sap flows without being concerned about your taphole drying up before the end of the traditional sugaring season (Farrell, 2013).

How sugarmakers can adapt – vacuum

Using a vacuum pump can mitigate some of the effects of climate change. A significant issue caused by warming temperatures is that there are more days during the sugaring season when it is too warm for sap to continuously flow from a taphole in a gravity-based system. By using a high vacuum system, the sap can keep flowing, even without any positive pressure created by freeze-thaw events. The vacuum pump creates the pressure differential drawing sap to the taphole as long as the temperatures are above freezing. By keeping the vacuum pump running whenever temperatures are above freezing you don't need to rely on freeze-thaw cycles for all of your sap flow (Farrell, 2013).

Appendix A: Bird-Friendly Maple Project Management Guidelines

Maple sugarbushes provide nesting habitat for a diversity of songbirds. Some of these bird species have more than 50% of their global breeding population in the northeastern forest. Others have been exhibiting long-term population declines for over 40 years. Through the planning and implementation of sugarbush management activities that develop a structurally and biologically diverse forest, the maple industry can play a vital role in global bird conservation efforts while simultaneously enhancing the health and sustainability of the sugarbush and promoting and potentially increasing market visibility of pure maple products.

The following guidelines help ensure bird habitat considerations are integrated into sugarbush management. They are also intended to be used as criteria for a pilot "bird-friendly" maple product recognition program. A key component of these criteria is on the intentional planning of bird considerations in addition to current conditions. Any requirements through other programs the land is enrolled in (NOFA-VT organic certification, VT Use Value Appraisal, etc.) must be adhered to.

General Requirements

- A current (within past 10 years) Forest Management Plan must be in place and reviewed by Audubon Vermont. Specific mention of enhancing and/or protecting songbird habitat as a management objective is required in addition to addressing criteria described by the remainder of this document.
- A forest bird habitat assessment must be conducted by an Audubon Vermont biologist or consulting forester. This assessment can be included in the forest inventory or conducted separately. The findings of the assessment can help identify current habitat conditions and inform future management decisions. Contact Audubon Vermont for guidance on conducting an assessment.
- Harvesting of trees in the sugarbush during the bird nesting season (May – mid-July) may reduce nest success and survivorship. In order to reduce this possibility any one area of the sugarbush must not be worked in during the nesting season more than once every ten years.
- The sugarbush must be part of a contiguous forest block of ≥100 acres. This helps ensure the availability of interior forest conditions critical to the nesting success of target bird species. The maple producer does not need to own or manage the entire forest block.
- Conversion of a stand to a sugarbush may require special consideration on those natural communities where maple is an associate species. The stand should be managed based on its natural community tapping the maples as feasible. Examples are red maple swamps, red spruce-northern hardwood, and sandplain forests.

(over)

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Tree Species Diversity

A diversity of tree species in a sugarbush can significantly reduce presence and impact of sugar maple insect and disease pests. Similarly, research on the bird community in managed sugarbushes suggests that both total bird abundance and species diversity decreases when maple (sugar and red) basal area increases in relation to total stand basal area.

- When establishing a new sugarbush, tree species other than sugar maple must account for ≥25% of the stand as measured by percent basal area. The Forest Management Plan must list this as an objective and describe how it will be maintained or achieved. In situations where the new sugarbush is already >75% sugar maple as measured by percent basal area, the Forest Management Plan must describe the causes for the limited tree species diversity as well as how future management will be used to increase native tree species diversity over the long-term.
- For existing sugarbushes, if non-sugar maple accounts for ≤25% of the stand as measured by percent basal area, the Forest Management Plan must describe the causes for the limited tree species diversity. In addition the Forest Management Plan must describe how future management will be used to increase native tree species diversity over the long-term.
- If non-native and invasive plants are present in the sugarbush a plan for their eradication and control must be described in the Forest Management Plan.

Forest Structure

A range of tree sizes, from seedlings to trees >30 inches diameter, provides for current and future tappable trees and promotes long-term health and sustainability of the stand. This variety of size classes creates layers of vegetation (structure) within the sugarbush that can be used by different bird species as nesting and foraging sites.

- Forest Management Plan must describe methods for stand tending and regeneration. Silvicultural options for doing so must be appropriate for stand conditions and in accordance with acceptable references set by the Vermont State Use Value Appraisal program. One such publication with particular relevance is "Silviculture with Birds in Mind: Options for Integrating Timber and Songbird Habitat Management in Northern Hardwood Stands in Vermont" (Audubon Vermont and the Vermont Department of Forests, Parks, and Recreation, 2011).
- Percent cover of understory (0-6 feet in height) and midstory (6-30 feet in height) vegetation (native trees and shrubs) must be ≥ 25% (based on ocular estimation) as averaged across all acres. In areas where cover <25% the Forest Management Plan must describe the cause(s) as well as describe how future management will be used to increase it.

Standing dead trees (snags), live trees with cavities, and woody material on the ground are important components of nutrient cycling in the sugarbush. Tree tops left in the forest after management activities or blowdown help protect seedlings from being browsed by deer. A variety of bird species use dead and dying trees, both standing and on the ground, for nesting, foraging, and cover.

