NORTH AMERICAN

# Maple Syrup Producers Manual

Second Edition

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# Maple Syrup Producers Manual

Second Edition

Produced By Ohio State University Extension
In Cooperation With
The North American Maple Syrup Council

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# ACKNOWLEDGMENTS

For almost five decades maple producers have depended on and been well served by five editions of the *North American Maple Sirup (Syrup) Producers Manual*[1]. During that time there have been many changes in the maple industry, including changes in technology, in maple markets, and in marketing strategies. In 2001 Richard Norman reminded the North American Maple Syrup Council of its commitment to periodically re-evaluate the need for revision of the 1996 manual. At that time the decision was made to revise, expand, and update the manual, and this edition is the result. Richard has served as the Council's liaison with the editors throughout the process.

This edition of the manual was developed by inviting leaders from within the maple industry to contribute to the authorship of chapters or portions of chapters addressing important aspects of maple products production and marketing. Twenty individuals were involved in providing information, drafting, and/or writing. Contributors to the authorship of each of the chapters and appendices in this manual were as follows:

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[1] Willits, C. O. 1958. Maple Sirup Producers Manual. USDA Hdbk. No. 134.
Willits, C. O. 1963. Maple Sirup Producers Manual. USDA Hdbk. No. 134.
Willits, C. O. 1965. Maple Sirup Producers Manual. USDA Hdbk. No. 134.
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In addition to the expanded and revised text, another feature that sets this edition of the manual apart from previous editions is the use of color photographs. Most of the pictures in the manual were provided by the editors and authors. Many, however, were not, and we would like to thank those who generously contributed their photographic skills to improving the quality and value of this manual. Their contributions are identified beside their pictures. A special thanks is extended to Mike Girard, Connecticut Maple Producer, and Mark Isselhardt, Research Technician at the Proctor Maple Research Center. Mike made available much of his extensive personal collection of photographs, and many of those are found throughout the manual. Mark acted as the unofficial photographer for the manual, willingly pursuing pictures needed to illustrate a particular point. Other individuals contributing photographs included:

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Weeks and Parker—*Native Trees of the Midwest: Identification, Wildlife Values, and Landscaping Use,* by Sally S. Weeks, Harmon P. Weeks, Jr., and George R. Parker. Published in 2005 by Purdue University Press

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Finally, many colleagues and friends participated in an exhaustive review of this manual throughout its development. Individuals throughout the industry with recognized expertise in particular areas were frequently consulted. To those many unnamed friends we express our sincere thanks. Each chapter was thoroughly reviewed several times for technical content by many of the contributing authors and the editors. The final value of a manual such as this, however, lies not only in its technical accuracy, but in its readability, clarity, and practical perspective. Sincere appreciation is expressed to those individuals who read the entire manual, and made valuable suggestions regarding not only its technical content, but also addressing those important characteristics.

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# Preface

In a society oriented to nearly constant change, many of us find solace in those things that endure. There is a sense of stability and comfort in things that change little or not at all, be they relationships, values, or processes.

The process of producing pure maple syrup is one that has experienced little change over the years. To be sure, improved equipment is available for sap collection, and adaptations to increase the efficiency of processing have occurred. Yet, the fundamentals of tapping maple trees and collecting sap, together with processing this sap by boiling, continues to be essentially the same process that Native Americans used centuries ago.

While the fundamentals of producing maple syrup have remained unchanged, the contemporary maple syrup operation bears little resemblance to the seasonal sugar camps of the past. Plastic tubing networks, vacuum pumps, reverse osmosis machines, forced-draft units, preheaters, pressure filters, and plastic containers are all innovative adaptations to improving yield and efficiency of production. Not only are contemporary maple sugar operators efficient, they have become proficient marketers as well. Maple syrup and other derived maple products continue to be sold locally, but are also available in gift shops, natural food stores, and retail grocery stores throughout the country, and through mail order catalogs and the Internet.

This manual is intended to serve as a basic handbook for the production of pure maple products. Current information and recommendations relating to all aspects of the industry are presented. These guidelines should be helpful to the hobby and beginning producer, as well as to those established within the industry, along with foresters, Extension personnel, and others providing information and assistance to maple producers. It should also be of interest to those who simply want to learn more about this uniquely North American enterprise. Although some of the procedures for collecting and processing sap may have changed and continue to evolve through the efforts of the innovative producers, those in the maple equipment industry, and the work of maple researchers, the fundamental process of production and the goodness of pure maple syrup have not. The delectable flavor of this unique product remains the same as always. For this simple fact, many of us are happy that no change represents progress.

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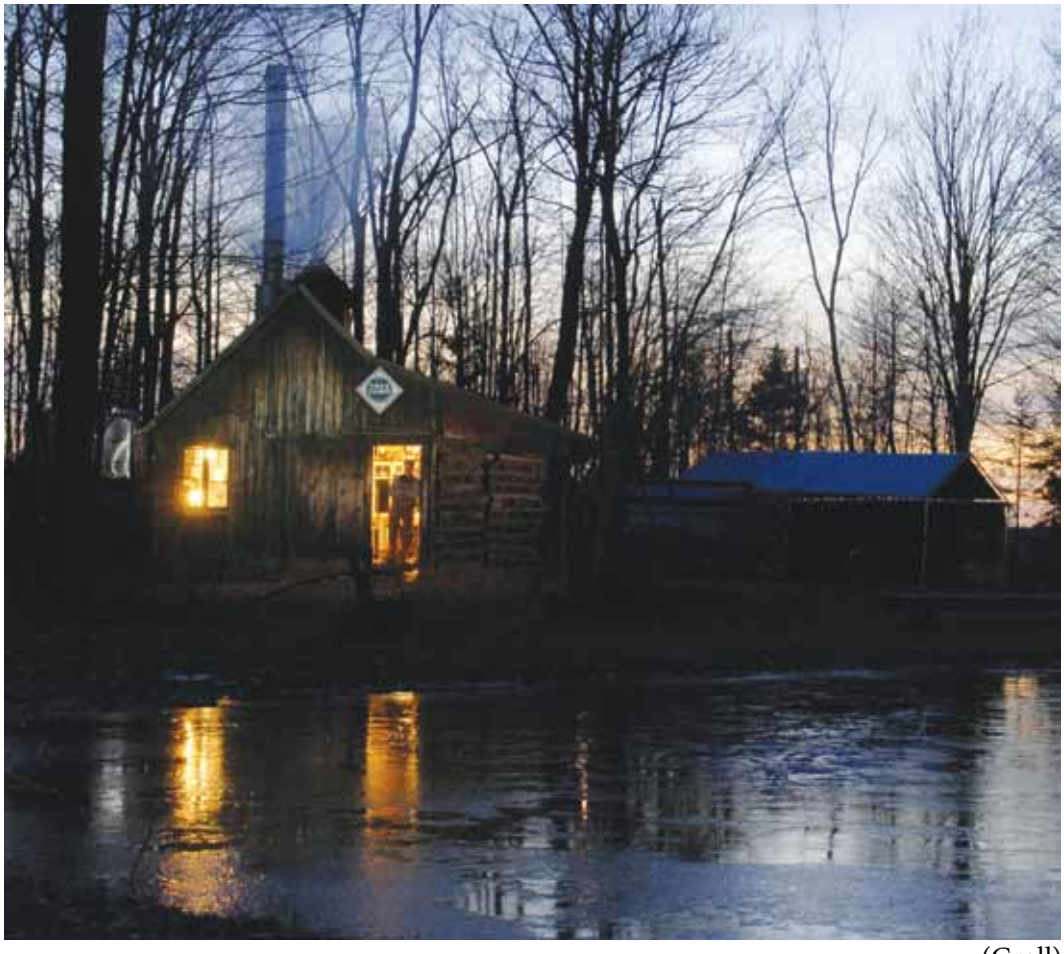
# Maple Syrup Producers Manual



(Groll)

Second Edition

# Chapter 1 · Introduction

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

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

A harbinger of spring was the arrival of the annual "sugaring" season (**Figure 1.1**). Capitalizing on a process that originated with Native North Americans, maple syrup and sugar production served as an important activity essential for maintaining the living characteristic of many early Americans. Not only did this season signal the "beginning of the end" of winter, it also provided the opportunity to participate in an activity characterized by hard work, but one that resulted in the production of those wonderful products known as pure maple syrup and sugar. This delectable sweetener made for memorable breakfasts when served over steaming pancakes or on crisp waffles. Maple syrup, a truly natural product excellent in its own right, also provided the source for other products such as maple sugar, maple crème, maple candies, maple taffy, and other delectable confections. Maple sugar served as the principal sugar for other uses including curing meats, as an additive to baked goods, and as a flavoring in sauces and other toppings.

These memories are still alive, and so is the production of pure maple syrup and related products. While substantial improvements have been made in techniques and equipment involved in sap collection and related production and processing (**Figure 1.2**), pure maple syrup is still a natural product, produced by the same process as that used by our forebears. Current production techniques might be more efficient and attentive to the safe production of a food, but the final product is little changed. While nature continues to provide the maple resource and the change of seasons necessary for the sap flow process to occur, the dedication and hard work of individuals still harvest and process this sap into the same delicious product as always. Certainly modern technology has been applied to the maple syrup industry. Today's sap collection systems involve plastic tubing and vacuum pumps, evaporation systems featuring

reverse osmosis sap concentration units, stainless steel evaporating pans with efficient preheating units, and precision controls to consistently produce the highest quality product. Contemporary packaging methodology assures consumers of having quality products available in the purest possible condition. While these modifications have resulted in more efficient and productive operations, the heart of maple syrup production is still the collection of maple sap from trees, and evaporation and concentration of the sugar in this sap by boiling to produce the unique flavor and character of pure maple syrup.

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

The pure maple syrup industry is alive and well. It has withstood the test of time and change and continues to occupy a unique place in North American agriculture. Nature continues to provide the raw resource while hard-working individuals collect and process this resource into pure maple syrup and related products for all to enjoy. This manual has been prepared to provide current information on all aspects of the sap collection and syrup production processes. It contains information that should be helpful to beginning as well as experienced producers whether they are managing small or large operations. Information presented has been obtained from relevant research studies and the experiences of producers and others who have dedicated themselves to understanding the processes and techniques involved in producing pure maple products. The pure maple syrup tradition continues; the maple season is greeted with the same anticipation and enthusiasm as always, and the products produced are as valued and treasured as ever (**Figure 1.3**).

Figure 1.3. Maple season is greeted with the same anticipation and enthusiasm as always, and the products produced are as valued and treasured as ever.

# Chapter 2 · History of Maple Syrup and Sugar Production

The collection of maple sap and production of pure maple syrup and sugar predate the founding and establishment of both the United States of America and the Canadian Federation. Maple syrup production is one of the few agricultural enterprises not originally brought to this country by European immigrants. While substantial improvements have been made in the equipment and techniques for both sap collection and syrup production, the principle of processing maple sap into maple syrup by evaporation and boiling remains the same.

## Origins of Maple Syrup Production

Present-day consumers owe Native Americans a sincere debt of gratitude for discovering that sap collected from maple trees could be processed into maple syrup. While no authenticated accounts exist as to how this process was discovered, there are several interesting legends. Undoubtedly some are simply folklore while others have been modified over time, yet it is highly likely that this discovery was accidental.

One popular legend involves a Native North American chief who in late winter supposedly hurled his tomahawk at a tree. The tree happened to be a maple and when the tomahawk stuck in the tree, creating a wound, sap began to flow. The clear liquid that dropped from the wound tasted somewhat sweet and was collected in a container that was placed on the ground below. The wife of the chief, believing the liquid was water, used it to cook venison. After cooking, both the meat and the sweet liquid that remained were found to have a unique, delicious flavor. Retracing how this occurred revealed that the sweet sap from the maple tree was the only difference. The process was repeated, the same results were obtained, and the rest is now history.

Another popular legend suggests that the first knowledge of sugar from a maple tree came from an early Native American who tasted an icicle hanging from a broken maple branch, and noticed that it was sweet. The "sap-sickle" had formed when a branch tip broke off during late winter, and the sap flowed out and froze. The evaporation and sublimation of water from the "sap-sickle" increased the sweetness of the remaining ice, resulting in a sweet and tasty treat hanging from the tree.

There are many other variations of this legend, yet the fact remains that wounding a maple tree in late winter/early spring resulted in the production of a clear liquid that could be processed by boiling into a deliciously sweet product that had many uses.

## Early Maple Production

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

The rural, farm-centered, subsistence lifestyle soon developed into a regular pattern. Spring was the time for planting, followed by a period of cultivation and eventually the late summer-fall harvest. This was followed by winter, the time for fuelwood production and anticipation of the coming spring. The maple season in late winter was much anticipated as it signaled the end of a

long winter and heralded the coming spring. "Sugaring," as the maple season was commonly referred to, became an integral part of the farm experience. Occurring at a time of the year when other farm activities of necessity were slowed down by the winter, activities in the sugarbush and sugarhouse caused many to view this as one of the most enjoyable times of the year. Winter in the north tended to be very confining and the opportunity to get out during periods of weather favorable for sap flow was a sure indication that spring was "just around the corner." In some communities maple sugaring was actually a social event, as the labor necessary for a moderate to large-sized operation required many hands. The work required was sometimes tedious and the hours were long, but the fruits of the labor were long remembered as maple syrup and other maple products found their way into many delicious foodstuffs, flavorings, and sweet treats prepared throughout the year.

Figure 2.1. Primitive spouts were small stem sections of sumac or elder that were hollowed out by removing the central core or pith tissue. (Girard)

## Sap Collection and Processing Methods

Substantial changes and improvements in the methods of sap collection and evaporation have occurred over the past several years, but the fundamentals of the processes remain unchanged. During late winter, temperature-induced physiological processes occur in maple trees such that wounding a tree results in a flow of sap that can be collected and processed into maple syrup. Native Americans tapped maple trees by making a rather rough gash through the bark in the trunk of the tree. Sap flowing from this wound was directed through a hollow twig or piece of bark into a wooden or bark container placed on the ground. Sap from several similar containers was collected and placed in a larger clay or wooden vessel. Clay vessels were heated over open fires to concentrate the sap sugar content. In contrast, sap in wooden vessels, which were often hollowed out logs, was concentrated by placing heated stones in the sap. Heat from the stones resulted in heating the sap, evaporation, and concentration of sugar in the sap. Repeating the process several times eventually resulted in a syrupy liquid, which undoubtedly was sweet, but also dark and somewhat "gritty." Other methods of concentrating the sugar in the sap allowed the sap to freeze. Because the sugar in the sap did not freeze, the ice was discarded. The liquid remaining was a sweet solution, but it did not have the characteristic flavor associated with maple syrup. That flavor is only produced when sap is heated.

Early settlers, both French and English, initially followed the destructive tapping practices of Native Americans by making gashes in the bark to create wounds through which sap would flow. Sap was collected in wooden troughs placed on the ground. These troughs were made of short, hollowed-out sections of tree trunks. Within a few years settlers modified their tapping practices so less wounding to the tree resulted. Metal augers were used to make a small hole in the trunk of the tree. In this "taphole" a spout or spile

was inserted to direct the sap into a collection container. In fact, the word *spile* probably comes from the fact that the spile is used to "spill" the sap from the tree into a container. These primitive spouts were small stem sections of sumac or elder[1] which were hollowed out by removing the central core or pith tissue **(Figure 2.1)**. Eventually commercially manufactured metal spouts replaced the wooden ones. A variety of different designs were available from several different manufacturers (**Figure 2.2)**. Some incorporated a built-in hook to support either the wooden or later metal sap collection pail at the taphole as opposed to placing it on the ground. Over time the hand-operated brace and bit replaced the auger as the standard tapping tool.

Figure 2.2. Eventually commercially manufactured metal spouts replaced wooden ones, with a variety of different designs available from several different manufacturers. (Girard)

For many years the hand-powered brace was the standard tapping tool. However, power tapping units ultimately found their way into the sugarbush. The first were rather heavy gasoline-powered backpack units with a flexible shaft that drove a small bit held in front of the operator. Later, storage battery-powered backpack units or gasoline-powered tappers became available and are still used by some. Today, a high proportion of tapping is done with battery-powered, cordless drills (utilizing multiple battery packs), though some producers still utilize a tapper consisting of a lightweight, gasoline-powered engine with a drill chuck built into the unit.

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

Containers used for collecting sap have progressed from vessels made of bark and hollowed-out logs to wooden buckets **(Figure 2.3)** to metal buckets **(Figure 2.4)** to plastic bags. Different-sized units have been used as well as containers of different designs. Each had its own advantages and disadvantages; however, all required at least daily visits during the sap season to collect the accumulated sap. Sometime prior to World War I, attempts began at developing a sap collection system that did not require a collection container at each taphole. A metal tubing system, known in some locations as the "gooseneck" system **(Figure 2.5)** was developed. However, because it was prone to leaks, was difficult to clean, required strict attention to grade (slope), and had to be custom-fitted to each location, it did not gain wide acceptance.

Figure 2.3. Early wooden sap buckets. (Girard)

Figure 2.4. Early metal sap buckets. (Girard)

Figure 2.5. Early gooseneck tubing system. (Girard)

The improvement in sap collection technology and equipment that had the greatest impact on the maple syrup industry was the introduction of plastic tubing. Plastic tubing significantly reduced both the labor and equipment cost associated with sap collection. As a result of substantial improvements in equipment design and installation techniques in recent years, systems are now adaptable to a wide variety of applications and sites. The addition of vacuum pumps to tubing networks has allowed significant increases in sap yields and facilitated rapid movement of sap through the network. Many tubing systems are now designed for year-round installation in the sugarbush, minimizing set-up and take-down labor. At the end of the season, taps are removed from trees, the system is washed "in place," and all openings are closed. The following year, new tapholes are drilled and the system is re-installed.

In the beginning, sap was gathered and transported to the evaporation site by hand. Most operations were relatively small and with plenty of labor this was not an insurmountable task. Gathering equipment often consisted of a couple of large wooden buckets suspended from a shoulder yoke **(Figure 2.6)**. However, as operations increased in size it became necessary to collect sap from several trees, empty the gathering pails into a gathering tank, and transport it to the evaporator. Initially this was done with a team of oxen or horses pulling a sledge or sled on which a wooden tub was mounted **(Figure 2.7)**. Eventually many operators replaced the wooden tubs with metal tanks, and the oxen or horses with tractors, although some horse-drawn collection tanks are still present. Where plastic tubing systems are used it is not necessary to collect sap directly from each tree. Rather**,** sap moves through the tubing system to a common collection point, preferably the sugarhouse. If it is necessary to move sap, pumping systems are installed to transport sap from one location to another. For large operations, where sap is collected from one or more sugarbushes, trucks equipped with holding tanks are used to transport the sap.

Figure 2.6. Early gathering equipment often consisted of a couple of large wooden buckets suspended from a shoulder yoke. (Girard)

Figure 2.7. Early gathering with animal-drawn sledge or sled. (Girard)

Equipment used for boiling and evaporating sap has changed over the years; however, the basic process involved has not. Early settlers used metal cauldrons or kettles to boil the collected sap. These vessels were suspended from a pole or tripod over an open fire **(Figure 2.8)**. As the amount of sap in the kettle was reduced by boiling, more sap was added. Eventually the concentration of sugar in the boiling sap was increased to that necessary for "finished syrup." The syrup produced by this method, although sweet, was strong flavored and dark because of prolonged boiling resulting from the continued addition of fresh sap. An innovation resulting in improved quality of the final product was the use of multiple kettles**.** Partially concentrated sap was transferred from one kettle to another as it progressively increased in sugar concentration. This process resulted in the production of lighter colored syrup as the boiling time required for sugar concentration was reduced.

Figure 2.8. Early settlers used metal cauldrons or kettles to boil the collected sap. (Girard).

Sometime in the mid-1800s the flat-bottomed pan for concentrating sap was introduced. Mounted on an arch (so called because of its shape), usually made of stone or brick **(Figure 2.9)**, this pan greatly increased the rate of boiling and evaporation due to the increased surface of both the boiling surface and the area to which heat could be applied. By 1860 the continuous flow evaporator had been invented. This was a modified flat pan equipped with sectional dividers open at one end that allowed sap to enter at one end of the pan and finished syrup to be drawn off at the other end. The advantage was more rapid evaporation and a "continuous evaporation" process that permitted less mixing of fresh sap and partially concentrated sap. The result was reduced boiling time and a higher quality final product. This was a major improvement over the batch system used with both kettles and flat pans where boiling would take place for several hours before removal of the final finished syrup.

One of the first evaporators to be patented and used in the maple industry was the Cooks Sugar Evaporator, patented June 22, 1858. It was manufactured by Blymer, Bates, and Day in Mansfield, Ohio, and was originally made for the production of molasses or sorghum syrup. However, it was evaluated for maple syrup production and was soon accepted as an evaporator without a rival. "More sugar and whiter" was acknowledged everywhere in the maple region to be the result.

Attempts to improve the efficiency of sap evaporators continued. A few years following the development of the continuous flow pan the flue pan was developed. This resulted in separating the evaporator into two individual pans, a front or syrup pan and a back or flue pan. The flue pan was a modified flat pan with several deep corrugations or individual wells in the bottom of the pan to increase the surface area to which heat was applied. The result was much more rapid boiling and evaporation. Partially concentrated sap flowed from the flue pan into the flat surface syrup pan where boiling continued and syrup was finished. The quality of the finished syrup was substantially increased due to the shortened evaporation time.

Figure 2.9. Sometime in the mid-1800s the flat-bottomed pan mounted on an arch developed for concentrating sap was introduced. (Girard)

The basic evaporator has remained unchanged since the development of the flue pan. However, several accessories have been developed over the years to increase evaporator efficiency. These generally attempt to use steam produced during evaporation to preheat incoming sap, thereby reducing the amount of both heat and time for processing sap into syrup. One of the first such devices was the sap preheater. Initially a series of coils was placed in the smoke stack of the arch and incoming sap was allowed to flow through these coils before it entered the evaporator. Later a hood was placed over the evaporator to direct the steam away from the evaporating surface. Placement of pipe sections on a suspended platform within the hood and directing incoming sap through these pipes significantly increased sap temperatures. The most recent developments designed to make more efficient use of heat produced in the evaporation process utilize a more complex preheating approach in which air is forced through sap in the flue pan to increase evaporation rates. All of these preheating devices have resulted in gains in evaporator efficiency. Modifications to increase the amount of air going into the firebox of wood-fired evaporators have also resulted in an increase in evaporator efficiency, as have modifications such as insulated arches and airtight doors, and preheating oil by running feed lines through the firebox to improve fuel atomization and combustion.

Evaporators were initially located in the open in the sugarbush. Kettles were suspended over open fires on tripods or log supports. Arches for flat pans were constructed of stones or bricks and fueled by wood collected from within the woodlot. Because the evaporators were "outdoors," syrup producers were subjected to whatever type of weather was present. It soon became apparent that some type of shelter was desirable, thus the "sugarhouse" came into being. The first shelters were nothing more than crude shacks or lean-tos in the woods. These were followed by the construction of cabin-type structures that over time have come to be identified as sugarhouses **(Figure 2.10)**. Initially these buildings were located in the woodlot, and many are still located there today; however, others have been relocated to a more accessible and convenient location where utilities such as electricity, running water, etc., are present. Over time some sugarhouses were located near public roads where modifications in their structure enabled them to be used not only as a production facility but also for marketing the finished product.

Figure 2.10. Early "sugarhouses" were cabin-type structures that, over time, evolved into the modern sugarhouse. (Girard)

## Maple Production in the 1800s

Consistent with the subsistence lifestyle of early settlers and colonists in the northeastern United States and Canada, maple syrup and maple sugar were the principal sweetening agents used in the home. The only other locally produced sweetening product was honey, although it was not as commonly available. Together maple syrup and honey found their way into several prepared food products, including their use in preserving, drying, and curing of many food staples, including

meats. Cane sugar, a rare and expensive commodity, was generally unavailable in most rural areas. When it could be obtained it was viewed and treated as a luxury product.

Maple products, especially maple sugar, continued their dominance as the principal food sweetening product until after the United States Civil War. Following the War, improvements in production techniques and transportation allowed cane sugar to become available in larger quantities and at lower prices than before. As a result, many urban residents increased their use of cane sugar and decreased their use of maple sugar. The reduced demand for maple sugar resulted in an increase in the amount of maple syrup marketed primarily for use as a topping for pancakes, waffles, and other similar products.

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

In the latter part of the nineteenth century syrup packers came on the scene. These were companies that originally may have produced their own syrup, but which later purchased syrup from other producers as well. Collected syrup was appropriately processed and stored either in large vats, or was processed into maple sugar. Maple sugar was sold to other food processing companies for use as flavoring components. The tobacco industry was a large consumer of maple sugar, which used it for flavor and aroma enhancement of different tobacco products. In more recent times some of these large packing companies packaged maple syrup for the retail trade, or sold it to other packers for use as syrup blends, candies and confections, or other maple products.

In the 1890s the first of several maple producer organizations was formed. Commonly shared objectives and goals of these state and regional associations were to facilitate sharing of ideas among members, to focus collective efforts in addressing common production problems, and in more recent years, to promote maple, discourage adulteration, and identify and support research and marketing projects appropriate to the maple industry.

## From 1900 to World War II

In the early part of the twentieth century maple production continued much as it had in previous years. Small, family-operated farms dominated the rural landscape and the production of pure maple products was an integral part of the diversified agricultural operation. Excess syrup was sold to neighbors or to urban residents who did not produce their own. A few innovative producers began marketing maple products outside the maple producing region using advertisements in national magazines and the development of private mailing lists. The income derived from sales of maple syrup was a significant source of cash for purchasing products that could not be produced on the farm. Some producers expanded their operations to provide syrup primarily for the wholesale market.

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

## World War II to the 1990s

Since World War II, significant changes have occurred in many aspects of both rural and urban life. Technology has advanced at a pace unparalleled at any time in the past. Transportation facilities have improved. A significant migration

of people from rural to suburban areas has occurred, and a reduction in the number of family-focused, diversified farms typical of previous times has also taken place. Specialization has occurred in many agricultural operations in maple producing regions as well as other sections of the continent. Within the maple syrup producing region the number of producers has declined. However, some of those remaining have increased the size of their operations and, in more than a few instances, have developed their maple syrup operation into a full-time business with the production of many maple sugar products derived from maple syrup and the establishment of both local and national retail markets.

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

While the number of maple syrup operations associated with small subsistence-type farms has declined, another significant class of maple producer has emerged in recent years. The number of individuals who live in rural areas but who do not depend on farm activities as the primary source of their livelihood has increased. Many of these rural residents, although employed elsewhere, have access to a maple woodlot. Each winter they will tap a few or several trees to produce their own pure maple syrup. While the total amount collectively produced by producers of this type is not large, the actual number of individuals involved is very significant and represents an increasingly common source of pure maple products in many rural areas.

## 2000 and Beyond

As the pure maple industry enters the twenty-first century, improvements in sap collection and processing have enabled products of the highest possible quality to be produced. While the maple resource and fundamentals of processing remain essentially unchanged, methods of sap collection, storage, evaporation, and packaging have all been impacted by improvements in technology. Changes in society have resulted in the development of more sophisticated consumers who are more knowledgeable and concerned about many things, including food quality and safety. Consistency in quality, absence of impurities and/or contaminants, and safety of food products has become a primary concern of many.

The maple industry is not immune from these concerns. In recent years the possibility of low levels of lead in finished syrup and syrup-derived products has resulted in a change in method of manufacture for maple sap and syrup related production and processing equipment. Much of the older processing equipment formerly used by many producers has been replaced. Stainless steel evaporators and related sap and syrup handling equipment are now manufactured using lead-free solder or welding. Syrup is packaged in containers made of materials that will not impart off-flavor or otherwise result in product degradation.

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

with marketing methods than with food safety, quality, or purity since most products identified and certified as being "organically produced" command a higher selling price. Producers of pure maple products have taken advantage of this marketing opportunity and many have promoted maple syrup and sugar products through organic food marketing outlets. In so doing, they satisfy a more demanding segment of the population while increasing economic returns.

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

# Chapter 3 · The Maple Resource

## North American Maple Resource

The commercial production of maple products in North America occurs primarily in the northeastern United States and southeastern Canada (**Figure 3.1**). This is the geographic area of greatest abundance of sugar maple *(Acer saccharum)* and black maple *(Acer nigrum),* the two most preferred and most commonly tapped maple species.

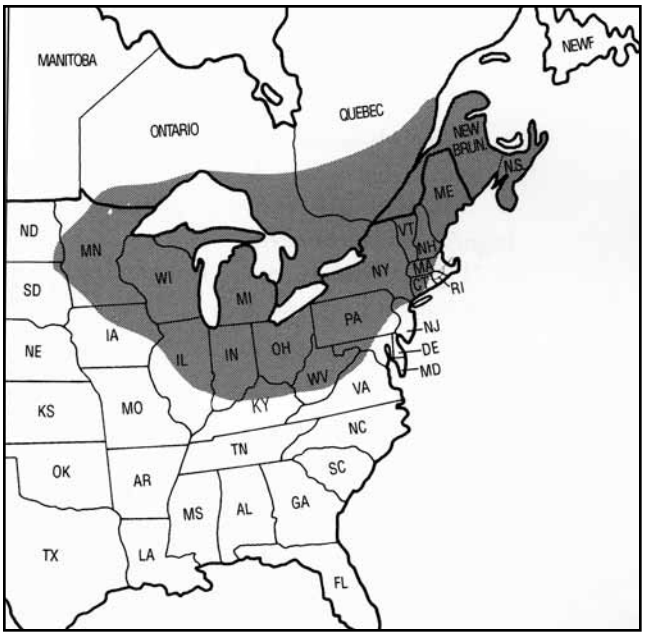



Figure 3.1. Area of commercial maple syrup production in North America.

There are thirteen native maple species in North America (**Table 3.1**). While many of these may be tapped, sugar and black maple along with red maple *(Acer rubrum)* are the most important commercial species. Silver maple *(Acer saccharinum)* is sometimes tapped along roadsides and in areas where it is the predominant maple species. A fifth member of the maple genus, boxelder *(Acer negundo),* is rarely tapped within the commercial maple syrup region, but is sometimes tapped in the prairie states and provinces where it is the only tapable native maple species.

**Table 3.2** contains a descriptive comparison and **Figures 3.2 through 3.6** illustrate leaf, bark, twig, and fruit characteristics of sugar, black, red, and silver maple, as well as boxelder. The four maples have leaves of similar shape; a single leaf blade with the characteristic maple shape, 3–5 lobes radiating out like fingers from the palm of a hand (palmately lobed) with notches (called sinuses) between the lobes. In contrast, boxelder has pinnately compound (ash-like) leaves consisting of 3–7 (rarely 9) leaflets. The leaves, buds, and twigs of all five species are arranged in pairs opposite each other along the branches. All five produce fruits called a double samara, which consist of a pair of winged seeds, connected to form a V- or U-shaped fruit.

Figure 3.2. Sugar maple leaves, fruit, twig, and bark. (VPI)

**Table 3.1. Maple species native to North America.**

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

Figure 3.3. Black maple leaf, fruit, twig, and bark. (Wray, VPI)

Figure 3.4. Red maple leaf, fruit, twig, and bark. (VPI)

Figure 3.5. Silver maple leaf, fruit, young and older bark, and twig. (VPI, Weeks and Parker)

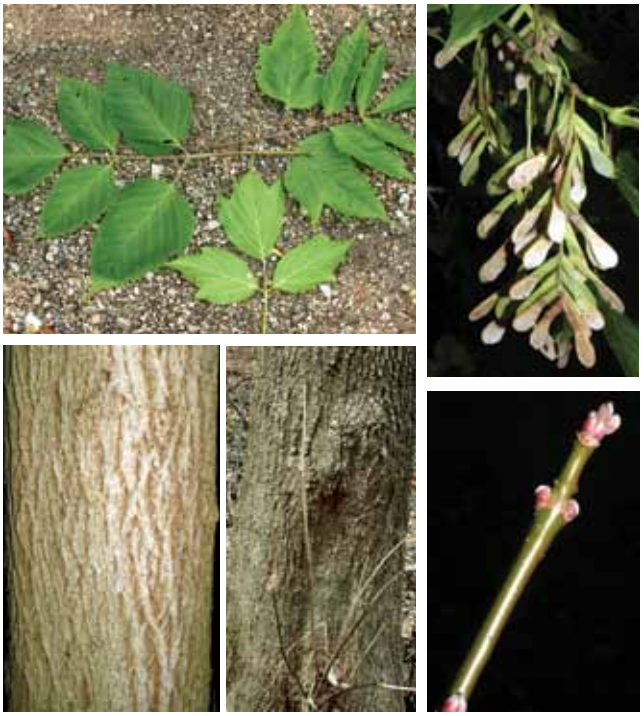


Figure 3.6. Boxelder leaves, fruit, young and older bark, and twig. (Weeks and Parker, Wray)

# Species Suitable for Making Maple Products

## Sugar and Black Maple

Sugar and black maple are very similar species and, because of their high sugar content, are the most preferred species for producing maple sap. Sugar maple occurs naturally throughout most of the northeastern United States and southeastern Canada (**Figure 3.7**). Black maple, on the other hand, occupies a much smaller natural range (**Figure 3.8**). Distinguishing between them may be more of an academic exercise than one useful in sugarbush management because (1) they are essentially identical in quality as sap producing trees, and (2) they are reported to hybridize, producing trees with a range of characteristics, making it difficult to clearly distinguish between them. Identifying characteristics of sugar and black maple are presented in **Table 3.2** and **Figures 3.2 and 3.3.** The leaves of both species have five lobes, are oppositely paired along the stem, and lack fine teeth along the margin. The bark of older trees has long plates or ridges that often peel away from the trunk but remain attached along one side. The twigs have oppositely paired, pointed lateral buds and a relatively long, pointed terminal bud. The fruit of black and sugar maple is identified by its size and horseshoe or "U" shape.

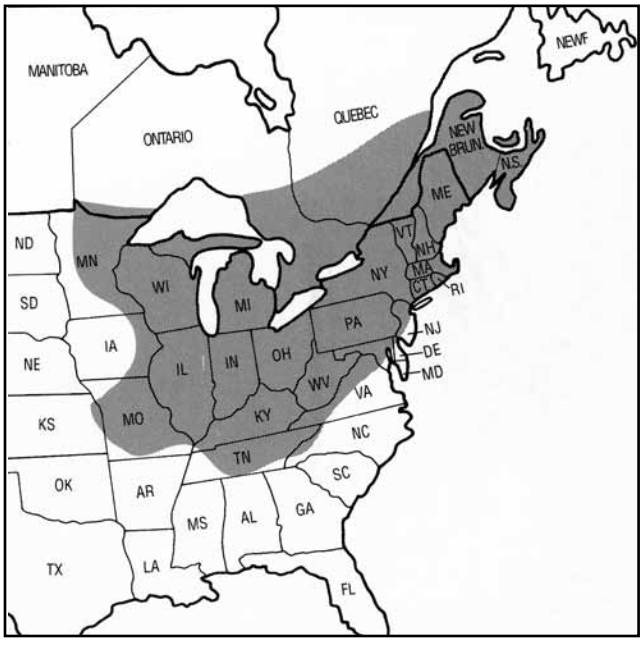



Figure 3.7. Sugar maple distribution.

**Table 3.2. Identifying characteristics of sugar, black, red, and silver maple and boxelder.**

| SPECIES | Leaf | Bark | Twig | Fruit |
|---|---|---|---|---|
| Sugar Maple | 3–6 inches wide: 5-lobed (rarely 3-lobed); bright green upper surface and a paler green lower surface; leaf margin without fine teeth (compare to red and silver maple). | Young trees up to 4–8 inches in diameter with smooth gray bark. Older trees developing furrows and ultimately long, irregular, thick vertical plates or ridges that curl outward. | A somewhat shiny, brownish, slender, relatively smooth twig with 1/4–3/8 inch long sharply pointed terminal bud. | Horseshoe-shaped double-winged fruit (called a double samara) with parallel or slightly divergent wings. Winged seed approximately 1 inch long. Fruits borne in clusters and mature in fall. |
| Black Maple | Similar to sugar maple but usually 3-lobed (sometimes 5-lobed); often appears to be drooping; often with a thicker leaf and leaf stem (petiole) than sugar maple; often with a distinct pubescence or hairiness on the underside of the leaves; usually with two wing-like or leaf-like growths at the base of the petiole (stipules). | Similar to sugar maple but usually darker and more deeply grooved or furrowed. | Similar to sugar maple but twig surface with small bumpy growths (lenticels—which are not raised much above the bark surface in sugar maple) often more hairy buds. | Similar to sugar maple, with perhaps a slightly larger seed. |
| Red Maple | 2–6 inches wide; 3-lobed (occasionally weakly 5-lobed); sharply V-shaped sinuses; small sharp teeth along margin. Sides of terminal lobe converge toward tip. Mature leaves have a whitish appearing underside. | Young trees up to 4–8 inches in diameter with a smooth light gray bark, developing into gray or black ridges and ultimately relatively broad, scaly plates. | Slender, shiny, usually reddish in color; terminal buds 1/8–1/4 inch long, blunt, red; odorless if bark bruised or scraped. | V-shaped, double-winged fruit about 1/2–1 inch long. Fruit matures in late spring. |
| Silver Maple | 5–7 inches wide; deeply clefted; 5-lobed with the sides of the terminal lobe diverging toward the tip; light green upper surface and a silvery white underside; leaf margin with fine teeth (but not the inner edges of the sinuses). | Silvery gray on young trees breaking into long, thin, scaly plates that give the trunks of older trees a very shaggy appearance. Considerable red is seen in bark pattern as scales develop. | Similar to red maple but often more chestnut brown in color. Bruised or scraped bark has a very fetid or foul odor. | V-shaped, double-winged fruit 1½–2½ inches long, with widely divergent wings. One of two seeds present is often poorly developed or aborted. Fruit matures in spring. |
| Boxelder | Pinnately compound with 3–7 (rarely 9) leaflets; leaflets green above and pale below, margins variably toothed or lobed, terminal leaflet often resembling a three-lobed maple leaf. | Relatively thin, pale gray to light brown; shallow ridges separated by narrow ridges on younger trees developing into deeper furrows on older trees. | Moderately stout, greenish to purple-green, buds usually white and hairy. | V-shaped double-winged fruit 1–1½ inches long; wings initially diverge from the seed and then converge slightly near the tips; fruit appears in late fall and often persists through winter. |

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

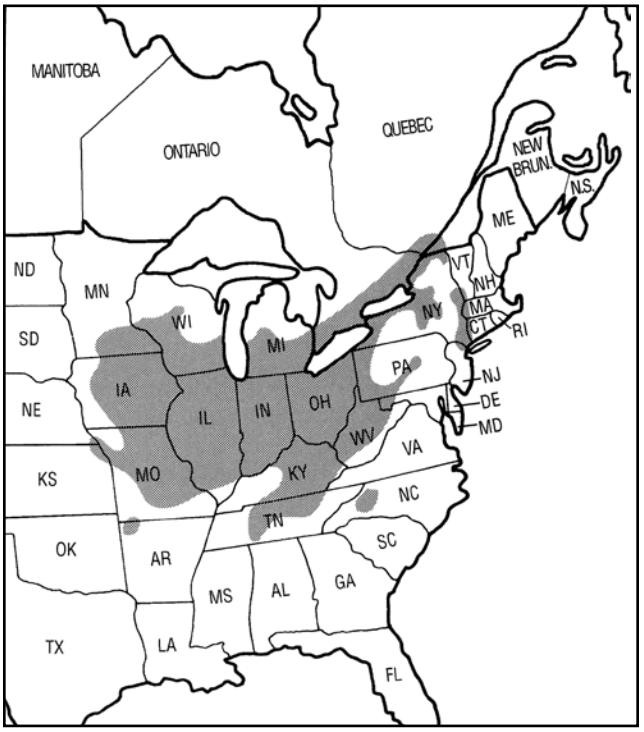



Figure 3.8. Black maple distribution.

