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Research: Taps

Innovations in Maple Sap Collection Systems: Spouts

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Maple sap tubing collection systems have undergone continuous evolution since being introduced. Over the past several decades, spouts in particular have changed considerably, with a marked shift towards smaller (1/4", 19/64", or 5/16") spouts, developed and introduced by CDL. Other modifications such as Bioseal Spouts (H2O), Check-Valve Spouts (Leader Evaporator), thin-walled spouts (DSD), and Max-Flow and Signature Spouts (CDL) have been introduced into the industry, among countless other variants. Over the same time period, the composition of spouts changed somewhat from a softer, more malleable "plastic" nylon to a more rigid nylon or polycarbonate material that is very hard and does not deform in the taphole. Some spouts are meant to be sanitized and reused over several seasons, while some types are meant to be seasonal and replaced each year.

Regardless of the style, all modern spouts tend to have fairly straight, minimally-tapered barrels compared to older (especially 7/16" spouts), which had a pronounced taper. This design feature facilitates a higher amount of contact of the spout barrel with the taphole, reducing heaving and minimizing vacuum leaks. Unfortunately, the extended contact of the spout barrel with wood tissue creates a new problem because a higher amount of wood tissue is blocked off by the spout barrel in the taphole.

Sap flows into tapholes from severed vessels in the wood xylem. Due to the physiology of maple trees, the outermost rings of xylem tend to be the most highly conductive of sap and also contain the highest concentration of stored sugar. Hydraulic conductivity, sap flow amount, and sap flow velocity, as well as sap sugar content all normally drop off with the age of the annual ring as we go deeper into the tree. Although it varies from tree to tree, sap flow at about 1.5" deep averages only about half that found at 0.5" deep and falls further to about 25% or less beyond 2" deep. This explains why drilling tapholes deeper than 2" deep results in little appreciable gain in sap yield (https://mapleresearch.org/pub/depth0321/).

Inserting a spout into tapholes changes the flow dynamics. Any vessel that is in direct contact with the spout cannot flow sap freely into the taphole and out of the spout. This phenomenon was not unrecognized before tubing, leading to various approaches being made to reduce contact of the spout with the surface of the taphole. These included flat knifelike projections of the spout inside the taphole in a single plane and various other means. This can be seen quite well in the books on spouts by Hale Mattoon (*Maple Spouts, Spiles and Taps* 2013 and *Maple Spouts Spiles Taps & Tools* 2017). Such spout adaptations could be helpful, but any amount of such projections within the taphole that contact wood are likely to negatively impact sap flow from affected wood vessels, and thus this style of approach was not deemed to be fruitful.

The reduction in sap flow due to recent spout design and geometry (small spouts, low-taper spouts with long barrels) has been largely masked by the increasing use of vacuum. Sap flows out of tapholes due to differences in pressure, with sap moving from areas of high pressure to areas of low pressure (much as water flows downhill or air flows out of a puncture in a tire). On gravity, this pressure is mostly due to head (the height of the sap column above the taphole) and stem pressure (due to expansion of air bubbles in wood fiber tissue upon thawing/warming). Vacuum will pull sap from a much larger part of the tree over time due to the higher pressure gradient it creates (the "outside" pressure the taphole experiences on the tubing system is artificially lowered by the vacuum pumps). The resulting higher pressure gradient on tubing systems with vacuum produces a higher sap volume flowing out of a taphole in any given sap run, but also generates a higher sap flow rate from the taphole during the time period of a sap run (the higher the difference in pressure between the inside of the tree and the tubing system, the higher the sap flow rate).

In other words, a taphole on vacuum will flow faster than a taphole on gravity. Thus, within a given amount of time in a sap run, more sap will be collected on a tubing system on vacuum than on one without. However, due to the design of current spouts, some vessel elements closest to the outer portion of the tree are blocked. This slows sap flow from the taphole to some degree due to the need for sap to be pulled around the obstruction to reach open vessels and flow out of the taphole. This sideways movement of sap can readily occur but is about ten times slower than flow from an unimpeded vessel. While over a long period of time all the sap will eventually make its way out, during short to moderate length flows - which are common during the early season (when thaws are often brief and limited to the outer unthawed portions of the stem) - sap movement out of the taphole can be slowed down considerably, resulting in lower yield.

The problem of vessel blockage is exacerbated by drilling tapholes too shallow (under 1.5") or by seating spouts too deeply (https://mapleresearch.org/pub/overdrive2020/). In either case, more wood vessels are blocked off by the spout, and less sap will be collected.

The solution to this problem is to not only get MORE sap out of tapholes, but to also get the sap out of a taphole FASTER. By getting sap out of the taphole more quickly, higher sap yields are generated, especially during brief or incomplete thaw periods, but also to a reduced amount during longer flows.

Over the past five years we have examined several different approaches to reducing this restriction in sap flow from shallow tree rings in an attempt to increase sap yield and sugar content of collected sap. After exploratory research in 2018 and 2019, we settled upon a basic design starting in 2020 that in continued testing has proved successful. The two main features of this new spout include a shorter barrel and barbs.

Shortening the barrel of the spout reduces the amount of wood vessels that are blocked off by contact of the spout with the taphole and reduces the distance sap must be pulled to get around the obstruction. However, shortening the barrel reduces the stability of the spout in the taphole and could lead to problem of heaving. A series of graduated barbs is used to prevent this. The spout is designed so that the first set of barbs engages in the xylem (wood) itself, close to, but inside of the cambium. The second set of barbs engages in the bark. The third set of barbs engages if the bark is thick, and is also intended to provide a positive "stop" for spout seating, thereby limiting overdriving of spouts. Use of the barb spout does require somewhat more force be used while tapping spouts in than standard spouts. Scraping is recommended for trees that have very thick bark.

Several candidate prototype (and control) spouts were machined from polycarbonate rod for the 2020, 2021, and 2022 sap flow seasons. All of these were made as straight-through spouts simply for ease in machining. Sap yields in 2020 and 2021 were 10.8% and 23.8% respectively, reflecting the different types of sap flow seasons experienced. Trials in 2022 were inconclusive due to undetermined machining error or material stock issues that resulted in microfracturing of both control and prototype spouts. Sap sugar content tended to be slightly (5-20%) higher with prototype spouts.

The University of Vermont has submitted a patent application for this new spout design and is working with an experienced injection molding company (Middle Valley Maple) on the final design and production of a molding tool to produce test articles for the 2023 season. We are working with several maple research and Extension groups as well as selected maple producers for more extensive testing during the 2023 and will incorporate feedback into the final design for anticipated marketing for the 2024 production season.