- Forest Management Plan must describe methods for snag and cavity tree retention and/or recruitment. An average of two (2) snags and/or cavity trees >10 inches diameter must be retained and/or recruited per acre. Snags and cavity trees do not need to be evenly distributed but rather averaged across all acres. Consider retention and recruitment in areas of sugarbush not being tapped. Large, old sugar maples may also be retained to achieve snag and cavity targets. They may be tapped until sap production ceases and then left to senesce naturally and become snags and eventually large woody material on the ground.
- Forest Management Plan must describe methods for retention and/or recruitment of woody material on the ground. A minimum of 4 logs >10 inches diameter and >3 feet in length must be retained and/or recruited per acre. Whole tree harvesting is not permitted and all material <3 inches diameter must be left in the forest. Where possible slash should be left high and not lopped .

For more information and additional resources contact Steve Hagenbuch (shagenbuch@audubon.org; 802-233-0332) or visit http://vt.audubon.org/bird-friendly-maple-project

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Frank & Brinna Sands Foundation, Inc.

Appendix B: Bird-Friendly Sugarbush Assessment

Forest bird habitat assessment step-by-step - Appendix materials provided by Steve Hagenbuch

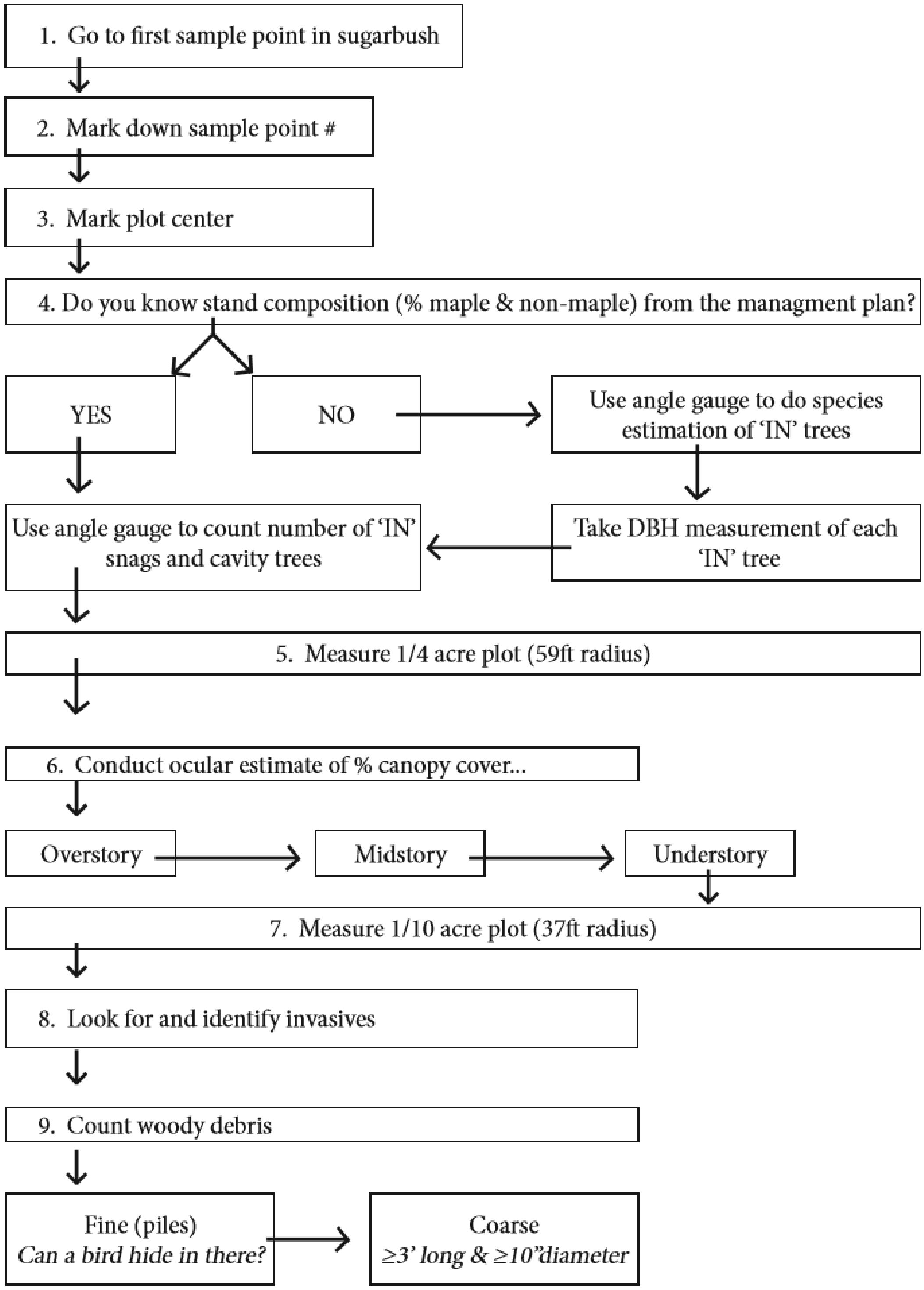
Assessment warm-up

1. Turn on GPS as you're approaching the property
2. Check in with landowner (if applicable)
3. Locate sugarbush within management plan stand list (if applicable). Note which sample points fall within that area.