Sugar and black maples are found on a variety of soils and site conditions, but neither tolerates excessively wet or dry sites, and both grow best on deep, moist, but well-drained soils. Black maple is more likely to be found along moist river bottoms. Both species can be found growing in pure stands, with each other, or with a wide variety of other hardwood species including American beech, American basswood, yellow birch, black cherry, northern red oak, yellow poplar, and black walnut. Both species have been planted extensively as roadside trees, which are often tapped as part of a sugaring operation. Plantations of sugar maple have also been established with the intent of developing efficient, productive sugarbushes. Both species are relatively long-lived, capable of living well beyond 200 years, attaining trunk diameters greater than 30 inches and heights greater than 100 feet.

Sugar and black maple both grow in the shade of other trees (referred to as being shade tolerant), and trees of many different ages and sizes are often found in a forest. Both species are also found in stands composed of trees that are essentially all the same age. Healthy sugar and black maple trees growing in overstocked uneven-aged or even-aged stands can be expected to achieve tapable size in 40 to 60 years, depending on overall site quality. Thinning or release cutting can dramatically decrease this age-to-tapable-size.

Sugar and black maple are particularly valued as sap producing trees because of their high sap sugar content and the late date at which they begin growth in the spring. Sugar and black maple have the highest sap sugar content of any of the native maples. While the exact sap sugar content of a tree will vary depending on many factors including genetics, site, and weather, sugar and black maples generally average between 2.0 and 2.5 percent sap sugar content. It is not unusual to find trees in a sugarbush well in excess of 3 percent or higher. Genetic research on sugar maple suggests that the sap sugar content of planted seedlings can be increased by selection and controlled breeding. Seedlings with comparatively high sap sugar content, often referred to as "super-sweets," are sometimes available from nurseries. Other things being equal, higher sap sugar content translates to lower costs of production and greater profits.

Black and sugar maples begin growth later in the spring than red or silver maple. As maples begin their growth, chemical changes occur in the sap that make it unsuitable for syrup production. The term "buddy sap" is often applied to late season sap, which produces syrup with a very disagreeable flavor and odor. Because sugar and black maple resume spring growth later than red or silver maple, useable sap may be collected from sugar and black maples for a longer period of time in the spring.

## Red Maple

Red maple is commonly tapped in areas where it is abundant, particularly in the southern and western portions of the commercial maple production region. Identifying characteristics of red

maple are presented in **Table 3.2** and shown in **Figure 3.4**. The leaves of red maple commonly have 3 lobes (occasionally 5) with the sides of the terminal lobe generally converging toward the tip, are oppositely paired along the stem, and have small teeth along the margin. The bark of older trees develops long, broad, scaly plates, which often peel away from the trunk while remaining attached at the top. The twigs have paired, oppositely arranged buds, a relatively short, blunt, rounded, red terminal bud, and no offensive odor when the reddish bark of the twig is bruised or scraped. The fruit is identified by its severe V-shape and relatively small size.

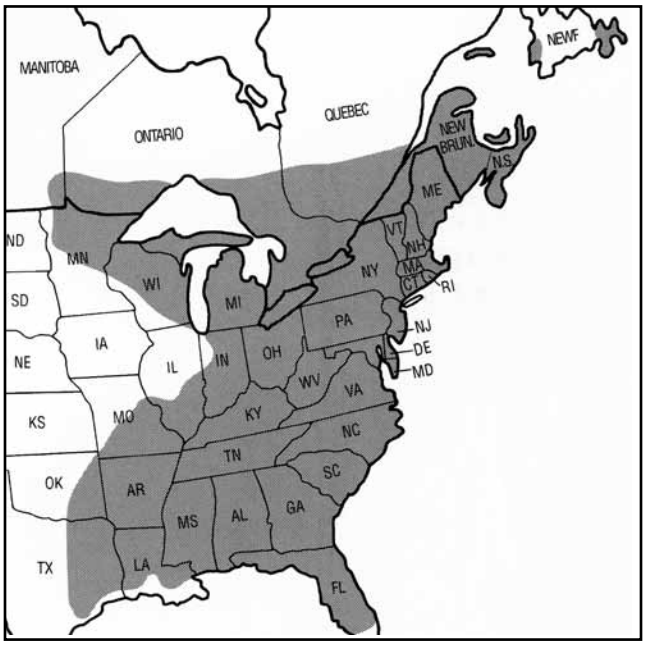



Figure 3.9. Red maple distribution.

Red maple is one of the most abundant and widespread hardwood trees in North America (**Figure 3.9**). Although it develops best on moderately well-drained to well-drained, moist soils, it commonly grows in conditions ranging from dry ridges to swamps. Because of the wide variety of sites on which red maple will occur, it is found growing naturally in pure stands and also with an enormous variety of other tree species ranging from gray birch and paper birch, to yellow poplar and black cherry, and including sugar and black maple. Its rapid growth and ability to thrive on a wide variety of sites have resulted in its widespread planting as ornamental and street trees, which are sometimes tapped as part of a sugaring operation. Compared to sugar and black maple, red maple is a relatively short-lived tree, rarely living longer than 150 years, and may be more susceptible to disease. Mature trees commonly average between 20 and 30 inches in diameter and 60 and 90 feet tall. Red maple is relatively shade tolerant and is found in both even-aged and uneven-aged forests. Thinning or release cutting will substantially shorten the age-to-tapable-size.

For the purpose of producing maple syrup, red maple's most attractive characteristic is its ability to thrive on a wide variety of site conditions. In some areas of the commercial maple range, red maple is the only maple present. One either taps red maple or they don't produce maple sap and maple syrup. In other areas, red maple may be tapped along with sugar and black maples.

It is important to emphasize that good, high-quality maple syrup can be made from red maple sap. However, for sugaring, red maple does have three important weaknesses. First, the sap sugar content of red maple may be less, on average, than that of nearby comparable sugar or black maples. This lower sap sugar content translates to higher costs of production and lower profits. However, because of variations in sap sugar content among trees, many red maples have sap sugar contents equal to or higher than many sugar and black maples. Secondly, red maple begins growth in the spring before sugar and black maples, resulting in a shorter collecting season. For this reason, red maples are often not put on the same tubing system as sugar and black. In addition, when the sap of some red maples is processed, an excessive amount of sugar sand is produced. Sugar sand or niter is a precipitate that forms during the evaporation process. Sugar sand can cause several problems during the production process. This characteristic, however, appears somewhat variable as some producers and limited research report processing red maple sap with very little sugar sand.

## Silver Maple

Silver maple is a rapidly growing maple found throughout much of the eastern United States and extreme southeastern Canada (**Figure 3.10**). Although it is often tapped in geographic areas

where it is abundant in forest stands or along roadsides, throughout much of the commercial maple region most maple producers will not tap silver maple.

Identifying characteristics of silver maple are presented in **Table 3.2** and shown in **Figure 3.5**. The leaves of silver maple have five lobes, with the sides of the terminal lobe diverging toward the tip; a paired opposite arrangement of the leaves; deep sinuses between the lobes; fine teeth along the margin but not on the inner sides of the sinuses; and silvery white underside. The bark of older trees develops small, narrow, scaly plates, which often peel away from the trunk while remaining attached at the top. The twigs have paired, oppositely arranged buds; a relatively short, blunt, rounded, red terminal bud; and a fetid or foul odor when the red to reddish-brown twig is bruised or scraped. The fruit, which matures in late spring, is identified by its V-shape, relatively large size, and often asymmetrical appearance, with one seed and wing visibly larger than the other.

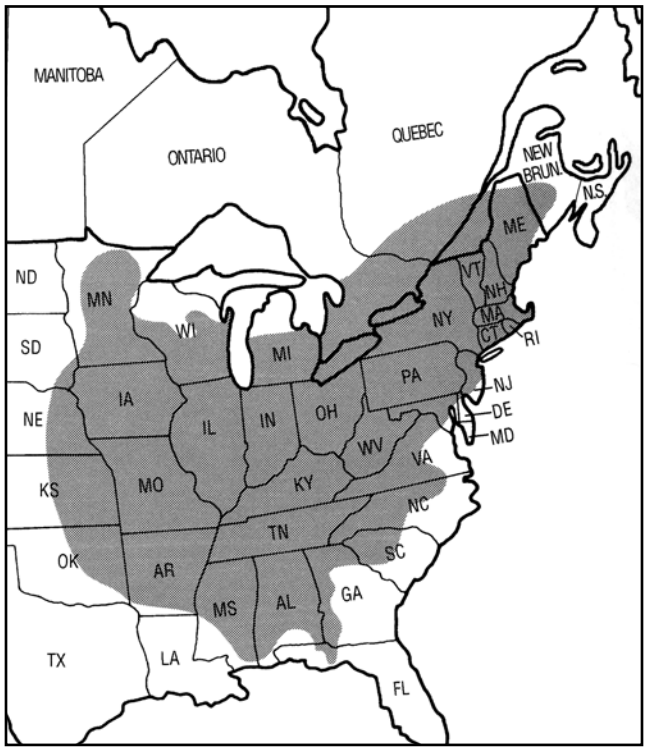



Figure 3.10. Silver maple distribution.

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

Like red maple, silver maple is a relatively short-lived tree when compared to sugar or black maple, living perhaps 130–150 years. Because of its fast growth rate, however, mature trees can achieve diameters in excess of 36 inches and heights in excess of 100 feet. On good sites with little competition from other trees, silver maple diameter growth may approach 1⁄2 inch per year (rates as high as 1 inch per year have been recorded). Silver maple's growth rate often responds dramatically to thinning or release cutting.

When compared to sugar, black, and red maple, silver maple is usually considered a distinctly fourth choice for sugaring for several reasons. First, sap sugar content is often lower than that of sugar, black, and red maple, and has been reported to drop substantially as the season progresses, both of which mean higher production costs and lower profits. However, silver maples with sap sugar contents in excess of 4 percent have been reported. Before disregarding silver maple because of assumed low sap sugar, particularly in a bucket operation, sap sugar content should be tested. Second, like red maple, growth begins earlier in the spring than sugar and black maple, and for that reason silver maple should not be put on the same tubing system as sugar and black. Third, like red maple, the evaporation of sap from some silver maples may produce an excessive amount of sugar sand. However, as with red maple, this

characteristic appears somewhat variable, as some producers and limited research report processing silver maple sap with very little sugar sand.

## Boxelder

Boxelder is geographically the most widespread member of the maple genus growing in North America (**Figure 3.11**), occurring naturally throughout much of the eastern and central United States, south-central Canada, and scattered throughout several western states. It is a relatively small, short-lived tree reaching 24–48 inches in diameter and 40–75 feet in height in 60 to 100 years. Typically, boxelder trees have a relatively short trunk and a bushy, spreading crown.

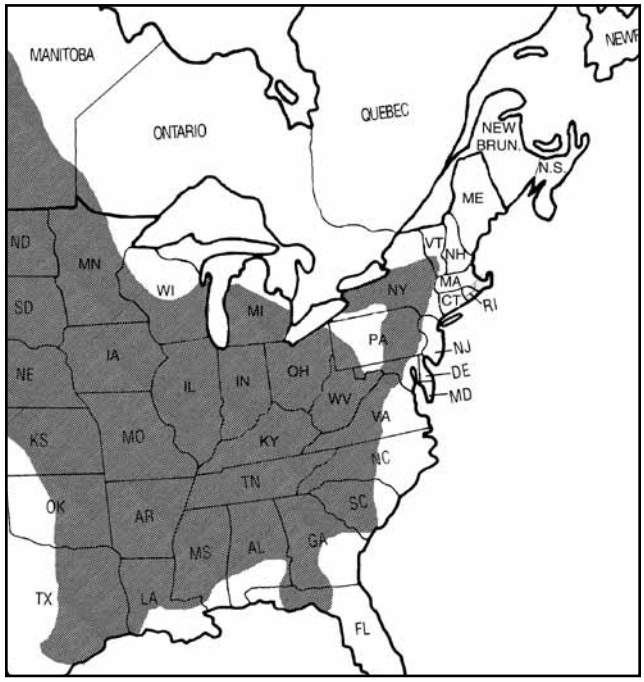



Figure 3.11. Boxelder distribution.

Identifying boxelder is relatively easy (**Table 3.2, Figure 3.6**)—it is the only native maple with pinnately compound leaves. Each leaf is made up of 3–7 (rarely 9) variably toothed or lobed leaflets, with the terminal leaflet often resembling a small, three-lobed maple leaf. The bark on the younger twigs is greenish; the bark on the trunk ranges from pale gray to light brown, with shallow fissures separated by narrow ridges on younger trees developing into much deeper furrows on older trees. The fruit is a 1–1½ inch long double samara with wings that initially diverge from the seed and then converge slightly near the tips.

Boxelder grows in a variety of climatic conditions, from New York to Florida, from Manitoba to New Mexico. Naturally, it is most commonly found growing in moister sites in bottomlands or along water, where it is associated with a wide variety of bottomland hardwoods including cottonwood, willow, hackberry, green ash, and others. However, boxelder will grow in an extremely wide variety of site conditions from hot to cold, and from droughty to wet and even periodically flooded.

Boxelder is rarely tapped within the commercial maple syrup range. Although some producers have reported making boxelder syrup with a maple-like flavor, most boxelder sap has a unique flavor that some have described as molasses-like, becoming quite strong in the darker grades. Boxelder sap should not be mixed with the sap from other maples if syrup with the traditional maple flavor is expected. On the other hand, boxelder syrup is a proven, saleable product produced commercially in the prairie provinces of Canada and often marketed as Manitoba Maple Syrup.

Conventional wisdom has always suggested that the sugar content of boxelder sap is substantially below that of other maples. Experience and limited research suggests this may not always be correct. While the sap sugar content of boxelder may be slightly below that of nearby sugar maples of comparable size, it is not unusual for boxelder sap sugar to average 2 percent or higher, and for individual trees to have sap sugar contents above 3 or even 4 percent. The sap volume obtained from boxelder, however, is substantially lower than that from other commonly tapped maples. An average tap in a bucket operation will commonly produce enough sap from a sugar maple to produce a quart of syrup per year. With boxelder, an average tap on a bucket operation will produce enough sap to produce between 1/3 and 1/2 quart of syrup per year.

## Other Maples

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

Neither of these species is commonly tapped. Striped maple is a small slender tree that rarely attains tapable size. It is most easily identified by the opposite paired arrangement of its leaves and branches, its 3-lobed leaf with fine teeth on the margin, and striping on the branches and young trunks. Mountain maple is essentially a shrub. It is most easily identified by the opposite paired arrangement of its leaves and branches and its 3-lobed leaf with coarse teeth. If these species occur in a sugarbush it is important to be able to identify them. They should not be confused with the desirable maple species when performing management practices such as thinning or release cuts.

Figure 3.12. Striped maple. (VPI)

Figure 3.13. Mountain maple. (VPI)

One exotic maple, Norway maple (*Acer platanoides*), is commonly planted as an ornamental and street tree and will attain tapable size. It is recognized by the opposite paired arrangements of its leaves and branches, its large, 7-lobed leaf without marginal teeth, and its 1½ to 2 inch long double samara with divergent wings (**Figure 3.14**). The sap of Norway maple is not commonly used commercially to produce maple syrup, but at least one study in Ontario by H. C. Larsson and P. Jaciw reported that the Norway maples tested had good quality sap with sugar content often approaching that of sugar maples, and that sugar maple and Norway maple syrups were selected almost equally by a taste panel.

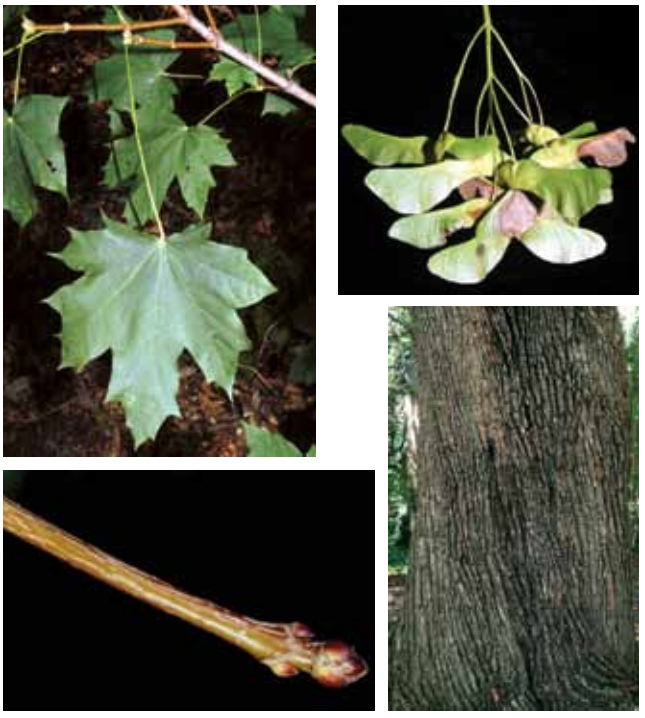


Figure 3.14. Norway maple. (VPI, Sydnor)

# Chapter 4 · Planning a Maple Syrup Operation

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

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

Important considerations and producer characteristics that affect the success of a commercial maple operation include available time and commitment; a suitable, well managed tree/forest resource; available or obtainable labor and equipment; adequate financial resources; the development of appropriate production, processing, storage, and marketing facilities; the development of sound marketing strategies; and the importance of secondary maple products (e.g. maple sugar, candy, nougat, cream, etc.) to the success of the business.

## Time and Commitment

The activities involved with collecting maple sap, processing it into maple syrup or other products, and marketing require considerable time and dedication. Before the first drop of sap is collected, a management plan for the sugarbush should be developed (Chapter 5), and a marketing strategy should be designed that identifies how much syrup and other products will be produced and to whom and how it will be marketed (Chapter 10). These decisions must be made before equipment is purchased and assembled to collect sap and process it into syrup and other products (Chapters 6, 7, 8, and 9), and before a production facility is constructed or developed from an existing structure (Chapter 12).

Getting ready for the season requires equipment to be cleaned and prepared for use. While repairs and some preparation can be done more leisurely in the off-season, the time just before "sugaring" season always seems hectic.

During the maple season, depending on the size and nature of the operation, literally hours each day can be spent in collecting sap and processing it into syrup, packaging, and cleanup. During the first few seasons additional time will be needed to learn or relearn how to most efficiently use the equipment and perform various activities. Obviously planning and allocating sufficient time is necessary, but flexibility is also required. Maple sap, unfortunately, does not flow uniformly throughout the season, nor are flows

necessarily predictable, and certainly they are not restricted to a typical "8 to 5" workday schedule. Sap flow can and does occur in the evenings and on weekends, and big flows often come without warning. Many producers, particularly if otherwise fully employed, find that assistance, whether from family, friends, or employees, is required if a maple operation of any significant size is to be undertaken. In fact, some new producers have found it wise to sell sap the first couple of years and concentrate on developing the tapping and collecting portion of their operation before proceeding to processing.

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

## The Maple Resource

Maple trees obviously are an essential resource for a maple syrup operation. The number and size of trees available will determine how much sap can be collected and, in turn, how much syrup can be produced. While variations in production may exist among trees and regions of the country, a good rule of thumb related to sap production is to assume that each taphole will produce enough sap (approximately 10 gallons) to make approximately 1 quart or 1 liter of syrup[2] in an average season. Keep in mind that this is only an estimate and both smaller and greater production is possible depending on tree size, method of sap collection, sap sugar content, etc. If a larger operation is desired than available tree resources will support, provision must be made for purchasing sap or renting trees or tapholes from nearby landowners.

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

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

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

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

If the management plan includes improvement or harvest cuts, these are best done as soon as possible, before semi-permanent installations such as tubing are erected. In addition to improving the health and productivity of the sugarbush, these activities may also provide needed income, and offer the opportunity to develop additional roads

[2]This production estimate does not apply to boxelder (see discussion in Chapter 3).

and trails. Again, recommendations and guidelines for these activities are presented in Chapter 5.

The inventory of trees in the sugarbush also provides critically important information for estimating production, designing a sap collection system (e.g. tubing layout), identifying tapping and processing equipment needs (e.g. how many buckets or how much tubing, what size pumps and storage tanks, what size evaporator, need for a reverse osmosis machine, size of processing facility, etc.), evaluating profitability, and the potential for future expansion. These topics and decisions are discussed in subsequent chapters in this manual.

## Labor Requirements

The amount of labor required for a maple operation is influenced by a variety of factors. Obviously the larger the operation, the more labor necessary to ensure that it will function efficiently. It may be possible for one person to operate a relatively small operation (perhaps a thousand taps or less) if he/she utilizes the most efficient sap collection and processing technologies and equipment available. With increasingly larger operations, part-time or full-time help moves from desirable to essential. The size of operation where this occurs depends on the owner/operator's (and the family's) available time to commit to the maple operation and character of the operation, especially the method of sap collection, types of processing equipment, method of fueling the evaporator, and methods of marketing the syrup produced.

The method of sap collection directly influences the amount of labor required. If a vacuum-equipped, tubing sap collection system is installed, the amount of labor necessary for sap collection during the season will be reduced considerably. Installation of the tubing system requires labor, but this can be completed during the off-season. If the system is left in place throughout the year, minimal labor is necessary to maintain the system between and during seasons. Chapter 6 provides an in-depth discussion of alternative sap collecting systems.

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

- forced-air draft units for wood-fired evaporators;
- sap preheaters to reduce the amount of time necessary to raise the temperature of sap to the boiling point;
- evaporator attachments to utilize the heat present in the evaporated water vapor;
- air injection units intended to produce lighter colored syrup, reduce niter, and shorten evaporation time[3]; and
- reverse osmosis units that significantly increase the sugar concentration of incoming sap, thereby obtaining an increase in the rate of syrup production as well as a reduction in the amount of time necessary for evaporation.

Efficiency improving accessories used with evaporators are discussed in Chapter 7.

Consideration must also be given to the method of fueling the evaporator. Oil, gas (both natural and propane), and wood-fueled evaporators are available. Both oil and gas fueled units are more automated; however, fuel must be purchased from a commercial source. Wood-fired evaporators may be more economical during operation, although substantial quantities of wood are required. If access to a woodlot to cut and process fuelwood is not available, then wood may have to be purchased. Cutting, processing, transporting, stacking, and storage of wood can and should be done during the non-maple season (to allow six to twelve months for adequate drying/seasoning), but this will require a significant commitment of both time and labor. The advantages and disadvantages of alternative fuels for firing an evaporator are discussed in Chapter 7.

[3]At the time of the writing of this manual, air injection units were relatively new, and their potential benefits and the conditions under which those benefits could be obtained were not completely understood.

## Financial Resources

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

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

It is also important to remember that, while there is money to be made in the maple syrup/product business, realistically, it is unlikely that any but the larger, more integrated and diversified maple syrup operations will provide enough income to support a family solely from income obtained from the production and sales of maple products. Potential producers are advised to approach the maple syrup-product business as additive to other enterprises, such as those related to agricultural or horticultural ventures. This allows expanded use of some equipment (e.g. tractors) while also using the time and resources available between maple seasons. Because the capital costs required to establish a new operation are high compared to the value received from the sale of maple products in any one year, a realistic expectation of profitability should not be made for the first few years. Rather, profitability should be calculated as an average per year over a time period such as five years.

## Location and Design of Processing Facilities

To process maple sap into maple syrup it is essential that a structure or building dedicated to this use be available. It may be possible to modify an existing structure; however, it may be more desirable to construct a new building, particularly if processing of maple syrup into other products is to be done. Maple production facilities should be of such quality and construction that all local requirements for "food processing facilities" are met. This may include the presence of hot and cold water, toilet facilities, adequate electrical service, ample ventilation, washable surfaces on packaging facilities, floor drains, exclusion of animal pests, adequate lighting, etc. If a new facility is to be constructed it is recommended that local and state building codes relative to food processing facilities be consulted. And, while there may be a great deal of variation among states and provinces about what standards are currently required for maple production facilities, it is important to remember that maple syrup and other products are food. Irrespective of what minimum standards might be, it is important that producers

assume the responsibility of maintaining a production facility appropriate for the production of a food product.

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

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

Design and construction of a sugarhouse depends on plans for marketing. If the principal purpose is to only process sap into syrup, the type and style of building can be quite simple. Adequate space for the evaporator and related syrup filtering and packing of containers will be the most important considerations. The size of the total building will depend on type of fuel used for the evaporator. If wood is used, adequate space must be provided for storage. A standard cord (4' x 4' x 8' or 128 cubic feet) will process approximately 20 to 25 gallons of finished syrup on a standard evaporator with no efficiency improving devices. The wood storage area should hold enough wood to process anticipated seasonal production. If 100 gallons of syrup are expected, then storage space for 4 to 5 cords of wood should be constructed. The wood storage area should be covered and well ventilated. If oil or gas fired evaporators will be used, the building can be smaller. Oil tanks can be covered to reduce condensation in partially filled tanks.

Most producers have observed that the sugarhouse is never large enough. Additional space is needed for equipment storage such as collection and gathering containers, pumps, storage tanks, empty containers, etc. Additionally, some thought should be given to possible expansion if the operation were to be enlarged. If plans include processing maple syrup into other products, a well-equipped kitchen should be provided. Hot and cold water, electrical lights, washable floor, and a supplemental heating system will add to the efficiency and comfort of those working. Regarding sugarhouse size, an experienced maple producer once gave very valuable advice, noting that one should "always build the sugarhouse twice as large as they think they will ever need—that way they will only have to add on to it once."

Chapter 12 provides a thorough discussion of considerations and recommendations for constructing a maple production facility.

## Marketing Methods

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

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

Regardless of how marketing is done, development of a marketing plan is recommended. This plan should include an analysis of your individual situation, a statement of specific marketing objectives, and a strategy (method) for obtaining your marketing objectives. Producers are urged to think through the marketing process just as they think through the establishment and construction of physical facilities. Producers should not expect that simply because a quality product is produced, sales and profits will be forthcoming. Successful marketing is earned through planning and hard work; it is not something that just happens. A thorough discussion of marketing maple products is presented in Chapter 10.

## Production of Secondary Products

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

If other products are to be produced, provisions for their production should be made. When this is to occur in the sugarhouse, an appropriate preparation area or sugar kitchen should be constructed[4]. Production of some of these products is made easier if specialized equipment is available, including mixers, stirring machines, cooling facilities, and molds. While these confections will increase the variety of products available and should, under most circumstances, result in increased sales and net income, labor and equipment costs associated with their production should be considered when planning a complete operation.

[4]Note that some states and provinces have very specific regulations concerning where maple candy and other products can be made and standards for the production facility. Some, for example, require secondary products to be made in a "kitchen" distinct and separate from the sugarhouse.

# Chapter 5 · Managing Maple Trees for Sap Production

Figure 5.1. At the heart of every maple sugaring operation is the sugarbush.

At the heart of every maple sugaring operation are maple trees. Usually these are in the form of a grouping of woods-grown trees called a sugarbush (**Figure 5.1**). Technology has allowed syrup producers to improve production by investing in equipment, and certainly equipment is important to an efficient maple operation. Likewise, the long-term sustainability of a maple operation depends on maintaining an inventory of healthy, productive trees. Just as a vegetable garden requires an overall management plan and regular attention to ensure the production of abundant, high quality crops, so too does a sugarbush if the long-term health of the trees and the efficient production of abundant sap is desired. In fact, from the perspective of maple producers, a healthy sugarbush is one where sap sugar production is typically limited only by tree genetic potential, topography, and soil conditions. The trees have a high rate of growth because of good canopy development, exposure to sunlight, site fertility, limited pests and diseases, and limited root system damage.

Historically, many maple producers took the sugarbush for granted, entering it each year only to carry out those activities necessary to collect sap. Other than removing dead trees or non-maple trees for fuel wood, often little attention was given to the impact that sap collection activities had on the trees, and little or no thought was given as to how the trees in the sugarbush could be managed to maintain or improve their health in order to maintain or increase sap production. However, over the past several decades this situation has changed. Concerns about over-tapping, an increase in the number of trees that are dying, and an overall decline of tree vigor in some regions have increased awareness of the need to manage and properly care for this basic resource. Through completing a few basic sugarbush management activities producers can

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

While maple producers can complete activities designed to improve the sugarbush, planning improvements requires both an understanding of maple operations and of how trees grow and respond to various treatments. For this reason, when developing and implementing sugarbush management plans, most maple producers will benefit from working closely with an experienced natural resource professional who understands sugarbush management.

In the following several sections of this chapter, suggestions and recommendations for developing a sugarbush management plan and completing several silvicultural activities are presented. Some producers may be inclined to dismiss many of these recommendations based on their belief that the response time to make significant change is too long, or that their own planning horizon does not justify the efforts involved. This is a mistake in that it should be the objective of every maple producer to maintain the productivity potential of the sugarbush as high as possible, and to ensure that healthy sugarbushes will be available for future generations of maple syrup producers. Management and sugarbush improvement activities should be on-going and should never be considered "complete." Improving composition, health, vigor, and productivity are objectives that should be constantly pursued. Surprisingly, management activities, especially when applied to younger stands of maple, can yield impressive results in a relatively short period of time.

## Sugarbush Planning—Developing a Management Plan

### Management Plan

A written management plan[5] is a critical tool for effective sugarbush management. The management plan identifies the maple producer's goals for the sugarbush; provides an inventory of the resources in the sugarbush, including the kind, number, and distribution of trees and the variety and character of soils present; identifies the management activities necessary to achieve the producer's goals; and provides a timeline for accomplishing those activities. Essentially, the management plan provides a "road map" for transforming the sugarbush from its current condition to the desired condition. Many producers have expectations for their woods that extend beyond maple syrup production; some may pursue agroforestry products, others timber, and still others recreational activities or leases. A management plan ensures that these activities mesh appropriately. Additionally, some activities such as a timber sale have tax and other economic considerations that benefit from, or even require, a management plan.

### Boundaries

The first step in managing a sugarbush is to determine the limits of the property. Locate the property boundaries (find the permanent markers) and be sure they can be easily found again. Make certain there is agreement with adjoining landowners as to the boundary locations. If no boundary markers exist, or if there is disagreement over boundary location, have a boundary survey done by a registered surveyor and have the results filed in the County Recorder's Office. Ask your surveyor to clearly mark the boundary line and locate the corners with permanent markers such as iron or concrete posts. Be aware that in some states or provinces only a licensed surveyor can install permanent boundary markers.

### Dividing the Sugarbush into Manageable Units

Once the boundaries are located, the next step is to subdivide the sugarbush into management units or stands—subdivisions of the sugarbush that contain relatively uniform areas that will be managed as a unit. All future activities can be organized and carried out on an individual stand basis. The small amount of time this initially takes is time well spent. Not only will this lead to better organization and use of time and labor, it also reduces the areas where specific management practices will be completed to a more manageable size. For example, the effort required to test the sugar content of all trees or to thin a large sugarbush can appear to be overwhelming. However, if the same task is to be completed on a smaller area, such as a 1 to 5 acre stand, it becomes more likely it will be done. Also, having some knowledge of the characteristics of each stand allows priorities to be established. Activities such as thinning can be done where the need is the greatest, instead of in a haphazard fashion over the entire sugarbush.

[5]Forest management plans are sometimes referred to as stewardship plans, particularly by state agency foresters who work with private landowners. The name comes from the fact that such a plan provides a "blueprint" for the landowner to be a good land steward.

The specific size of individual stands will vary with the variability and total size of the sugarbush. Generally, individual stands that range from 1 to 5 acres in size are suitable for management units. To function as the basic management unit of the sugarbush, each stand should be as uniform as possible in characteristics such as tree species composition, age, and size; soil type; topography; forest use history (grazed, logged, etc.); and tree health. When and where possible, use existing boundaries such as roads, trails, drainage ridges, fences, fields, etc., to separate stands. If natural features are not present to separate stands, some type of permanent boundary marker should be established.

Separating some sugarbushes into stands is easy; others are more difficult. Examining topographic maps, aerial photos, orthophotos, historic photos, and other property maps may be helpful. Topographic maps, aerial photos, and orthophotos are available in the United States at the local Soil and Water Conservation District office and in Canada at the nearest office of the Centre for Topographic Information of Natural Resources Canada. These resources will show if different stands exist based on visible characteristics such as tree species, tree age, tree size, tree crown size, etc. These are easily seen, along with other features such as roads, streams, buildings, etc. Ordering enlarged aerial photographs or having them enlarged is often quite helpful. Site-sensitive herbaceous plants, such as some ferns and wildflowers, can also help producers separate one stand from another.

Topographic maps are also helpful in deciding the location for any new roads or trails, and can be used in making a preliminary evaluation for a tubing sap collection layout.

Producers who enjoy using cutting-edge technology should explore the use of global position (GPS) equipment and Geographic Information System (GIS) software to accurately map sugarbush and stand boundaries, and the location of individual trees or other features as desired.

## Inventory—Know Your Resource

How many maple trees are present, where are they located, how fast are they growing, and what is their condition? Are they all the same age and/or size? Are the various stands properly stocked for their age and size of trees, allowing for good growth, or are they overstocked, in need of a thinning? These and other important questions can be answered with an inventory, a systematic gathering of data and observations that will serve as the basis for both sugarbush management and production decisions.

The method used to make an inventory will depend on the size and character of the sugarbush. For a very large sugarbush it is probable the inventory will involve sampling a number of plots rather than measuring every tree in the entire sugarbush. If the sugarbush is relatively small and uniform, it might be treated as one large stand, with several plots inventoried and the data and observations combined to characterize the sugarbush as a whole. However, in most instances the sugarbush will not be uniform enough to be treated in this manner, and individual plots will need to be established and inventoried, and data collected and summarized to characterize individual stands. Data collected should include tree species, diameter at breast height (dbh)[6], age, height, and health; taphole healing rate; soil characteristics; and topography including slope. Some data, such as tree species and diameter, will be collected for all trees on each plot. Other data, such as tree height, might be collected from a few trees. Still other data, such as slope or soil type, will be recorded for the plot as a whole.

Although gathering much of the data required in a sugarbush inventory is not difficult, producers unfamiliar with forest inventory methods should seek assistance from a service, extension, or consulting forester familiar with sugarbush management. Advice regarding inventory components and design, number and size of plots, what data to collect, tree health, stocking levels, etc., will be helpful.

[6]The diameter of forest trees is commonly measured at breast height, defined as 4½ feet (1.4 meters) above ground and abbreviated dbh.

### Management Recommendations—The Action Plan

The final section of a sugarbush management plan identifies and describes what actions need to occur in the sugarbush as a whole and in each stand to achieve the objectives of the producer. Simply put, this section answers the following question: Given a producer's specific objectives, what actions should be carried out to accomplish those objectives and when should they occur? Many of the recommendations in this section will be silvicultural recommendations—recommendations of practices intended to improve the growth rate, species composition, health, or quality (such as sap sugar concentration) of the sugarbush or to encourage the establishment of new maple trees[7]. Silvicultural recommendations might include recommendations for improvement cutting or thinning, harvest/regeneration cutting, pruning, tree planting, fertilization, and others. Other management recommendations might include road development and maintenance, and activities related to protecting the sugarbush from insects, diseases, animal damage, grazing, fire, and weather-related damage. A discussion of these various management actions follows in the remainder of this chapter.

## Sugarbush Silviculture

### Sugarbush Stand Structure—Uneven-Aged vs. Even-aged

To a large extent, the age/size distribution of the trees in a sugarbush will determine how it should be managed. Forests are classified as either even-aged or uneven-aged based on the age/size structure. Maples, along with some of their close natural associates such as American beech, survive and grow slowly in competition with and in the shade of other trees. Trees that tolerate shade can develop into uneven-aged stands. Such forest stands contain trees of many ages and sizes (**Figures 5.1 and 5.2**). In such stands, the larger trees form the upper canopy while the smaller trees are present in a progression of sizes from abundant seedlings growing near the forest floor to larger saplings and poles. In the natural development of such a stand, when a larger tree dies, is cut, or is destroyed, the smaller trees below compete to take its place. In some cases the smaller trees are younger than the larger trees. However, in other areas such as those that were farmed throughout the 1800s, many of the smaller trees are slower growing and less vigorous maples, but may be as old or nearly as old as the larger trees.

Figure 5.2. An uneven-aged sugarbush is one that contains trees of many ages and sizes. (Dickmann)

An even-aged forest is one in which all of the trees are essentially the same age, and a high proportion are approximately the same size (**Figure 5.3**). For the sake of simplicity, all trees in an even-aged stand can be visualized as becoming established within a relatively short time period (a few years) as the result of some activity such as the reforestation of an abandoned agricultural field or pasture, a clearcut harvest, or fire. Differences in tree size might be slight, or they might be significant as a result of individual tree genetics, competition among trees, or poor growing conditions in the vicinity of the tree. Because of land use practices (such as grazing) and forest cutting practices (clearcutting or thinning that retained only the larger trees), many even-aged maple stands, including many sugarbushes, are present throughout much of the commercial maple region.

In many ways, the sugarbush can be thought of like a garden, only covering more acres and having a greater longevity. A garden may have some areas of even-aged plants, like sweet corn,

[7]Silviculture is a forestry term defined as the art and science of controlling the establishment, growth, composition, health, and quality of forests to attain management objectives.

and other areas with different ages of plants, like raspberries, asparagus, or strawberries. Crowding in young garden plants prompts thinning to ensure adequate sun and soil resources for the crop. Even among mature plants, weedy or unproductive competitors are removed. Each entry into the garden results in removing both young and old plants. At some point, actions in the garden prepare for replacement by new plants. Similarly, the sugarbush benefits from actions to improve the trees currently in the sugarbush, including intermediate cuts and fertilization (if appropriate). Actions that focus on establishing new trees include reproductive cuts, often designed to promote natural regeneration, and tree planting.

Figure 5.3. An even-aged sugarbush is one in which all of the trees are essentially the same age, and a high proportion are approximately the same size.

## Improving the Current Sugarbush—Intermediate Cuts

Not all young maples are of equal value to a maple sap collection operation, and other tree species in the stand may not contribute to the producer's goals for the property. As groups of young maple and other tree species grow, competition for sun and soil resources increases. If the trees are to realize their maximum potential for sap production, optimal growth conditions must be maintained; this may require periodic thinning of the stand by removing some trees, including maples. That is the purpose of an intermediate cut—the forester's term for cuttings done to improve the growth and quality of trees left after the cut (referred to as the residual stand)[8]. During an intermediate cut, more desirable trees are retained and less desirable trees are removed.

A productive sugarbush will contain a preponderance of vigorous, healthy, fast growing maples that have deep, wide crowns. Ideally the sap sugar content of all trees remaining in the stand will be high. Unfortunately, a sugarbush composed of such trees will not develop naturally. Two conditions exist in developing maple stands that, if left unaltered, will reduce productivity. First, in most naturally occurring maple stands many non-maple species are present, including black cherry, northern red oak, American beech, white ash, hemlock, basswood, and others. These trees occupy growing space, but do not contribute to sap production. This does not, however, mean that all non-maple trees should be removed. Some non-maple trees may be retained in the stand to support tubing systems or because they contribute to other ownership goals, such as quality timber production or wildlife habitat. If localized areas in the sugarbush are wet or dry, species other than sugar maple will be more vigorous and should be favored over maple. Also, under most circumstances the creation of a pure maple monoculture is not desirable, as the presence of other species contributes to diversity, increases nutrient cycling, reduces spread of insects and diseases, and promotes overall health of the sugarbush.