Assessment

1. Walk to first sample point → are there maple lines in the area? If so, proceed to Step 2. If not, move to next sample point.
2. **Mark sample point ID number.**
3. **Mark plot center with flag or stick.**
4. *If possible, take 2 photos*: 1 facing north and 1 facing south
5. Do you know **forest species composition** (from management plan)?
    a. *If yes, proceed to step d (SNAGS)*
    b. *If no… collect forest composition data for sample point*
        i. stand at plot center and use the angle gauge to determine which trees are 'IN'
        ii. 'IN' trees are those that fill the entire 10 window when holding the angle gauge chain taught from your cheek straight outward and aimed at the chest-height level of a tree trunk.
        iii. Do this for a 360º turn in the plot center.
    c. Record the species and DBH of each 'IN' tree
        i. Record if any 'IN' tree has a cavity
    d. **Record any dead 'IN' trees (snags) and measure DBH**
    e. If there are no snags and you do not need to collect species composition data (steps b-c), mark a ZERO in the left-hand matrix to indicate that you completed this step.
6. **Measure ¼ acre plot around plot center.**
    a. use tape to measure 59 feet from plot center, mark that spot with a flag.
    b. use tape to measure 59 feet from plot center in opposite direction, mark that spot with a flag.
7. **Estimate the % cover of foliage** within that ¼ acre plot. Be sure to estimate a value that represents the entire plot area.
    a. *Overstory*: highest canopy area; can use sunlight on forest floor to suggest density.
    b. *Midstory*: any foliage between 5-30ft (not the total tree height, just the foliage density in that height range)
        i. identify top 2-3 species that comprise midstory
    c. *Understory*: foliage under 5ft. These are woody stemmed plants (no ferns): seedlings, saplings, and shrubs.
        i. identify top 2-3 species that comprise understory
8. **Measure $\frac{1}{10}$ acre plot around plot center.**
    a. use tape to measure 37 feet from plot center, mark that spot with a flag.
    b. use tape to measure 37 feet from plot center in opposite direction, mark that spot with a flag.
9. **Look for invasive, non-native species within plot area**
    a. estimate extent of invasion
    b. identify species present
10. **Count woody debris within plot area**
    a. Coarse: these are dead logs that are ≥3 feet in length and ≥10 inches in diameter
    b. Fine: these are piles of sticks and brush that are sufficiently dense and large for a bird to use as cover.
11. Retrieve flags and collect all measuring equipment.
12. Move to next sample point.

Appendix B: Forest Bird Habitat Assessment Flow Chart



Appendix B: Bird-Friendly Maple Project Habitat Assessment Form

Property name: ____ **Date:** ______________

Your initial(s): __________

Sample point ID # __________

Do you know forest species composition? (Y/N)

If yes -- count only 'in' snags

If no -- count and measure all 'in' trees

Tree	Species	DBH	Cavity? (Y/N)	Dead? (Y/N)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

measure 1/4 acre plot (59ft radius)					
Estimate % cover of the following:					
Overstory	0	1-25%	26-50%	51-75%	76-100%
Midstory (5-30ft)	0	1-25%	26-50%	51-75%	76-100%
	Dominant species:				
Understory (woody plants)	0	1-25%	26-50%	51-75%	76-100%
	Dominant species:				

measure 1/10 acre plot (37ft radius)

Non-native, invasive species

Extent of invasion: None Light Moderate Heavy

Species present: *(circle all that apply)*

japanese barberry buckthorn honeysuckle multiflora rose

OTHER:

Woody material (on the forest floor)

Coarse *# of logs (≥3' long & ≥10" diameter)* __________

Fine *# of piles (a bird could use as cover)* __________

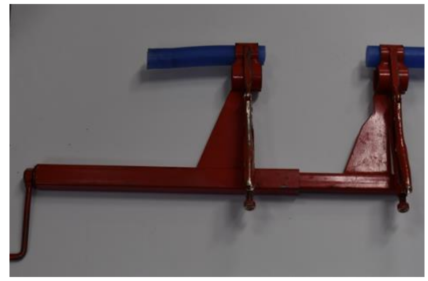
Notes: *(birds or wildlife, other observations)*

Appendix C: Tools and Materials Photo Guide

There are a variety of tools used by producers in the sugaring industry. This guide is intended to provide you with a quick visual image reference of some of the most commonly used sugaring tools. This is not intended to be a complete guide of tools used in the sugaring industry. (Image source Isslehardt, 2019)

One-handed tubing tool

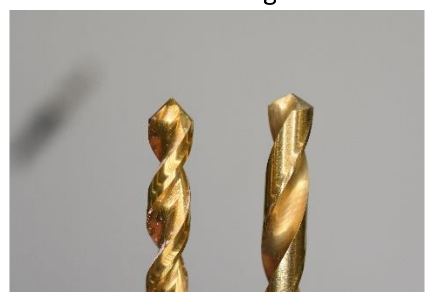
Two-handed tubing tool



Mainline tubing tool

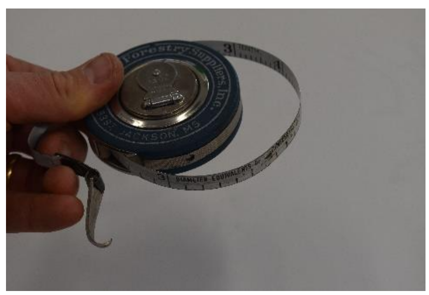
Mainline punch

Drill

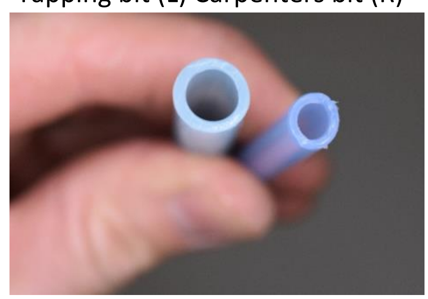


Tapping bit (L) Carpenters bit (R)