The second condition that reduces the productivity of a sugarbush is overcrowding. Young sugarbushes may contain several thousand trees per acre; more mature, productive sugarbushes eventually have only several dozen trees per acre. When stands are developing, high tree density results in relatively slow individual tree diameter growth and the development of trees with long, relatively branch-free trunks and short, narrow crowns. An intermediate cut reduces competition, and encourages more rapid growth and the development of larger crowns on the residual maples. Also, the amount of sugar in the sap may vary widely among maple trees in the stand as

[8]Intermediate cuts performed in stands of different ages and age structures are given different technical names by foresters (e.g. thinning, improvement cut, release cut, etc.).

a result of crown position, crown size, and genetic characteristics. An intermediate cut retains maples that have the greatest potential to provide large volumes of sap with a high sugar concentration.

Potential goals of an intermediate cut in a sugarbush include:

- Vigorous maple crop trees with large, wide, and deep crowns will develop and should produce sap with higher sugar concentration.
- Trees selected for keeping (residual crop trees) will grow more rapidly, thus attaining tapable size more quickly.
- More rapid tree growth resulting in the production of wood that produces more sap and can be re-tapped sooner.
- Reduction of the number of non-sap producing trees in the sugarbush.
- Removal of defective, diseased, and insect-infested maples from the sugarbush, eliminating potentially poor producers and a source of future insect and disease problems.
- Removal of low-quality, poorer producing maples in favor of higher quality, better producing maples.
- Production of wood products including fuelwood for fueling the evaporator, domestic heating, or sale.

In the majority of sugarbush stands an intermediate cut is the management activity that will produce the most benefit. Ideally, intermediate cutting will begin early and continue as needed to maintain tree growth, vigor, and production. However, properly carried out intermediate cuts in previously unmanaged stands will result in increased tree diameter growth, healthier crowns, and sweeter sap. As a general rule, trees less than 15 inches in diameter will respond very positively to an intermediate cut; trees larger than 15 inches in diameter will respond, but less dramatically. In fact, the response of larger trees may be more in their ability to maintain production, rather than in improving it.

The steps necessary to carry out an improvement cut include:

- Determine if a cut is appropriate.
- Determine if a cut is timely relative to other activities identified in your management plan (e.g. tubing replacement).
- Determine the best method to guide cutting intensity. Methods include crop tree release, tree spacing, and residual basal area. The selection among these methods, described later in this chapter, depends on operator skill and experience, and the age of the trees. Often methods are combined.
- Inventory the stand, taking special note of potential cut versus leave trees and the abundance of defective trees.
- Set a goal, such as trees per acre or basal area per acre, to retain through the cut.
- Mark the crop trees and trees to be removed in this cutting for later identification. This is commonly done with tree marking paint. Crop trees should be marked with one color of paint (**Figure 5.4**). This will need refreshing every few years as the paint weathers. Trees to be cut are commonly marked with different colored paint. Usually a 3- to 4-inch diameter spot or "X" is made 4.5 feet above the ground. All trees should be marked on the same side so that the spots will be visible from the same direction. A 16-ounce aerosol spray can contains enough paint for about 200 spots.
- Cut trees marked for removal.

Producers inexperienced in implementing an improvement cut should seek assistance from a forester familiar with sugarbush management. Producers should participate in a chainsaw safety course, with a certified instructor, before beginning work in the woods. Always wear personal protective equipment such as chaps, helmet, hearing and eye protection, and steel-toe boots. Consult Chapter 13 in this manual for additional discussion on chainsaw and sugarbush safety.

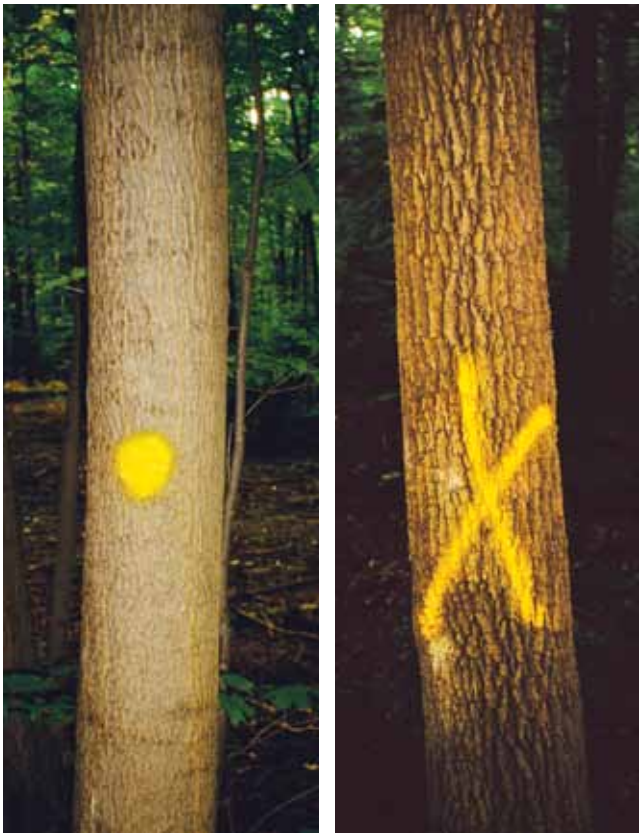


Figure 5.4. Crop trees and/or cut trees should be marked for later identification. One system would mark the crop trees with a dot and the cut trees with an "x" of the same or different color.

## Determining Whether You Need an Improvement Cut

The decision to undertake an improvement cut depends on being able to determine that the sugar maple trees in the stand are suffering from excess competition, particularly for sunlight, that is limiting their growth and development. Several conditions can be used as indicators of excessive competition. Measurements of tree diameter growth and stand stocking will verify that excess competition exists. Tree symptoms indicating excessive competition include:

- Flattening of the tree's crown on the side in response to competition from the crowns of adjacent trees (**Figure 5.5**)
- Death of lower branches (**Figure 5.6**).
- Reduction over time in sap volume production or sap sugar concentration.
- Slow taphole closure (healing). Because taphole closure rate depends on a number of factors including tree age, tree health and vigor, taphole size, and quality of the site, it should be evaluated by comparisons with the closure rate of tapholes of healthy, vigorously growing trees of the same size growing on a comparable site.

Figure 5.5. The flattening of a tree's crown on the side, shown on the tree to the right, is a symptom of excessive competition from adjacent trees.

Figure 5.6. The death and loss of excessive amounts of lower branches ultimately resulting in small crowns is a symptom of excessive competition.

Tree diameter growth can be evaluated using an increment borer (**Figure 5.7**). Sustained slow growth or the sudden or steady decline in the diameter growth of several representative trees in a stand commonly suggests excessive competition. Again, because of variations in site quality, expected growth should be evaluated by comparison with a healthy, vigorously growing tree of the same size growing on a comparable site. For example, annual growth rings between 1/10th and 1/15th inch (0.25 and 0.17 cm) or less wide (10 to 15 rings per radial inch or 4 to 6 rings per radial centimeter) are not uncommon for sugar maple throughout much of the southern commercial maple range—less growth on poorer sites, somewhat more on better sites. Further north, growth rings would be smaller. Growth rings less than 1/16th inch wide (0.16 cm) on trees greater than 18 inches (46 cm) dbh or 1/8th inch wide (0.32 cm) on trees in the 10 inch to 14 inch (25 to 36 cm) dbh size range may result in too little clear wood developing to sustain continued tapping at any but conservative levels.

Finally, the stocking level of trees in the stand can be compared to that recommended for optimum growth. Basal area is a commonly used measure of stocking. The basal area of an individual tree is its trunk's cross-sectional area determined 4.5 feet (1.37 m) above ground. As an example, the basal area of a 13.5 inch (34.3 cm) diameter tree is 1 square foot[9] (0.092 square meters). The sum of the basal areas of all of the trees on an acre (or a hectare) is a measure of stocking. Again, as an example, if there were 65 13.5-inch diameter trees on an acre (161 34.3 cm trees on a hectare), the basal area would be 65 square feet per acre (or 14.8 square meters per hectare). Research has shown that the basal area of a stand is a good indicator of the amount of competition occurring, and that levels of basal area stocking can be identified that substantially reduce competition and encourage the growth and development of individual trees for specific purposes. Basal area guides are different for different species, and different for different forest products and purposes. **Tables 5.2 and 5.3**, discussed below, provide basal area guides for developing sugarbushes.

Figure 5.7. An increment borer (in use, top) is used to extract a core of wood from the trunk of a tree that shows the tree rings. If the core is taken to the center of the tree, the tree's age can be determined by counting the annual rings. Shorter cores are used to determine the tree's growth rate over some time period, usually the past 5 or 10 years, or to look for a slowing of the tree's growth rate, a possible indicator of increased competition from surrounding trees.

## Identifying Trees to Retain and Trees to Cut

Three distinctly different approaches can be used as a guide to identify the specific trees to cut when implementing an intermediate cut: crop tree release, tree spacing, and residual basal area.

[9]The cross sectional area of a circle is calculated using the formula area = $\pi r^2$, where r is the radius of the circle and the value of $\pi$ is 3.14. The cross-sectional area, and therefore the basal area, of a 13.5 inch diameter tree = 3.14 $(6.75)^2$ = 143.1 sq. in. Since there are 144 square inches in a square foot, the basal area of a 13.5-inch diameter tree = 143.1/144 = 0.993 sq. ft., or essentially 1 square foot. In the metric system the basal area of a 34.3 cm diameter = 3.14 $(17.15)^2$ = 923.54 sq. cm. or 0.092 sq. meters.

These approaches are discussed in the following section. Irrespective of approach used, the characteristics desired in the trees retained in the stand after cutting are the same.

- Emphasize retention of maples, with preference given to sugar and black over red and silver. High value sawtimber trees that do not compete with maple sap trees also benefit from release and may eventually produce valuable timber revenue.
- Only retain healthy trees, without any evidence of insects, disease, physical damage, or stress.
- Crop trees should be of good form—single-stemmed trunks with full, deep, wide crowns without acute branch forking (**Figure 5.8**).
- In even-aged stands, crop trees should have their crowns in the upper canopy of the sugarbush. In uneven-aged stands, crop trees should have a main branch or branches that point upward rather than being flat-topped.
- Where possible, crop trees should be trees that originated from seed as opposed to trees that developed from stump sprouts.
- If possible, select crop trees that have sap sugar content higher than the average for the sugarbush.

Figure 5.8. Crop trees should be of good form—single-stemmed trunks with full, deep, wide crowns without acute branch forking. In the picture, trees numbered 1 and 2 would be acceptable crop trees. Tree number 1 has a superior crown, with less severe branch forking and a more rounded crown top. Tree number 3 is unacceptable as a croptree because of its severe forking (unless there were no other maples to choose from).

Also, when implementing an intermediate cut, it is important to minimize cutting within a 50-foot (15 meter) border on the windward side(s) of the sugarbush. Maintaining a higher density of trees along the windward borders will act as a windbreak, conserving moisture in the sugarbush and reducing potential wind damage. An alternative to this strategy is to establish a two- or three-row conifer windbreak on the windward side of the sugarbush, and postpone the intermediate cutting in that part of the sugarbush until the windbreak becomes effective.

## Testing Sap Sugar Content

The sap sugar content of a tree can be measured using a hydrometer or refractometer. A refractometer requires only a drop of sap and is preferred. A refractometer determines the sugar content of sap by measuring optical density. Because sap sugar content measurements from several trees are going to be compared to determine which trees have the highest sap sugar content, the measurements must be comparable. Sap sugar content of a maple is not a constant value, but varies with season of the year, time of day, from day to day, and even sometimes with changing weather conditions during the day (e.g. sunny to cloudy, calm to very windy, etc.).

To obtain comparable data when measuring the sap sugar of a group of trees, sampling and testing should occur within a relatively short time period during which weather conditions are fairly uniform. The most common approach is to make sap sugar measurements on trees to be compared within a one- or two-hour period. Sap sugar content measurements can be made anytime in the dormant season that sap is running (including during the fall, after a cool night), as long as the primary directive of making measurements of trees to be compared occurs at the same time is followed.

With small trees, the simplest way to obtain a drop of sap is by cutting a twig with pruning shears. With larger trees, where branches cannot be reached, a hole must be made in the trunk and the sap extracted. Usually a small drill or hammer and awl are used **(Figure 5.9)**. Some device,

such as a #13 or #16 hypodermic needle, a small glue-gun needle, or a toothpick is then inserted into the hole to carry the sap away from the tree. Once sap flow has started and flowed for a brief period, a drop is collected on the refractometer **(Figure 5.9)**.

Whichever method is chosen, the same method should be used to obtain all samples to be compared. Sap collected from different parts of the same tree may have different sugar contents. Sampling on all trees should be made at the same relative location (height and compass orientation).

Figure 5.9. Sap sugar testing with a refractometer. With small trees, cut a twig with pruning shears. With larger trees, make a hole into the sapwood of the trunk with a small drill or hammer and awl and place a toothpick, #13 or #16 hypodermic needle, small glue-gun needle, medical pipette, or similar device into the hole to carry the sap away from the tree trunk where it can be collected on the refractometer.

When using a refractometer:

- Be sure it is clean, calibrated, and the scale is in focus. Check the instrument's acceptable temperature range to verify it can be used in the existing temperatures.
- Once a drop of sap has been placed on the refractometer, close the refractometer and quickly read the scale to avoid evaporation from the drop causing an incorrect reading.
- Make appropriate temperature correction to Brix reading if refractometer is not self-adjusting for temperature[10].
- Ideally, the refractometer should be dried with a soft tissue, rinsed with water (preferably distilled), and dried again after each reading. When working rapidly, the refractometer is often dried with a tissue after each measurement and rinsed and dried after 10–15 measurements (every 10–15 minutes).
- Research suggests that measurements should be made only if sap is dripping at a rate of more than 1 drop every 8 seconds[11]. Measurements at slower drip rates may be altered by wind.

To use time efficiently, a group of adjacent trees should be worked together. This avoids delays caused by waiting for each tree to produce a drop of sap. When beginning sampling, if all the trees in the first group are not running, stop sampling and return later. All trees do not begin or end their flow at the same time during the day. If sap sugar measurements are started before all of the trees are flowing, time will be wasted returning to re-measure those trees that start flowing later, and the measurements will be less comparable. Stop when several sampled trees are no longer flowing.

[10]One might argue that it is probably not necessary to correct for temperature when comparing the relative sap sugar content of trees in a group when the testing occurs over a short period of time during which the temperature does not significantly change.

[11]Smith, Clay H. and George M. Keiser. 1971. *Testing Maple Sap for Sweetness with a Refractometer*. USDA For. Ser. Res. Note NE-138. 4 pp.

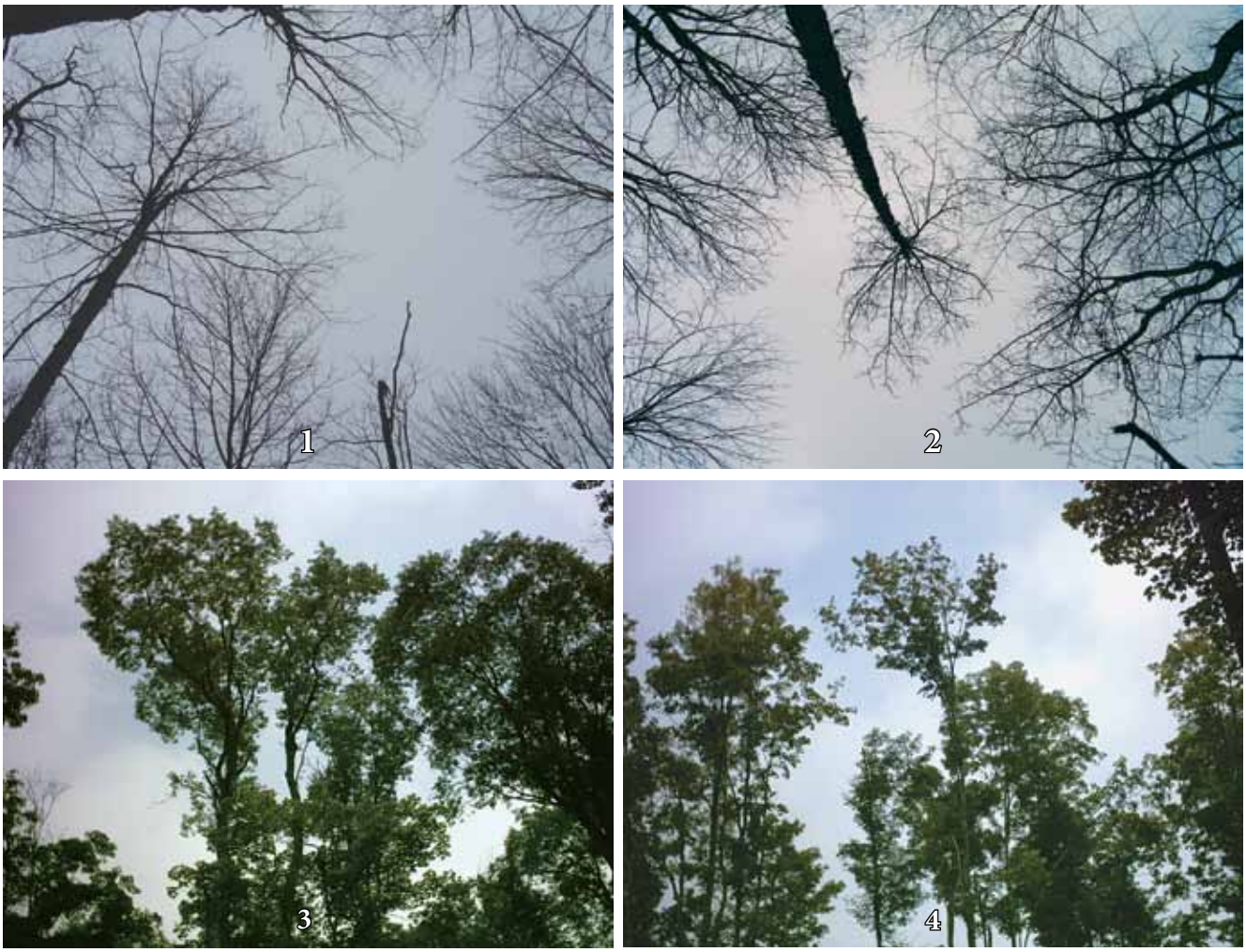



Figure 5.10. Maple crop trees released from surrounding competition on 1, 2, 3, or 4 sides.

## Approaches to Intermediate Cut

Crop tree release, tree spacing, and basal area each represent an approach that can be used as a guide for implementing an intermediate cut. Each method can be used alone, but results are often better if the methods are integrated. It should be remembered that these methods are guides and should not be applied without continually critically assessing their impact on the stand. Methods of utilizing the approaches in stands containing trees of different sizes will be discussed following a brief description of the three approaches.

### Crop Tree Release

In this approach, current or potential crop trees are selected for release from the surrounding competition based on the selection criteria identified previously. Selected trees are released by cutting adjacent trees whose crowns touch the crown of the crop tree, or in the case of smaller trees, whose crowns come within a specified distance of the crop tree's crown (**Figure 5.10**). This approach directs the management activity on the release of the present or potential crop trees. Trees whose crowns do not touch those of a crop tree (or come within a certain distance of the crop tree) are not cut, nor are trees whose crowns are completely below a crop tree's crown. In sugarbushes containing larger trees that have never been released, the initial release of crop trees may be done on only one or two sides of the crown to avoid removing too many trees at one time, opening the stand excessively and potentially stressing the crop trees. The number of trees released depends on the size of the trees, with allowances being made in younger stands for loss of some

of the potential crop trees. Appropriate numbers of crop trees to release will be discussed under recommendations for various stand size classes. When using this approach it is important to mark both the crop trees and the trees to be removed for future identification.

## Tree Spacing

The tree spacing method identifies the minimum acceptable distance between the centers of the trunks of adjacent trees, with that distance determined by the diameter of the trees (**Tables 5.1a and 5.1b**). For example, if an 8-inch (20.3 cm) diameter red oak is 13 feet (4 meters) from a 6-inch (15.2 cm) diameter sugar maple, and the sugar maple is to be retained, the red oak is too close and should be removed. **Table 5.1** indicates that a 6-inch (15.2 cm) diameter tree and an 8-inch (20.3 cm) diameter tree should be 20 feet (6.1 meters) apart. Spacing guidelines work better in young stands and with inexperienced crews. Spacing recommendations should be used as a guide and not strictly applied, as strict application leaves little flexibility for the manager. In the above example, if the 8-inch (20.3 cm) red oak and the 6-inch (15.2 cm) sugar maple had been 17 or 18 feet (5.2 to 5.5 meters) apart, the red oak would probably have been retained unless it was needed for fuelwood. However, it would be removed later when both trees had increased in diameter. In older stands the application of spacing guidelines becomes increasingly more difficult—trees do not grow at perfect spacing and there are increasingly fewer trees.

**Table 5.1a. Sugarbush tree spacing guide in English units—numbers in the table are the minimum recommended distance in feet between adjacent trees of specified diameters (in inches) to allow optimal growth for sap quality and volume[12].**

| Tree Diameter (in) | 4 | 6 | 8 | 10 | 12 | 14 | 16 |
|---|---|---|---|---|---|---|---|
| 4 | 13 | | | | | | |
| 6 | 18 | 19 | | | | | |
| 8 | 19 | 20 | 21 | | | | |
| 10 | 20 | 21 | 22 | 23 | | | |
| 12 | 21 | 22 | 23 | 24 | 26 | | |
| 14 | 23 | 24 | 25 | 27 | 28 | 28 | |
| 16 | 24 | 25 | 26 | 27 | 28 | 29 | 31 |

**Table 5.1b. Sugarbush tree spacing guide in metric units—numbers in the table are the minimum recommended distance in meters between adjacent trees of specified diameters (in centimeters) to allow optimal growth for sap quality and volume[12].**

| Tree Diameter (cm) | 10.2 | 15.2 | 20.3 | 25.4 | 30.5 | 35.6 | 40.6 |
|---|---|---|---|---|---|---|---|
| 10.2 | 4.0 | | | | | | |
| 15.2 | 5.5 | 5.8 | | | | | |
| 20.3 | 5.8 | 6.1 | 6.4 | | | | |
| 25.4 | 6.1 | 6.4 | 6.7 | 7.0 | | | |
| 30.5 | 6.4 | 6.7 | 7.0 | 7.3 | 7.9 | | |
| 35.6 | 7.0 | 7.3 | 7.6 | 8.2 | 8.5 | 8.5 | |
| 40.6 | 7.3 | 7.6 | 7.9 | 8.2 | 8.5 | 8.8 | 9.4 |

[12]Adapted from Koelling and Heiligmann, 1996; Lancaster et al., 1974; and Morrow, 1976.

Figure 5.11. Using a penny to estimate sugarbush basal area. As the penny is rotated in a circle, compare the width of the penny to the width of each tree at breast height. In the picture to the right, count the tree if the penny appears smaller than the tree's width (left-most penny); don't count the tree if the penny appears larger than the tree's width (right-most penny); and count the tree as a 1/2 if the penny appears the same size as the tree's width (middle penny). Be sure to look at all trees, no matter how near or far.

## Basal Area

As defined previously, the basal area of an individual tree is the surface area of that tree's trunk or main stem cross-section measured 4.5 feet (1.37 meters) above ground, and the sum of the basal areas for all of trees on an acre, reported in square feet per acre, is an indicator of the stocking or density of trees per acre[13]. The basal area of a stand can be calculated from the diameters of trees present in the stand, from the diameters of trees present in one or more sample plots in the stand, or by using an angle-gauge or basal area prism. Angle-gauges and basal area prisms are common forestry tools used to estimate basal area from a point sample, without having to calculate the basal areas of individual trees. Both can be purchased from forestry equipment companies. However, a penny held in one's hand can be used very effectively as an angle-gauge to estimate square feet of basal area per acre, and this can easily be converted to square meters per hectare using the conversion factor of 1 $ft^2$/acre is equal to 0.23 $m^2$/ha.

To use a penny to estimate stocking in square feet of basal area per acre, pinch the penny along an edge between the thumb and index finger, raise the penny and hold it directly in front of your face at a distance of 25 inches (63.5 cm), and slowly turn your body around in a complete circle keeping your feet centered over the same spot (**Figure 5.11**). As you rotate, compare the width of the penny with the width at breast height of each tree that is visible (no matter how large or small, no matter how near or far), and count the number of trees that appear larger than the width of the penny (**Figure 5.11**). If a tree appears to be exactly the same width as the penny, count that tree as a half. Multiply the number of trees counted (as wider than the penny) by 10. The resulting number is an estimate of the stand's basal area in square feet per acre. As an example, if 8 trees were counted as wider than the penny, the stand's basal area would be estimated as 80 $ft^2$/acre or 18.4 $m^2$/ha based on that point sample.

Use of the basal area stocking guides (**Tables 5.2a, 5.2b, 5.3a, and 5.3b**) also requires that the average tree diameter be estimated. Calculate average diameter based on an arithmetic average of the diameter at breast height of the trees you select using the penny or angle gauge, but reduce the estimate for average tree diameter by 2 to 4 inches (5 to

[13]For review, see discussion in earlier section entitled "Determining Whether You Need an Improvement Cut."

10 centimeters) if there are a significant number of trees less than 10 inches (25.4 cm) dbh[14].

An unmanaged sugarbush in which the trees averaged 10 inches (25.4 cm) dbh might have a basal area of 90 to 120 $ft^2$/acre (20.7 to 27.6 $m^2$/ha) or higher. In contrast, a managed, well-stocked sugarbush containing trees of similar size would have a basal area around 43 $ft^2$/acre (9.9 $m^2$/ha) immediately after an intermediate cut, and would be judged as in need of an intermediate cut if the basal area was 65 $ft^2$/acre (15 $m^2$/ha) or greater. The trees in the unmanaged stand are obviously subjected to considerably greater competition from other trees, and will individually grow much more slowly and develop much smaller crowns than the trees in the stand being managed at the lower basal area.

[14]When using a penny or a 10-factor prism or angle gauge, each tree represents 10 sq. ft. of basal area regardless of tree diameter, but the number of trees per acre each tree represents is inversely related to its diameter. For example a 4-inch diameter tree represents 115 trees per acre, an 8-inch diameter tree represents 29 trees per acre, and a 12-inch tree represents 13 trees per acre. A precise estimate of average dbh would require weighting diameter by numbers of trees per acre, but a satisfactory estimate of average diameter can be obtained using the recommended approach. For those interested, at the time of this printing, inventory analysis software is available through USFS at **http://www.fs.fed.us/ne/burlington/ned/**.

**Tables 5.2a and 5.2b** present residual basal area recommendations for managed sugarbush stands of specific averaged diameters to obtain maximum sap quality (high sugar content) and volume production. Table 5.2a uses English units of measurement; Table 5.2b uses metric units of measurement. The residual basal area per acre or hectare (column 3 in both tables) is the recommended basal area of the stand of a specific diameter immediately after an intermediate cut (i.e. residual is what is left behind). If basal area is being used as the principal guide, once cut, a stand would not normally be cut again until the basal area approached the maximum desirable basal area per acre (hectare) for the stand (column 2) at its current diameter. For example, using Table 5.2a, suppose a stand averaging 6 inches in diameter were cut to a residual basal area of 25 square feet and 127 trees per acre, and the trees then grew at an average rate of 1/4 inch per year. In 15 years the trees would average around 10 inches in diameter and if all the trees survived, the basal area would be around 69 square feet per acre, and the stand would again be in need of an intermediate cut which would reduce the stocking to around 43 square feet per acre.

**Table 5.2a. Residual basal area, approximate number of trees, and average grid spacing distances for managed sugarbush stands to obtain maximum sap quality and production using English units of measure[12].**

| Average DBH of Overstory Trees (in) | Approximate Maximum Desirable Basal Area in $ft^2$/acre | Residual Basal Area in $ft^2$/acre | Approximate Number of Residual Trees Per Acre | Average Grid Spacing of Trees in Feet |
|---|---|---|---|---|
| 6 | 38 | 25 | 127 | 19 |
| 8 | 51 | 34 | 97 | 21 |
| 10 | 65 | 43 | 79 | 23 |
| 12 | 75 | 50 | 64 | 26 |
| 14 | 89 | 59 | 55 | 28 |
| 16 | 96 | 64 | 46 | 31 |
| 18 | 103 | 69 | 39 | 33 |
| 20 | 110 | 74 | 34 | 36 |

**Table 5.2b. Residual basal area, approximate number of trees, and average grid spacing distances for managed sugarbush stands to obtain maximum sap quality and production using metric units of measure[12].**

| Average DBH of Overstory Trees (cm) | Approximate Maximum Desirable Basal Area in $m^2$/ha | Residual Basal Area in $m^2$/ha | Approximate Number of Residual Trees Per Hectare | Average Grid Spacing of Trees in Meters |
|---|---|---|---|---|
| 15.2 | 8.7 | 5.8 | 314 | 5.8 |
| 20.3 | 11.7 | 7.8 | 240 | 6.4 |
| 25.4 | 15.0 | 9.9 | 195 | 7.0 |
| 30.5 | 17.3 | 11.5 | 158 | 7.9 |
| 35.6 | 20.5 | 13.6 | 136 | 8.5 |
| 40.6 | 22.1 | 14.7 | 114 | 9.4 |
| 45.7 | 23.7 | 15.9 | 96 | 10.1 |
| 50.8 | 25.3 | 17.0 | 84 | 11.0 |

**Table 5.3a. Residual basal area, approximate number of trees, and average grid spacing distances for previously unmanaged sugarbush stands receiving their first intermediate cut at the designated average diameter using English units of measure[12].**

| Average DBH of Overstory Trees (in) | Residual Basal Area in $ft^2$/acre | Approximate Number of Trees Per Acre | Average Grid Spacing in Feet |
|---|---|---|---|
| 6 | 25–35 | 125–180 | 17 |
| 8 | 35–45+ | 100–130+ | 20 |
| 10 | 55–65 | 100–120 | 20 |
| 12 | 65–75 | 80–95 | 22 |
| 14 | 70–80 | 65–75 | 25 |
| 16 | 75–90 | 55–65 | 27 |

**Table 5.3b. Residual basal area, approximate number of trees, and average grid spacing distances for previously unmanaged sugarbush stands receiving their first intermediate cut at the designated average diameter using metric units of measure[12].**

| Average DBH of Overstory Trees (cm) | Residual Basal Area in $m^2$/ha | Approximate Number of Trees Per Hectare | Average Grid Spacing in Meters |
|---|---|---|---|
| 15.2 | 6.9–8.1 | 370-445 | 4.9 |
| 20.3 | 8.1–10.4 | 247–321+ | 6.1 |
| 25.4 | 12.6–15.0 | 247–296 | 6.1 |
| 30.5 | 15.0–17.3 | 197–235 | 6.7 |
| 35.6 | 16.1–18.4 | 160–185 | 7.6 |
| 40.6 | 17.3–20.7 | 136–160 | 8.2 |

**Tables 5.3a and 5.3b** present residual basal area recommendations for previously unmanaged sugarbush stands receiving the first intermediate cut at the designated average diameter. As discussed above, the stocking and therefore the basal area of an unmanaged stand is commonly much higher (contains many more trees) than the stocking of a stand that had already received at least one intermediate cut. The density of uncut stands must be reduced gradually to avoid undue stress on the trees, as well as avoiding sunscald and subsequent insect and/or disease problems, and excessive epicormic branching or suckering. The stocking of unmanaged stands will vary considerably due to a variety of factors including site quality, stand age structure, and past history. The stocking guides (**Tables 5.3a and 5.3b**), therefore, provide a fairly broad range for the residual basal area stocking for each diameter class in order to respond to specific stand characteristics. It would be wise to consult with a forester experienced in sugarbush management when initiating an intermediate cut in previously unmanaged stands, particularly if the stand is in a larger diameter class.

## Improvement Cutting Guidelines for Stands of Different Sizes/Ages

### Recommendations For Even-Aged Stands—1 to 2 Inch (2.5 to 5 cm) Diameter Trees

Ideally, intermediate cuts in young even-aged stands should begin when the vigorous trees are between 1 and 2 inches (2.5 and 5 cm) in diameter and 10 to 15 feet (3 to 4.6 m) tall **(Figure 5.12)**. Selection of crop trees at this time will encourage the development of short trunks and deep, broad crowns.

Realistically, however, intermediate cuts in this size stand are not common, particularly if the area contains a large amount of maple. Even-aged stands with trees in this size range will commonly contain more than 5,000 trees per acre (12,350 trees per hectare). If there is a high proportion of maple, the prospect of evaluating all trees is overwhelming. If, on the other hand, the area contains only a few maples, far less evaluation is required and the potential maple crop trees will most certainly benefit from release.

Figure 5.12. Ideally, intermediate cuts in young even-aged stands should begin when the vigorous trees are between 1 and 2 inches (2.5 and 5 cm) in diameter and 10 to 15 feet (3 to 4.6 m) tall.

Where an intermediate cut is to be performed in a stand of this size, select one potential maple crop tree every 15 feet (4.5 m)—actual spacing may be from 10 to 20 feet (3 to 6 m) apart, but average should be 15 feet (4.5 m). This spacing will identify approximately 200 potential maple crop trees per acre (494 per hectare). Select crop trees based on the criteria discussed above.[15] Remove trees competing with maple crop trees whose crown margins are within 3 to 7 feet (1 to 2 m) of the crop tree crown margin, or any neighboring tree whose crown edge is within 10 feet (3 m) of the crop tree's stem[16]. Residual basal area has minimal utility as a stocking guide in these small stands.

### Recommendations For Even-Aged Stands—3 to 8 Inch (7.5 to 20 cm) Diameter Trees

It is in stands of this size class, termed pole-sized, that intermediate cuttings for sugarbush management are usually started (**Figure 5.13**). In unthinned stands of this size, depending on tree size, the total number of trees has decreased to between several hundred and about two thousand per acre (between several hundred and five thousand per hectare), and natural crown dominance is becoming evident. Trees will have segregated vertically, with some now starting to tower over

[15]See section entitled "Identifying Trees to Retain and Trees to Cut."

[16]Adapted from Voorhis, 1986. Northern J. Applied Forestry 3:106-108.

others. Potential crop trees are easier to select, and the time and costs required to perform an intermediate cut in these stands are less than for younger stands.

Figure 5.13. Intermediate cuts are commonly started in pole-sized stands, with diameters ranging from 3 to 8 inches (7.5 to 20 cm).

When cutting in a 3- to 8-inch (7.5 to 20 cm) diameter stand that has never been cut, it is advisable to perform the intermediate cut gradually, over perhaps five years, rather than all at once. Rapidly reducing the competition around crop trees can cause undue stress on the remaining trees, as well as sunscald and excessive branching. Thinning can be accomplished most effectively by releasing the trees from competition on only one or two sides at any one time. If the harvested wood is to be used for fuelwood for the evaporator, such a harvesting scheme can provide a continual source of wood. Also, when releasing 3- to 8-inch (7.5 to 20 cm) diameter trees, substantially smaller, overtopped competitors may be left. Leaving some of the overtopped competitors that partially shade the crop tree trunks may be beneficial by reducing sunscald and associated problems, and also could provide replacements in case of mortality of crop trees.

When an intermediate cut is to be done in a stand of this size, identify 100 to 150 crop trees per acre (247 to 370 per hectare) by selecting a crop tree every 20 feet (6 m)—actual spacing may vary from 15 to 25 feet (4.5 to 7.5 m), but should average about 20 feet (6 m). Select crop trees that have good form, are free from disease and insect problems, and that have large, full crowns. In this size class it becomes more practical to measure the sap sugar concentrations of potential crop trees and include that information as part of the decision of which trees to retain. Remove trees competing with maple crop trees according to one of or a combination of the following guidelines:

- Cut trees whose crown margins touch or are within 5 to 7 feet (1.5 to 2 m) of the crown margin of crop trees. In unmanaged stands, it is usually desirable to implement the cut over several years to minimize shock to the crop trees.
- Remove trees closer to crop trees than the distance specified in **Table 5.1a or 5.1b.** In unmanaged stands, it is usually desirable to implement the cut over several years to minimize shock to the crop trees.
- Determine precut basal area and average diameter. Compare the basal area with the approximate maximum desirable basal area per acre for a stand of that size. If the basal area is approaching or greater than that value, the stand will benefit from an intermediate cut. If the stand has had an intermediate cut, reduce the stocking to the appropriate residual basal area (column 3, **Table 5.2a or 5.2b**) by removing the less desirable trees. If the stand has not had an intermediate cut, reduce the stocking to no lower than the residual basal area recommendations in column 2 of **Table 5.3a or 5.3b.** When using basal area as a stocking guide, remember that precut and residual basal area measurements include all trees present, not just the maple.

### Recommendations for Even-Aged Stands—9 to 15 Inch (23 to 38 cm) Diameter Trees

Intermediate cuts begun in these modest diameter stands, termed pole and small sawtimber sized, should continue to maintain healthy,

vigorous, rapidly growing crop trees with deep, wide crowns (**Figure 5.14**). If intermediate cuts have not been completed in the past, do not be too aggressive in cutting. Older trees, and especially those in lower crown classes, have slowed in height growth and may have lost many of their lower crown branches. Accordingly, they will generally respond less dramatically and more slowly to release from competition than younger trees. Nevertheless, intermediate cuttings in previously uncut stands will still improve tree health and vigor and encourage wider crowns and faster diameter growth.

Figure 5.14. Intermediate cuts begun in 9 to 15 inch (23 to 28 cm) diameter stands should continue to maintain healthy, vigorous, rapidly growing crop trees with deep, wide crowns.

When cutting in a stand that has not previously been cut, it is essential that the cut be done gradually, over perhaps five years, rather than all at once. Drastically reducing the competition around crop trees all at once in trees this size will definitely cause undue stress on the trees, sunscald, and other problems. As with the previous size class, this can usually be accomplished most effectively by releasing the trees on only one or two sides at any one time. With progressive cutting, scheduling of activities becomes increasingly important to coordinate cutting with other activities such as the installation of new tubing systems.

Also, as in the previous size class, when releasing crop trees in this size class, substantially smaller, overtopped competitors may be left. Leaving some of these overtopped trees that partially shade the crop tree trunks may actually be beneficial by reducing sunscald and other associated problems. However, less desirable trees that wholly or partially shade the crop trees should eventually be removed.

When an intermediate cut is to be done in a stand of this size, select 80 to 100 crop trees per acre (200 to 250 per hectare) by identifying a crop tree every 20 to 25 feet (6 to 7.5 m). Strive for even spacing among the crop trees. Select crop trees that have good form, are free from disease and insect problems, and that have large, healthy crowns. In this size class, particularly at the small end where there are more trees to choose from, it is also practical to include sap sugar concentrations in the decision of which crop trees to retain. Remove trees competing with maple crop trees according to one of or a combination of the following guidelines:

- Cut trees whose crown margins touch or are within 5 to 7 feet (1.5 to 2 m) of the crown margin of crop trees. In unmanaged stands, it is usually desirable to implement the cut over several years to minimize shock to the crop trees.
- Remove trees closer to crop trees than the distance specified in **Table 5.1a or 5.1b.** In unmanaged stands, it is usually desirable to implement the cut over several years to minimize shock to the crop trees, releasing only one or two sides of the crown at a time.
- Determine precut basal area and average diameter. Compare the basal area with the approximate maximum desirable basal area per acre for a stand of that size (column 2, **Table 5.2a or 5.2b**). If the basal area is approaching or greater than that value, the stand will benefit from an intermediate cut. If the stand has had a previous intermediate cut, reduce the stocking to the appropriate residual basal area (column 3, **Table 5.2**) by removing the less desirable trees. If the stand has not had an intermediate cut, reduce the stocking to no lower than the residual basal area recommendations in column 2 of **Table 5.3a or 5.3b.** When using basal area as a stocking guide, remember that precut and residual basal area measurements include all trees present, not just the maple.