Tapping hammer



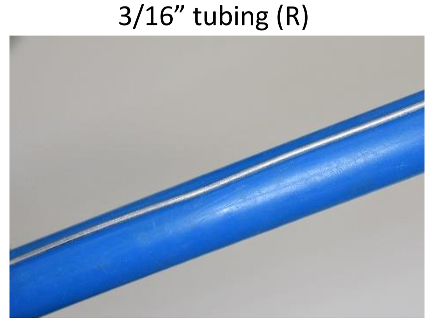
DBH tape



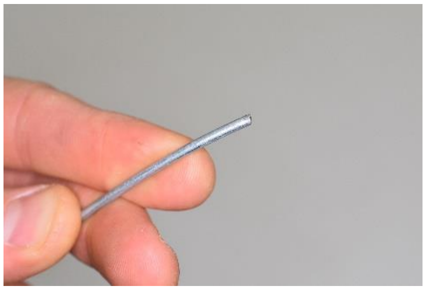
5/16" tubing (L) vs.
3/16" tubing (R)

1" mainline

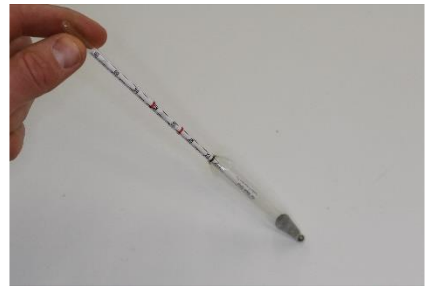
1.5" mainline



12.5-gauge wire (support mainline)


14-gauge wire (side tie)

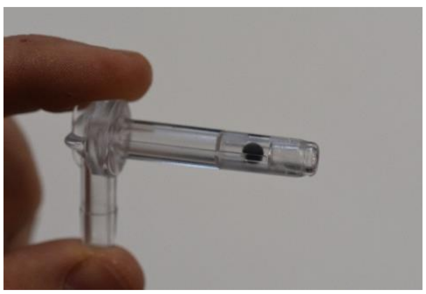

Sight level


Hydrometer


Hydrometer cup

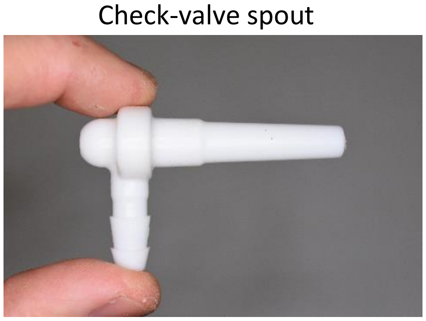

Digital refractometer


Optical refractometer


Check-valve spout

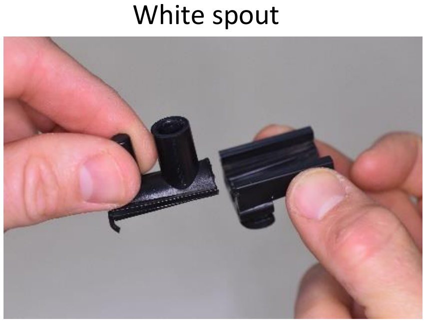

Black spout


Clear spout


White spout


Spout remover


Lateral line straight connector


Lateral line slide fitting


Lateral line end line hook


Lateral line tee


Dead end tee (right)


Dead end tee (left)


End ring

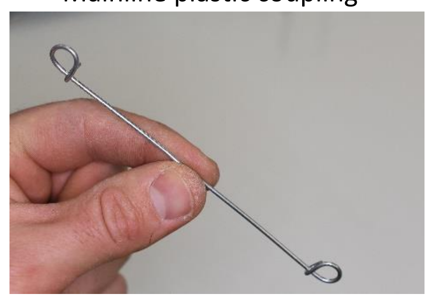

Mainline saddle entrance fitting


Mainline plug


Mainline plastic coupling

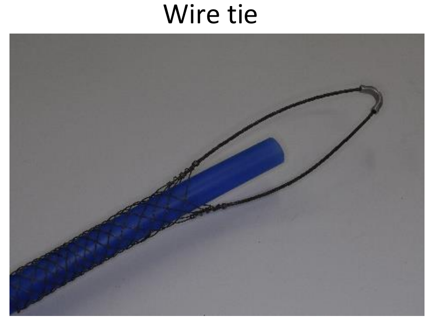

Mainline plastic tee

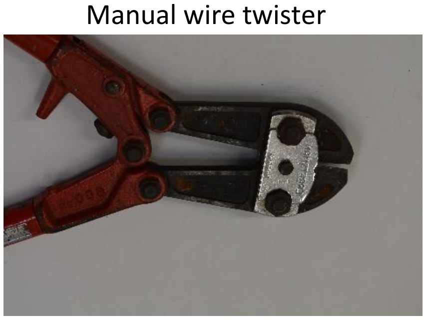

Mainline quick coupler


Wire tie

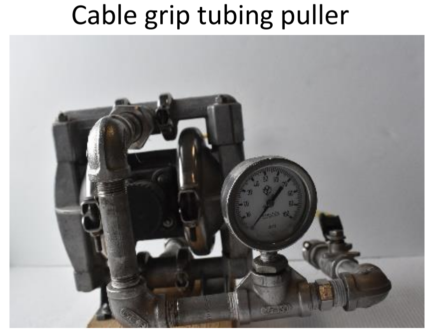

Manual wire twister


Wire tensioning device


Cable grip tubing puller


Wire cutter


Filter press


Diaphram pump

Gravity filter (cone)

Vacuum pump

Releaser

Hose clamp

Nut driver

Pressure guage

Tubing cutter

Temporary maple syrup grading comparator kit

Permanent maple syrup grading comparator kit

Score sheet produced and provided by the Vermont Maple Sugar Makers Association

VERMONT MAPLE SUGAR MAKERS' ASSOCIATION

VMSMA
Vermont Maple Syrup
production • education • promotion

189 VT Route 15

Jericho, VT 05465

802-498-7767 | mgordon@vermontmaple.org

SUGARING OPERATIONS CERTIFICATION SCORE SHEET

Business Name: ______________________

Address: ______________________

Phone: ______________________

Contact Person: ______________________

Email: ______________________

Number of Taps

In order to be certified, the operation must not have more than 10 points total deducted during the inspection. The numbers opposite each item indicate the maximum number of points that the inspector can deduct. Deductions of less than the maximum may be made according to the interpretation of the inspector and the effort of the producer to comply.

LEAD

If the operation uses any lead-containing equipment which contacts sap or syrup, such as lead soldered pans, galvanized buckets or storage tanks, the inspector will open a randomly selected container (barrel or retail unit) and take a sample for analysis.
The cost of analysis will be about $30 and will be paid by the producer. If the results are less than 250ppb, no points will be deducted; **if the results exceed the VT State limit of 250ppb, the operation cannot be certified.**

DOES OPERATION USE ANY LEAD-CONTAINING EQUIPMENT?	SAMPLE RESULTS, PPB	COMMENTS
☐ Yes ☐ No		

BUILDINGS *(including those used for sap storage, pumping, reverse osmosis, boiling, and canning)*			
DESCRIPTION	**MAXIMUM DEDUCTIONS**	**DEDUCTION**	**COMMENTS**
All light bulbs over sap or syrup, including over tanks, releasers, boiling pans, filters, and canning equipment, are protected by shields or slip on tubes to prevent broken glass from falling into food contact equipment, sap or syrup.	5		
The exhaust from vacuum pump(s) or other equipment producing petroleum fumes is located in a way to prevent contamination of sap or syrup with fumes.	5		
The interior of the buildings are neat and clean.	5		
There is protection to prevent loose debris (flaking paint, etc.) from falling into a tank, pan, or other container that will contact sap or syrup.	3		
Birds and bats must be excluded from these buildings.	3		
All surfaces in these buildings which could contact sap or syrup are clean and free from dirt, mold, debris or evidence of pests at the time of use.	3		
The producer will document the startup cleaning procedures used for tanks, pans, and all food-contact equipment.	3		
The building(s) used for reverse osmosis, boiling, and/or canning must have floors that can drain and are washable. Dirt floors are prohibited.	3		
A check valve is present between the vacuum pump and releaser.	3		

Food Contact Materials

The producer and inspector will confirm that sap or syrup does not contact any non-food-grade materials, including but not limited to the following:

Description	Maximum Deductions	Deduction	Comments
Rusty metal tanks or buckets.	5		
Buckets, tanks or other containers that were originally made for a non-food product.	5		
Non food-grade diatomaceous earth.	5		
Compressor without a settling bowl.	5		
Non food-grade tubing or pipe used for sap or syrup transfer.	5		
Sap transfer pump also used for pumping non-maple liquids other than clean water.	5		
Bronze gear pump used for sap transfer.	5		
Tanks or buckets with painted interiors.	5		

Filters

The producer will confirm the following:

Description	Maximum Deductions	Deduction	Comments
Sap filters are clean at the time of use with no evidence of mold or unsuitable odors.	3		
Pool filters, if used for sap filtration, use clean sand or food-grade diatomaceous earth.	3		
Filter press and filter papers are clean with no evidence of mold or unsuitable odors.	3		
Only food grade lubricant is used in the filter press pump.	3		
Any diatomaceous earth used is food grade and is kept in its original bag, which when opened, should be placed in a clean dry container with a lid.	3		

SANITATION *The inspector will confirm the following:*			
DESCRIPTION	**MAXIMUM DEDUCTIONS**	**DEDUCTION**	**COMMENTS**
A hand washing station consisting of clean flowing water, liquid soap, and disposable towels is present.	5		
Domestic animals are not allowed in the rooms where sap and syrup are being collected, boiled, packed or otherwise processed.	3		
The availability of a clean water source for cleaning equipment (a well, municipal water, or condensate from a clean source). No pond or brook water is used for cleaning equipment. *Note: It is encouraged, but not necessary, that a coliform test be conducted on your water source annually.*	3		
All interior trash containers are kept clean and emptied regularly.	3		

PRODUCT CODING *The inspector will confirm the following:*			
DESCRIPTION	**MAXIMUM DEDUCTIONS**	**DEDUCTION**	**COMMENTS**
All filled drums and containers are coded and the producer has kept production records for both bulk and retail that relate the code on the container to the date and batch number.	10		

FOOD ALLERGENS

The producer will confirm the following:

DESCRIPTION	MAXIMUM DEDUCTIONS	DEDUCTION	COMMENTS
Steps have been taken to prevent contamination of sap or syrup by allergens (milk, eggs, peanuts, tree nuts, soy, wheat, fish, crustacean/shellfish) by prohibiting such practices as using a container containing a food allergen residue, using a defoamer that contains an allergen such as dairy, heating foodstuffs such as eggs or hotdogs in or over the evaporator, and/or not washing hands between eating food allergens and handling equipment that contacts sap or syrup.	10		

PESTICIDES, HERBICIDES, AND PETROLEUM PRODUCTS

The inspector will confirm the following:

DESCRIPTION	MAXIMUM DEDUCTIONS	DEDUCTION	COMMENTS
Pesticides and herbicides not kept in any room where sap or syrup is present	3		
Any motor or tool using a petroleum product is located a suitable distance away from sap or syrup and any equipment that does or will in the future contain sap or syrup.	3		
Any motor or tool using a petroleum product must have secondary containment to avoid a petroleum spill if it is located in the same room as sap or syrup.	3		

Containers – Bulk & Retail *The inspector will confirm the following:*			
Description	**Maximum Deductions**	**Deduction**	**Comments**
Drums and other bulk containers are stored and treated in a manner to prevent contamination with petroleum containing products and other chemicals. This includes the prohibition of placing petroleum containing equipment, containers of cleaners, pesticides, herbicides, tools, etc. on top of empty or full drums.	5		
Drums and other bulk containers not actively being filled are protected from debris and pests via sealed bungs or other means.	5		
All retail containers used for syrup packaging are stored in a manner that will prevent contamination, with debris, animals, or other sources, prior to filling.	5		
Any epoxy-lined drums used for syrup storage are in good condition with no evidence of the epoxy lining flaking off.	3		
The producer will verbally describe the packing process used for drums and retail containers.	3		
The producer will confirm the following			
All bulk syrup containers are cleaned and inspected for foreign debris, rust, and unsuitable odors prior to filling.	3		
All syrup in retail containers is packed at a minimum of 180˚F.	3		
All retail containers are inspected for foreign debris and/or inverted prior to filling.	3		

Maple Equipment Cleaning Chemicals

The inspector will confirm the following:

Description	Maximum Deductions	Deduction	Comments
All chemicals are in their original containers with the label intact.	5		
All chemicals used for cleaning equipment are stored in a secure space and properly separated by type, such as acids separated from bases.	5		
A Material Safety Data Sheet (MSDS) is present for every chemical used in the maple operation, including but not limited to cleaners for tubing, pans, and reverse osmosis membranes.	3		
Personal protective equipment consisting of a minimum of impervious gloves and apron, goggles or face shield, and eye wash must be present in the area where equipment cleaning chemicals are used.	3		
There are appropriate methods and equipment for neutralizing and disposing of waste water solutions resulting from cleaning maple equipment.	3		
The producer will demonstrate the following:			
For each equipment cleaning chemical used there is at least one designated individual who is responsible for using, storing and disposing of the chemical, as well as instructing anyone else who might use that chemical.	3		
The responsible individual for each chemical must be familiar with the basic safety information listed on the MSDS, and be able to explain it to the inspector	3		

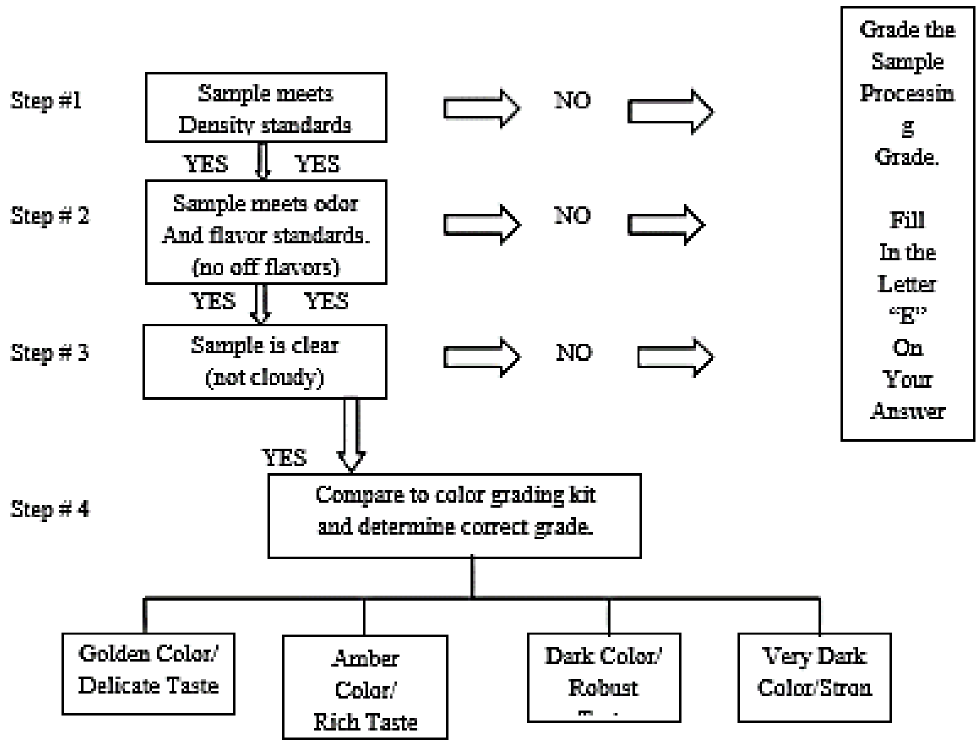
Total Deductions		
Maximum Allowed Deductions	**Deduction**	**Comments**
10		

Inspected By:
Date:

Appendix E: Maple Syrup Grading Flow Sheet

CONSERVATION CONTEST
MAPLE SYRUP GRADING FLOW SHEET
VERMONT FARM SHOW

Directions: Rate all for color, clarity, density, and flavor, following the steps below. After determining the final grade for each sample, record your answers on your Scantron card.