## Recommendations for Even-Aged Stands—15 Inch (38 cm) and Larger Diameter Trees

The benefit from an intermediate cut in stands of this size depends on its previous management (**Figure 5.15**). Stands with previous intermediate cuts that are being managed near the stocking levels recommended in Table 5.2a or 5.2b will benefit substantially as they will commonly be receiving their last intermediate cut at a diameter of 15 inches (38 cm) or greater. In contrast, trees in stands with no previous intermediate cuts will respond far less. Nonetheless, an intermediate cut in these stands, if done conservatively, can maintain if not improve tree vigor. Caution must be exercised, however, that the potential for sap production is not dramatically reduced by removing too many trees at any one time. Certainly an intermediate cut in a previously uncut stand with an average diameter of 20 inches (50 cm) or more would be uncommon, unless a partial objective was to create large canopy gaps in which young maple reproduction would become established. In this situation, cutting often focuses on the removal of trees that are obviously declining in health.

Figure 5.15. Benefits from intermediate cuts in stands 15 inches (38 cm) in diameter and larger depend on their previous management.

When an intermediate cut is to be done in a stand of this size, select 35 to 75 crop trees per acre (85 to 185 per hectare) by identifying a crop tree every 25 to 35 feet (7.5 to 11 m). Strive for even spacing among the crop trees. Select crop trees that have good form, are free from disease and insect problems, and that have large, healthy crowns. In this size class, sap sugar concentrations may be helpful in making individual decisions, but options in identifying trees to be removed will be limited by the relatively low number of trees present per acre. Remove trees competing with maple crop trees according to one of or a combination of the following guidelines:

- Cut trees whose crown margins touch the crown margin of crop trees. In previously unmanaged stands, it is usually desirable to implement the cut over several years to minimize shock to the crop trees, releasing only one or two sides of the crown at a time.
- Determine precut basal area and average diameter. For previously cut stands, compare the basal area with the approximate maximum desirable basal area per acre for a stand of that size (column 2, **Table 5.2a or 5.2b**). If the basal area is approaching or greater than that value, the stand will benefit from an intermediate cut and the stand stocking should be reduced to as close to the appropriate residual basal area as possible (column 3, **Table 5.2a or 5.2b**) by removing the less desirable trees. If the stand has not had an intermediate cut, reduce the stocking to no lower than the residual basal area recommendations in column 2 of **Table 5.3a or 5.3b.** In previously unmanaged stands of this size, it is often particularly desirable to implement the cut over several years to minimize shock to the crop trees. When using basal area as a stocking guide, remember that precut and residual basal area measurements include all trees present, not just the maple.

## Recommendations for Uneven-Aged Stands (Figure 5.2)

Intermediate cuttings in uneven-aged sugarbushes have traditionally concentrated on releasing crop trees 6 inches (15 cm) in diameter and larger. Such an approach, however, ignores the opportunity to have a substantial impact on the growth and quality of the future crop trees by selecting and releasing healthy, vigorously growing, young trees of good form and relatively high sugar content. Intermediate cuttings in uneven-aged stands should be applied down to the 2-inch (5 cm) diameter class if the long-term health and productivity of the sugarbush is to be maximized.

In practice, it is often helpful to view the uneven-aged sugarbush stand as a group of even-aged stands where all age classes collectively occupy the same area of land. Depending on the history of the stand, groups of even-aged trees may occupy different locations in the stand, but most commonly they occupy the same area with the younger, smaller age classes growing beneath the older, larger ones. The mature age/size classes may be in need of cutting to stimulate regeneration or the growth of younger trees growing beneath. The younger age/size classes, if too dense, will benefit from thinning to concentrate growth on the better trees.

To perform an intermediate cut in an uneven-aged stand, select crop trees within each size/age class that have good form, are free from disease and insect problems, and that have large, healthy crowns. Use sap sugar concentration as a selection criteria if considerable variation exists among trees. If considerable variation exists in sap sugar concentration, identify and release 25 to 50 maples per acre (60 to 125 per hectare) less than 6 inches (15 cm) in diameter that have higher sugar content to provide the foundation for a high quality future stand.

Unlike even-aged stands, it is not necessary to extend the cut over several years in previously uncut stands to minimize shock to the crop trees unless the crop trees are in the upper canopy. Crop trees in the upper canopy of previously uncut stands, however, will be subjected to the same stresses as trees in even-age stands, and should be released over several years. Crop tree crown release and tree spacing are common guides for intermediate cuts in uneven-aged stands. When using crop tree crown release, cut trees whose crown margins touch or are within 5 to 7 feet (1.5 to 2 m) of the crown margin of crop trees as appropriate for the trees' size as discussed in the previous sections for even-aged stands. When using tree spacing, remove trees closer to crop trees than the distance specified in **Table 5.1a or 5.1b.**

## Removing Competing Trees

The best way to remove the trees competing with maple crop trees is to cut them, and hopefully use or sell the wood. When no use or market exists for the wood, or when more is available than can be used, killing the trees in place by girdling is an alternative (**Figure 5.16**). However, before girdling extensively in the sugarbush, evaluate its long-term impact. Girdling will certainly achieve the objective. Killing the tree eliminates it as a competitor, but the release of crop trees often is slower with girdling because of delayed mortality, and girdling produces standing dead trees that will gradually decay and break apart. Over time, dead trees in the sugarbush may create an undue hazard to people working during sap collection or to equipment such as tubing. They also increase the risk of disease and insect problems.

The use of herbicides in conjunction with girdling is not commonly recommended in a sugarbush.

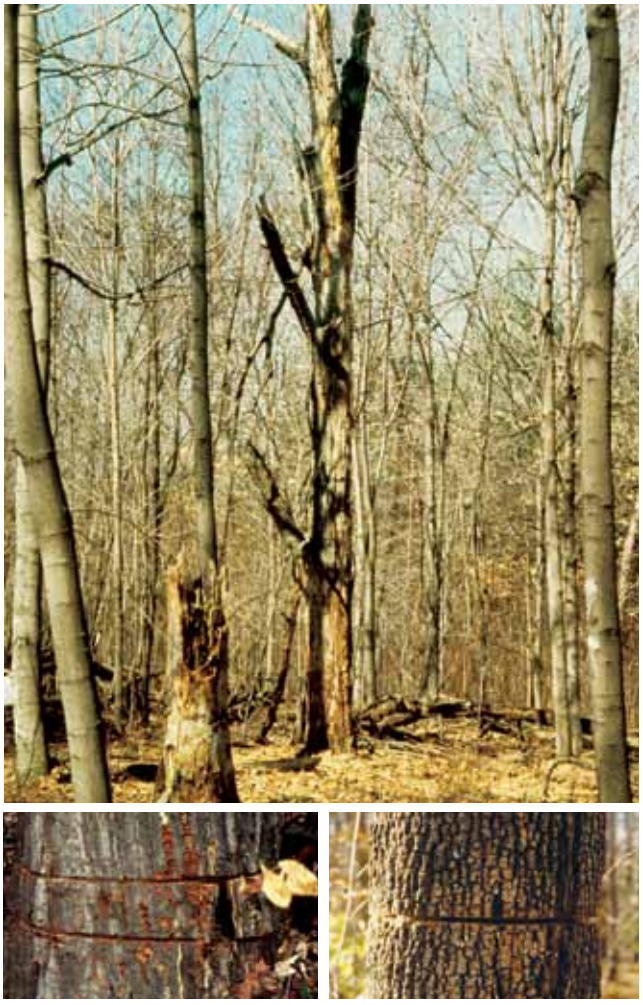


Figure 5.16. When no use or market exists for the wood, or when more is available than can be used, killing the trees in place by girdling is an alternative. Either a single or double chainsaw girdle (for more difficult to kill species) can be used. However, killing and leaving the dead trees in the sugarbush may create a hazard that one must constantly be aware of.

## Improving the Sugarbush—Pruning

Pruning may be done on younger trees in a sugarbush to eliminate forks or acute branching (**Figure 5.17**), and in older trees to remove branches that have been damaged or that interfere with sap collection operations. In small trees, pruning to remove one branch of a double-trunk tree is especially desirable as it eliminates the likelihood the tree will split during a windstorm or because of heavy ice and/or snow accumulations. Proper pruning technique is necessary to maintain healthy trees. When done incorrectly, pruning can create wounds that cause undue stress in the tree and may take several years to heal, exposing the tree to infection longer than necessary.

Figure 5.17. Terminal forking in young maple trees should be pruned to one central leader; acute branching should be eliminated whenever possible. In this case, the two lateral branches should be removed, or, if their removal would remove too much of the crown, they should each be cut back approximately one-half to two-thirds of the way.

Proper pruning technique depends on the size of the branch being removed. If the branch is small enough that its weight can be held in one hand, removing the branch requires a single cut with pruning shears or a pruning saw. When using a pruning saw, place the saw blade at the outer edge of the branch collar (**Figure 5.18**) and saw through the branch keeping the cut in the branch wood at the outer edge of the collar. Support the weight of the branch with the free hand to prevent its weight from breaking the branch free toward the end of the cut and tearing bark from the trunk. Be sure to use a sharp pruning saw and make the cut clean and straight. It is important not to cut into the branch collar as this will lengthen healing time.

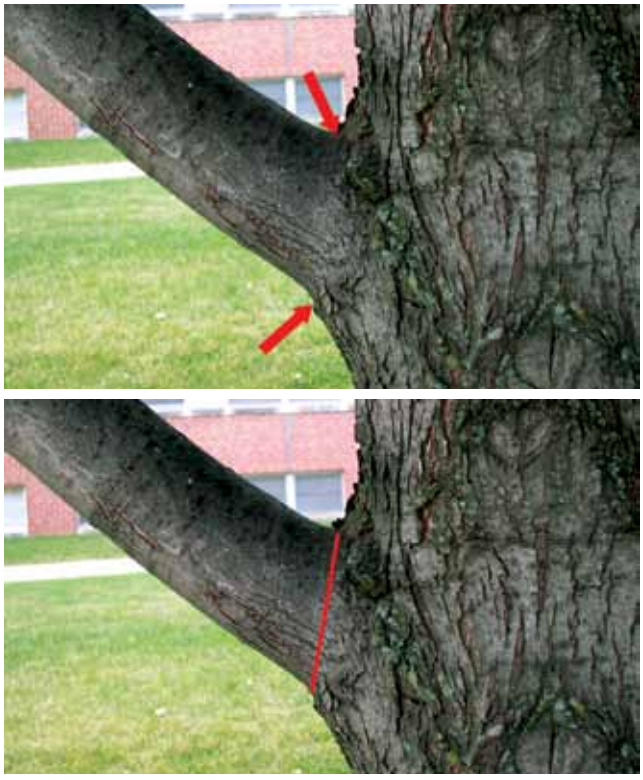


Figure 5.18. When pruning branches at the trunk or a main branch, remove the branch to be pruned just outside the branch collar. The branch collar is the swollen area around the base of a branch. In the illustration above, the branch collar extends to the arrows (top) and red line. Anatomically, the branch collar is part of the trunk. A correct pruning cut will follow the red line on the lower illustration. If the branch collar is cut, healing of the pruning wound will take longer.

If the branch being removed is too heavy to safely support in one hand, removing the branch requires three cuts (**Figure 5.19**). First, cut about 1/4 to 1/3 of the way through the branch on its underside about a foot from the trunk. Then make a second cut 3 to 5 inches beyond the undercut, depending on the branch diameter. When this cut reaches the depth of the undercut, the branch will break through to the undercut but will not go beyond and tear bark from the trunk. Finally, remove the branch stub by cutting along the branch collar.

The time of year forest trees are pruned is less important to overall tree health than the use of proper pruning technique. That said, recommendations for pruning hardwood forest trees generally suggest pruning during the dormant season. To the extent possible, this recommendation should be followed when pruning young maples to eliminate forking and acute branching and to develop a branch-free lower trunk. Recognize that when pruning maples or other species that exhibit "sap runs" in the spring, these species will exude sap from the pruning wounds if pruned during late winter or early spring. This sap loss, however, will have a negligible effect on tree health. The dormant season is also an excellent time to remove branches from larger trees that have been damaged or are in the way of sugarbush activities. However, the best time to do such pruning is probably immediately upon observing the need—or it may be forgotten and not done at all. Trees are fairly resilient, and will generally tolerate some pruning at any time of year.

The use of pruning paint or any other substance to treat the pruning cuts is not recommended. Tree wounds will heal most effectively if cut cleanly just outside the branch collar and left untreated. The use of wound dressings may actually slow the healing process.

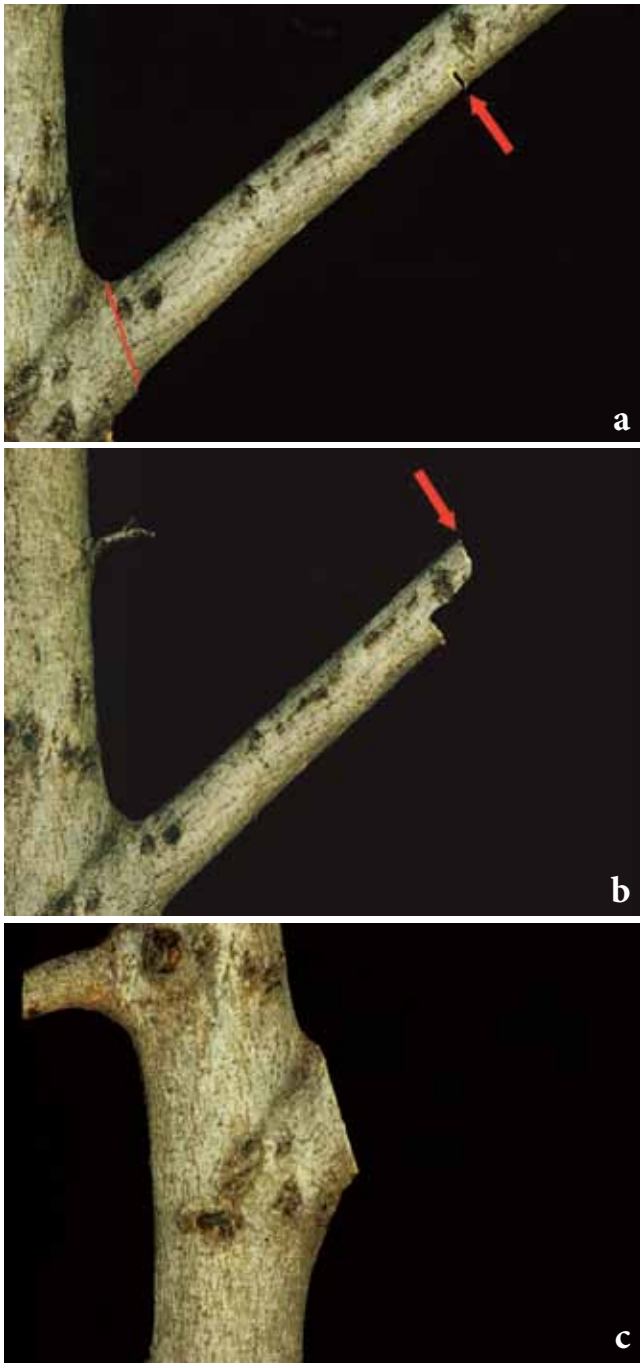



Figure 5.19. Three-cut pruning method used to remove a branch too heavy to support with one hand. Illustration "a" shows location of branch collar (red line) and the location of the first cut. Illustration "b" shows the second cut. Illustration "c" shows the final cut removing the branch at the branch collar.

## Improving the Sugarbush—Liming and Fertilization

Liming and fertilization have long been of interest to maple producers as potential methods of increasing the health and productivity of their

maples. Over the years, researchers and producers have experimented with both liming and fertilization, often with mixed results. In some instances, tree vigor, growth, sap volume, and sap sweetness increased; in others it did not.

There are at least two reasons for these mixed results: first, a failure by both researchers and producers to evaluate the soil and plant nutrient status before liming or fertilizing; and second, incomplete knowledge of the nutritional requirements of maple trees and how they can be best met. In recent years, however, research and experience has demonstrated that, used correctly, liming and/or fertilization can be valuable tools for improving the vigor, growth, and productivity of maple trees growing in certain geographic areas and under certain site conditions, particularly where soils are deficient in calcium and/or magnesium, and where soil pH is quite low (acidic).

The challenge is distinguishing where liming and/or fertilizing can potentially be of benefit from areas where it will not, or where it could even produce undesirable results. Liming and/or fertilization with nutrients that are not limiting the vigor, growth, or other productivity of a stand is a waste of time and money. Furthermore, the application of some nutrients in excess amounts can reduce tree performance on many sites (e.g. excess magnesium can interfere with potassium absorption by tree roots).

Also, for liming and/or fertilization to have the greatest positive effect on tree vigor, growth, and sap volume and sweetness, it must be evaluated together with stand density. If the intent of fertilization is to produce not only healthier, more vigorous maples, but to stimulate crown development as well, stand density must be low enough to allow the crowns to expand.

## Evaluating the Potential Benefit of Liming and/or Fertilization

Producers and others evaluating the potential benefit of liming and/or fertilizing maple trees can and should utilize a variety of tools and indicators. Ultimately, knowledge of the nutritional status of the maple trees (determined from a foliar sample) and the soil characteristics (e.g. pH and buffer pH[17]) is required to develop the proper recommendation. However, for producers who have not formally evaluated the soil characteristics and nutritional status of their sugarbush, characteristics of the trees or the site can often be informative.

Certainly trees and stands that exhibit slow growth and low vigor, including thin crowns, branch die-back, and slow-closing tapholes, should be evaluated. While such symptoms can be caused by other factors (e.g. too much or too little soil moisture), soil pH and/or fertility may be responsible.

Most nutrients, when they are severely deficient, produce visible discoloration patterns on the leaves (**Table 5.4**). Foliar deficiency symptoms are probably most easily observed on smaller trees (e.g. a planting) or on roadside or yard trees where the crowns and leaves can more easily be seen (**Figure 5.20**). The absence of foliar deficiency symptoms, on the other hand, does not indicate that the trees' nutritional needs are being adequately met, only that there is no nutrient deficiency severe enough to cause foliar deficiency symptoms.

**Table 5.4. Visible foliar symptoms of nutrient deficiencies.**

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

[17]Buffer pH, sometimes referred to as lime test index, is a measure of the soil's resistance to pH change when lime is added. It is used to determine how much lime to add to an area to raise the soil pH a desired amount.

Figure 5.20. Foliar symptom of manganese deficiency.

Knowledge of the bedrock present in a geographic area can suggest whether liming or fertilization may be beneficial. In many areas of the commercial maple region, particularly parts of New England and portions of New York, Pennsylvania, Ontario, and Quebec, the bedrock is granite, schist, or other rock low in calcium and often magnesium. Soils produced from the weathering of these parent materials usually have low pH and relatively low calcium and magnesium levels. Research and experience in many of these areas have demonstrated improvement in sugar maple vigor, growth rate, and even total sugar production in response to liming. If the sugarbush is located in such an area, however, do not assume the sugarbush necessarily represents the prevailing soil conditions—soil and foliar testing may be required. While some of these areas are unglaciated, many have been partially or completed glaciated and the material deposited by the glaciers can substantially modify the soil present in a particular locale. Throughout much of the rest of the commercial maple region, limestone is present in the soil parent material, resulting in soils with higher pH and higher calcium and magnesium levels.

A final qualitative indicator of the nutritional character of a sugarbush can be the herbaceous and other woody plants growing in the stand. While there are no "indicator" plants that positively indicate whether or not a sugarbush will benefit from liming or fertilization, there are plants that indicate the relative pH and nutritional richness of the site and therefore the potential that the stand will benefit from liming or fertilization. Wilmot and Perkins[18] in Vermont have suggested that the herbaceous species such as maidenhair fern *(Adiantum pedatum),* blue cohosh *(Caulophyllum thalictroides),* Herb Robert *(Geranium robertianum),* Jack-in-the-pulpit *(Arisaema triphyllum),* wood nettle *(Laportea canadensis),* and Dutchman's breeches *(Dicentra cucullaria),* and trees basswood *(Tilia Americana),* white ash *(Fraxinus Americana),* butternut *(Juglans cinerea),* and northern white cedar *(Thuja occidentalis)* all indicate relatively rich soils with relatively high pH and adequate nutrients—a site where sugar maple should grow well without fertilization. They further suggest that the absence of such plants along with sparse maple regeneration and the presence of trees such as American beech *(Fagus grandifolia),* yellow and paper birch *(Betula alleghaniensis* and *Betula papyrifera),* red and striped maple *(Acer rubrum* and *Acer pensylvanicum),* red spruce (*Picea rubens*), and eastern hemlock *(Tsuga canadensis)* often identifies a more acid site with lower levels of nutrients important to maple. In areas such as Vermont, where relatively extreme variations in soil pH and nutrient richness exist, indicator plants might be particularly useful.

In some geographic areas, these qualitative indicators may provide a sufficient basis for a recommendation, particularly concerning the need for lime. In other areas, however, the development of an appropriate recommendation of whether or not to lime or fertilize, and if so with what and how much, will require evaluation of a soil and foliar sample of the management area (stand).

Throughout the maple region, deficiencies in calcium, magnesium, and potassium and problems related to strongly acid soils are the most common tree nutrition/soil fertility problems reported. When foliar and soil analyses are performed, a thorough assessment of tree or stand nutritional status should not be limited to these factors, but should evaluate all appropriate nutrient and soil conditions. Foliar nutrient analysis and soil analysis are two widely used tests for evaluating plant nutritional status and soil fertility. With a foliar

[18]Wilmot, Timothy and Timothy Perkins. 2004. *Fertilizing a Sugarbush*. Proctor Maple Research Center, University of Vermont. 8 pp.

nutrient analysis, a representative sample of plant foliage is collected, analyzed for nutrient content, and the results compared to what is acceptable or desirable for the species. With soil analysis, a representative soil sample is collected, analyzed for pH and content of selected nutrients, and the results compared to what is deemed sufficient or desirable for the species.

## Foliar Nutrient Testing and Analysis

Research and experience has indicated that while the foliar nutrient content of healthy, vigorous trees of a particular species can be quite variable depending on individual site conditions, there are minimum levels necessary to maintain healthy, rapidly growing trees. While additional research is needed with maple species, **Table 5.5** identifies recommended minimum concentrations of selected foliar nutrients for healthy sugar maple trees based on current research and experience. Although these values were developed specifically from research and experience with sugar maple, they can also provide guidance when evaluating other maple species, though some maples, such as red maple, may require less calcium to thrive. It should also be emphasized that while the values in the table are recommended minimum levels for healthy, vigorous sugar maples, the performance of sugar maple may continue to improve with increasing calcium levels above 1 percent to perhaps 1.2 percent.

**Table 5.5. Recommended minimum sugar maple foliar nutrient content expressed as a proportion (percent, ppm, or mg/kg) of the total oven-dried weight of the foliage.**

| | Recommended Minimum Foliar Nutrient Content | | |
|---|---|---|---|
| **Nutrient** | **%** | **ppm** | **mg/kg** |
| Nitrogen | 2.0 | 20,000 | 20,000 |
| Phosphorus | 0.1 | 1000 | 1000 |
| Potassium | 0.6 | 6000 | 6000 |
| Calcium | 0.8 | 8000 | 8000 |
| Magnesium | 0.1 | 1000 | 1000 |

Nutrient analyses of collected foliar samples can be performed by many agricultural testing laboratories[19]. Trees sampled should represent as uniform an area and condition as possible. Clearly identify why the testing is being completed and design the sampling to provide the appropriate answer. Take more than one sample when needed (e.g. two different stands on two different soil types; trees with large healthy leaves versus trees with smaller, off-colored leaves; etc). Remember, the analysis is being performed to evaluate a specific situation and develop a liming and fertilizer strategy if needed. Mixing leaves that represent different conditions will produce results and recommendations that do not match any existing condition. Foliar samples should be collected in mid-August to mid-September and contain approximately thirty sun leaves collected from the mid to upper crown of trees located uniformly throughout the sample area. Leaves are commonly collected with a long-handled pole pruner, but with proper safety precautions, twigs and leaves can also be removed by shooting with either a shotgun or small caliber rifle. Consult guidelines from individual labs concerning how foliar samples should be handled and submitted.

## Soil Testing and Analysis

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

As with foliar samples, soil sample analysis can be performed by many agricultural testing laboratories. The soil sample should represent as uniform an area and condition as possible (e.g. same soil type, same topography, similar drainage, etc.). If an area (e.g. stand) is being evaluated that contains two dissimilar areas with respect to soil characteristics, a soil sample should be

[19]To locate an agricultural testing laboratory that performs foliar nutrient analysis, contact your County Extension office or nearest university or agency that works with the agricultural community.

collected for each area. The soil sample should consist of 15 to 20 subsamples collected randomly (often in a zigzag pattern) throughout the sample area. Each subsample should consist of a slice or core of the upper 5 to 7 inches (13 to 18 cm) of the mineral soil, with the surface leaf litter discarded. The slice can be obtained by using a trowel or shovel to dig a block of soil 3 to 4 inches (7 to 10 cm) on a side and 5 to 7 inches (13 to 18 cm) deep; the core can be obtained using a soil probe and sampling to a depth of 5 to 7 inches (13 to 18 cm). Avoid odd or atypical areas when selecting subsampling locations. The subsamples should be mixed together (preferably in a plastic bucket) to form a representative sample, which is then handled according to the directions from the testing laboratory. Detailed guidelines for obtaining, handling, and submitting soil samples are available from individual testing labs and many universities and agencies that work with the agricultural community. Often this information is provided online.

Most maple species thrive in a pH range from approximately 5.0 to 7.0. Outside that range they survive, but not with the same vigor or productivity. As noted, research and experience have both shown that in areas of the commercial maple syrup range where soil pH in the upper soil is below 5.0, the health, vigor, and productivity of maples can often be substantially improved through the application of lime or dolomite, which increases the pH and provides additional calcium and magnesium (in the case of dolomite). When liming is appropriate, buffer pH provides a guide to determine how much lime or dolomite should be applied to raise the pH to a desired level. Where possible, it would be desirable to raise soil pH to the 5.7 to 6.0 range for all maple species. In many situations, however, where pH is severely acid, moving pH into the low 5s may be all that is feasible. The decision concerning whether to use calcite lime (calcium only) or dolomite (calcium and magnesium) should be made based on the foliar test results for magnesium—if the magnesium level is satisfactory, calcite lime can be used; if the magnesium level is low, dolomite should be used.

Two cautions need to be raised when liming maple stands. The amount of lime to be applied should be correctly determined to achieve the desired pH—too much lime can raise the soil pH to levels that will induce micronutrient deficiencies, particularly of manganese. Also, research and experience have shown that heavy applications of lime can result in the calcium and magnesium reducing the availability of potassium in the soil and/or interfering with the trees' absorption of potassium. While it would always be prudent to perform a follow-up foliar test about four years after liming, when heavier rates of lime are used it would be highly recommended.

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

Nitrogen is an essential nutrient for plant growth, and a foliar level of at least 2 percent was identified above as desirable for healthy, vigorously growing sugar maples. Many soil test results, however, do not include information on available soil nitrogen, and there are no current guidelines for interpreting such information for maple even if it were provided. The potential value of fertilizing a sugarbush with nitrogen alone has not been well studied and is not well enough understood to make specific recommendations. Producers considering such action should strongly consider "experimenting" on a small area of the sugarbush and evaluate through tree performance and foliar

testing whether or not the fertilization accomplished the objectives.

When soil-applied fertilizers and lime are to be applied in a sugarbush, they are usually best applied in the spring or in the fall after the leaves have dropped. Depending on the amount of lime or fertilizer to be applied, material can be spread by hand or with appropriate spreaders. Many sugarbushes have been limed by distributing the bags evenly throughout the application area and then uniformly distributing the lime by casting it throughout the bush with a shovel. More accurate distributions can be obtained using spreaders. If pelletized lime or fertilizer is used, a "hand-held" spinner spreader is well suited for applications in a sugarbush stand. A drop spreader can be used if lime or fertilizer is in powdered form. In either case, the spreader must be calibrated to insure that it is spreading at the desired rate. This can be accomplished by measuring the amount spread over an area of known size and adjusting the spreader opening until the desired rate is achieved. Calibrations should be performed for each applicator, as two individuals walking at different rates apply substantially different amounts of fertilizer. Tractor- or ATV-drawn spreaders can be used in larger areas, though some soil compaction will occur and extreme care must be taken not to damage young trees, lower tree trunks, and roots. Tractor or ATV-drawn spreaders must also be calibrated at the speed they will be driven. Many universities and agencies that work with the agricultural community have fact sheets describing the calibration of fertilizer spreaders.

## Maintaining a Sugarbush—Reproductive Cuts

Critical but frequently overlooked parts of sugarbush management are those activities aimed at encouraging the establishment and growth of new maple trees—the sugarbush of the future. Because maple trees grow for a couple of hundred years or more, and because it may take fifty or more years to grow an unmanaged maple to a tapable size, some maple producers decide that reproducing the sugarbush does not concern them. While that may be true in some younger, even-aged stands, in other stands (e.g. older, even-aged stands or uneven-aged stands) carrying out activities aimed at encouraging the establishment and growth of new maple trees is highly desirable. Many producers view such activities as an exciting opportunity to ensure that the resource will be healthy and productive for their future and beyond. It is their legacy to future sugarmakers. Regenerating a sugarbush requires a plan for replacing trees in the existing sugarbush as they grow older, become less productive, and ultimately die.

There are also some very practical reasons for being concerned about sugarbush reproduction. Reproducing declining portions of a sugarbush today will provide healthy, vigorous, high-yielding trees of tapable size on some sites within as little as 25 to 35 years. This certainly is within the planning horizon of many sugarbush managers. Also, in the future the sugarbush may pass to succeeding generations within the family or be sold. In either case, a healthy, vigorous sugarbush is of far more value than one consisting only of old, over-mature trees. It is also much more resilient and will recover more quickly from natural disturbances such as ice or wind storms.

### Regenerating Uneven-Aged Stands

How sugarbushes should be regenerated depends on many factors, one of the most important of which is stand structure. For producers desiring to maintain or create a stand with uneven-aged structure, reproducing the sugarbush involves removing the larger non-maple species and the older, declining maples individually or in small groups to create gaps in the canopy into which younger maples grow (**Figure 5.21**). Avoid removing large groups of trees in one area as this may favor shade intolerant species, such as black cherry and red oak, over the more shade tolerant maples. Over time, such selection harvesting, accompanied by intermediate cuts (discussed earlier), can develop and maintain an uneven-aged stand containing a high proportion of high-quality maples. The uneven-aged stand will commonly have three to five or more distinct age classes corresponding to the number of times selection harvests were performed. Depending on the size

of the trees and the pattern of harvest (group versus individual), trees in each age class may occur in several small patches 1/10th to 1/4th acre (0.4 to 0.1 hectare) in size, or the trees in each age class may be interspersed throughout the stand.

Figure 5.21. Harvesting trees individually or in small groups in a sugarbush provides openings in which younger maples can grow. Notice the high stumps. Stumps should be cut as flush to the ground as possible to minimize fungal development.

## Regenerating Even-Aged Stands

As noted previously, even-aged sugarbushes are the norm throughout much of the commercial maple region. How those stands are reproduced depends on a variety of factors, especially the size of the sugarbush and the need of the producer for sap from the stand. Producers unwilling to take an area of the sugarbush out of production for an extended period of time can perform periodic selection harvests that will stimulate reproduction and gradually convert the stand to an uneven-aged structure. The use of selection harvests to reproduce even-aged sugarbushes will undoubtedly be the most common approach, as the number of taps lost to production is minimized. However, other even-aged stands, particularly those containing older, declining maples that are part of a relatively large sugarbush, may be managed on an even-aged basis using clearcutting or a more gradual harvest referred to as a shelterwood cutting.

**Clearcutting** commonly removes all trees above a small minimum diameter (e.g. 2 inches or 5 cm) at one time (**Figure 5.22**). The new forest develops from young trees already present at the time of cutting and from those that become established shortly after the cut. It is critical to note that clearcutting will usually only succeed in naturally establishing maple if an adequate number of maple saplings (stems greater than 5 feet tall [1.5 m]—termed advanced regeneration) exist in the area to be harvested at the time of cutting. If this advanced regeneration does not exist, faster-establishing species such as black cherry, yellow poplar, red oak (actual composition of new species will depend on specific region of the country where the sugarbush is located), and others will successfully establish rather than maples. Planting maples is one way to insure advanced regeneration. Use the more shade-tolerant sugar and/or black maple under an existing stand five to ten years before an anticipated clearcut. Maples can also be planted after the clearcut, though they will take more care to insure their survival and development.

Figure 5.22. Clearcut area three years after harvest. Maples in the cut area may need release from faster establishing species if they are to survive and develop into a future sugarbush.

A **shelterwood cut** involves cutting the trees in the stand in a series of two or three cuts that gradually open the forest, creating an environment that encourages the establishment of the shade-tolerant maples (**Figure 5.23**). While not a commonly used harvesting method, it can be used to reproduce an even-aged maple stand when few young maple trees are present at the time of cutting. Two additional benefits of a shelterwood cut are that the stand (or at least a portion of it) continues to produce sap until the final cut, and the harvest is more gradual and less visually dramatic than a clearcut.

Previously managed stands that contain healthy, reasonably vigorous, large maples and few undesirable trees can often be regenerated with a **two-cut shelterwood**. Such stands are commonly created through the application of intermediate cuts as discussed earlier. The first cut, termed the seed cut, removes all but 15 to 40 relatively evenly spaced vigorous maples per acre (37 to 100 per hectare) that serve as seed trees. The larger the retained trees, the fewer should be retained. It is desirable to cut as many of the older trees as possible in the seed cut to minimize the damage to the reproduction that will occur as a result of the final cut (often called the removal cut)—particularly if the older trees have large crowns. If successful, the seed cut should result in 10,000 to 15,000 seedlings/saplings per acre (25,000 to 37,000 per hectare) over the next several years. If unsuccessful, maple seedlings can be planted. When the saplings reach 8 to 10 feet (2.4 to 3 m) in height, all of the seed trees can be removed in a final cut. Note that many of the saplings will be damaged or broken during the harvest, but they will quickly sprout from their well-established root systems and produce rapidly growing trees. Producers considering retaining all or a significant portion of the seed trees beyond this time to continue tapping need to weigh carefully the value of the sap that will be collected against the resulting slower growth of the young maples and the damage that will be done to them when the seed trees are ultimately harvested. Many years can be added to the time until the new stand is ready to tap by postponing the final cut.

Figure 5.23. First cut of a shelterwood harvest. While not a common method of harvesting maple, a shelterwood harvest maintains a partially shaded environment, which may encourage the establishment and growth of shade tolerant maples, is less visually dramatic than a clearcut, and retains a portion of the larger maples on the site for a period of time after the first cut. These maples are available for tapping until their removal.

Previously unmanaged stands with less vigorous maples in the overstory and numerous undesirable species often require a **three-cut shelterwood**. Overstory trees in such stands are usually more numerous and have much smaller and narrower crowns than those growing in managed stands that have been periodically thinned. In a three-cut shelterwood the seed cut is preceded by a preparatory cut the objectives of which are to improve the health, vigor, and future seed production of the future seed trees, to remove undesired species (aspen, paper birch, and others), and in colder regions to improve the conditions for germinating maple seed by reducing the amount of accumulated humus on the forest floor. In practice, a preparatory cut could be viewed as very similar to an intermediate cut (actually a thinning from below) in which trees are removed from the stand beginning with those in the lower canopy (termed overtopped trees) and continuing up through the canopy until enough trees are removed to allow for the expansion of the future seed trees' crowns. In practice, undesirable species can be removed from all positions in the canopy. The seed cut and final cut in these stands would be similar to those in the previously managed stands, though more seed trees would commonly be retained in these unmanaged stands as the crowns would be smaller.

### Developing and Implementing a Regeneration Plan

So far, several different methods for regenerating individual stands have been discussed. However, it is most effective to consider the sugarbush as a whole when developing a long-term plan for maple reproduction. If the sugarbush is relatively small, uneven-aged, and relatively uniform, it may be appropriate to manage it as one stand, implementing selection harvests as needed. With larger, less uniform sugarbushes, it generally will be more productive to divide the sugarbush into separate stands, each with its own management prescription (as discussed earlier). The appropriateness, timing, and type of regeneration harvest for a particular stand will then be dictated by the characteristics of the stand and producer's preferences (e.g. the need to retain specific trees to produce sap). This is particularly true for even-aged stands, where regeneration concerns in young, vigorous stands may be decades or more in the future, while the need for regeneration activities in a stand predominated by older, declining maples may be more immediate.

Some producers will choose to perform the cutting themselves; others will have it done by a commercial logging company. If cutting is done by the sugarbush owner, he/she should be completely familiar with logging techniques and the safe use of appropriate equipment, and have appropriately trained and experienced personnel available to complete the operation. If it is to be done commercially, sugarbush owners should be familiar with effective methods of marketing timber and supervising a timber sale or retain the services of a forester to execute the sale on their behalf. Also, be aware that commercial harvests generally require a minimum volume of timber to be attractive to potential buyers. Producers with small acreage and those with larger acreages implementing a small cut might consider partnering with neighbors to achieve the minimum volume and avoid the temptation to overcut the stand. Also, the timing of the regeneration cuts is best synchronized with other management activities such as intermediate cuts, road building, access to new areas, or tubing replacement.

Developing and carrying out an effective plan for reproducing a sugarbush requires a high level of knowledge about forest growth, species-site relationships, timber harvesting, and a variety of other factors. As with other sugarbush management prescriptions, maple producers are advised to work closely with a forester or other resource management professional experienced in sugarbush management.

## Establishing a Sugarbush—Tree Planting

Planting provides the opportunity to use easily accessed, suitable sites to establish a rapidly growing, vigorous stand of maples that may reach tapable size in 20 to 30 years (**Figure 5.24**). This is considerably less time than for maples in

unmanaged sugarbushes. Planting can be done with seedlings or saplings dug from existing stands or obtained from nurseries[20].

Figure 5.24. Planting provides the opportunity to use easily accessed, suitable sites to establish a rapidly growing, vigorous stand of maples.

For reasons described previously, sugar or black maple should be the species of choice for best sugar yields. While sugar maple grows on a variety of sites, planting should be done only on better sites characterized by deep, medium-textured, fertile, moist, and well-drained soils.

Very dry sites, poorly drained sites, and low areas that form frost pockets should be avoided. Tree growth and sap production is influenced by topography. Southeast-facing slopes tend to have the best combination of sunlight, moisture, and temperature. North slopes, in contrast, may have good moisture, but less light and lower temperatures.

The question is often raised concerning whether it is desirable to plant a monoculture of any species, including maple, or whether a mixed species planting would be better. Monocultures contain only one species and are, therefore, potentially more vulnerable to damage or destruction from insects or disease. While such a concern is certainly valid for large-scale plantings, most sugarbush plantings are relatively small and are specifically intended for maple sap production. To the extent that other species are included in the final crop trees, sap yield will be reduced. Also, other tree species, crops, and other vegetation in the surrounding landscape may provide some protection against the spread of pests to the plantation.

## Obtaining and Planting Seedlings and Transplants

Maple plantings are commonly established either by planting young seedlings (commonly two to three years old) obtained from a nursery, by transplanting larger, older, "wild-grown" trees that have already become established in the sugarbush or at another location, or by planting larger nursery grown transplants.

### If the planting is to be established using young seedlings:

a. Order seedlings as early as possible (e.g. early fall for planting the following spring) to avoid desired seedlings being sold out. Check with your local, state, or provincial resource professional concerning the availability of genetically improved "super sweet" seedlings.
b. Plant in the spring unless you have been advised differently by a resource professional experienced in planting in your region.

[20]For best survival and growth, seedlings obtained from a nursery should be grown from seed collected locally or within the same climatic zone as the planting.

c. Before planting, eliminate any undesirable woody vegetation, such as vines, brambles, trees, and shrubs from the planting area. This can be done most effectively in the fall prior to spring planting with a combination of cutting and the application of appropriately labeled herbicides (e.g. a glyphosate containing herbicide).

d. If possible, arrange for delivery of seedlings as near to the date of planting as possible. Seedlings are commonly packaged in Kraft-paper bags containing moss or some other moisture holding medium. If kept cool, seedlings can be stored in these shipping bags for four to seven days provided the moss or other medium is kept moist (not wet). Effective storage for longer periods generally requires refrigerated storage of the bags or the temporary "heeling in" of the seedlings in a soil filled trench.

e. Keep the seedling roots moist at all times prior to planting. Once the planting process has begun, this is best done by keeping moist moss around the roots and keeping the seedlings shaded. Do not store sugar maple seedlings in a bucket of water—the roots of most tree seedlings can be damaged by extended submersion.

f. Consider planting seedlings at spacings between 8 feet by 8 feet and 16.5 feet by 16.5 feet[21]. Stands planted within this spacing range do not require excessive numbers of seedlings per acre, yet provide ample opportunity for thinning as the planting matures.

g. Carefully measure and lay out the location of planting rows and trees within rows. Careful tree placement will make trees easier to locate, reduce damage and loss from mowing, and establish proper spacing for future thinning. Many techniques and aids can be used to achieve proper spacing such as poles cut or marked to the spacing length, rope with knots or fingernail polish marks at spacing intervals, and survey flags to mark rows or planting locations. Sight down and along rows and across diagonals to straighten rows.

h. Plant only healthy, vigorous, well-formed seedlings, free from damage, defects, or signs of insects or disease (e.g. mold). Handle and plant carefully to avoid damaging the seedlings.

i. Do not plant bare-root maple seedlings with a planting bar. Use a shovel or planting auger. For best survival and growth, seedlings should be planted in a hole with a cone of soil in the center over which the roots are draped. This method places the roots in the most natural position, minimizes root damage, and most effectively establishes root-soil contact in the largest volume of soil.

j. Plant seedlings at or very near the same depth as they grew in the nursery. This depth is the tree's root collar, the area where stem changes to root. This can be located by changes in the color and surface texture of the bark. Trees planted too deep or too shallow will do poorly.

k. Refill the hole with the soil that was removed, packing the soil firmly as it is returned.

l. If water is available, a couple gallons gently poured on the soil after planting will help settle the soil around the roots. Do not water the seedling until the hole has been completely refilled with soil. Watering during dry periods for at least the first year will help with survival and growth. A bark or hardwood chip mulch can help with moisture retention.

### If planting is to be established using larger, wild-grown transplants:

a. When possible, select transplants a year ahead and root prune[22].

b. Look for healthy, vigorous trees approximately 1 inch (2.5 cm) in diameter from open areas within or along the edge of the sugarbush. Select straight trees that are free from stem defects and that have a strong terminal leader (avoid flat-topped trees lacking

[21]2.5 m by 2.5 m and 5 m by 5 m.

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

a single strong terminal leader). When possible, avoid digging trees in dense areas of the sugarbush, as they will be more difficult to remove, will not have as vigorous root growth, and may be sensitive to sunscald when moved to a more open area.

c. Wild-grown maples can be transplanted in either spring (before buds begin to swell) or fall (after leaf drop), and can be successfully transplanted either bare-root or with a soil ball around the root. The use of a soil ball is recommended whenever possible to minimize stress on the tree.

d. Current recommendations for root ball size for maples and similar trees growing under natural conditions are as follows[23]:

| Trunk Diameter 4" Above Ground | Root Ball Diameter | Root Ball Depth |
|---|---|---|
| ½ inch (1.3 cm) | 14 in (35.6 cm) | 9 in (23 cm) |
| ¾ inch (1.9 cm) | 16 in (40.6 cm) | 10½ in (27 cm) |
| 1 inch (2.5 cm) | 18 in (45.7 cm) | 11¾ in (30 m) |
| 1¼ inch (3.2 cm) | 20 in (50.8 cm) | 12 in (31 cm) |
| 1½ inch (3.8 cm) | 22 in (55.9 cm) | 13¼ in (34 cm) |

The root ball diameters and depths in the table should be viewed as minimums. A serious challenge in moving maples with a root ball is holding the root ball together, particularly as ball diameters get above 18 inches. Another challenge is moving the weight involved. Soil weighs approximately 84 pounds per cubic foot. The recommended soil ball for a 1-inch diameter transplant weighs slightly less than 300 pounds.

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

f. When bare-rooting wild-grown maple transplants, excavate the root systems to a depth of approximately 12 inches and a minimum root-spread (diameter) as listed in the following table[23]:

| Trunk Diameter 4" Above Ground | Minimum Root Spread |
|---|---|
| ½ inch (1.3 cm) | 16 in (41 cm) |
| ¾ inch (1.9 cm) | 21 in (53 cm) |
| 1 inch (2.5 cm) | 24 in (61 cm) |
| 1¼ inch (3.2 cm) | 26 in (66 cm) |
| 1½ inch (3.8 cm) | 29 in (74 cm) |

Excavation of bare-root transplants can proceed in a manner similar as that for balled transplants, except that a ball of soil is not retained around the root systems.

g. Plant balled transplants in a hole deep enough to accommodate the root ball. The burlap need not be removed, but any twine used to bind the ball should be removed. Plant bare-root transplants in a manner similar to the method used for small seedlings—in a hole with a cone of soil in the center over which the roots are draped. Position the transplants (balled or bare-rooted) at the same depth as they previously grew (see discussion above on locating root collar).

h. Refill the hole with the soil that was removed, packing the soil firmly as it is returned.

i. Each transplant should be given artificial support to prevent excessive swaying and

[23]2004 American Standards for Nursery Stock, American Nursery & Landscape Association.

breaking. This can be done by driving a 6 to 8 foot (1.8 to 2.4 meter) stake into the ground near the base of the tree and securing the tree to the stake with a short length of wire running through a garden hose (to protect the tree's bark). Where prevailing winds are obvious, place the stake on the windward side of the tree. Where winds are strong and variable in direction, a two or three stake system may be preferable.

j. If water is available, several gallons gently poured on the soil after planting will help settle the soil around the root ball or roots. Do not water the seedling until the hole has been completely refilled with soil. Watering during dry periods for at least the first year will help with survival and growth. A bark or hardwood chip mulch can help with moisture retention.

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

Because of the time and labor involved with transplanting large saplings, they are often spaced at least 25 feet (7.5 m) apart—at the desired spacing of the trees when grown. They can, however, be spaced closer together, perhaps 10 to 15 feet (3 to 4.5 meters), with the intention of removing poorer performing trees as the canopy closes. If wider spacing is used, interplanting of "nurse" species, such as European black alder, should be considered. Nurse trees help suppress weeds and provide some wind protection. Some, such as European black alder, are nitrogen-fixing and will improve soil fertility. Consult local resource professionals for recommendations of nurse tree species suitable for your area. As the maples begin to close canopy, the nurse trees should be removed. Alternatively, annual cash crops such as u-pick raspberries or pumpkins can supplement income until the maple trees attain tapable size.

## Weed Control in Plantings

To perform well, planted maples benefit greatly from good weed control for several years after planting. This is to reduce competition for light, moisture, and nutrients. It will require more than 10 years for maples to produce enough shade to suppress competing vegetation. Following planting, grasses and broadleaf weeds should be eliminated from around the base of the trees with herbicide (e.g. glyphosate directed spray or other properly registered herbicide), shallow cultivation (no deeper than 1 to 1½ inches or 2½ to 4 cm), or frequent mowing. Do not strike maple bark with the string of a string mower as it can girdle the tree. Mice and voles can damage seedlings during the winter. Bare soil around the tree discourages their activity while dense weeds; deep, coarse mulch (e.g. straw); and weed mats, particularly if loose, can provide a good winter habitat for small rodents.

Producers desiring organic certification should check guidelines regarding the use of herbicides.

## Protecting Plantings from Animal Damage

Maple trees may be damaged or destroyed by the feeding of mice, voles, rabbits, porcupines, or deer. Most feeding damage on tree bark occurs during winter, so early fall is a critical time to apply wildlife control strategies. Deer will eat leaves and young twigs. Chemical repellents have shown variable success and many must be applied every five to six weeks if feeding damage persists. The best approach is to use wire or plastic mesh tree shelters. Wire fencing with 1-inch (2.5 cm) mesh formed into a circular guard will prevent deer, rabbit, and porcupine feeding. Where deer are active, fencing will need to be extended to 6 feet above ground or snow level. For rabbits, the guards need to reach at least 20 inches (50 cm) above ground or snow level.

Solid plastic tree shelters and tight mesh shelters should be avoided as these adversely affect the environment around the seedling. They also provide a good environment for wasps, Japanese beetles, and other insects that can damage the plants. If such shelters are used, cover the top around the tree stem with plastic netting so that songbirds do not become trapped inside the tubes. Also, in some areas, tubes should be removed annually to avoid damage or death as a result of the seedling breaking dormancy too early in the spring and being damaged by cold temperature.

Excluding mice and voles from the base of the tree will require 1/4-inch mesh wire hardware cloth near the base of the tree. The hardware cloth should be at least 6 inches larger in diameter than the tree stem to allow for growth, be taller than the anticipated snow depth, and have its base buried 6 inches in the ground to prevent burrowing beneath the barrier. Management of ground cover can effectively control mice and meadow voles. This involves maintaining short grass or bare soil around the base of the tree, and mowing between trees in the developing orchard. Mowing close to the ground in the fall will reduce habitat voles need to over-winter and better expose them to predators like fox and hawks. Again, if a string mower is used, be careful not to strike the bark as this will damage or even girdle the trees. Trapping also should be considered to reduce vole populations. Bait snap traps or small box traps with apple slices. Covering the trap with a roofing shingle or other similar object will improve capture success.

## Fertilizing Plantings

Ideally, sugar or other maple species should be planted on sites where the native soil can support vigorous, healthy trees without fertilization or liming. To do otherwise is to commit future time and resources to maintaining soil pH or fertility. Soils should be tested prior to planting to avoid, when possible, sites with insufficient fertility or ones with an excessively high or low pH. Where possible, soils with a pH between 5.5 and 7.0 are most desirable. If maples are present on the site, an analysis of their foliar nutrient content may provide a guide as to how well the site is providing adequate nutrition. See the section in this chapter on fertilization for a discussion of soil and foliar nutrient testing.

Where initial applications of lime or phosphorus are needed, they should be applied and incorporated into the soil before planting. If available, compost or good forest soil may help with poor soil conditions. Applications of liquid or granular fertilizer should normally not be made during the first year after planting. After the first year, fertilizer may be applied if soil or foliar analysis or plant performance indicates the need. If fertilizer is applied, it should be on the area covered by the tree crown. If fertilizing in response to a specific nutrient deficiency identified with a soil or foliar analysis, apply the appropriate fertilizer at the recommended rate as discussed in the section in this chapter on fertilization. If fertilizing simply to improve seedling health, vigor, and growth rate with no test identifying a deficiency, use a complete fertilizer with N-P-K analysis of 10-10-10 applied at a rate of 3 to 4 pounds per 100 square feet (1.3 to 1.8 kg per 9 square meters) of soil surface. This translates to 3½ to 4½ ounces spread over a 3-foot diameter circle (118 to 153 gm over a 1-meter diameter circle).

## Pruning Plantings

The form and shape of young maples should be examined each spring and pruned when necessary. The ultimate goal is to develop a tree that has a single trunk clear of branches up to at least 8 feet (2.5 m) and then branches into a full crown. Sugar production results from a full canopy of leaves having maximum exposure to sunlight. Multiple terminals should be removed, retaining the straightest, most central leader (**Figure 5.17**). Laterals with excessive growth should be cut back to keep the crown balanced. Terminal leaders that have been damaged or destroyed should be pruned back to a pair of lateral branches, with one lateral selected to become the new leader and the other removed or severely cut back. Lower branches generally need not be pruned unless they interfere with access to the trunk or with mowing (**Figure 5.25**).

Several rules should be followed when pruning. First, no more than 25 to 30 percent of the tree's crown should be removed in any one year. Rarely would a young maple require this severe pruning. Second, at least the upper 50 percent of the tree's trunk should contain live branches. Third, branches should be pruned at the branch collar, not flush against the trunk. Fourth, prune in the spring after the sap has stopped running.

Figure 5.25. Small branches should be pruned with sharp by-pass type hand pruners.

## Managing Roadside Trees

Many producers find roadside trees to be above average sap producers. This is believed to be the result of their larger crowns and root systems, better light exposure, and because they commonly receive better care than individual forest trees. As with forest trees, the management objective is to maintain a healthy, vigorous, large-crowned tree (**Figure 5.26**). The approach, however, is more like maintaining an ornamental tree rather than a forest tree. Of particular concern are pruning, fertilization, watering, and protection.

As with forest trees, pruning should be done to remove broken or badly damaged branches, and branches that interfere with activities. Use the same techniques as discussed above for pruning forest trees. Whenever possible, pruning for powerlines should be done with the "drop-crotch" method rather than "heading back." In recent years, growth inhibitors have been used to slow the growth of right-of-way trees to reduce the frequency of pruning. Growth inhibitors are not recommended for use with maples to be tapped.

Just as soil and foliar testing are the basis for sugarbush fertilization, they also should be the basis for fertilizing roadside trees. While many roadside maples receive periodic fertilizing when the surrounding lawns are fertilized, deficiencies normally need to be addressed with direct tree fertilization, which places the fertilizer in the soil next to the tree roots. Fertilizer applications to individual trees are commonly injected or cored into the upper 12 to 15 inches (30 to 38 cm) of soil on a 2 to 4 foot (60 to 120 cm) grid under the outer two-thirds of the crown and extending an additional one-third beyond the crown edge. Ornamental trees are often maintenance fertilized annually with 3 pounds of 10-10-10 fertilizer per 100 square feet of application area (1.3 kg per 9 $m^2$) or twice that amount every other year. If there are no other environmental factors limiting the tree's health and performance, such fertilization may help, and, under most conditions, will do no harm. When a tree exhibits low vigor and poor growth, however, it is important to identify the cause and not assume maintenance fertilization will solve the problem.

Roadside trees can and should be watered during periods of severe dry weather. With a sprinkler, apply the equivalent of 1 inch (2.5 cm) of precipitation every seven to ten days during a severe dry period.

Figure 5.26. A healthy, vigorous, large-crowned roadside maple.

Protecting roadside trees from destructive agents is just as important as protecting forest trees. Because of their location and easier access, it is usually easier to monitor and treat roadside tree problems. One major concern with roadside trees that is not a concern with forest trees is road salt. Every effort should be made to eliminate or at least reduce use of road salt near tapped maple trees. Extensive exposure to road salt can lead to the rapid decline and death of maples. It is also possible that the roots of maple trees can absorb a small amount of the sodium and chloride present in salt; under extreme conditions this has the possibility of imparting an off-flavor to the sap and syrup produced. Where roadside salt is used near tapped maples, be sure the sap is not off-flavored before it is dumped in the collection tank. In fact, when possible, it may be appropriate to process sap from roadside trees separately from sap collected in a typical sugarbush.

## Protecting the Sugarbush

Sugarbushes are vulnerable to a variety of environmental factors that may affect their health and productivity or, at the extreme, kill some or all of the trees. These factors include wild and domestic animals, insects and disease, fire, weather, and human activities. An important responsibility of sugarbush management is to be continually alert for these problems and to act promptly to reduce or eliminate their impact. When doing this, it is important to remember that while we tend to look at each of these damage agents separately, they all contribute to total physiological stress on the trees. Drought experienced by a healthy, vigorously growing sugarbush is not the same as a drought experienced by a sugarbush that has had 30 percent defoliation by insects during the last two years. Evaluation of the effect of any damage agent on a sugarbush must be done in the context of the overall health of the bush and all of the damage agents affecting it.

### Livestock Grazing

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

Goats have been used experimentally in groups of 20 animals per acre (49 per hectare) to reduce the abundance of understory brush such as American beech, striped maple, and raspberry. The use of these animals requires daily attention with timely rotation for fresh forage and to avoid damage to desired stems. In the experiment, leafy stems were consumed, but goats receiving daily nutritional supplements did not damage sugar maple bark or tubing systems. Under such a management system, goats, and presumably other ruminants, would access a sugarbush less than once per decade for only a few days. Producers lacking experience with goats or sheep should consult their Extension livestock specialist.

### Other Animal Damage

Damage by wildlife to mature crop trees is uncommon. Occasionally, porcupines will gnaw on the bark of maples, partially or completely girdling the trees. When this occurs, the offending animal should be located (often in their den) and relocated or destroyed. Porcupines do not venture far; however, their damage, while localized, can be significant.

Damage to maple reproduction from deer, rabbits, squirrels, and other animals can be extensive at times. The most effective method for reducing this damage is to place tree shelters or fencing around the seedlings. Tree shelters not only protect the seedlings from animal damage, but

modify the seedling's environment (see comments in Tree Planting section). While initially expensive, both tree shelters and fencing can be reused. Increased hunting pressure can also be effective in reducing the number of animals present.

Under most circumstances, wildlife has little impact on maple equipment, with the exception of squirrels gnawing on tubing. For whatever reason, whether because of the salt from handling and cleaning, the sugar in the sap, or just the instinct to gnaw, squirrels chew and puncture tubing and tube fittings. To deal with this problem, registered poison bait, hunting or trapping, approved repellants on the tubing, and changing to an alternative cleaning solution (10 percent vinegar in water solution) or method (power washers using only water and air) have all been tried with varying degrees of success. The use of poison bait cannot be recommended because of the potential for the contamination of sap. Repellants on the tubing have included commercial preparations and a variety of homemade concoctions, but the advisability of using them may be debatable as they may cause more problems than they solve. Extreme care is needed to ensure that none of the collected sap is contaminated with the repellant, and their use makes handling and repairing tubing more difficult.

## Insects

The sugarbush is home to many insects, most of which are important parts of the forest ecosystem and do little or no significant damage to the maple trees. There are, however, several insects that can cause substantial economic loss in a sugarbush. These include a number of defoliators, such as gypsy moth *(Lymantria dispar),* forest tent caterpillar *(Malacosoma disstria),* fall cankerworm *(Alsophila pometaria),* Bruce spanworm *(Operophtera bruceata),* saddled prominent caterpillar *(Heterocampa guttivitta),* greenstriped mapleworm *(Dryocampa rubicunda),* orange-humped mapleworm *(Symmerista leucitys),* maple leafcutter *(Paraclemensia acerifoliella),* pear thrips *(Taeniothrips inconsequns),* and lecanium scales (*Lecanium* sp.); and several wood boring insects including the sugar maple borer *(Glycobius speciosus)* (**Figure 5.27**).

Fortunately, these insects are usually present in relatively low numbers. They are kept in check by habitat conditions, weather, and natural enemies. However, under certain conditions they become abundant enough to cause considerable damage. One needs only to recall recent experiences in the northeastern United States with gypsy moth, pear thrips, forest tent caterpillar, and lecanium scales to develop respect for the potential impact insects can have on a sugarbush. Fortunately, keeping sugarbush trees healthy and vigorous through regular intermediate cuttings will normally reduce the long-term impact of many of these insects. Boring insects will usually be less common, and defoliating insects will usually have less of an impact in such forests.

The first step in dealing with potential insect problems is to learn to identify the insects. Insect identification is beyond the scope of this manual, but there are several excellent publications available on the subject[24] and pictures, descriptions, and discussions of most are available online. Once a potentially serious insect problem has been detected, verify the identification with a knowledgeable professional and evaluate alternate treatment strategies.

Treatment strategies will vary with the pest and the level of infestation. With some insects, such as the sugar maple borer, which commonly infests weakened or damaged trees, the best treatment may be sanitation cutting along with improving the health and vigor of trees in the sugarbush. With other insects, such as the defoliators, the decision will come down to deciding whether the insects are present in large enough numbers to cause unacceptable economic loss or permanent damage to the sugarbush. If the anticipated loss is extensive, then an appropriate control should be selected. At present, control generally involves the

[24]An excellent reference for sugarbush managers with colored pictures of common insect and disease problems encountered in a sugarbush is USDA For. Ser. Gen. Tech. Rep. NE-129, *Sugarbush Management: A Guide to Maintaining Tree Health*, written by David R. Houston, Douglas C. Allen, and David Lachance. At publication time, hard copy could be ordered from the USFS Northeastern Research Station or downloaded from their web site.

Figure 5.27. Among the insects that have the potential to cause serious economic loss in the sugarbush are gypsy moth (a), orangehumped mapleworm (b), pear thrips (c), forest tent caterpillar [larva (d) egg clusters (e)], lecanium scale (f), and sugar maple borer damage (g). (a-OSU; b,d,e-Boggs; f-Shetlar)

use of some form of insecticide spray[25]. The specific spray and time of application must be determined for the particular insect pest present. The use of insecticides, however, is often problematic, as very few insecticides are approved for use on maples producing a food product.

It is important to note that healthy, vigorously growing trees are less likely to develop problems from insects such as the native borers, which primarily attack already weakened or damaged trees. Likewise, healthy trees are better able to endure and recover from infestation and defoliation by many of the other sugarbush insect pests as well.

Finally, two insects every maple producer should be familiar with because of their potential for devastation at the time of publication are the Asian longhorned beetle *(Anoplophora glabripennis)* and emerald ash borer *(Agrilus planipennis)*. Both have the potential to significantly alter a sugarbush; the Asian longhorned beetle by attacking maples, and the emerald ash borer by attacking native ash trees, which are a significant component of many sugarbushes.

The **Asian longhorned beetle** (ALB, **Figure 5.28**) is a non-native pest believed to have been introduced to North America in 1996 in cargo packing materials from Asia. It currently threatens a variety of hardwood trees in North America, with maples among its preferred host species. At the time of publication, significant outbreaks have been identified in New York City; the Jersey City and Carteret area of New Jersey; areas in and around Chicago, Illinois; and Toronto, Ontario, Canada. Adult ALB are large, glossy black beetles with irregular white spots, and very long, black and white banded antennae. They can be seen from late spring to fall. Larva, which can reach 2 inches (5 cm) in length, are found from fall to spring feeding initially under the bark and later into the sapwood. It is the larva that are the destructive form of this insect, forming galleries throughout the inner bark and sapwood of the tree, destroying the tree's ability to conduct food and sap (**Figure 5.29**). The presence of these galleries; egg-laying niches (**Figure 5.29**); and 1/2 inch (12.7 mm), circular emergence holes (**Figure 5.29**) are signs that ALB is present. Producers observing either the insect or its signs should report the sighting to their state or provincial Department of Agriculture, local or state Extension office, state or provincial Departments of Forestry or Natural Resources, or the nearest office of the USDA Animal and Plant Health Inspection Service or Canadian Food Inspection Agency. At the time of writing, there were no known effective prevention or control measures for ALB other than the complete removal (including the stump to 12 inches below ground) of infested trees.

Figure 5.28. Adult Asian longhorned beetles (top) are large, glossy black beetles with irregular white spots, and very long, black and white banded antennae. Larvae (bottom), which can reach 2 inches (5 cm) in length, can be found from fall to spring feeding initially under the bark and later into the sapwood. (U.S.F.S.)

[25]Approved insecticides may vary by jurisdiction. Check with local resource professionals.

Figure 5.29. Signs of Asian longhorned beetle include galleries formed under the bark and in the sapwood (top, bark removed), egg-laying niches (bottom left at end of finger), and 1/2 inch (12.7 mm) circular emergence holes (seen in all three pictures). (U.S.F.S.)

**Emerald ash borer** (EAB) (**Figure 5.30**) is also a non-native insect, believed to have been introduced sometime during the 1990s and first detected in southeastern Michigan in 2002. At the time of this writing, EAB had already killed more than 10 million ash trees in southern Michigan and had moved into Ohio, Indiana, and Ontario. It has the potential, if not controlled and/or eradicated, to kill literally all of the native ash it encounters. EAB is of concern to those maple producers whose sugarbushes contain native ash species because of the impact the unplanned loss of those trees might have on the sugarbush, and because of the potentially disruptive eradication procedures that might be implemented by the responsible agency. The adult EAB is a metallic green colored beetle approximately 1/2 inch (12.7 mm) long and 1/16th inch (1.6 mm) wide. Depending on the year and location, they could be seen from about mid-May until early August. The white, segmented, flattened larva, which reach 1 inch (2.54 cm) in length when mature, are found from fall to spring feeding on the inner bark and very outer layers of the sapwood. As with ALB, it is the larva that are the destructive form of EAB, forming S-shaped galleries throughout the inner bark and sapwood of the tree, reducing or destroying the tree's ability to conduct food and water (**Figure 5.31**). The presence of these galleries; the presence of 1/8th inch (3.2 mm) diameter, D-shaped exit holes (**Figure 5.31**); and the death of all or part of the tree accompanied or followed by the development of shoots or sprouts arising below the dead portions of the trunk (**Figure 5.31**) are all signs of potential EAB infestation. As with ALB, producers observing either the insect or its signs should report the sighting to their state or provincial Department of Agriculture, local or state Extension office, state or provincial Departments of Forestry or Natural Resources, or the nearest office of the USDA Animal and Plant Health Inspection Service or Canadian Food Inspection Agency. At the time of writing, there were no known effective prevention or control measures for EAB appropriate for sugarbushes other than the destruction of infested trees.

Figure 5.30. The adult emerald ash borer is a metallic green colored beetle approximately 1/2 inch (12.7 mm) long; the larva is white, segmented, and flattened, and can grow to 1 inch in length. (OSU)

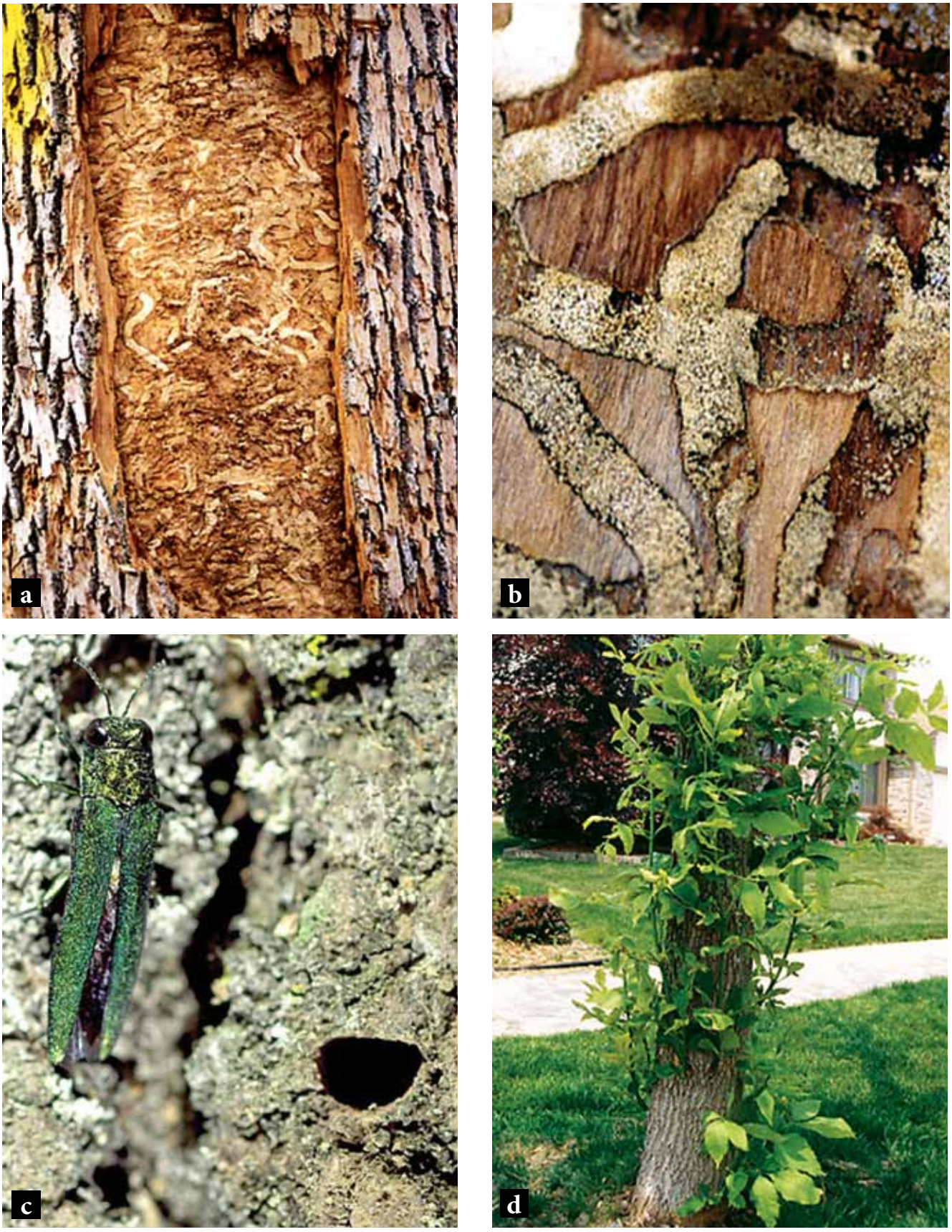



Figure 5.31. Extensive emerald ash borer galleries (a), close-up of galleries showing packed frass (b), exit hole and adult beetle (c), and sprouts arising below the dead portion of the ash tree (d). (OSU)

## Diseases

Disease in a sugarbush may be caused by a variety of factors including environmental extremes and biological agents. The most important maple diseases are caused by fungi, including several leaf diseases such as the leaf spots and anthracnose, cankers such as *Nectria* sp. and *Eutypella* sp., and stem and root rots such as *Ganoderma applanatum* (*Fomes applanatus*) and *Armillaria* sp. (**Figure 5.32**). Again, as with insects, producers need to become familiar with the major diseases that affect maples.[24]

Diseases and disease-causing fungi are present in all sugarbushes and are probably responsible for the loss of more productivity than all other factors combined. Disease impact, however, is far less in a healthy, vigorous sugarbush. Therefore, developing such a sugarbush is the first step in dealing with diseases. Healthy, vigorous trees are far more resistant to many diseases and are better able to survive if infection occurs in contrast to trees that are weak and stressed. Every effort should be made to minimize injuring trees, as injured trees are less vigorous and the injury provides an entry point for many fungi. Trees that become infected with stem cankers or stem or

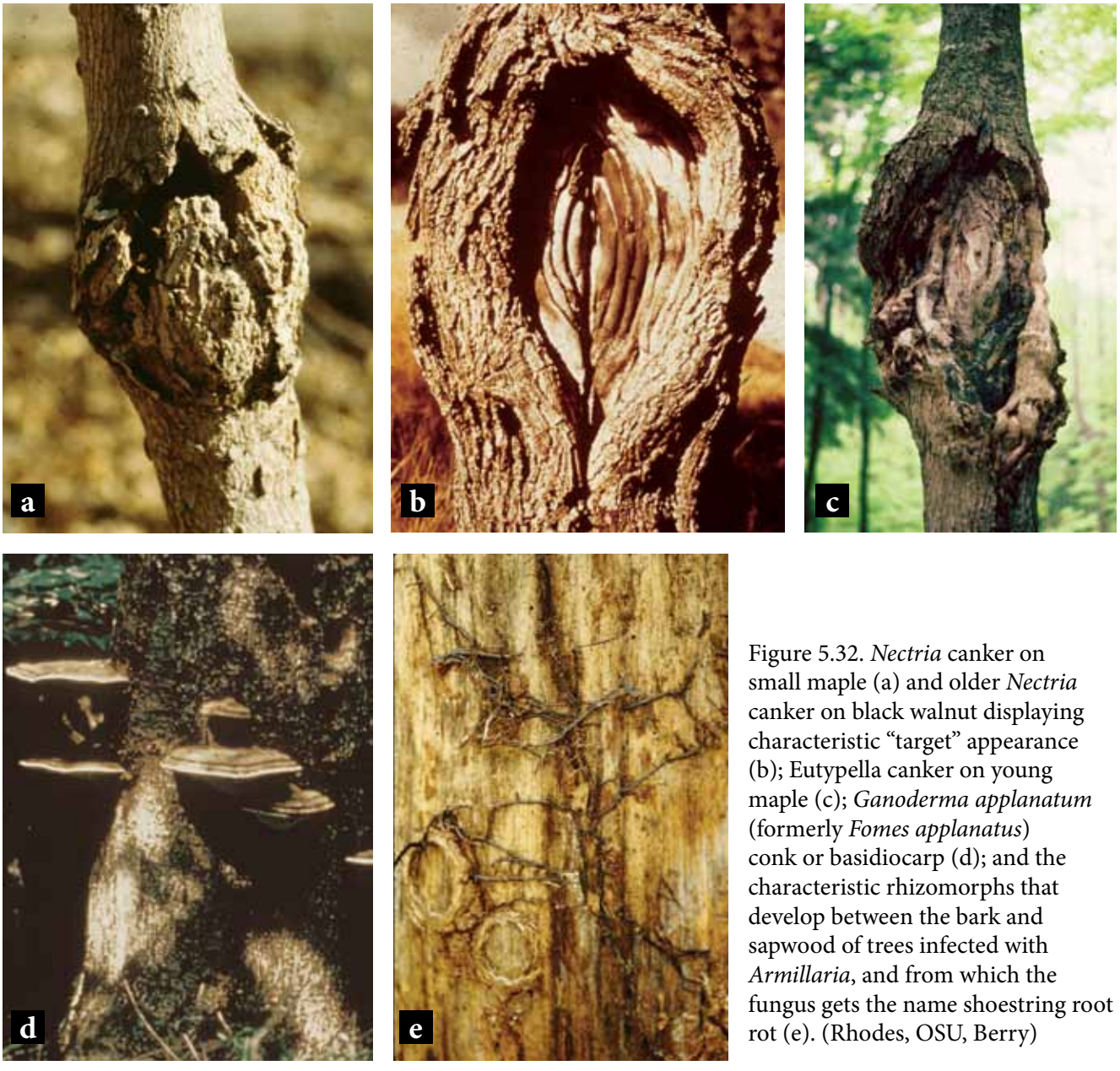



Figure 5.32. *Nectria* canker on small maple (a) and older *Nectria* canker on black walnut displaying characteristic "target" appearance (b); Eutypella canker on young maple (c); *Ganoderma applanatum* (formerly *Fomes applanatus*) conk or basidiocarp (d); and the characteristic rhizomorphs that develop between the bark and sapwood of trees infected with *Armillaria*, and from which the fungus gets the name shoestring root rot (e). (Rhodes, OSU, Berry)

root rotting fungi should be removed. In cases of severe sugarbush infection, a forest pathologist or other specialist should be consulted.

Maple decline is a category of diseases that deserve special mention. Maple decline, or maple dieback as it is sometimes called, is a progressive loss of vigor and deterioration of maples caused by a combination of several stress-causing agents. Some of these agents include repeated drought or insect defoliation, often in stands with relatively low levels of soil calcium and magnesium, followed by infection from a fungus such as *Armillaria* sp. (root rot). Symptoms of dieback or decline often begin with abnormal foliage high in the crown, and progress to dead twigs and branches. Usually affected trees are growing more slowly than healthy trees. Eventually the entire tree may die. Preventing or minimizing dieback involves both increasing tree vigor and eliminating or reducing stress-causing factors in the sugarbush. Among other things, this includes avoiding heavy intermediate cuts that severely stress the trees, not leaving high stumps from harvested trees in which rots such as *Armillaria* can develop, taking appropriate action against major outbreaks of defoliating insects before severe stress occurs, avoiding tree injuries, and using the correct number of taps for the size and vigor of the tree and reducing or not tapping during years of severe stress (e.g. drought). Fertilization with calcium and magnesium on sites where they are particularly low may, at some time in the future, become a strategy for addressing the early symptoms of maple decline, but not enough is known at the present to make that recommendation.

## Fire

The old adage that "an ounce of prevention is worth a pound of cure" is certainly true when considering fire in a sugarbush. In a very short time, fire can destroy all or part of the time and money invested. Everyone working in the sugarbush during periods of fire danger should be aware of fire hazards, including equipment and careless smoking. Evaporator(s) should have a "sound" stack with an effective spark arrester, as should any other potential spark-producing equipment such as wood-burning stoves.

The telephone number of the fire department or other responsible agency should be posted beside the phone. When a fire does occur, getting it under control as quickly as possible is critical. Every sugarhouse should have a source of water under pressure (install a pump if necessary) and a hose, along with backpack pumps, shovels, rakes, and brooms. A practice fire-control exercise at the beginning of sugaring season is not foolish or a waste of time, but is good preparation. Everyone should know their responsibility and how to use each piece of equipment. Consult Chapter 13 on safety in this manual for additional recommendations.

## Weather-Climatic Factors

Severe weather or adverse climatic conditions can result in heavy damage in a sugarbush, and additional physiological stress on trees not damaged. High winds break branches and cause windthrow, particularly in sugarbushes growing on wet and/or shallow soils. The impact of wind can be substantially reduced by maintaining a 50 foot (15 meter) wide dense border of trees on the windward side(s) of the sugarbush, or planting a windbreak along the windward edge(s). To maintain tree vigor, where possible, branches damaged by windstorms should be pruned to create a clean wound that will heal in minimum time. Windthrown trees should be removed before they become a source of fungal infection. Broken branches or toppled trees from snow, ice, or freezing rain should be taken care of in a similar manner.

Ice storms occur relatively commonly within the maple-producing region, perhaps as frequently as one large ice storm every seven to ten years somewhere in the region. Fortunately maple and other trees have adapted ways to deal with physiological stresses caused by ice damage. Indeed, most sugarbushes, upon close inspection, will show evidence of previous ice storms through unusual branching patterns at the same height on several trees. Producers must learn to distinguish between visually dramatic and physiologically significant ice damage. The most important issue is producer safety associated with working under suspended broken branches.

Ice storms that occur during the dormant season will look dramatic with sometimes significant accumulations of branch tips and debris on the forest floor. However, unless a tree has a large wound that exposes several square inches or more of wood or removes 50 to 75 percent of the crown, the long-term physiological significance is usually small. Healthy trees can often lose 50 to 75 percent of their crown without appreciable change in long-term capacity for growth and production. The risk of ice damage to the tree comes from the open wounds and thus the potential spread of stain and decay microorganisms. Stain does not weaken the tree, but predisposes the stained wood to decay fungi if there is another wound and causes the affected wood to be unsuited for tapping.

Limited research exists to guide tapping and management following an ice storm. For heavily damaged trees, those that have lost more than 60 percent of the crown, production in the first year will be low, but given good growing conditions, will increase over the next four years. For less heavily damaged trees, production decreases will be less, and recovery to previous sap volumes faster. Use taphole closure rates and percent crown loss to guide tapping in the first year. Vigorously growing trees with limited crown loss can be tapped as normal in the first year. Trees not growing vigorously with limited crown recovery should be tapped conservatively or not at all. Sap sugar concentrations in the first year after damage may not be affected, but may be reduced in subsequent years until crown leaf area recovers.

Extreme cold that results in deep freezing of sugarbush soil can damage tree roots. Under natural conditions, the litter on the forest floor and snow cover provide insulation that prevents deep freezing. Grazing livestock in a sugarbush destroys the litter cover, and if the animals are in the bush during the winter, destroys the snow cover, allowing deeper soil freezing and more root damage.

Frost cracks in the trunk of a tree are caused when the trunk cannot withstand the expanding and contracting forces created by heating and cooling. While not common in a forest, they can be a problem in a sugarbush with lower stem or root injuries, or along the forest edge.

The relatively smooth bark of previously shaded maple trees is quite sensitive to sudden exposure to direct and prolonged sunlight. The result frequently is sunscald, the death of areas of bark on the south and southwest side of the trunk. Excessively heavy intermediate cuttings, which open large holes in the tree canopy, should be avoided.

Both too much or too little water can be a problem. Drought is commonly thought of as a major problem. If it occurs during the summer when the trees are storing carbohydrates, it can reduce the health and vigor of the trees. With forest maples, there is commonly little that can be done directly to alleviate the effects of drought. Its severity, however, should be evaluated together with other tree stresses (e.g. insect defoliation) to determine whether tapping should be reduced or suspended.