Find sample number below and mark correct letter on answer sheet for this sample

Final Grade of Sample	7 8	79	8 0	8 1	8 1		8 1	8 2
Golden Color/Delicate Taste	A	A	A	A	A		A	A
Amber Color/Rich Taste	B	B	B	B	B		B	B
Dark Color/Robust Taste	C	C	C	C	C		C	C
Very Dark Color/Strong Taste	D	D	D	D	D		D	D
Processing Grade	E	E	E	E	E		E	E

Appendix F: Record Keeping

Sample record sheets for boiling, vacuum readings, and barrel records. Records adapted from PMRC.

Boiling Records

Date			
Sugarmaker(s)			
Boiling Time		**Raw Sap**	
Start Time		**Start (gal.)**	
Stop Time		**Stop (gal.)**	
Total Time		**Total boiled (gal.)**	

Syrup					
Gal.	**Grade**	**Batch #**	**Syrup Total**	**Running Total**	**Barrel #**

Comments (i.e. cleaned pan, off density, clarity, other significant info.)

Evaporator Notes		**Weather**		
Time		**Yesterday High**		
		Overnight Low		
		Time		

Filtrate/Filter Press Notes

Vacuum Readings

Date	Time	Inches of Vacuum	Outdoor Temp °F	Notes (time vac. on/off, leak, etc.)	Who? (Initials)

Barrel Records

Barrel #	Date	Barrel Start Weight	Barrel End Weight	Syrup Weight (lb)	Syrup Gallons	Syrup Grade	Batch #	Barrel Filled ? (Y/N)	Date Barrel Filled	Comments

Glossary

Definitions from the *North American Maple Syrup Producers Manual* and *A guide to Improving and Maintaining Sugar Bush Health and Productivity*.

Arch: Fame structure supporting the evaporator pans and enclosing the firebox (wood fired evaporator) or other heat sources, e.g. oil burners, gas burners, etc.

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 channels that increase the heat transfer surface area.

Basal area: Cross-sectional area of a tree's trunk determined 4 ½ feet above ground ("breast height"). Usually expressed on a tree, stand, or area (acre or hectare) basis.

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.

Bench (benchland): A long narrow strip of level or gently inclined land that is situated between steeper slopes above and below it.

Brix scale: Scale comparing the density of maple syrup to that of a sugar solution with a known percentage of sugar.

Canopy: All layers of branches and leaves in a forest above the forest floor.

Capital investments: Money invested in a business venture with an expectation of income and that the money will be recovered through earnings generated by the business over several years. Examples include real estate purchase and building construction. Capital investments not include day-to-day operating costs.

Clarity: Component of maple syrup grading guidelines expressing the transparency or translucence of syrup; freedom from haze or cloudiness caused by suspended solids.

Climate: Prevailing weather conditions of an area.

Cold test: Determining the density of a sample of cold maple syrup (60°F). Cold testing is commonly done with a hydrometer using the second red line.

Concentrate: Sap that passes through a reverse osmosis unit which has an enriched sap sugar content and is next placed in the evaporator.

Crop tree: Trees identified in a forest stand that are to be retained and favored to be vigorous because they contribute to ownership objectives, such as sap or timber value.

Cross flow pans: Syrup pans, usually with one partition and two compartments, through which the sap moves from side to side rather than back to front. Commonly set in pairs on the front portion of the arch, cross flow pans are usually provided in threes, and are intended to be rotated and cleaned frequently as a way to control niter build-up.

Defoamer: Substance periodically added to the evaporator in very small amounts to reduce foaming.

Density: The concentration, usually expressed as a percentage, of solids in pure maple syrup.

Diameter breast height: Diameter of a tree measured 4 ½ feet from the ground.

Diatomaceous earth: Naturally-occurring silica product used to facilitate and increase the efficiency of pressure filtering of maple syrup to remove suspended particulate material (sugar sand).

Drop flue: Back pans constructed with flues extending below the rail of the supporting arch.

Dropline: Relatively short length of 5/16-inch or 3/16-inch tubing used to connect an individual spout to a lateral tubing line.

Dual conductor (wet-dry conductor): Specially designed tubing mainline system that utilizes two separate lines, one to transport sap to the collection tank (wet line) and the other for vacuum transfer further into the tubing system (dry line).

Evaporator: A device designed to efficiently process maple sap into maple syrup by evaporation through 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.

Even-aged stand: Stand in which the trees are predominantly within the same age class, and approximately the same size.

Feed line: Conducting line from feed tank that supplies sap to the evaporator.

Fibers: Elongated cells that are part of the xylem. They provide structural support in plant stems and roots.

Filter press (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.

Flavor: Component of maple syrup grades that recognizes the unique taste associated with pure maple syrup.

Flooding the evaporator: 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.

Food-grade Materials that have been determined to be safe for use in the manufacture of food products.

Front pan (syrup pan): Pan or set of pans, usually further divided into partitions into which partially evaporated sap flows from the flue pan and is further boiled until being drawn off.

Gradient: Increasing sugar concentration of sap within an evaporator as measured from the input point in the sap pan to the take-off point in the syrup pan.

Gravity filter (flat or cone filter): Method of syrup filtration that relies on gravity to move syrup through a filtering medium.

Gross sales: The grand total of all product and service sales during a period before accounting for any costs.

Heartwood: Inner, dark-appearing wood no longer involved in sap transport.

Hot test: Determining the density of a sample of hot syrup (211°F). Hot testing is commonly doe with a hydrometer using the first red line.

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.

Invasive species: Species that are found outside of their normal range and pose a direct threat to the economic, ecological, or social functioning of the ecosystem in which they have been introduced. Invasive species can be animals, plants, or other organisms (U.S. Department of Agriculture, n.d).