Too much water can also be a problem, particularly in wet sugarbushes. By reducing the ability of tree roots to obtain oxygen and eliminate carbon dioxide, too much water can be just as detrimental as too little, and can result in severe tree stress or mortality.

## Human Activities

Throughout this chapter, the importance of minimizing disturbances or impacts of all activities in the sugarbush has been emphasized. Sugarbush management activities need to be done correctly to minimize physiological stress. In all sugarbush activities, from releasing crop trees and cutting fuelwood to tapping, every effort needs to be made to avoid injuring trees and to minimize soil compaction. It is also extremely important to remember that tapping the tree is a human activity that directly affects the health and well-being of the sugarbush. Tap correctly, tap conservatively, and adjust tapping levels according to the condition of the trees (Chapter 6).

Recovery from nearly all types of stress is highly dependent upon the growing conditions and stress factors that impinge upon trees after the initial stress condition appears. When stress is

prolonged, or multiple stress factors interact, trees may display dieback, decline disease, and eventually mortality. If the stress factor(s) subside, recovery can occur.

## Sugarbush Roads

The sugarbush road system plays an essential role in sugarbush management and in collecting and transporting sap (**Figure 5.33**). Well-planned and constructed roads provide access to all parts of the sugarbush, while minimizing impacts to the health and productivity of the trees. However, with a road system, as with any other disruptive activity in the sugarbush, the best approach is usually to strive to keep the disturbances to a minimum.

Figure 5.33. An example of an acceptable sugarbush road. The road has a ditch on the uphill side, is crowned and slightly sloped to the downhill side, and enough light is currently available to maintain vegetative cover on the road.

Sugar maples can prosper on a variety of sites over a broad geographic region. However, their health and productivity are dependent on their environment. The upper 5 to 12 inches (12 to 30 cm) of soil contains 70 to 80 percent of a sugar maple's roots, and most of the roots important in water and nutrient absorption and gas exchange. For this reason, sugar maples are particularly sensitive to soil compaction. A tree in severely compacted soil may exhibit poor growth, crown dieback, and be more prone to windthrow as a result of portions of its root system being damaged or killed. However, long before these symptoms are visible, maple trees subject to soil compaction may have reduced vigor, be more susceptible to insect and disease problems and other environmental stresses, and may suffer reduced yield as sugar trees.

The critical root zone of a maple tree is the soil area under the crown and beyond that contains a high proportion of the tree's feeder roots. While we commonly think of this critical root zone as being primarily under and extending a limited distance beyond the tree's crown, it can extend a distance of three to five times the crown radius. In a typical sugarbush it is, in fact, almost impossible to not be standing in the critical root zone of one or more sugar maples. This understanding clarifies the potential impact of soil compaction on sugar maple health and productivity. A correctly designed sugarbush road system will minimize the number of roads that will meet production needs, build the roads correctly, and locate and manage them to minimize their impact on the sugar trees.

As a general rule, producers are advised to avoid developing large, heavily compacted graveled roads in the sugarbush (**Figure 5.34**). An exception to this would be the need for a main road to the sugarhouse to support delivery or transport vehicles, or customers in passenger cars. Another

set of exceptions would relate to possible "non-sugaring" uses of the sugarbush. If, for example, the main road through the bush is a frequently used access road, it should be developed to handle the type and frequency of vehicles that use it for that purpose.

Figure 5.34. As a general rule, producers are advised to avoid developing large, heavily compacted, graveled roads in the sugarbush. Exceptions to this would be the need for a main road to the sugarhouse to support delivery or transport vehicles or customers in passenger cars. Under those circumstances, both the main road and the parking areas around the sugarhouse should be finished for access in all types of weather and conditions.

## Location and Design of Roads

The location and design of sugarbush roads depends upon the topography, soil characteristics, the kinds of vehicles used, and the purpose of the roads. Wherever possible, roads should follow slope contours and avoid wet areas. Tools to help decide the best location for roads are aerial photographs, topographic maps, and local county soil surveys. Aerial photos will reveal natural drainage areas, while topographic maps reveal the slope increases and decreases to avoid in road placement. County soil surveys will detail the characteristics of the soils in the sugarbush, and commonly contain tables rating the suitability of those soils for road construction. When considering where to place a road, be sure to visit the proposed location several times during sugaring season, and any other time of the year the road will be used, to avoid placing the road in an area dry in the summer but wet during times of heavy use. Roads that are incorporated into steeper grades require the use of appropriate water diversion and drainage devices that are discussed later in this chapter.

The pattern of the road system will also be influenced by its purpose. Most sugarbush roads are used to inspect, tap, gain rapid access in case of fire, and accomplish forest management activities. Bucket systems will usually require a more extensive road system than tubing. Nevertheless, roads and vehicle traffic in a bucket sugarbush should be kept to a reasonable minimum. Roads should be located to minimally impact maple critical root zones, so put the roads next to or under nonmaple species whenever possible. Minimize the amount of off-road travel by the gathering vehicle. Tradition often has the gathering vehicle traveling close to each sugar tree to shorten the distance sap has to be carried. While some such off-road travel is undoubtedly necessary, recognize that with many vehicle types it will result in soil compaction and possible further damage of roots due to rutting. The use of gathering vehicles with "flotation" type tires will reduce the potential for such damage.

The type of transportation and gathering vehicles used in the sugarbush will also affect the type of roads required and the impact of off-road travel. Of particular importance are the vehicle weight and type and number of tires. Other things being equal, the greater the vehicle weight, the "harder"

or more developed the roads need to be, and the greater the risk of compaction with off-road travel. For a vehicle of any given size, the more tires it has, the wider the tires, and the lower the tire pressure, the lower the risk of soil compaction. Large flotation-type tires would seem ideal for the sugarbush. Moreover, the wider tires are less likely to cut ruts in the soil, resulting in less erosion and damage to tree roots. These factors help explain why ATVs with flotation tires are gaining popularity as transportation and tow vehicles in the sugarbush. They are relatively small, require less road development than most other forms of transportation, and have comparatively low off-road impact.

## Managing Small Amounts of Slow Moving Water

Proper construction and maintenance are critical to a successful road system. Sugarbush roads are almost always unsurfaced forest roads[26]. The greatest concern with such roads is water erosion that can result in temporarily impassable sections. When dealing with surface water flow and its potential to cause erosion, it is the volume and the velocity of the water that causes most road problems. The larger the volume of water and the faster its moves over the surface of the road, the more erosion will result. The prime objective when managing water on roads is to slow it down and get it off the road as quickly as possible.

On flat topography, this is accomplished by crowning or sloping (in-sloping to a ditch on the uphill side of the road or out-sloping to the downhill side) the road surface to facilitate water runoff (**Figure 5.33**). Exposing the road to sunlight by thinning adjacent trees will also help dry the road surface, but this is probably only appropriate where the adjacent trees are nonmaples or are maples scheduled for removal in an improvement cut.

[26]Many states and provinces in the commercial maple region publish manuals discussing and illustrating methods of constructing woods roads. Contact your Extension office or state forestry agency for a BMP guide that addresses conditions and regulations in your state.

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

A broad-based dip is a low, relatively flat, out-sloped diversion in the roadbed designed to intercept water flowing down the roadbed and drain it to the side, off the road surface (**Figure 5.35**). The design of a broad-based dip is a slight lowering and out-sloping of the road surface, followed by a slight raising of the road surface, producing a slightly out-sloped trough in the overall falling grade. Broad-based dips are generally flat enough to allow vehicles to proceed through them with only a slight reduction in road speed.

Figure 5.35. A broad-based dip is a low, relatively flat, out-sloped diversion in the roadbed designed to intercept water flowing down the roadbed and drain it to the side, off the road surface.

Open top culverts are structured openings at a down-slope angle across a road that intercept water and carry it off the road (**Figure 5.36**). Open top culverts can be made from a variety of materials, but are most commonly made from treated lumber or a combination of logs and treated lumber. **Tables 5.6a and 5.6b** provide recommended spacing for open top culverts for roads of different slopes.

Figure 5.36. Open top culverts are structured openings at a down-slope angle across a road that intercept water and carry it off the road. Notice that this culvert demonstrates a lack of adequate maintenance—open top culverts need to be periodically cleaned.

**Table 5.6a. Open top culvert spacing based on percent slope of the road using English units of measure.**

| Slope (Percent) | Distance (Feet) |
|---|---|
| 0–2 | 500–300 |
| 3–5 | 250–180 |
| 6–10 | 165–140 |
| 11–15 | 135–130 |
| 16–20 | 125–120 |

**Table 5.6b. Open top culvert spacing based on percent slope of the road using metric units of measure.**

| Slope (Percent) | Distance (Meters) |
|---|---|
| 0–2 | 152–91 |
| 3–5 | 76–55 |
| 6–10 | 50–42 |
| 11–15 | 41–40 |
| 16–20 | 38–36 |

Closed culverts, sometimes called cross-drainage culverts, are conduits to move water from one side of the road to the other without flowing on the road surface (e.g. to move water from a drainage ditch on the up-slope side of a road to the down-slope side) (**Figure 5.37**). These can be made of a variety of materials, but the most common are plastic, metal, or concrete. Closed culverts must be properly sized and set. If they are too small they can back water up, causing erosion and a surface water hazard. Improperly set and they may not drain effectively or they may easily become blocked with debris. **Tables 5.7a and 5.7b** provide culvert size guidelines based on the size of the land area being drained. If there is uncertainty about the size of culvert needed or the proper method of installation, consult a detailed reference on forest road building or contact a local soil conservation/management agency or forestry consultant for assistance.

Figure 5.37. Closed culverts are conduits that move water from one side of the road to the other without it flowing on the road surface. A closed culvert would be used, for example, to move water from a drainage ditch on the up-slope side of a road to the down-slope side.

**Table 5.7a. Culvert size based on drainage area using English units of measure.**

| Pipe Diameter (inches) | Land Area Above Pipe (acres) |
|---|---|
| 12 | 2 |
| 15 | 4 |
| 18 | 7 |
| 21 | 12 |
| 24 | 16 |
| 30 | 27 |
| 36 | 47 |
| 42 | 64 |
| 48 | 90 |
| 54 | 120 |
| 60 | 160 |
| 66 | 205 |
| 72 | 250 |
| 78 | 350 |

**Table 5.7b. Culvert size based on drainage area using metric units of measure.**

| Pipe Diameter (cm) | Land Area Above Pipe (hectares) |
|---|---|
| 30 | 0.8 |
| 38 | 1.6 |
| 46 | 2.8 |
| 53 | 4.9 |
| 61 | 6.5 |
| 76 | 10.9 |
| 91 | 19 |
| 107 | 26 |
| 122 | 36 |
| 137 | 48 |
| 152 | 64 |
| 168 | 83 |
| 183 | 101 |
| 198 | 141 |

## Road Maintenance

Once roads are established it is essential they be maintained. Well-planned and constructed roads will certainly have lower maintenance requirements than those built without such attention. All roads need to be inspected frequently and problems addressed when they first arise, rather than later when the problem has grown and the solution is more time consuming and expensive. Avoid using equipment with the potential to compact or rut when the soils are wet. Delay as long as possible after a rain or heavy, wet snow before using such equipment on woods roads, or especially off-road among the trees.

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

Also, where feasible, the seeding of infrequently used sugarbush roads, work areas, and parking areas can reduce erosion, rutting, and the frequency and intensity of maintenance. Seeding a road with grass or other appropriate cover crop can be an attractive alternative to bare soil, and the cover crop will play an important role in minimizing the amount of surface water runoff and erosion. Recognize that most cover crops require a reasonable amount of sunlight to thrive. For recommendations of appropriate cover crops and seeding rates, consult the local, state/provincial, or national soil and water management agency.

## Controlling Access

A final consideration is control of access to and through the sugarbush. The sugarbush represents the primary resource on which the maple enterprise is based, and it includes considerable capital investment. While it is impossible to completely prevent someone who truly wants access to the sugarbush from getting in, it is possible to discourage entrance. This can be done with gates or logs across primary access roads, and most certainly a "no trespassing" sign. Often a simple rope or chain across the road—well flagged for safety reasons—will keep honest people from entering.

The road system in the sugarbush is critically important to success, and represents a considerable investment of time and often money. Its design and construction impact the efficiency, health, and productivity of the sugarbush. The planning and construction of a woods road system is not, however, something that most of us are trained to do. Individuals without experience in designing and constructing woods roads are encouraged to seek the advice of others, including appropriate governmental agencies or private consultants.

# Chapter 6 · Maple Sap Production—Tapping, Collection, and Storage

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

The sugar in maple sap is the product of photosynthesis that occurred during the previous growing season. The process of photosynthesis captures light energy and transforms it into carbohydrates (sugars) that are used in the normal growth and life processes of the tree during the active growing season. Additionally, some photosynthetic products are stored in the tree, predominately in the form of starch, to serve as an energy source to maintain the life processes necessary for survival during the long dormant period when there are no leaves on the tree. The energy to resume growth the following spring also comes from stored photosynthetic products. During the winter some starch is converted back to sugar (mainly sucrose) that is dissolved in the sap. The amount of sugar in the sap depends on several factors including the genetics of the individual tree, the quality of the site on which the tree is growing, tree health and nutritional status, the tree's diameter, the size of the crown relative to the diameter, environmental conditions the previous growing season, and the time of year. The sap sugar concentration is usually considerably lower in the fall than in the spring. Sap sugar is sometimes lower in the early spring, then rises rapidly, followed by a slow decline as the season progresses. However, the quantity and timing of changes in sugar content are influenced by current weather conditions as well as those present the previous growing season.

Exudation of sap from wounds in maple, including tapholes, may occur anytime during the "winter" dormant season when branch and stem temperatures fluctuate above and below the freezing point. In the north central and northeastern United States and adjacent Canada this can occur from early October through the following April. However, the largest flows take place in late winter and early spring during the months of February, March, and April. During this period winter begins to lose its grip in many parts of the maple region. Colder days and nights give way to periods when temperatures during the day frequently rise above the freezing point. When these warmer daytime temperatures are followed by below freezing periods, usually at night, strong sap flows can be expected upon warming (**Figure 6.1**).

## Sap Flow Mechanism

Fluctuations in wood temperature above and below freezing during the dormant season are responsible for sap flow in maples. These temperature changes create periods of alternating negative and positive stem pressures. At this time of the year negative pressures can develop when the air temperature falls below freezing, and positive pressures may develop when the

Figure 6.1. When warmer daytime temperatures are followed by below freezing periods, strong sap flows can be expected.

temperature rises above the freezing point. Under some conditions the positive pressure may reach levels that are significantly higher than normal atmospheric pressure. These changes in pressure are the result of certain properties of maple wood, which, although not unique in the plant world, are extremely uncommon. In hardwood trees a great many fiber cells in the xylem (the wood beneath the bark) surround the sap conducting vessels. In maple these fiber cells are air-filled, whereas in most other tree species they are sap-filled. When freezing conditions are present in late winter/early spring, small ice crystals begin to form inside each of these air-filled fiber cells, much like frost forming on a windowpane. As the ice crystals form, the humidity within the fiber cells falls rapidly, causing moist air to be drawn in from adjacent vessels. As this moisture is pulled into the fibers, the layer of ice crystals within each fiber thickens and the air bubble becomes increasingly compressed. The movement of sap into fiber cell pulls water from the vessels, and this pull is transmitted throughout the branches and the trunk down to the roots (this occurs because water molecules are very cohesive; that is, they have a strong tendency to stick together). Strong negative pressure (suction) results throughout the tree; in fact, the suction is great enough to pull sap back into a taphole from tubing unless a drop line is present. At the same time, other weaker forces caused by the contraction and the dissolving of air bubbles in the cooling sap also add to the suction. 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, effectively blocking the pathway for water uptake. When cooling takes place slowly over many hours the resulting accumulation of sap in the fiber cells and throughout the tree is greater than if rapid freezing of the twigs occurs.

When the temperature next rises above freezing and the frozen branches thaw, the pressure in the tree at the taphole transitions rapidly from negative to positive. Thawing of the ice in the fiber cells allows the compressed bubbles to expand and push the sap back into the vessels. Coupled with the pressure from bubble expansion are two additional forces: gravity and osmosis. Since the sap accumulated as ice in branch fiber cells that are located high above the taphole, this additional sap, once returned to the vessels exerts a downward force similar to a standing column of water, with the greatest pressure at the base of the tree. In addition, it is believed that osmosis contributes to sap pressure because the movement of water into the fiber cells during the cooling period excludes sucrose (the sugar molecules cannot pass through the fiber cell walls). Once thawed, sucrose in the sap draws water out of the fibers by normal osmotic behavior. This helps explain the observation that a tree with a higher sap sugar concentration than its neighbor typically has higher sap pressure and yields more sap. These combined forces can result in a 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 (keep in mind that this phenomenon is present in maple trees not to benefit maple sap collectors but to refill portions of the wood that became desiccated during the winter) then sap will be exuded as the trunk thaws. The sap flow rate will be proportional to the pressure inside the tree, and pressure will almost always be highest at the beginning of the thawing period.

As time passes, other forces in the maple tree will begin to counteract the positive sap pressure and lessen it. These forces include evaporation of water from branches on sunny days, which exerts a pull on the sap towards the point of water loss and away from the taphole, as well as various internal leaks throughout the tree's sap system, and perhaps other forces. The result is that sap pressure will begin to dissipate within a few hours after the thaw has begun, and without a new freeze-thaw cycle, the pressure inside the tree will eventually subside and equal the pressure outside. At this point, sap will cease to flow from the hole under gravity. How long it takes before this occurs may vary greatly from sap run to sap run, depending on such factors as the length of the previous freeze, how slowly the freeze occurred, the available soil moisture, the size of the tree, and other factors. An additional variable, particularly at the beginning of the sugaring season, is that a portion of the tree trunk some distance inside the bark is often frozen during early sap runs, and the sap in that portion is unavailable. Thus, when the

temperature remains above freezing, the sap run may last half a day or it may last several days, and flow may be rapid or slow during this period. In general, the rate of sap flow will continue to slow the longer the run lasts. While cooling, but not freezing, of small branches during spring nights can sometimes renew the pressure in the tree enough for sap to resume flowing for a few hours the next morning when the temperature warms, only freezing of the small branches will cause the initial sap flow rate to be reestablished.

## Ideal Conditions for Sap Flow

Most sap flow events can be predicted reasonably well from air temperature alone. For strong sap flows to be repeated, a suitable temperature cycle above and below freezing must occur to allow strong positive sap pressure to develop. Maple producers should be aware that the nighttime air temperature measured a few feet off the ground is often several degrees lower than the temperature in the tree canopy, particularly on nights with minimal wind, and branches may not have frozen even if puddles on the ground are covered with ice. Early in the season or after very low temperatures during the season, it may take one or more days of above freezing temperatures for the wood around the taphole to thaw enough so that sap flow can occur. Similarly, air temperatures only slightly below freezing may be insufficient to cause tree branches to freeze.

## When to Tap

The largest and most consistent sap flows typically occur in late winter and early spring during the months of February, March, and April. This is the commercial maple syrup season. Fall tapping has seldom proved economical because of low sap sugar concentrations and shorter periods of sap flow. Exactly when the season begins and ends in a particular year depends on geographic location and local temperature patterns. The challenge for the maple syrup producer is to determine when to begin tapping in a particular year since tapping that is completed too late misses the early sap flows that will not be recovered. Likewise, tapping too early may expose the producer to an increased risk of lost production later in the season due to plugging of the xylem vessels by microbial growth (taphole "drying"). However, it should be remembered that the quality of syrup produced early in a particular season is usually higher than that produced toward the end of the season.

Current understanding of the sap flow process and improvements in weather forecasting allow better prediction of when sap flow is likely to occur. In most areas of the maple region, five-day weather forecasts are sufficiently reliable to be useful in determining when to start tapping. Longer-range weather forecasts are generally less reliable. New producers are advised to communicate with experienced producers in their area to gain information on when sap flow has started and ended in previous years. In some areas, researchers or producer organizations survey producers and maintain records of maple season starting and ending dates. These, together with following local weather forecasts, will provide an approximate guide as to when it is time to tap. Producers are encouraged to keep records of weather and sap flow at their location to aid in relating regional forecasts to their location.

Whenever possible, it is desirable to avoid tapping frozen wood as this can lead to the development of small splits around the taphole when the spout is set. For small operations of a few hundred taps this is not normally difficult. The time required to tap is relatively short, and tapping can often be completed within a few hours before the anticipated first run. On the other hand, larger operations with several thousand or more taps must generally tap earlier in order to be finished before the first good sap run. Because of the time required to tap in larger operations, tapping is guided more by the calendar and is often done in frozen wood. When frozen wood must be tapped, it is important to use a sharp tapping bit and to seat the spouts gently to prevent bark splits.

## Characteristics of Tapable Trees

Generally, any healthy maple tree larger than 10 to 12 inches in diameter at breast height (4½ feet above ground) may be tapped. Characteristics of superior maple trees and criteria for

selecting them are discussed in Chapter 5. It should be reemphasized that higher-quality syrup and greater economic returns will be achieved by tapping healthy trees that produce large volumes of high sugar content sap as opposed to tapping unhealthy trees, or those with small crowns. When tapping only a portion of the maples in a sugarbush, select trees with large crowns or trees known to produce larger sap volumes with higher sap sugar concentrations, unless there are other reasons for not selecting a specific tree such as small size, unhealthy appearance, or it is located too far from other trees.

As discussed in Chapter 5, it is not recommended that unhealthy or low-vigor trees be tapped. Usually sap production from such trees will be low; furthermore, the rate of taphole closure on non-vigorous trees is usually slow, thus increasing exposure for the entrance of decay causing organisms. Tapholes in healthy trees usually complete closure in one to three years (**Figure 6.2**); those in unhealthy trees take longer. Slow closing tapholes may result in increased insect and disease problems and a reduced tapping surface on the tree trunk due to more open tapholes, increased cambium dieback, and increased sapwood discoloration. Additionally, sap collected from unhealthy or low-vigor trees may be low in sugar content and produce off-flavored syrup.

Figure 6.2. Tapholes in healthy trees will close in one to three years, depending on the age of the tree and the quality of the site. The taphole in this young maple has completely closed by August in the year in which it was tapped.

## The Tapping Process

Although tapping is a seemingly simple task, the selection of trees to tap and the tapping techniques used can affect the amount of sap produced and the economic success of the operation.

The objective of tapping is to create a taphole that will produce large volumes of quality sap in an economical manner while maintaining the long-term production potential of the tree. Correct tapping will minimize taphole damage to the trees and microbial contamination of the sap. Sap that is free of microbial contamination has the potential to produce syrup of the highest quality. Microorganism contamination of sap is a major contributor to the production of darker grades of syrup; furthermore, some contaminated sap may result in the presence of off-flavors in the finished syrup. A contaminated taphole may also produce less total sap during a season due to blockage of the sap producing vessels

The techniques of correct tapping include observing the following:

- Using appropriate equipment
- Tapping when the wood is partially or completely thawed immediately before the first sap flow is anticipated
- Identifying the proper number, size, and placement of tapholes for each tree
- Maintaining tapping equipment in a clean and sanitary condition
- Seating spouts correctly

## Tapping Equipment

The basic equipment required for tapping maple trees is an appropriately sized drill bit, a gasoline or electric tapping machine or drill (hand augers can be used for smaller operations), clean spouts (spiles), and a small mallet.

Use a clean, sharp drill bit appropriate to the size of spouts to be used. When using a power drill, use a fast cutting tapping bit (**Figure 6.3**). Dull bits are more difficult to use, create fuzzy, ragged tapholes that may impede sap flow, provide additional surfaces within the taphole for microorganism growth, and are more likely to

produce oval holes, which allow sap leakage and contamination by microorganisms. Drill bits should be kept as clean as possible to minimize contamination of the taphole. An effective way of cleaning drill bits is to wash them in a detergent solution, thoroughly rinse following washing, and allow them to soak for a few minutes in a bleach solution (1 ounce commercial household bleach in 1 pint of water) or in alcohol[27]. If bleach is used, the bits should be rinsed with clean water before use to avoid contaminating the tapholes with the bleach solution. If decayed or rotting wood is encountered while tapping, bits should be rewashed with bleach or alcohol to prevent transferring possible microbial contamination to other trees. Avoid allowing the drill bit to come in contact with the ground or other unclean surfaces while in use. A supply of clean, sharp bits should be available for changing as needed.

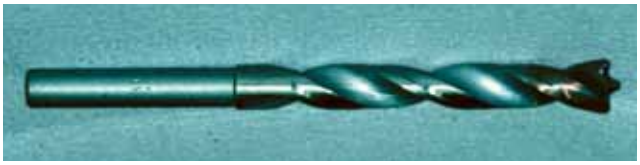


Figure 6.3. When using a power tapper, use a clean, sharp, fast-cutting tapping bit.

Battery operated drills (18 volts or more) work well for drilling 5/16-inch holes that are commonly recommended for vacuum tubing systems. These drills are easy to operate and light to carry. Gas powered tapping machines are recommended for drilling 7/16-inch holes used by some producers. Battery operated drills can be used to make these larger diameter tapholes; however, it will be necessary to change the battery more frequently.

Spouts (or spiles) have three important functions: (1) transfer sap from the taphole into a collection container or tubing, (2) provide support for holding a sap collection container or connection for tubing, and (3) provide a seal to minimize leakage around the taphole. Minimizing leakage is important in the maintenance and operation of vacuum tubing installations, to reduce the likelihood of contamination of the taphole by microorganisms, and to retard the initiation of the wound closure process. Spout design and construction has changed over time. Originally spouts were made from hollowed-out sumac or elder[28] stems, but over the years they have evolved into a wide variety of metal and plastic spouts that are available in different sizes and designs. A number of different spouts for tubing or bucket/bag operations are currently in use (**Figure 6.4**). Each has its perceived advantages and disadvantages. A 7/16-inch hole size is standard for non-vacuum systems, although some maple syrup producers are now using 5/16-inch spouts[29] for non-vacuum systems as well. Results from research have indicated that spouts with a 5/16-inch hole size will yield about the same amount of sap in vacuum systems as can be expected from larger spouts in most years. Sap yields with 5/16-inch spouts without vacuum is generally equal to that of 7/16-inch spouts, but in some years a small reduction in yield may be observed. The smaller diameter holes associated with smaller spouts will close significantly faster than larger holes. Also, less wood is removed from the tree during tapping, and therefore, somewhat less internal damage to the tree is expected. Research on spouts of even smaller size for use strictly in vacuum tubing operations is presently on-going.

When buckets are used for sap collection, spouts are removed from the trees at the end of the season and taken to the sugarhouse or other location where they should be cleaned with a detergent or bleach solution, thoroughly rinsed, and allowed to dry. Following cleaning they should be stored in a clean and dry location. Before use the following year, it is a good idea to wash them with boiling water to make sure all possible sources of contamination are removed. Once spouts are cleaned, every effort should be made to keep

[27]Alcohol appropriate for use with food. There may be some limitations as to the type of alcohols specifically approved for this application; checking with local health departments is recommended. Further, while it may be appropriate to clean bits in this way, bleach or alcohol should NOT be put into tapholes. Some evidence suggests that doing so may actually reduce sap yield.

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

[29]The designation of 5/16" as a spout size is also meant to include the 19/64" spout version marketed by some manufacturers.

them clean. Spouts should be transported to the sugarbush under conditions that will keep them clean. Do not allow spouts to come into contact with other surfaces where possible contamination could occur prior to being placed into the taphole.

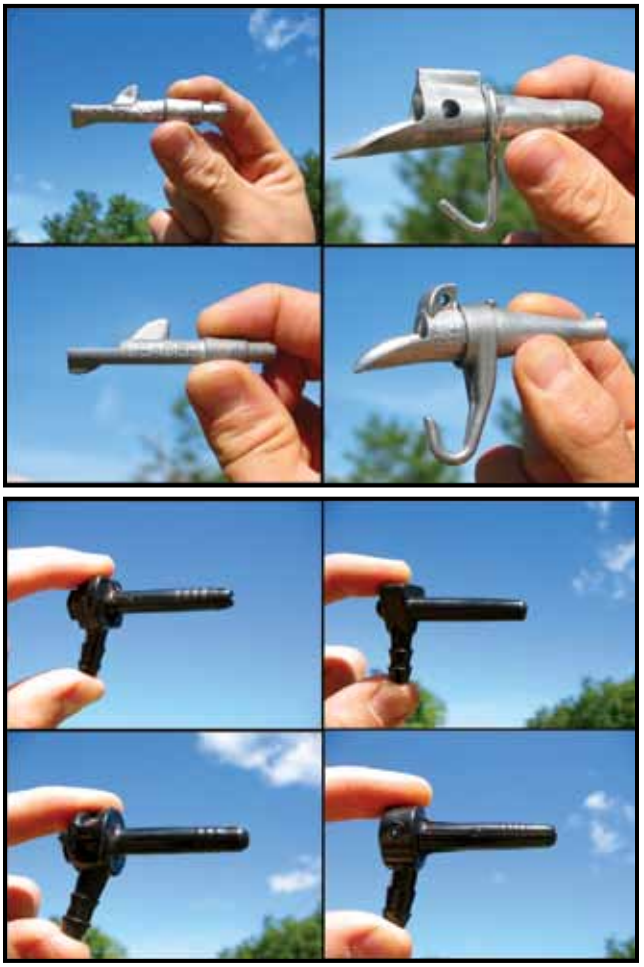


Figure 6.4. Examples of spouts for use with buckets (upper four) and tubing (lower four).

With tubing systems, spouts usually remain connected to the tubing after they are removed from the tree. Washing and sanitizing becomes more difficult, but should be part of the end-of-season cleanup, as dirty spouts can be a source of bacterial contamination for a new taphole. The cleaning of tubing and related collection equipment is discussed later in this chapter.

## Taphole Number, Size, and Location

Proper tapping is defined as using the correct number of taps in a tree and separating or spacing them to minimize the likelihood of tapping into old tapholes or discolored wood. Over the years, various tapping guidelines have used tree diameter as a guideline in determining the number of allowable taps. Traditional tapping guidelines permit up to four buckets on large maples (**Table 6.1**). Conservative tapping guidelines currently followed by many producers recommend no more than two taps per tree regardless of diameter.

Historically, researchers and producers were confident that healthy, vigorous maple trees could support the tapping intensity outlined in **Table 6.1**. However, many maple trees in sugarbushes are older and are affected by a variety of stress-causing factors including overcrowding, broken branches, pockets of decay, defoliation by insects, adverse weather factors (such as drought), soil compaction, and air pollution. As a result, tapping guidelines have become more conservative, with one commonly recommended guideline suggesting 12 inches as the smallest tree to tap, and no more than 1 or 2 taps in any tree (**Table 6.2**). It is probable that wounding a tree by tapping has a greater potential impact on tree health than the amount of sap collected. Concerns about tree health and the impact of too many tapholes on tree vigor provide the basis for following conservative tapping guidelines. Furthermore, it has been observed, both from controlled research studies and from field observations, that the volume of sap per taphole can increase substantially when fewer tapholes per tree are used, especially when sap is collected using vacuum. Using more taps per tree does not necessarily mean obtaining proportionally more sap.

Tree diameters can be easily measured using a diameter or circumference tape (tree diameter = circumference divided by 3.14), or estimated more quickly with a Biltmore stick. A Biltmore stick is a yardstick-like scale that is placed against the trunk of the tree and sighted across to read tree diameter. Diameter tapes and Biltmore sticks (or tree scale sticks, but not to be confused with a "log" scale stick) can be purchased from forestry equipment supply companies. To avoid having to measure or estimate tree diameter each year, some producers who use bucket sap collection equipment will use permanent marking paint to

mark a dot code on the tree indicating the number of taps (e.g. 1 dot = 1 tap, 2 dots = 2 taps). If trees are marked, it is suggested that all trees be marked on the same side so the number of taps is easily determined at a glance.

**Table 6.1. Traditional tapping guideline.**

| Tree Diameter (inches/cm) | Tree Circumference (inches/cm) | Number of Taps |
|---|---|---|
| 10–15/25–38 | 31–47/79–119 | 1 |
| 15–20/38–50 | 47–63/119–160 | 2 |
| 20–25/50–64 | 63–78/160–198 | 3 |
| 25+/64+ | 78+/198+ | 4 |

**Table 6.2. More conservative tapping guideline.**

| Tree Diameter (inches/cm) | Tree Circumference (inches/cm) | Number of Taps |
|---|---|---|
| 12–18/30–46 | 38–57/94–145 | 1 |
| 18+/46+ | 57+/145+ | 2 |

Tapping guidelines have traditionally suggested that tapping rates be reduced or tapping suspended for severely stressed trees. Producers are urged to evaluate the health and overall condition of each tree, being particularly aware of symptoms or causes of tree stress such as severe weather conditions (e.g. drought), major trunk wounds, slow healing wounds, substantial insect or disease problems, defoliation, fewer and smaller leaves than normal, and branch dieback. From a tree health perspective, subjecting stressed trees to the additional impact of tapping may slow the recovery of unhealthy or otherwise low-vigor trees, and such trees might benefit from a reduced tapping rate. However, from a practical perspective, the decision may be one of balancing tree health with the potential lost production resulting from the reduced tapping rate. Certainly where few trees are involved, or where there are alternative trees to tap, it is advisable to temporarily reduce or suspend tapping of severely stressed trees. In other instances, such as the severe ice storm of 1998 in the northeastern United States and adjacent Canada, where economic necessity required that severely damaged trees be tapped that same season, tree condition should be continually monitored to ensure recovery, even though it may occur at a slower rate.

Tapholes can be located anywhere on the trunk of the tree. Taphole location is usually in a place on the trunk that can be easily reached and that will allow for ease of collection, especially if buckets are used. It is also important that the taphole be located in an area where there is "good wood"; that is, avoid tapping in decayed areas, too close to older tapholes, or in areas where discolored wood is present. The tapping band should be wide enough vertically to permit proper taphole spacing. Taphole depth should not exceed 2 inches (5 cm) into the wood; some producers who use vacuum tubing systems only tap to a depth of 1 inch (2.5 cm). When vacuum is not present, it has been demonstrated that sap yields will increase with increasing depth of the taphole, up to about 2 inches (5 cm); however, the risk of penetrating previously tapped wood is greater with deeper holes. Because bark thickness of tapable maples varies between 3/8 inch and 1 inch (1–2.5 cm), adjustments to total tapping depth are necessary so tapholes extend the desired depth into the wood (**Table 6.3**). When tapping trees of low to moderate vigor, shallower tapping may reduce the amount of physical injury to the tree.

**Table 6.3. Bark thickness of maple trees.**[30]

| Tree Diameter at Tapping Height inches (cm) | Approximate Bark Thickness inches (mm) |
|---|---|
| 10–14 (25–36) | 3/8 (68) |
| 16–20 (41–51) | 1/2 (13) |
| 22–26 (56–66) | 5/8 (16) |
| 28–32 (71–81) | 3/4 (19) |
| 32–36 (71–91) | 7/8 (22) |
| 38–42 (96–107) | 1 (25) |

Slant the taphole so the back of the hole is slightly higher than the front (approximately 10°) (**Figure 6.5**). This is to ensure that sap drains out of the taphole. The more sap remaining in the tapholes

[30]Smith, Clay H. 1968. Bark Thickness: Is It Important? *Maple Syrup Digest* 7(3): 19.

between sap runs, the greater the potential for microorganism contamination, and of freezing sap loosening the spouts.

Figure 6.5. Slant taphole so the back of the hole is slightly higher (approximately 10°) to minimize sap collecting in the taphole between runs.

Make every effort to avoid the creation of oval or oblong-shaped tapholes when tapping. Spouts will not seat properly in oval-shaped tapholes, leading to leakage. Leakage results in loss of sap, loss of vacuum, the possibility of increased microorganism growth in the taphole, and taphole drying. Oval-shaped holes can be minimized by using sharp drill bits, not tapping too fast, holding the drill unit firmly so the bit does not "rest" on the front of the taphole, and making sure the operator is standing in a firm and stable position when the taphole is being drilled. Be aware that reaching over the head to make tapholes at higher locations on the trunk or tapping while on snowshoes will increase the likelihood of making oval-shaped tapholes.

If the trees have been tapped before, new tapholes should be at least 2 inches (5 cm) and preferably 4 inches (10 cm) to the side of and at least 6 inches above or below the previous season's tapholes. Tapholes drilled in successive years should not be placed in a straight line around the tree. A useful pattern is to drill each new taphole to the side and slightly above or below old tapholes. This results in a spiral pattern of tapping around the tree that, over the years, utilizes the entire tapping face of the trunk. Moving in a regular direction around the trunk avoids re-tapping a previously tapped area before the tree has enough time to grow new wood over the old tap hole. The zone of discoloration may extend 12 to 18 inches (30 to 46 cm) above and below a taphole (**Figure 6.6**); tapping in stained or discolored wood should be avoided, as it will reduce the quantity and quality of sap produced. If tapholes close in one to two years, it becomes nearly impossible to determine where previous tapping has occurred unless there is a regular strategy of taphole placement.

Figure 6.6. The zone of discoloration from a taphole (or other wound) can extend 12 or more inches above and below.

On a similar note, tapholes should be located at least 6 inches (15 cm) from old branch scars or other wounds, even if they appear to have healed. Tapholes should be made only into "sound," healthy, light-colored wood. Decayed or discolored wood should not be tapped. Although tapholes located on the south side of a tree trunk may produce sap a few days earlier than those on the north, there is no evidence that tapping face (north, south, east, or west) affects total seasonal sap yields. In bucket operations, the side of the tree trunk on which tapholes are located should

be governed more by taphole spacing and minimizing collection time and costs[31]. Likewise, there is no indication that tapping over a large root or under a large branch will increase sap yield, and if such a practice is continued over a long period of time, cluster tapping with an attendant loss of tappable wood in that area will result.

## Taphole Cleanliness and Sanitation

Tapholes should be free of wood shavings or bark fragments. This can be achieved by using a high speed drill and a sharp bit. If sawdust or shavings remain in the taphole, they should be removed using a small twig or a metal wire; a nail driven into a small dowel also works well. Do not "blow the taphole clean," as this may contribute to microorganism contamination.

Several different approaches have been tried to kill or prevent the growth of microorganisms in the taphole. These include using a dilute bleach solution, ethyl alcohol, hydrogen peroxide, and paraformaldehyde. Solutions sprayed into the newly drilled taphole have a very short-term effect and are not considered worth the effort and expense. Furthermore, some of these sanitizing materials may have the potential to interfere with taphole closure when the tap is removed at the end of the season. Some research evidence suggests that using such solutions hastens taphole drying out, resulting in reduced sap yield.

For many years, small pills or pellets containing paraformaldehyde were routinely placed in tapholes to retard the growth of microorganisms and thereby increase both the yield and quality of sap. Because the pellet was somewhat insoluble, fragments remained in the taphole during the season, thus contributing to reducing microbial populations. However, over the past several years, concerns relating to the influence of paraformaldehyde on wood discoloration and longer term susceptibility to wood decay have increased.

[31]This is distinctly different from the question of when to tap sugarbushes on north-facing versus south-facing slopes. In general, because they warm up earlier in the spring, sugarbushes on south-facing slopes will "run" earlier and should be tapped before those on north-facing slopes.

Results from research studies indicate the discoloration zone resulting from tapping is larger when paraformaldehyde pellets are used, and the amount of wood decay associated with this discolored wood increases. Other concerns relate to the purity of the maple syrup produced from sap collected from tapholes where paraformaldehyde pellets were used. Accordingly, the use of these pellets has been discontinued, and it is presently illegal to use paraformaldehyde in tapholes in Canada and the United States. Screening and laboratory tests are now available to detect the use of paraformaldehyde in maple sap and syrup.

There is value in using sanitized spouts as previously considered. Spouts that have not been cleaned and treated with a sanitizing solution are a likely source for introducing undesirable microorganisms into the taphole. There is a belief among some maple producers that sap yields are higher with new as opposed to used spouts. This observation has not been confirmed by research, and presently there is no justification for recommending annual replacement of spouts. However, there is strong evidence that all spouts, both new and old, should be thoroughly cleaned and sanitized before use.

## Seating and Removing Spouts

Immediately after drilling the taphole, a spout should be gently but firmly seated in the taphole (**Figure 6.7**). In a bucket/bag operation, spouts must be seated firmly enough to prevent sap leakage and to support the weight of a full bucket or bag. In a tubing operation, spouts must be seated firmly enough to prevent sap or air leakage, or from being dislodged by wind movement of trees and occasional small falling branches.

Seating of 7/16-inch spouts is accomplished with a small wooden, plastic, or rubber mallet. However, care must be exercised not to seat spouts too robustly. Spouts seated with excessive force, especially in frozen wood, may split the bark and wood around the taphole resulting in leakage and slow closure, and may block sap flow into the taphole from the outer sapwood. Smaller spouts (5/16-inch) are easier to seat and appear to provide a tighter seal compared to 7/16-inch spouts.

Some producers have found twisting them by hand a quarter turn into the taphole will effectively seat the smaller spouts.

While it is important to avoid damaging the tree by using excessive force to seat the spout, it is also necessary, particularly with vacuum sap collection, to maintain a good seal between the tree and the spout. Loosening of spouts can occur when the trunk freezes and thaws repeatedly, and this can lead to vacuum leaks, which may reduce the amount of sap collected. Producers should check their spouts during the sugaring season, in particular looking for rapid sap movement through sap lines that indicates leaks, as this may be caused by spouts loosening.

Spouts must be gently removed from the tapholes immediately following the sugaring season. Care in spout removal will reduce injury to the cambium and facilitate taphole closure. Spouts left in tapholes during the growing season will interfere with closure and will cause more injury when eventually removed. Plugging tapholes after spout removal is not recommended as the plug could interfere with the tree's natural wound closure mechanisms as well as contribute to increased decay in the vicinity of the taphole.

Figure 6.7. Immediately after drilling, a spout should be gently but firmly seated in the taphole. (Girard)

## Retapping or Reaming Existing Tapholes

Early tapping, a long maple season, or a prolonged warm spell during the maple season can result in excessive microorganism growth in tapholes. These conditions cause a reduction in sap flow as well as the production of lower quality sap. To address this problem, some producers redrill the earlier taphole or make new tapholes in the tree. The potential sap yield lost by not retapping must be weighed against the costs of retapping. At the same time, it is important to remember that retapping, even if done with fewer taps, increases the number of tapholes and therefore the number of wounds in the trees. Retapping should be the exception rather than the rule and should be done only in dealing with an unusual situation in a particular year.

Reaming tapholes that have become blocked by the growth of microorganisms is a method that has been used by some producers to "freshen" the taphole. While reaming may have less impact on the tree than retapping with a new taphole, it usually does not remove sufficient microorganisms and those remaining continue to grow, contaminating the sap and quickly reducing or blocking flow. Reaming may be a means of obtaining a little more sap, but the renewed flow will usually be short lived, and the quality of syrup produced will not necessarily improve. As a generalization, reaming of existing tapholes is not recommended.

## Sap Collection and Transfer

The methods of collecting and transferring sap to the sugarhouse vary significantly among maple syrup operations. These variations reflect size of the operation, purpose and/or objectives for tapping trees and producing syrup, equipment and financial resources available, availability of labor, and perhaps most importantly, personal preference. Many maple operations rely on buckets or bags for collecting and transferring sap. Others have converted all or part of their sugarbush to a tubing collection and transfer system. There are certainly advantages and disadvantages to each system; the choice between them depending on a great many factors including size of operation,

capital resources and planning horizon of the producer, characteristics of the sugarbush, and personal objectives of the producer.

Tubing systems significantly reduce the labor and time required during the sap season, and additionally have the potential to yield significantly more sap when equipped with an effective vacuum pumping system. While tubing is the principal method of collecting sap in large maple operations, some small to moderate size producers continue to prefer buckets. Reasons given include maintaining the traditional approach, buckets are available and do not require investment in a new collection system (tubing), and it is easier to monitor the production of each tree. A main advantage to buckets is less maintenance—the whole system is taken down at the end of each season. Buckets and spouts can also be cleaned and sanitized more easily, and there are fewer problems with animals. Furthermore, buckets have the capacity to hold a large volume of sap that tends to remain cooler and therefore of higher quality than sap flowing through tubing. However, it must be emphasized that considerably more labor is required to collect sap during the season than that required for a well-designed and functioning tubing system. Further, older metal spouts and buckets can be a significant source of lead to maple syrup unless managed properly.

## Sap Collection and Transfer with a Bucket/Bag System

Traditional sap collection systems use a bucket or bag suspended on the spout (**Figure 6.8**). Obviously, all sap collected in a bucket/bag collection system occurs due to gravity and not vacuum. Buckets must be emptied periodically; collected sap is transferred to larger gathering tanks for transport to the sugarhouse. The frequency of gathering will depend on the size of the collecting container and the rate of sap flow. A major requirement for producing syrup of the highest possible quality is to gather and process sap as quickly as possible. To minimize microbial growth (particularly during warm periods) and lead accumulation in certain types of buckets (see comments below), sap should normally spend no more than a few hours in the collecting container.

Buckets are the most common collecting container and 16-quart galvanized buckets are the type most commonly used. However, sap buckets constructed of different material such as aluminum and plastic[32] are available as well. The popularity of galvanized buckets is related, at least in part, to their historic low cost and perceived germicidal properties. It was believed by some that the minute quantity of zinc that was dissolved from the galvanized coating by the sap tended to reduce microbial growth. While this may be true, the germicidal effect is nullified if the bucket is not kept clean and the zinc coating is overlaid with a film formed from the sap.

As a general rule, only buckets specifically manufactured for maple collection should be used. Many older buckets (including some galvanized) contain lead, either in the galvanizing coating, in the solder, or in the metal itself. These buckets should be used with caution; frequent emptying will keep the lead level of the sap low, but sap allowed to remain uncollected in lead-containing buckets for a day or more may accumulate unacceptable levels of lead. Old terneplate[33] or tin buckets contain excessively high levels of lead and should not be used for sap collecting. Producers who collect sap in containers that may contain lead should regularly have samples of the collected sap tested for lead[34]. No container capable of rusting should be used, and containers with thin galvanized coatings should be avoided as the coatings may quickly wear exposing a surface that will rust. Under no circumstances should a container that has ever contained a hazardous material be used for collecting sap. Non-food grade plastic containers, including plastic trash containers and stock tanks,

[32]Plastic containers must be manufactured from plastic approved for food use.

[33]Terneplate buckets are buckets made from metal coated with lead or a tin-lead mixture. They have not been manufactured for decades. Terneplate buckets can best be identified by the soft metal coating that has a dull appearance.

[34]Consult local resource professional for the names of appropriate testing facilities.

are similarly not suitable for sap collection. The plastic formulations used in these containers may be made of materials that are unsuitable for food contact.

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

Each bucket should have a cover to keep out rain and falling debris (**Figure 6.8**). Rain dilutes sap resulting in a lower sugar content that requires more sap, time, and fuel to produce the same amount of syrup. Debris is a physical contaminant that must be filtered out; additionally it has the potential to introduce off-flavors or microorganisms. Bucket covers come in two general types, those that attach with a wire pin to the spout and those that clamp to the bucket top. Note that covers that attach to the spout require spouts with a ring on the top for attachment (**Figure 6.4**). Also, if buckets are to be emptied by rotating (spinning) them on the spout, covers should be the kind that clamp to the bucket top.

Figure 6.8. Traditional bucket/bag collecting systems collect sap in buckets or bags suspended on the spout.

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

a. Because of their small bulk and weight they require less storage space and are easier to transport and hang.
b. They provide the spout and taphole greater protection from microorganisms.
c. Emptying bags is easier; they can be rotated on the spout and dumped with one hand.
d. They do not require a separate cover.
e. Ice formed during cold spells as well as sunlight may reduce microbial development.

Frequently cited disadvantages of sap bags include the following:

a. They may break at the seams, particularly if sap in a full bag freezes.
b. They may tear or be damaged by rodents.
c. They are difficult to empty when filled with ice.
d. The bag may be too small to hold a large run.
e. Washing and rinsing bags may be difficult.
f. Sap may warm rapidly in the sun.

## Gathering and Transporting Sap—Bucket or Bag System

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

To reduce the effort of carrying pails, some producers use a suction pump to transfer sap

from buckets to a larger tank mounted on a tractor-drawn trailer or wagon. A few producers use horses to pull the gathering tank.

As has been suggested, sap should remain in the bucket, bag, or gathering pail for only a few hours before it is collected and processed, particularly during periods of warm temperature. During small sap flow periods that produce insufficient volumes of sap to justify starting the evaporator, buckets should still be emptied even though this is time consuming and expensive. Sap left standing in buckets for even short periods of time in warm weather will deteriorate in quality. Low quality or spoiled sap that remains in the bucket or bag will contaminate the sap produced in subsequent runs, and any sap in storage tanks to which it is added. Once spoiled sap is present in collecting, gathering, or storage tanks, these containers should be thoroughly cleaned and sanitized before they are again used for collecting or storing high quality sap.

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

Sap should be passed through a coarse filter before being transferred to storage tanks to remove debris (**Figure 6.9**). This filtering can be done either as the sap is poured into the collecting tanks or as it is being transferred from the collecting tanks to the storage tanks.

Figure 6.9. Sap collected in buckets should be filtered before it is transferred to the storage tanks. Depending on conditions and handling, a variety of debris can collect in the sap.

## Cleaning and Care of Collection Equipment

Sap collecting equipment should be kept as clean as possible, and ideally should be used only for collecting and holding maple sap. At the end of the maple season, buckets and reusable plastic bags should be thoroughly washed with hot water and detergent and thoroughly rinsed with potable water to remove all traces of the detergent. If bleach is used, thorough rinsing is a must. As an acceptable alternative, some producers clean and sanitize buckets at the end of the season with high-pressure steam. Additionally, rewashing buckets/bags during the season with a water/bleach solution and rinsing thoroughly with water (triple rinse) is completed by some producers to remove any built-up film of sugar and microorganisms. While time consuming, this practice can, particularly during maple seasons with a prolonged warm period, result in much higher quality syrup being made during the latter part of the season.

Using bucket-washing brushes that are available in a variety of sizes will markedly improve the speed and thoroughness of bucket cleaning.

After rinsing, buckets/bags should be drain-dried and stacked for storage. It is important that this post-season cleaning not be postponed. The thin layer of dried sap on the surface of the buckets/bags will support the growth of microorganisms. If washing is delayed, it becomes increasingly difficult to remove sap and debris accumulations. Prior to use in the spring, buckets should be washed with hot water, rinsed with a bleach solution (5 to 10 percent solution made with 5 percent unscented household bleach in water), and thoroughly rinsed with hot water to remove all traces of the bleach solution.

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

## Sap Collection and Transfer with Plastic Tubing

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

## Tubing System Concepts

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

1. All systems should be designed so gravity will help sap move through the system. When tubing is properly installed, it is tight, straight, and slopes continuously downhill (**Figure 6.10**).
2. Tubing systems used with vacuum pumps are constructed differently than systems that rely on gravity alone for sap movement, particularly in terms of the number of taps on each lateral (5/16") line (approximately 5 to 7 per line with vacuum, 10 to 15 without vacuum).
3. Tubing systems should generally be as simple and direct as possible, with the fewest fittings possible (fittings reduce internal diameter and may restrict efficient sap movement).
4. Tubing systems can contaminate fresh sap unless they can drain fully and can be kept clean.
5. Tubing systems must be inspected and maintained on a regular basis to minimize sap leaks and vacuum loss, and must be cleaned at the end of each sap season.

6. Tubing systems need to be replaced every 10 to 15 years, to accommodate aging and deterioration of the plastic, as well as in-growth of new trees and mortality of old trees.

A properly designed, installed, and operating tubing system will substantially reduce the amount of labor associated with sap collection. Additionally, it is possible to obtain larger sap yields from properly installed and maintained systems.

Figure 6.10. Tubing systems should be designed so gravity helps sap move through the system. When properly installed, tubing is tight, straight, and sloping downhill.

## Design of Tubing Systems

A tubing system is comprised of a network of plastic lines of various diameters, resembling a number of small streams flowing into a larger river and ultimately to a reservoir (**Figure 6.10**). The smallest "streams" are the lateral lines of 5/16-inch tubing that pass from tree to tree. Sap from the lateral lines flows into mainlines, which are 3/4 inch diameter or larger. Sap from these mainlines may flow into larger mainlines, sometimes called conductors that transfer sap to storage tanks.

To design an efficient tubing collection system for a particular sugarbush, it is necessary to plan carefully before installation is begun. The tubing network should be designed to accommodate the number and distribution of tapable trees and the prevailing topography. Maple producers who do not feel comfortable planning a tubing system on their own are advised to seek help from an experienced producer, an equipment dealer, an experienced tubing consultant/installer, or a forester with experience in tubing installation. Planning can be facilitated if a topographic map of the sugarbush is obtained or constructed. This map should show location of the sugarhouse or sap collection point, roadways, streams, and other significant features. Many producers have found it helpful to locate individual or groups of maple trees on the map as well. It will be helpful if the finished map is as close to scale as possible.

The purpose of a sugarbush inventory and resulting map is to assist in planning the location of collection tanks and main tubing lines. The most critical step is locating the collection tank. Normally it will be at the lowest point in the sugarbush, although this may be modified by access considerations. In some sugarbushes it is possible to locate the collection tank at the sugarhouse; however, in many cases, sap will need to flow to a collection station some distance from the sugarhouse and be pumped or transported by truck from there to a tank at the sugarhouse.

## Using Vacuum with the Tubing System

Many producers who set up a tubing system intend to connect their lines to a vacuum pump to maximize sap yield. Increases of 50 to 100 percent (or more) in sap yield may be achieved with a well-designed and installed vacuum system. Some sugarmakers may choose to collect sap using tubing without a vacuum pump. There are differences in the way each system should be set up. The following descriptions of tubing systems assume that the producer will be using mechanical vacuum. Even if a pump is not employed initially, it is wise to prepare the system for the incorporation of vacuum if there is any possibility that it might be added in the future. Such obstacles as the lack of electrical service or the need for remote starting of pumps can be easily overcome with technology and equipment, available through many maple equipment dealers. For those producers who are certain that a vacuum

pump will never be added to the tubing system, refer to the section below, entitled "Using Tubing Without a Vacuum Pump" for a description of the differences in tubing layout between vacuum and non-vacuum systems.

## Locating Mainlines and Laterals

"Mainlines" in a tubing system are all the transfer or pipelines larger than the 5/16-inch diameter lateral lines that pass from tree to tree. A taphole from a tree is not normally connected directly to a mainline, but to a 5/16-inch lateral line by means of a dropline. The lateral 5/16-inch lateral lines are connected to mainlines. These mainlines are the conduits used to transfer sap to the collection tank in as direct a path as possible. Mainlines must be installed on a fairly constant grade, without dips or sags, and should be supported on wire that is strung tightly along the mainline path (**Figure 6.11**). For this reason, mainlines are a permanent part of the tubing system, and their location must be carefully chosen.

Location of mainlines is dependent on location and density of tapable trees present in the sugarbush. Mainline location often will follow the natural surface drainage pattern in the sugarbush. Where a uniform slope is present, line location is somewhat arbitrary as long as all tapable trees are nearly equally accessed and proper lateral line layout is facilitated. Where natural slope exists, lateral lines branching off mainlines should run up the slope from the mainlines, rather than across the slope. This arrangement will maximize natural vacuum, which can be achieved in 5/16-inch lateral lines when they are full.

Some producers may be tempted to put out fewer mainlines than are necessary, as mainline installation is more time consuming and expensive than installation of 5/16-inch (lateral) lines. Too few mainlines will result in wide spacing between mainlines, which will necessitate long lateral lines. Long lateral lines with many taps on each line are inefficient for moving sap or transferring vacuum from a distant pump; furthermore, long lateral lines are prone to sagging. Additionally, if mainlines are far apart, they need to be of large diameter for good movement of sap and vacuum. Large diameter mainlines are more expensive and bulky to move through the woods, as well as more difficult to install. For these reasons, present practice holds that the most efficient system has many mainlines that are located fairly close together. Vacuum transfer and sap flow is most efficient when there are only 5 to 7 taps (maximum 10) connected to each lateral line. In order to limit taps to this number, mainlines in most sugarbushes on a vacuum system will typically be about 150 feet apart.

Unless one has considerable experience in setting up a tubing system, it is best to mark out the location of mainlines as part of the inspection and planning before they are installed. Plastic flagging or tree-marking paint is useful for this task. A slope of 2 to 4 percent is ideal for a mainline. This is best determined using a sight level, Abney level, or transit. The length of mainline sections should be measured to determine the length and sizes of mainline and the fittings required.

Figure 6.11. Mainlines must be installed on a fairly constant grade, without dips or sags, and should be supported on wire that is strung tightly along the mainline path.

## Mainline Size

The size of the mainline is critical for tubing installation if efficient sap flow and vacuum transfer is to be achieved. The line must be sized to accommodate peak flows while allowing adequate vacuum transfer. Most mainlines are sized rang-

ing from 3/4 inch to 2 inches. Mainlines smaller than 3/4 inch are not recommended because of a reduction in ability to transfer sap and vacuum.

Mainlines need to both carry the sap and allow space for air to be removed from the tubing to produce a vacuum. The number of taps entering a mainline determines how much sap will be in the mainline. This liquid will reduce the space for air and will make the tubing effectively smaller in diameter. Consequently, tubing diameters must be larger for longer lengths and where more taps are present. A general rule is that lines should be no more than 1/3 full of sap at any time to avoid turbulence within the tube, which will slow the movement of both air and sap.

How large should a mainline be to accommodate both sap and air? If the secondary mainlines are approximately 150 feet (46 meters) apart, this will result in an area of the sugarbush that is about 150 feet (46 meters) by 1000 feet (305 meters), or about 3.5 acres (1.4 hectare), to drain into each mainline. At a normal density of 70 to 90 taps per acre (170 to 220 taps per hectare), a 3/4-inch or 1-inch mainline (considering the slope and potential size of runs as discussed below) no longer than 1000 ft (305 meters) will be adequate size for handling the sap from this number of taps during periods of maximum flow. If the line is placed at the bottom of a drainage, and lateral lines feed into it from both sides, the area of sugarbush feeding this one line could be as much as 300 feet by 1000 feet (92 meters by 305 meters) and a 1-inch mainline should be used. As secondary mainlines are joined, the size of the downstream mainline will need to be increased, perhaps to 1 inch or 1½ inches in diameter. A wet/dry conductor system, described in a later section, should be considered for very long runs of mainline. Maple equipment dealers or Extension educators should be consulted about recommended mainline sizes as research on proper sizing continues.

Recommendations of the appropriate number of taps for mainlines of different sizes vary somewhat throughout the maple region, and occasionally among knowledgeable producers and tubing installers within a region. Some of this variation may be due to tradition, but some is certainly the result of different producer or installer experience and perhaps different expected peak sap production. Differences in expected peak sap production can be the result of geographic location, tree size, tree health, and tubing system design including the number of taps per tree and the amount of vacuum, and other factors.

**Table 6.4** identifies the number of taps commonly recommended for different size mainline on three slope conditions—slopes of less than 5 percent, 5 to 10 percent, and greater than 10 percent. Note that a range of tap numbers is provided for each combination of mainline size and slope. This range reflects the variability described above. It is suggested that producers planning or upgrading a tubing installation discuss mainline sizing with those familiar with successful tubing installation in their area[35]. Note also that the appropriate number of taps for a mainline in a specific situation should rarely exceed those recommended in the table, but could often be less than the maximum number recommended due to local conditions, particularly the expected size of the larger sap runs.

Although sap moves faster as slope increases and, therefore, more sap can be moved through the same sized mainline on a steep slope than a shallow slope without filling the pipe more than 1/3 full, steep mainline installation is not recommended. Where the mainline levels out following a steep section, it is likely to fill with sap or the sap will become excessively turbulent, which will block the removal of air from upstream sections and reduce vacuum at the taps. A maximum mainline slope of 4 to 5 percent should be the goal of installations even on steep land; with the lines placed across the slope rather than straight up and down.

[35]Visit with successful producers gathering with tubing, tubing consultants/installers, or knowledgeable educators (Extension or service foresters, or others). Do not, however, assume that having a well-run tubing operation necessarily means that a producer is obtaining the maximum yield from his or her sugarbush. Inquire about yield of sap per tap. One of the results of using too small mainline is reduced sap yield.

**Table 6.4. Recommended number of taps for mainline of different diameter on slopes of different steepness.**

| 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 Systems on Flat Ground

When a tubing system is installed on very flat ground, it may not be possible to achieve the ideal or recommended slope in the mainline; but it is critical that there is enough pitch to allow the sap to drain by gravity. A slope as low as 1/2 percent for the mainline will work, as long as the line is very tight with no sags and the grade is consistently downhill. Where the ground is flat, slope can be gained by installing the line higher off the ground the further into the sugarbush it goes, up to a practical height of about 6 feet (1.8 meters). Mainlines on very flat ground may have to be shorter than 1000 feet (305 meters), necessitating dividing the woods into compartments with several remote tanks, each serving a group of mainlines. Care should be taken in measuring the slope of the line to ensure that there are no flat spots or dips. Mainlines on very flat land may need to be larger than 3/4 inch, particularly as the lengths approach 1000 feet long. Lines that are 1 inch or 1¼ inches in diameter will be the smallest that many sugarmakers should use.

## Mainline Tubing Types and Color

Currently commercially available maple tubing and black water pipe approved for potable water are both commonly used for mainlines[36]. Black water pipe is quite rigid and totally opaque; some producers prefer a softer, translucent (usually blue) mainline. This material is more expensive than water pipe but somewhat easier to work with, and it is possible to see sap movement through the walls of the tubing. Dark green or orange pipeline should be avoided in most cases, as these plastics may not be suitable for food-material application.

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

Mainline color will affect the heating of the sap within. In colder, north or east-facing sugarbushes, it may be preferable to have all black lines, so that any sun striking them will help thaw sap that may be frozen inside. On south or west-facing slopes, or in areas of the maple region where daytime temperatures are often well above freezing during the sap collecting season, light-colored tubing may be preferable to prevent heating of the sap so the potential for producing high quality syrup is reduced. Some producers paint black tubing with white latex paint to reduce solar heating.

## Mainline Support—Wire Installation

Mainlines must be tied to a rigid support wire in order to prevent sags. Producers commonly use either 9 gauge soft wire, or 12.5 gauge high-tensile wire for this support. Both are about equal as regards strength; 12.5 gauge wire is less expensive and will not stretch over time, but is somewhat more difficult to handle, kinks more readily, and can be more difficult to install. Use care when installing mainline wire, as stretched wire is dangerous if it breaks.

Once the location of mainlines has been determined, the support wire should be installed. There are two basic methods for installing mainline support wire: (1) making the wire initially very tight with a fence wire tensioner (**Figure**

[36]Producers should check with local resource professional concerning the advisability of using black water pipe.

**6.12**) and (2) installing it loose and pulling it tight with side ties (**Figure 6.13**). While the first method usually requires the least maintenance over time and results in the shortest possible mainline, the second method can be useful if one needs access to the woods with a vehicle for thinning or other activities, as the line can be laid on the ground without disconnecting the pipeline once the side ties are loosened. Many producers employ both methods in supporting and tensioning mainlines. The object of either method is to erect a wire that does not sag and can support a mainline full of sap.

Figure 6.12. Tightening mainline support wire with a fence wire tensioner.

Figure 6.13. Tightening mainline support wire with side ties.

To begin wire installation, the wire is first pulled into the sugarbush on a predetermined path, played out from a wire spooler (**Figure 6.14**) or by a helper who is turning the coil to avoid kinks (see section on "Installing Lateral Tubing" below). Some producers prefer to install a single length of wire to the point where the mainline will end, while others prefer to install wire in approximately 500 feet (152.5 meter) sections so that a break in the wire will not affect the whole line. If the latter method is used, one wire can be ended and the next one started at the same tree, and the mainline passed from one wire to the next without interruption. The wire must be firmly anchored at the last tree or to another stable support such as a post or ground anchor. This can be done by mounting a J-shaped hook into the tree or post (**Figure 6.15**), or by forming a loop around the tree (post) and anchoring the wire to itself with some form of wire splice (Gripple, etc.) or a knot (**Figure 6.16**). If it passes around the tree, the wire should be encased in a short section of tubing to protect the tree. Even with this protection, the loop around the end tree should be moved up or down every year or two to prevent damage to the tree. Slats of pressure treated or decay resistant wood between the tree and this protective tubing will allow the wire to be moved up and down more easily. The wire is then cut and fastened at the other end. If a fence wire tensioner is used, it is usually at the lower end of the wire (**Figure 6.12**).

Figure 6.14. A wire spooler is a useful tool for avoiding kinks in wire when pulling it through the sugarbush.

Figure 6.15. J hook used to anchor mainline support wire to a tree or post.

Figure 6.16. Wire splice (Gripple) being applied to tensioned mainline support wire.

The wire should be supported in such a way that it maintains as uniform a grade as possible. If there are small trees along the path of the wire, these can be used for support, or the wire can be pulled to trees with side ties. However, the support wire should not zigzag excessively if this is done. If adequate support trees are not available, cedar posts, pressure treated lumber, or steel posts can be used. Wire that follows a 4 to 5 percent grade needs support about every 40 feet (12 meters), while wire on a flatter grade needs closer spaced supports to prevent sagging. On flat land with 1 percent or less slope, support is critical because even slight sagging could cause a failure of the sap to drain. Support every 10 feet (3 meters) may be necessary in these situations. For tying to trees or side-tying to tension the main wire, #12 or #14 soft wire is usually used. This size wire will usually break before the mainline wire gives way if a large branch or tree falls on the mainline, thus sparing the producer a major repair. The side-tying wire is looped around the mainline support wire and twisted around itself, then looped around a tree inside a short piece of tubing to protect the bark and brought back again to the mainline wire (**Figure 6.13**).

## Mainline Tubing Installation

Mainline tubing is installed following the exact path of the support wire. As mainline comes in large rolls, it is best not to carry the whole roll into the woods, but instead to pull the free end while the coil is unrolled by a helper (**Figure 6.17**), or set on a spooler that can turn smoothly (**Figure 6.14**). If there is snow on the ground, mainline can sometimes be unrolled by setting the whole coil on the ground and driving wooden stakes through the center of the roll into the ground; the coil turns easily on the snow and is unrolled as if it were on a spooler.

Figure 6.17. The most effective way to distribute mainline in the woods is generally to pull the free end while the coil is unrolled by a helper.

At the end of the support wire, the tubing is plugged or a valve installed and fastened to a hook, or by some other method to the tree (**Figure 6.18**). Some producers like to install a valve at the end of the line as an aid in washing the mainline. The line is next attached to the support

wire using a wire tie about every 10 feet (3 meters). At the end of the support wire, the tubing is passed through a tubing grip and pulled tight by hand (**Figure 6.19**). It is not recommended to use a mechanical tensioner to tighten the tubing. The tubing may need to be retightened in a few days if it becomes loose on the support wire, particularly if the air temperature is higher than on the day of installation. Once the tubing is tight, installation of wire ties every 1 to 2 feet (0.3 to 0.6 meter) should be completed so that the mainline tubing is in firm contact with the support wire.

Fittings, either plastic or stainless steel, are used to attach lengths of mainline tubing together.

Figure 6.18. At the end of the mainline a plug (top) or a valve (bottom) is installed. The valve can be used during tubing cleaning.

Quick disconnects are helpful where the mainline crosses a road so it can be uncoupled when not in use. With most mainline materials, particularly black water pipe, it is not possible to push fittings on by hand. The recommended installation method is to use a mainline installation tool, which grips the tubing and holds it in place, then pushes the tubing over both sides of the fitting by turning a crank that closes the tool (**Figure 6.20**). The tubing does not need to be heated when using this tool. Alternative methods used by some producers involve heating the end of the tubing, either with hot water (carried in an insulated thermos) or a propane torch. A stainless steel hose clamp should then be tightened around the cut end of the tubing to prevent leaks. Use a nut-driver wrench to tighten mainline hose clamps, as simply tightening the clamp using a screwdriver will not tighten the clamp sufficiently.

Figure 6.19. Tubing grip on end of mainline used to pull tubing "hand-tight."

If mainline is installed during summer or early fall when the temperatures are considerably different than the sap season, then shrinking or expanding of the plastic may add to mainline maintenance. Mainline that is very tight during the summer may shrink enough during the winter to pull away from fittings; conversely, mainline that is tight in the winter may expand and snake back and forth from the support wire in the summer. Installers should be aware of these potential problems and should check all mainlines before the sap season and make adjustments or tighten fittings as necessary.

Figure 6.20. Mainline installation tool, which grips the tubing and holds it in place while it is cut, then pushes the tubing over both sides of the fitting by turning a crank that closes the tool.

## Lateral (5/16 inch) Tubing

### Tubing Type

Buying tubing, both 5/16 inch and mainline, can be confusing as manufacturers have used a variety of names for similar products. Until the 1990s, all 5/16-inch line was made from polyvinyl chloride (PVC), a supple, kink-free plastic. PVC tubing could be found in a wide variety of colors and different wall thicknesses. Tubing was either ribbed or smooth. PVC tubing is readily workable, meaning that fittings can be pushed on without a tool and will remain relatively tight, and it coils easily for producers who wish to disassemble the tubing system after the sugaring season. Disadvantages of this type of tubing include a tendency for stretching, which means constant upkeep to remove sags, decreasing internal diameter with stretching, and difficulty in cleaning, as bacteria are able to grow into its more porous (than polyethylene) interior walls. These issues tend to cumulatively result in greatly diminished sap yields over time, thus necessitating periodic replacement of PVC lateral lines. Some producers still prefer PVC for new installations.

In the 1990s, polyethylene tubing became available in the maple industry. Poly tubing, as it is often described, is usually found in two forms: rigid or stiff, and semi-rigid or semi-stiff. Poly tubing is far less stretchy than PVC. Although they can adhere to the interior surface, microbes cannot penetrate into the plastic; this makes cleaning somewhat easier and more effective. Many producers prefer rigid tubing because it has minimal stretch and a very smooth inner surface. Additionally, it is lighter in weight and less expensive than other types. Other producers prefer the semi-rigid form, suggesting that it is easier to handle, forms a better seal on fittings, and is easier to unroll and roll up. Producers sometimes use stiff tubing for lateral lines and a semi-rigid for droplines, which are handled more frequently and therefore more prone to develop leaks. In either case, fittings should only be put on polyethylene tubing with a tubing tool, as they will leak air otherwise. The useful life span of polyethylene tubing systems has not been well established, but is the subject of on-going research.

Information, comments, and cautions concerning food-grade mainline tubing also applies to lateral line tubing.

### Tubing Fittings

In addition to rolls of tubing, a maple producer setting up a sap collecting system will need a variety of fittings to connect the tubing to the

mainline, to the tree, and for other purposes. These fittings must be constructed of food grade materials. In addition to reading information and suggestions provided here, it is recommended that new producers read one or more maple equipment catalogs or consult an equipment dealer and personally examine the various fittings that are available.

There are several possible fittings for connecting 5/16-inch tubing to mainline. A star fitting has multiple (usually four or six) ports for connecting multiple lateral lines to one point in the mainline (**Figure 6.21**). This fitting requires that the mainline be cut for its installation. Another option is a saddle-type or multi-fitting that connects only one or two lateral lines at a time to the mainline and does not require cutting the mainline; instead, a small hole is drilled in the top for installation (**Figure 6.22**). These fittings are attached to the mainline with one or two ratcheted plastic cuffs. When using a saddle fitting, some sort of strain relief should be employed on the lateral line to keep the rubber gasket of the multi-fitting from pulling away from the mainline and causing a vacuum leak. Straight connectors with hooks are available for this purpose. Another method is to use a 3-foot (1 meter) length of hollow braid, 1/4-inch (6 mm) poly rope slid over the end of the tubing, tied to the mainline wire, and pulled tight. The advantage of this latter method is that tension adjustments in the sap tubing can easily be made.

Figure 6.21. A star fitting at the end of a mainline. This star fitting is actually the bottom fitting of a sap ladder, discussed later in this chapter. When a star fitting is installed in a mainline to receive lateral lines, it is commonly installed with the star on top of the mainline rather than on the bottom, as it is in this installation.

Figure 6.22. A saddle-type or multi-fitting is installed by drilling a small hole in the mainline and placing the fitting (right in picture) over the hole. The hook connector (left in the picture) hooks onto the mainline support wire and relieves the tension on the fitting.

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

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

Special fittings anchor the lateral line to the tree at the end of each line, so that the line can be stretched tight and hold its position. There are several fittings that perform this function, including various ring and Y fittings (**Figure 6.23**). A ring fitting allows the producer to take up slack in the lateral line, if necessary, without cutting it. Producers are advised to experiment with

different types to determine what works best in each situation. Finally, a straight fitting (connector) can be used to connect lengths of tubing together. Careful planning is necessary to minimize the number of pieces that need to be connected to make up each lateral line, as each junction creates a small restriction to sap and vacuum transfer as well as a dead spot for microbes to accumulate.

It is not recommended to install branches lines to a lateral line. If the mainlines are located no more than 150 feet (46 meters) apart, and if each lateral line is limited to five to seven taps, the need for branch lines can be eliminated.

Figure 6.23. One of a variety of fittings designed to anchor the end of a lateral line. This particular end ring fitting accommodates a dropline (in the producer's hand).

## Installing Lateral Tubing

There are several different approaches that are used to install lateral lines. These largely reflect the amount of help available as well as personal preference. The basic objective is to stretch the tubing between the mainline and the last tree, in a fairly straight line, so that it receives five to seven taps and is no more than about 150 feet (46 meters) in length. Droplines at each tree are best spliced in after the lateral line is installed. Most producers find it easier to run lateral lines from the most distant tree toward the mainline, although some prefer to work out from the mainline. If working out from the mainline, a hooked fitting or hollow braided rope can be used to hold the lateral line to the support wire while the line is being stretched. The lateral line should pass against the outside of each tree so it will be supported and not sag. In a cluster of trees, it is better to use a second lateral line than to zigzag back and forth trying to connect all taps on one line. When available, a co-worker can follow and hold the line tight against the tree just passed. At the last tree, the line is anchored by a loop of tubing that goes around the tree. It is important that a relatively uniform downhill slope be maintained in the lateral line so sap will rapidly move to the mainline.

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

## Connecting Fittings to the Lateral Line

Virtually all fittings used with maple tubing have two or three barbs or ridges where tubing is attached. Care must be taken to install the tubing over these barbs, so that the fitting is tight, and will not pull off or allow air into the lines during the sap season. When using soft tubing it may be possible to press fittings on by hand, but in most cases a tubing tool should be used for this purpose. Tubing tools of different designs are available; some can be used with one hand and some require two hands. The basic principle of either tool is to grip the cut ends of the tubing in a small vise and push the tubing onto the fitting when the tool is closed (**Figure 6.24**). With a bit of practice, assembling fittings in this manner becomes quite easy. It is possible to push fittings into tubing by other methods, such as softening the tubing with hot water, although this can be more difficult when working in the sugarbush. Some producers use a heat source such as a disposable cigarette lighter or small propane torch to soften the ends of tubing by heating; however,

it is possible to heat the ends of tubing too much and some distortion of the tubing can occur. It is not recommended to soften the ends of tubing by placing it in the mouth and chewing on it. Even with the tubing tool, care should be taken not to damage the barbs. When removing a fitting for later use, care should also be taken not to score the barbs with a knife or clippers, as this will lead to an air leak. When using rigid polyethylene tubing, fittings once installed should not be rotated around on the tubing as this may also create small leaks that are extremely difficult to locate, but that cumulatively can negatively impact vacuum levels achieved.

Figure 6.24. Double tubing tool (top) being used to cut in dropline; one-hand tubing tool (bottom) being used to install hook connector (see Figure 6.22).

## Connecting the Lateral Line to the Mainline

In the past, four-way or six-way manifolds were commonly used to attach multiple lateral lines to the same point on the mainline. This method, while still favored by many sugarmakers, can result in unnecessarily long lateral lines if the fitting is not carefully located, since several lines must be directed to the fitting rather than following the shortest distance to the mainline. The use of multiple manifolds also adds more internal restrictions to the mainline. Using saddle fittings overcomes some of these concerns. Depending on the type of saddle used, a saddle fitting will connect lateral lines singly or in pairs, at any point in the mainline. This allows the installer to choose the shortest path from the mainline to the first tree, which results in the shortest possible lateral line with the greatest possible slope. The saddle has the advantage of easy installation, because the mainline does not need to be cut, but only drilled. This is best done with a drill type fitting called a mainline punch (**Figure 6.25**), which will make a smoother hole than an electric drill. Care should be taken to place the fitting exactly over the hole, and to lay the rubber gasket flat on the mainline. The ratcheted cuffs should then be closed firmly using adjustable pliers. When installing a saddle, use a hooked fitting or similar device to provide strain relief on the mainline. When using a hook on the support wire or a length of hollow-braid rope, the hole for the saddle should be 9 to 12 inches (23 to 30 cm) from the hook or rope knot (**Figure 6.22**). The hooked fitting is then connected to the saddle with a short loop of tubing. This loop, which will force the sap to move uphill briefly before entering the mainline, can be used to quickly check the rate of sap movement through the lateral line when searching for leaks.

Figure 6.25. Mainline punch used to drill hole in mainline when installing saddle fitting.

## Installing Droplines

Once the lateral line is in place, the droplines are installed. Droplines should be 30 or more inches long (75 cm or longer) to allow the tapholes to be well spread out on the tree from year to year. Droplines can be pre-made and grouped into conveniently sized bundles prior to their installation in the sugarbush. The two-handed tubing tool (**Figure 6.24**) makes it easy to install droplines without losing tension in the lateral line. When locating each dropline, the Tee does not need to be against the tree; in fact, placing the Tee a few inches away from the trunk may discourage squirrels and other rodents from chewing on the fittings.

## Using Tubing without a Vacuum Pump

While many producers who set up a tubing system do so with the intention of connecting it to a vacuum pump, tubing systems without vacuum pumps have many of the same advantages as the system described above. Properly installed, a closed (non-vented) tubing system can develop natural vacuum that will increase sap yield over gravity (bucket) collection or older vented tubing systems. Natural vacuum develops when a column of liquid (sap) fills the tubing, and moves slowly towards the mainline. Since only sap, not air, can enter the system, the movement of sap through the lines creates a vacuum at the taphole. In some situations where the lines are well graded or the natural slope of the land is fairly steep, the level of natural vacuum achieved can be considerable. In order for this to work, the tubing must be full of liquid. This occurs during heavy sap flow periods. The lateral lines should have 10 to 15 taps each and mainlines should be located about 250 feet (76 meters) apart to allow for longer lines passing by more trees. Care must be taken to keep the lines tight, and sloping downhill at all points, as any dip will slow the flow of sap at that point, thus reducing the potential for vacuum.

In the past, venting of spouts has been used in some installations to supposedly prevent airlocks. This was most common when tubing was laid on the ground. Venting serves no useful purpose and will both eliminate the benefit of natural vacuum from a gravity tubing system and reduce sap yield over a closed tubing system by increasing taphole drying. Eliminating sags in tubing will prevent air locks.