Invert sugar: Six carbon sugars, glucose and fructose, which both have the chemical formula $C_6H_{12}O_6$. Invert sugars are produced by the breakdown of sucrose, commonly by the action of microorganisms.

Lateral line: Smaller tubing lines (5/16-inch or 3/16-inch in diameter) used to collect and transport sap from individual tapholes (droplines) to mainlines.

Mainline: Larger diameter plastic tubing used to collect and transport sap from several lateral tubing lines to a common collection tank.

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.

Maple sap: Watery liquid collected from maple trees during the dormant season. Composed mainly of water, with a small percent

age of sugar (primarily sucrose) and other lesser compounds. Maple syrup is produced from maple sap.

Maple syrup: A sweet, viscous liquid made by boiling sap until the boiling temperature of the liquid is at least 7.1°F above the boiling temperature of pure water, and which contains at least 66.9% solids (primarily sucrose) by weight.

Margin, leaf: Peripheral boarder or edge of a leaf, as in “red maple leaves commonly have small teeth along their margin”.

Natural vacuum: Vacuum that develops in a non-vented tubing system as a result of sap moving through the lateral and mainlines.

Niter (sugar sand): Substance that precipitates during the evaporation process.

Off-flavored: Identifies the presence of non-maple flavors in pure maple syrup; most off-flavors are considered objectionable.

Operating costs: Costs associated with the maintenance and administration of a business on a day-to-day basis. These costs are generally re-occurring each year.

Outer bark: The outer most layers of stems and roots of woody plants. It provides protection, retains moisture, acts as a defense mechanism, and insulates against cold and heat.

Overstocked: The situation in which trees are so closely spaced that they compete for resources and do not reach full growth potential. The stand or forest has more trees than are desired for the intended objective.

Permanent comparator: Grading kit that contains colored glass or plastic 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.

Phloem: Tissues in plants that conduct foods (sugar and metabolic products) made in the leaves to all other parts of the plant. Phloem is composed of living cells.

Photosynthesis: The process by which the energy from sunlight is used to synthesize carbohydrates from carbon dioxide and water in the presence of chlorophyll. (G.I.)

Raised flue: Back pans constructed with bottom flush with the rails of the supporting arch, with flues extending upward.

Ray cells: Live xylem cells which extend radially (outward from the center of the tree). Ray cells allow the products of photosynthesis to move in and out of storage in the xylem tissues and hold annual growth rings together.

Refractometer: Instrument used to measure the density of sap or syrup by determining the refractive index (the bending of light passing through the solution).

Releaser: Device used to transfer (release) sap collected with a vacuum equipped tubing system without reducing (breaking) the vacuum in the system.

Reverse flow: Syrup pans through which the sap moves back to front. These pans have two draw-off valves, one on each side, and a valve system that allows the sugarmaker to reverse the flow in the syrup pan and draw off from alternating sides. This reduces the accumulation of sugar sand.

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, but too small to allow the passage of sugar and other large molecules.

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. Sugarmakers in Vermont should use the rule of 88.2 since syrup is required to have a density 66.9°Brix.

Saddle manifold (fitting): 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.

Samara: Winged fruit. The fruit of maple trees is a double samara joined at the seed end to form a "U" or "V" shape.

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 sap is alternately under positive and negative pressure during the dormant season in response to temperature changes, resulting in sap exudation from tapholes.

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.

Sapwood: The outer, lighter portion of the wood in a tree trunk, at least some of which is involved in the conduction of sap.

Shade tolerance: The relative ability of some tree species to regenerate and survive under the shade of other trees and shrubs.

Silviculture: The art, science, and practice of controlling the establishment, growth, composition, health, and quality of a forest to attain management objectives.

Spout: Device placed in a taphole to channel sap into an attached collection container or tubing.

Stand structure: Distribution of tree sizes/ages within a stand (viz. even-aged stands versus uneven-aged stands).

Stocking, stand: Expression of the amount of tree growth present on an area as compared to what is considered optimum based on pre-established standards (e.g., stocking guide), as in "the sugarbush is 70% stocked."

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.

Sugarmaker: Individual who make sample syrup.

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.

Syrup density: Component of grading referring to the concentration of solids, mostly sugars, in maple syrup. Finished syrup has a density of 66.0° Brix to 66.9°Brix.

Syrup grade: Designation assigned to pure maple syrup based on several attributes, including color, clarity, density and flavor.

Taphole: Hole (typically 5/16-inch or 3/16-inch diameter) drilled in the trunk of a maple tree from which sap is collected.

Taphole closure: Process through which a taphole closes-over via the growth of callus tissue following removal of the spout.

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.

Temporary comparator: 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.

Topography: The configuration of the land surface, described in terms of such things as elevation and slope.

Tubing: Flexible, plastic (usually 5/16-inch or 3/16-inch diameter) 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, mainfolds, etc.

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 5/16-inch or 3/16-inch tubing.

Understory: A layer of vegetation beneath the main canopy of a forest.

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 pump: Pump used to create a negative pressure that is transferred via a tubing network to individual tapholes.

Value-added product: Secondary products produced from pure maple syrup such as maple sugar, maple cream, maple candies, etc.

Vascular cambium: The main growth tissue in stems and roots. It produces secondary xylem inwards (towards the pith) and secondary phloem outwards (towards the bark). Located between the xylem and the phloem.

Windthrow (blowdown): Trees uprooted or broken by wind.

Xylem: Vascular tissue in plants that conducts water and minerals upward from the roots to the stems and leaves. Xylem helps to form the woody element in the stem.

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