## The Conductor System

If the suggestions regarding installation of the mainlines have been followed, it is not uncommon that in some situations the 1000 foot (305 meter) maximum mainline length is not sufficient to reach the collection tank. If this situation exists it is recommended that a larger diameter mainline be used when the length has to exceed 1000 feet. If a single conductor line is used it needs to be large enough in diameter to accommodate a heavy sap flow of all the trees in the sugarbush while still allowing for good vacuum transfer. As has been mentioned, lines that are more than 1/3 full are less efficient at moving air (vacuum) because of turbulence created in the line. Thus in a large system, mainlines of 1½-inch to 2-inch diameter or larger might be needed (**Table 6.4**). Equipment dealers can provide assistance in choosing the correct diameter for mainlines. Another approach to increasing the rate of sap movement through longer mainlines is to install a dual conductor system.

## The Dual Conductor or Wet Line/Dry Line Tubing System

One of the recent innovations in tubing layout is the dual conductor or wet line/dry line system. This entails having two parallel mainlines, arranged one above the other, to independently carry sap (lower line) and to transfer vacuum (upper line). While the construction of such a system is more complicated than a single pipe system, it has advantages over the latter, including potentially higher vacuum at the trees and cooler sap arriving at the sugarhouse. The dual conductor system is particularly advantageous where mainlines are very long and where sap from many (over 700) taps is collected into one conductor line. Using the dual line system, the pair of lines extend into the sugarbush, from which

single mainlines less than 1000 feet (305 meters) in length branch off. At the point where a mainline branches off, a manifold (sometimes referred to as vacuum booster) connects the dual lines (**Figure 6.26**). This manifold can be purchased commercially or manufactured using inexpensive plumbing parts. In this way, the vacuum transfer is very efficient, as air (vacuum) moves through the upper, dry line from the pump to the manifold. As sap is drawn from lateral lines connected to trees in the sugarbush into the manifold, it nearly fills the wet line, which is smaller in diameter than it would have to be if the line was transferring both air and sap. Since smaller diameter line can be used for the pair of conductors, for example a 1-inch dry line and a 3/4-inch wet line for 1000 taps compared to a 1¼-inch single line, the price of the dual lines often does not exceed a single line system, although there is considerably more labor involved in setting up the two lines. An additional advantage of the dual line system is that the sap stays cooler on a sunny day when traveling through the wet line, because it is nearly full, than it would in a single conductor system where the sap fills only 1/3 of the line. Still another advantage to a dual conductor system is that sap can start to flow through the dry line early in the morning when the wet line is frozen, thus acting as a backup wet line until the wet mainline has thawed to allow normal flow to occur.

Assuming that a reasonable slope (4 to 5 percent) can be achieved, suggested line sizes for a dual line system, with the smaller wet pipe on the bottom, the larger dry pipe on top are as follows: 3/4 inch and 1 inch for 1000 taps; 1 inch and 1¼ inch for 2000 taps; 1¼ inch and 1½ inch for 3500 taps; and 1½ inch and 2 inch for 6000 taps. These numbers are for the lower end of the system that carries the most sap; pipe size can be reduced for lines located toward the upper end of the system.

In a dual line system the wet line is strictly a conductor line that receives the flow from the branch mainlines. Lateral lines should enter the branch mainlines, not the wet line. A dual line system is intended to accommodate the fact that the wet line will be full of sap and not an effective conductor of air. In fact, the sap in the wet line moves downhill primarily by gravity. Connecting laterals to a wet line will leave the laterals without a source of vacuum.

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

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

Figure 6.26. Manifold connecting lateral mainline to vacuum (upper) and sap (lower) lines in a dual conductor or wet line/dry line tubing system.

## Moving Sap Up Hill and Lifting Sap Vertically

Mechanical vacuum enables the movement of sap "uphill" if necessary. A mechanical extractor (often called a reverse flow extractor in this application) is placed at a low point in the sugarbush where sap is collected and transferred uphill to a collection point (**Figure 6.27**). The system requires good vacuum transfer. The reverse flow extractor system allows sap collection from taps situated at a lower elevation than a collection tank.

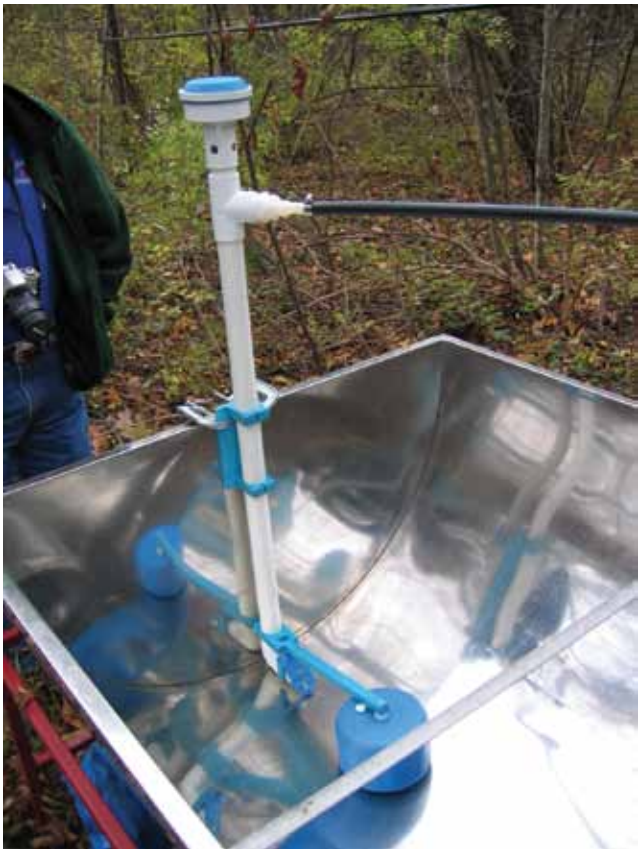


Figure 6.27. A mechanical vacuum extractor can be used to transfer sap collected from taps situated at an elevation lower than a collection or storage tank.

A sap ladder is a relatively inexpensive method used for lifting sap in situations such as over an access road or obstacle such as a hill using an existing vacuum sap collection system. Individuals have reported lifting sap up to 14 feet (4.25 meters) from areas with a few hundred taps. There are two main types of sap ladders: the pipe ladder (**Figure 6.28**) and the star ladder (**Figure 6.29**). The star ladder is commonly used with mainlines serving less than 500 taps and a two-pipe (or double pipe) ladder with mainlines serving more than 500 taps. In this application, a sap ladder utilizes vacuum (15 inches [38 cm] of mercury or greater) to lift sap from one mainline to another directly above it. Lower vacuum levels will reduce the performance of the system. Additionally, sap ladders may reduce the overall vacuum level in the line.

Figure 6.28. Pipe sap ladder in foreground. Producer has hand on shut-off valve that can be used to convert two pipe sap ladder to a single pipe sap ladder.

Figure 6.29. Star sap ladder. Sap flowing from right to left in the lower mainline (on the right) is raised to the upper mainline on the left.

**Figure 6.29** shows a common configuration of a star ladder. In this configuration the two mainlines are attached to threaded mainline manifolds (star fittings), with the manifold on the lower mainline inverted (e.g. placed with the manifold below the mainline). Sap flowing in the lower pipeline is lifted by vacuum to the upper line through the 5/16-inch sap collection tubing lines. Sap in the upper line then flows under vacuum and gravity in a graded pipeline to the collection point.

**Figure 6.28** shows a common configuration of a two-pipe ladder. In this configuration a shut-off valve has been placed in one of the pipes allowing the ladder to be used as a one-pipe ladder during periods of low sap flow.

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

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

## Cleaning Tubing Systems

To collect large volumes of high quality sap it is imperative that tubing collection systems be kept clean. To maintain an acceptable level of cleanliness it is necessary to wash the tubing system as soon as possible at the end of each season. The objective of washing is to remove uncollected sap that may be present, as well as accumulations of microbial growth. As referred to previously, the choice of tubing material, especially the smoothness of interior surfaces, can have an important effect on the ease of cleaning.

Many sugarmakers with small tubing operations choose to take down all lateral lines at the end of the season. Removed tubing is often washed by flushing each line with hot water provided by connecting the line to a household hot water system, or by some other means that force a large quantity of clean, potable water through each line and spout. Producers with larger tubing operations, or even those with small operations who have access to the right equipment, usually chose to wash their tubing in the sugarbush.

One of the most effective methods of washing tubing is with a pressure washing system. In this system, water under high pressure is mixed with air and pumped through the tubing. The compressed air adds to the turbulence of the water, which helps to physically remove material from the inner surfaces. An air/water mix also makes it possible to push water uphill in steep terrain where a solid column of water would be more difficult to pump. Commercial gas and electric powered tubing washers are available (**Figure 6.30**), though some producers assemble their own utilizing a water pump, an air compressor, plastic pipe, and associated valves and gauges.

Figure 6.30. Gasoline powered air/water pressure tubing washer. Essentially a gasoline engine powered air compressor and a water pump (hidden to right of gasoline engine) along with appropriate gauges, valves, and supporting hardware to provide a pressurized mix of air and water to the black line on the right.

Certain preparations must be made before a tubing system can be properly washed with a pressure washing system. Because the water will be pushed against the system with considerable force, all fittings must be tight and fastened with hose clamps. Temporary repairs that were made to repair leaks in the mainline, such as using electrical tape placed over the opening to prevent a vacuum leak, may blow off under pressure and should be reinforced with hose clamps or replaced with new

sections of mainline. On the other hand, washing tubing with a pressure washing provides opportunity for the producer to locate and repair small leaks in the system that otherwise might go unnoticed. Valves should be installed at every junction where one mainline branches from another. This will allow the wash water to be concentrated in a small area of the tubing system, rather than have it spread over a larger area, thereby dissipating the pressure. If several mainlines empty into one tank, pressure washing is made easier by connecting them to a single short line, which can then be attached to the air/water outlet of the pump. This will result in a short mainline with many branches. Valves should be installed at each branch so that the pump can alternately service one mainline after another as the valves are respectively opened and closed.

Only potable water should be used for cleaning the tubing. It is not recommended to use pond or river water as more microbial organisms may be added than are being removed. Thorough cleaning of a tubing system with a pressure washer requires about 1/3 gallon (1¼ liter) of water per tap. This amount will vary depending on the size of the system, as well as the length of the lines involved.

Washing sap collection lines can be accomplished in a number of ways, depending on producer preference and tubing system design. Below are some recommendations that may be helpful:

1. Connect the pressure washer to the end of the system closest to the sap tank. Flush the primary mainline with the valves to any secondary mainlines closed and the valve at the far end of the primary line open (if such a valve is present). Flushing should continue until the water runs clear[37].
2. Once the primary line is cleaned, the shut-off valve at the far end is closed. If there are secondary mainlines, begin cleaning the one closest to the sap tank by shutting valves leading to any other secondary mainline. Flush this branch mainline by opening the valve at the far end just as in #1.
3. Begin cleaning the lateral lines connected to this mainline, starting with the line closest to the sap tank. Work down the line and pull three or four spouts out of the tapholes and let the water spray out. After 10 or 20 seconds plug the spouts onto the peg or cup on the T, or use some other method to close them off tightly. Some producers attempt to scrub the end of the spout with a cloth or sponge before plugging it. This may be effective in removing dirt from the spout, but is also likely to get the operator quite wet.

Below are some alternative methods to pressure washing:

4. If two or more people are present to help with washing, all the spouts on one or more lateral lines can be removed from the trees before the lines are washed, as long as adequate washing pressure is maintained. Be sure to plug each spout when finished. When moving from one line to the next it is easy to miss a spout or two; it is preferable to remove all spouts on a single line at the same time.
5. A common alternative to the method described in #3 is to start each lateral line by pulling the end spout and allowing water to flush through the whole line. The end spout from several lines can be removed at the same time. Do this before other spouts are removed on each line.
6. Another alternative is to begin the cleaning operation by cleaning the lateral line farthest from the sap tank, and then working towards the lowest end of each mainline. It is possible to also work down each lateral line in the same manner, beginning at the far end and working towards the mainline[38].

Many producers maintain modern tubing systems using water alone. This is the preferred

[37]This process cleans large debris and spoiled sap from mainlines without forcing it through lateral lines.

[38]The order in which secondary mainlines and lateral lines are cleaned is very important when shut-off valves are not present at the end of mainlines and at the base of secondary mainlines. If secondary mainlines and laterals closest to the pressure washer are cleaned first, the amount of mainline debris forced through the lateral and spout is minimized. If, on the other hand, cleaning is begun with those laterals and secondary mainline farthest from the washer, much of the debris accumulated in the mainline will be forced through those farthest laterals and spouts.

method as no chemicals are introduced into the system. However, some maple syrup producers use chemical cleaners and sanitizers. If sanitizers are used it is important that all products used are approved, as appropriate, by either the Canadian Food Inspection Agency (CFIA) in Canada or the Environmental Protection Agency (EPA) in the United States. In Canada, all sanitizers must be registered by the Canadian Pest Management Regulatory Agency. Cleaners are not regulated; however, producers should determine which products are recommended for use in their jurisdiction.

Sanitizing, disinfecting, and cleaning chemicals currently in use in the maple industry include:

- Sodium hypochlorite (the active ingredient in bleach) solution was once a commonly used sanitizing agent in the maple industry, and is still used by some to sanitize tubing. While sodium hypochlorite is an accepted sanitizing agent in the food industry, its use in maple tubing presents some challenges. It is effective but difficult to rinse completely from the tubing, and, if not completely removed it has the potential to contribute to the production of off-flavored syrup. Animals, particularly squirrels, are attracted to the sodium hypochlorite residue, and will frequently chew tubing and fittings that have been washed with a bleach solution. It has been observed that a significant decrease in squirrel damage often occurs after the use of washing solutions containing bleach has been discontinued. If a decision is made to use a bleach washing solution it is suggested that it be used at a rate of 500 to 600 ppm[39]. If household bleach is used as the source of sodium hypochlorite, 500 ppm is obtained by mixing 1 part of 5 percent household bleach to 99 parts water; 600 ppm is obtained by mixing 1 part of 5 percent household bleach with 83⅓ parts water. Note that these ratios change if a sodium hypochlorite source other than 5 percent household bleach is used. When using other concentrations of sodium hypochlorite, the following formula can be used to determine the mixing ratio:

$$\text{Volume of Bleach} = \frac{\text{(Desired Volume of Cleaning Solution) X (Desired Concentration of Sodium Hypochlorite in ppm)}}{\text{(Percent Concentration Sodium Hypochlorite in Bleach) X (10,000)}}$$

  For satisfactory results the sodium hypochlorite solution may require anywhere from 5 minutes to several hours of contact time. Traditionally, many producers have allowed the solution to remain in the tubing over night, followed by a thorough rinsing the following day. Because all traces of sodium hypochlorite are difficult to remove by rinsing, the use of bleach solutions to clean tubing is not as widely used as it once was.
- Food-grade hydrogen peroxide also is a good disinfectant. The current recommended rate for hydrogen peroxide is 1000 ppm (2 parts hydrogen peroxide with a 5 percent active ingredient in 98 parts water). Hydrogen peroxide is more expensive than bleach, but it breaks down without leaving any residue and does not attract squirrels or other rodents.
- Acid cleaners, such as phosphoric acid, are sold under a variety of brand names as cleaners to be used in the maple industry for the removal of sugar and salt deposits from evaporators and other similar equipment. While some producers are using these cleaners to clean tubing (at a greater dilution rate than that used for evaporators) acid cleaners are not recommended for use in cleaning tubing.
- Household and industrial soaps and cleaners and any other sanitizer not appropriately labeled for use in maple tubing should not be used to clean tubing.

Whatever the method and materials used to clean tubing, it is important to remember that as tubing ages, natural deterioration of the inner tubing surface makes removal of microbial growth increasingly more difficult. Current recommendations are for a 10 to 15 year replacement cycle for all tubing.

It is important to maintain records of the cleaning and sanitizing treatments that are used to

[39]This rate is substantially lower than the 2500 ppm (1 part 5 percent household bleach with 19 parts water) sometimes used by producers. It is, however, substantially higher than the rate commonly recommended for sanitizing food preparation surfaces, which is often 200 ppm. This rate is recommended with the understanding that the tubing will be thoroughly rinsed after treatment.

clean tubing and related sap collection equipment. Traceability in food production is becoming increasingly important, and if a problem such as off-flavor develops, it is important to be able to relate it back to a possible cause. When chemicals have been used to clean tubing collection systems, some producers choose to discard the first collected sap until the lines have been thoroughly filled and rinsed with sap.

## Mechanical Vacuum Systems

Sap flows from wounds in trees when there is a higher pressure within the stem than outside the tree in the atmosphere. Vacuum pumping removes air from the tubing system and the taphole, thereby lowering the pressure within the tubing and at the taphole. In so doing, a pressure gradient between the inside of the tree and the tubing network is created. The differential pressure gradient established by vacuum permits sap to flow even when atmospheric pressure outside the tree and internal hydraulic pressure within the tree are the same. This pressure differential also results in more rapid sap removal from the tree when conditions are favorable for sap flow. Research has demonstrated that an appropriately configured and effectively working vacuum pump (**Figure 6.31**) attached to a tubing system can increase sap yield by 50 to 100 percent or more.

Figure 6.31. An oil-cooled vacuum pump appropriate for use with a tubing system.

In each sap season, there are a number of days when conditions are not ideal for a good sap run (e.g. no significant difference exists between internal pressure within the tree and outside atmospheric pressure). When this condition is present, sap flow can be induced or prolonged by the use of vacuum. This increase in sap flow can increase total seasonal sap yields substantially, and may turn an average or below average season into a good sap season.

Although any level of vacuum will increase flow, to be economically viable a vacuum system must be capable of producing a vacuum gauge reading of 15 inches of mercury at the far end of the lateral tubing. This usually requires that the level of vacuum at the pump be higher due to vacuum loss that occurs within the tubing system. The higher the vacuum level is, the greater the yield of sap. Recent research testing vacuum levels at the tree as high as 23 inches of mercury has shown that high vacuum does not physically damage the tree, nor does it significantly change the concentration of sap sugar or mineral nutrients in the sap compared to sap collected by gravity.

## Vacuum Pumps

The basic vacuum system consists of a vacuum pump (the source of the vacuum) (**Figure 6.31**) and a mechanically or electrically operated extractor (also called a releaser) (**Figure 6.32**), which transfers sap from the tubing network into a collection chamber, and then to a storage tank. While this sap transfer is occurring, an extractor is necessary to maintain vacuum within the tubing system. Several different types of mechanical vacuum pumps are available. It is often preferable that vacuum pumps be electrically powered since electric units lend themselves to increased automation as well as requiring less daily maintenance. Gasoline motors can also be used, although more time is required for refueling and maintenance. Several types of vacuum pumps are available including rotary-vane, piston type, and liquid-ring. Older rotary-vane vacuum pumps, originally designed for use on dairy farms, are available in some regions and have been used successfully for maple sap vacuum systems. If these types of pumps are used it is important to

remember that they must not be allowed to run dry of oil, and that some pump damage is possible when they are operated for an extended period of time at vacuum levels higher than about 13 to 15 inches of mercury.

A common type of vacuum pump designed for maple systems uses a rotary-vane impeller. These pumps are available with an oil-reclaiming unit, also termed a "flood system," in which the oil for lubrication and cooling is recycled and re-used. Pumps may be air or liquid-cooled. Water-cooled pumps, such as the liquid-ring pumps, require a source of water for cooling, but can easily achieve vacuum levels of 26 to 28 inches mercury as long as the temperature of the cooling water stays low. They are designed for continuous running, but if water-cooled must be protected from freezing. Some liquid-ring pumps use oil for cooling and do not have to be protected from freezing. The newest type of pump, available through dairy equipment manufacturers, is a variable drive pump. Variable drive pumps use vacuum sensors in the tubing system to reduce motor speed when desired vacuum levels are reached. This feature significantly reduces total energy use in a well-designed and maintained tubing installation.

Figure 6.32. Two different types of extractors.

A vacuum pump produces a vacuum in the tubing system by removing air from the tubing lines. If the tree-tubing system were a totally airtight system, once the vacuum was developed it would remain without the need to remove additional air. However, the tree-tubing system is not completely airtight. Air enters from the taphole through leaks in the tubing and from small amounts of gases that are dissolved in the sap. As a result, a tubing system must have the proper pump capacity to maintain the desired vacuum level. Pump capacity is measured in the amount of air moved, expressed in cubic feet per minute (cfm). A common rule of thumb suggests that pump capacity should range from 1 to 1½ cfm for every 100 taps (e.g. 1000 taps would have a pump of 10 to 15 cfm)[40]. These guidelines assume that mainlines are properly sized so that there is little reduction in pumping capacity (cfm) to the lateral lines. Ultimately it is the vacuum level at the taphole out in the sugarbush, as influenced by the pumping capacity, that directly affects sap yield. Obviously, regular maintenance of the tubing network to minimize leakage is extremely important if optimal vacuum levels are to be achieved and maintained.

A device to trap any moisture in the vacuum line, commonly referred to as a moisture trap, must be

[40]Some producer experience suggested that in extremely flat terrain a pump capacity of 2 cfm or more for every 100 taps can lead to substantially greater sap yields.

installed between the pump and the extractor to reduce the potential for sap to enter and damage the pump (**Figure 6.33**). It is commonly recommended that a vacuum gauge and relief valve be installed at the pump to enable the desired level of vacuum to be maintained.

Figure 6.33. One form of moisture trap. A moisture trap should be installed between the vacuum pump and the extractor to reduce the potential for moisture damage to the pump.

## Operation and Maintenance of Vacuum Systems

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

To achieve the maximum benefit of a vacuum system, the pump should be in operation during any period when sap will flow throughout the production season. The pump should be turned on when extractors are free of ice and mainlines are running at the very beginning of a sap flow event. If vacuum pumps are activated too early while ice is prevalent, ice can clog the extractor valves and delay thawing of mainlines. Ice crystals can also accumulate at the locations of couplers or any other restriction in the mainline such as a lateral manifold. When sap flow ceases because air temperatures have dropped, such as occurs towards the end of the day, the vacuum pump should be shut off. If freezing temperatures do not occur (e.g. during periods of weeping flows), the vacuum pump may be operated night and day if desired. The pump can be operated manually with an on/off switch, or a temperature-sensing switch can be installed to start or stop the pump at or near the freezing point. A sensing switch can also be installed in the extractor to turn the pump on or off in relation to the presence of sap in the extractor unit.

## Extractors

The vacuum pump is connected to an extractor (**Figure 6.32**) or dump unit attached to the mainline system. The purpose of an extractor is to collect sap from mainlines and allow it to be moved to a larger tank without interrupting the vacuum. Extractors are either mechanical or

electrical or hybrids of the two types. Mechanical extractors work by gravity and empty sap directly into a storage tank when the weight or volume of sap triggers a mechanical release mechanism. Mechanical releasers sit on top of the sap tank, thus the incoming mainlines must be higher than the top of the tank to use this type of releaser. When the vacuum pump is not running, any free-flowing sap trickles through the extractor or from open valves from the mainline, reducing the risk of freezing. Electric extractors operate with a liquid pump that removes sap from the collector to a storage tank. The storage tank can be located above or at some distance from the extractor. Extractors are available in a variety of sizes ranging from those designed for several hundred taps to those designed for many thousands of taps.

## Sap Storage

Sap storage is an important step in the production of quality maple products. Adequate sap storage is necessary not only to hold sap until it is processed, but also to supply a constant flow of sap to the evaporator or other sap processing equipment. Proper sap storage involves correct sizing of storage facilities, maintaining cleanliness, and managing temperature and light levels.

Sap storage capacity is a function of the number of taps, how quickly boiling can occur, the capacity of a reverse osmosis unit if used, and the size of the evaporator. To avoid losing sap during heavy runs, it is suggested that a sap storage capacity equivalent to two good days of sap flow be available. On the average this amounts to 2 to 3 gallons of storage per tap. In locations where back-to-back large flows are common, or good vacuum levels are achieved, some producers choose to have as much as 4 gallons of sap storage capacity per tap. However, this large storage capacity is the exception rather than the rule, and certainly is influenced by many factors, including how quickly sap can be processed. Estimates of total storage capacity should include the storage tanks at the sugarhouse plus any secondary storage tanks (transfer or dump tanks) in the woods. Producers collecting with buckets/bags should also recognize that buckets/bags provide additional storage. While bucket/bag storage does not replace adequate tank storage at the sugarhouse, it is important in estimating storage needs to handle periods of large sap flow.

In most maple operations, sap is stored in tanks located at or adjacent to the sugarhouse. It is desirable, even for small-sized operations, to have more than one storage tank at the sugarhouse. This allows empty tanks to be cleaned to receive fresh sap rather than dumping freshly collected sap into a tank partially filled with older sap.

Tanks must be constructed of food-grade materials that will not contribute to contamination of the sap. For ease of cleaning, surfaces should be nonabsorbent, smooth, corrosion resistant, and able to withstand repeated cleaning and sanitation. Stainless steel, food-grade plastic, fiberglass, and glass meet these standards. Porous tanks, such as unsealed concrete, are not suitable as sap storage tanks. Tanks with lead solder or rust should not be used. It must be remembered that the evaporation process concentrates contaminants. Commercial sap storage tanks are available from maple equipment vendors. Glass-lined or stainless steel-lined tanks from the dairy, brewery, or food processing industries are often used. Both new and used tanks from a wide variety of sources are available. If used tanks are selected for sap storage, only tanks that meet requirements for storing food grade materials should be purchased.

Sap storage tank location requires planning. Wherever possible, tanks should be located to allow gravity filling and emptying. When this is impractical, electric or gasoline powered pumps can be used. Use strong supports and platforms when it is necessary to elevate tanks. Storage tanks filled with sap are heavy and require substantial support (one U.S. gallon of sap weighs slightly more than 8⅓ pounds; one liter of sap weighs essentially 1 kilogram).

Storage tanks should be placed in cool locations, not inside the sugarhouse near the evaporator. Some options for accomplishing this include underground tanks; placing the tanks on the cooler, shaded side of the sugarhouse (usually on the north side); placing tanks in a separate room of the sugarhouse; or building a tank shelter

adjacent to the sugarhouse. Tanks located outside and in an above-ground location should be reflective white or silver in color. All tanks with open tops should be covered to prevent contamination from foreign materials such as dust and rain. Tank covers should be appropriately colored and designed to allow air circulation to avoid heat build-up.

Sap storage tank design and location should also facilitate cleaning and maintenance. Closed tanks should have easy access. The insides of the tanks should be relatively smooth to avoid areas that are difficult to clean and where residue can collect. Producers using enclosed tanks need to follow safety precautions when cleaning in confined spaces. Each time a tank is emptied it should be thoroughly brushed and rinsed, preferably with hot water. At the end of the season, storage tanks should be thoroughly scrubbed with a nylon brush and bleach solution and triple rinsed with potable water to remove any residue. As with other sap processing equipment, this cleaning should not be postponed since any residue will dry and will form a film layer that is difficult to remove. Use caution when cleaning tanks with chlorine solutions, particularly with enclosed tanks (workers should wear respirators to avoid breathing fumes when cleaning with chlorine solutions). Prior to being used at the beginning of the season, storage tanks should be cleaned and rinsed with chlorine solution and triple rinsed with potable water.

Sap storage tanks must be well maintained. Leaks should be repaired using only food-grade materials. Under no condition should solder containing lead be used. Although corroded tanks can sometimes be painted, it is not a recommended practice. Surface preparation is difficult, but critical, for proper coverage and long-term paint durability. Rust and lead-based paint can be completely removed only by sand blasting or the use of an acid bath. Only a two-part, food-grade, epoxy resin paint should be used to coat the interior of the tank. This type of paint is costly, has a very short shelf-life after being mixed (20 to 45 minutes, depending on the temperature), and is difficult to apply properly. Only professionals should attempt surface preparation and painting. Painting is best done at the end of the season to allow time for paint to completely harden and for odors to dissipate, thereby reducing the possibility of flavor contamination. Many paints that are purportedly for "food use" are actually for **incidental** food contact, and are not meant to be used for extended food contact such as buckets or tanks.

Other considerations associated with sap storage tanks include the use of sight tubes with closed or elevated tanks for easier determination of sap supply, and the proper grading of transfer pipes between the tanks and the evaporator to reduce freezing and to provide effective tank drainage. In addition, some large producers use dump or transfer tanks in the sugarbush. For example, a 500- or 1000-gallon tank might be permanently located in the sugarbush as a dump tank. Sap dumped into this tank is transferred by gravity or pump to the storage tanks at the sugarhouse. Such systems must use float valves to prevent accidental overflow and sap loss at the sugarhouse. All of the desirable characteristics identified for sap storage tanks at the sugarhouse apply equally to dump or transfer tanks (e.g. they must be kept cool, and they must be clean and periodically re-cleaned).

## Ultraviolet Lights and Sap Filters

The importance of minimizing microorganism contamination in producing quality maple products has been repeatedly emphasized. Two pieces of equipment that are used by some maple producers to minimize microorganism contamination of sap are ultraviolet lights (UV) and small pore filters.

Passing sap through an in-line UV unit when the sap is transferred from the collecting tank into the sap storage tank has been demonstrated to reduce the amount of living microorganisms (particularly bacteria) in stored sap (**Figure 6.34**). In many instances this has resulted in longer sap storage times without a reduction in the grade of syrup produced, and in the production of higher-quality syrup, particularly late in the season when microorganism contamination is usually highest.

Commercial in-line UV units for use in treating maple sap are available through maple equipment dealers. However, only UV units designed specifically for maple sap have been verified as effective. Commercial units designed for water systems are less effective. All UV units must be properly maintained and operated within the flow limits for which they were designed. Caution is necessary when using ultraviolet light as it can cause serious eye damage. Ultraviolet lights suspended over sap storage tanks are dangerous to the naked eye. Ozone-based sterilization units have been introduced into the maple industry, although their efficacy has not been well established, and some research seems to indicate that sap sugar interferes with ozone action.

Passing sap through a small-pore filtering system as the sap is transferred into the storage tank can also markedly reduce the microorganism content of the sap (**Figure 6.34**).Microorganisms in sap range in size from hundreds of microns to less than a micron[41]. They have the potential to rapidly increase in number, especially if sap temperatures are high. Commercial sap filters, as well as other types of liquid food filters, can be used to filter microorganisms from sap, potentially extending its storage life and improving the quality of syrup produced. These filters range from coarse bag filters that only remove coarse and fine debris, to cartridge filters that remove fine debris and microorganisms down to the specifications of the filter (e.g. 5 microns), to food-grade diatomaceous earth (DE) filters that remove microorganisms down to the specifications of the DE. In general, the finer the filter, the more effective will be the filtering process. Usually when very fine filtration is desired, a series of filters are used to perform the filtering process in stages in order to avoid rapidly plugging the fine filter. Research and experience has demonstrated that effective filtration with a relatively fine filter can often markedly improve the color of syrup produced from late-season sap.

Figure 6.34. Two models of in-line ultraviolet filters (UV filters). The blue filter in the left picture is a small pore, cartridge filter.

[41]A micron is one millionth of a meter.

# Chapter 7 · Maple Syrup Production

Converting maple sap into syrup is accomplished by the concentration of sap solids, primarily sugar, through the removal of water, chiefly by evaporation through boiling. The process involves many complex physical and chemical transformations that together affect density, color, and flavor of the product. A wide variety of equipment and practices to remove water and achieve these changes are used. However, the primary goal is the same—to produce a natural, pure, high quality food product.

This chapter focuses on the process of sap concentration, including the use of reverse osmosis. Producers should be aware that some states and provinces have developed voluntary quality assurance programs that incorporate "Best Management Practices." Participation in these programs is recommended for production of maple products of the highest possible quality.

## The Evaporator and its Function

Over the past half century the process of transforming maple sap into maple syrup has undergone tremendous change, driven by several factors. The desire and need to decrease the amount of time required for evaporation, produce a safe, high-quality food product, and reduce production costs have been realized primarily through improvements in fuel efficiency, and changes in available materials and manufacturing techniques.

The earliest method of evaporation was probably the use of a hollowed-out log into which hot stones were added (**Figure 7.1**). Over time a metal kettle that was suspended over an open fire replaced the hollow log (**Figure 7.2**). In both cases, as evaporation occurred, fresh sap would be added until a large enough volume of finished product (syrup) was produced. The result of this "batch process" was a very strong-tasting and dark product that resulted from many hours of sustained boiling.

Figure 7.1. The earliest method of evaporation was probably the use of a hollowed-out log into which hot stones were added.

Figure 7.2. Over time a metal kettle that was suspended over an open fire replaced the hollow log.

The addition of multiple kettles improved both the speed of production and quality of the syrup (**Figure 7.3**). Partially evaporated sap processed in one kettle would be transferred, usually by ladle, to a second kettle. This avoided the mixing of fresh sap with partially evaporated sap and improved

the quality of the syrup produced. Occasionally three to four kettles would be used, with gradually increasing sugar levels in each. Ladling among the pans resulted in a semi-continuous, batch process.

Figure 7.3. The addition of multiple kettles improved both the speed of production and quality of the syrup.

Subsequent innovations were the use of large flat-bottomed pans (rather than kettles) to increase evaporative surface area and thus evaporation rate, and the enclosure of the firebox to retain and concentrate heat under the pans, and to keep wood ash out of the boiling pan. Both of these changes resulted in significant increases in fuel efficiency and rate of evaporation. Pans were soon partitioned into sections to allow separation into different degrees of product completion (sugar concentrations), with transfer from one section to another by ladling or siphoning.

The first "modern style" evaporators appeared around 1900. These incorporated deep channels into the pans or the addition of raised flues, again to increase heating surface area and thus evaporation rate. An enclosed heat source under the pans, combined with the flues, resulted in large efficiency increases in both fuel and time. The reduced fuel and time required to process sap into syrup also resulted in an improvement of syrup quality and dramatically lowered production costs. More recently, accessories to the evaporator such as the Piggy-Back, STEAM-AWAY®, and air injectors have been used to further increase efficiency and to produce higher quality syrup.

Initially, nearly all methods of evaporation (kettles, flat pans, or improved evaporators) used wood as the fuel source. While modern-day evaporators utilize a variety of fuels (wood, fuel oil, kerosene, propane, and natural gas), fuel oil and wood are still the most common.

## The Modern Evaporator

The primary factor distinguishing present-day evaporators from earlier forms is the almost continuous nature of the process for transforming sap to syrup. Where original evaporator units utilized the batch or semi-continuous process,

Figure 7.4. Older, basic evaporator (top) and more modern evaporator (bottom) showing arch, front (syrup) pan with partitions, and back (sap) pan with flues.

modern-day evaporators are designed to have continuous or nearly continuous flow. Sap is introduced into one portion of the evaporator; the sugar concentration increases as it moves through the evaporator system until it is drawn-off as syrup. Flow is moderated via a system of mechanical floats or electronically controlled valves with relatively little operator intervention required once the evaporator is running.

Newer, more tightly constructed sugarhouses often require ventilation ducts to supply adequate air for the proper combustion of the fuels. Increased air inlets may also be needed for adequate venting of steam from the evaporator.

Modern evaporator systems are comprised of four distinct parts: the arch or firebox, the heat source itself (fuel and burner), the back or sap pan, and one or more front or syrup pan(s). The rear pan, which is also called the sap or flue pan, is normally about two-thirds the length of the entire evaporator and is connected to one or more front or syrup pans. The pans are piped together when the evaporator is in use, but can usually be separated with valves or plugs to facilitate their removal from the arch for cleaning and repair. Partitions are built into the pans to form channels to direct the flow of sap through the evaporator so that sap follows a winding path from the inlet to the outlet. This prevents fresh sap from mixing with partially processed sap and allows a sugar concentration gradient to be established along the length of the evaporator pathway. The location of the partitions and the size and shape of the channels they form vary among manufacturers and models. The pans (front and back) rest atop the arch (**Figure 7.4**).

## The Sap or Flue Pan

The flue pan is so named because of the construction of the pan bottom; deep channels or flues are built into the pan, greatly increasing their surface area and thus the heat exchange capacity when compared to a flat-bottomed pan (**Figure 7.4 and 7.6**). One or more partitions guide the sap from the entry point to the pan exit point. Very rapid boiling takes place in this pan and the resulting water vapor can be used to heat incoming sap, or even to initiate some evaporation from incoming sap using an attachment such as a STEAM-AWAY® or a Piggyback. Condensed, the water vapor can serve as a source of clean hot water.

The amount of sap that flows into the flue pan is controlled by a float or electronically operated valve fitted into a regulator box (**Figure 7.5**). The float is adjusted to control the depth of sap in the evaporator pans. From this entry point, sap flows via a distribution pipe into the flue pan. With reverse flow syrup pans (described below) the producer selects one side of the evaporator to draw syrup off, and then selects the proper sap distribution pipe, using a plug or valve, so that the sap will take the longest possible path through the evaporator during the boiling process. With some front pans the syrup is always drawn off on the same side and there is no need to direct the incoming sap to more than one side.

Figure 7.5 Regulator box on the side of the flue pan, which controls the flow of sap into the flue pan. In this regulator box, sap flow into the flue pan is controlled by a float valve.

Figure 7.6. Evaporator with a raised flue sap pan and two cross flow syrup pans (left) and an evaporator with a drop flue sap pan and a reverse flow syrup pan (right). In regard to the sap pans, note that the top of the raised flue sap pan sits somewhat higher relative to the syrup pan than the drop flue sap pan. With respect to the syrup pans, note that this particular reverse flow pan has four parallel channels and a fifth at right angle (nearest the sap pan) that allows the flow to be reversed without changing the draw-off side. Many reverse flow pans do not have the right angle channel but only the parallel channels, and the draw-off side must be switched when the flow is reversed.

Flue pans, which sit on the arch behind the syrup pan, are of two types—"drop flue" and "raised flue" (**Figure 7.6**). With "drop flue" pans the flues extend down into the arch; with "raised flue" pans the flues rise 6 or 7 inches into the pan. The choice between using a raised or a drop flue pan is largely a matter of individual preference and local tradition, although there are advantages to each design. Some manufacturers build heat exchange pipes into the dropped portion of the pan, rather than using open flues.

**Drop Flue**—Sap pans are built with the flues or corrugations, running lengthwise. These flues are below the level of the top of the arch when properly installed. Heat from the burning fuel passes directly between the flues on its way toward the rear of the arch and up the smoke stack. Drop flue evaporators are usually slightly less expensive than raised flue evaporators since a single float box controls the level of sap in both the flue and syrup pans. With wood-fired arches, care must be exercised during firing to not damage the front ends of the flues as wood is pushed back into the arch.

**Raised Flue**—A sap pan designed so the flues rise 6 or 7 inches above the top of the arch, with the sap level being several inches higher than the liquid in the syrup pan, is called a raised flue pan. In a raised flue pan, a second float box controls the flow of sap from the flue pan to the syrup pan. Because of this second float box, a producer using a raised flue pan can independently regulate the level of sap in each pan. If there is a need to add sap quickly to the syrup pan, this can be accomplished by pressing down on the float of the front box to deliver needed sap to the front pan. In

wood-fired evaporators the raised flue construction provides protection to the bottom of the flues from damage during firing.

Another major difference in the two pan types is that the flue ends are open in raised flue pans and closed in drop flue pans. In a drop flue pan, sap can only move up or down at the flue ends. This can be considered a disadvantage because suspended sugar sand can become trapped. In contrast, the ends of raised flues are open to a channel that surrounds the outside of the pan to the depth of the flue bottom. This allows sap to move horizontally out of the flue ends and helps to minimize burning that can occur when sugar sand or niter collects in the enclosed dropped flue end. On the other hand, the outside channel of the raised flue pan is less exposed to the fire and may be a less efficient place for heating the sap. The question of which type of flue pan is more efficient for heating sap is subject to considerable debate, and may differ with the type of arch and fuel being used.

Recent changes in the design of some flue pans include taller sides and an increased number of partitions in the pan. Newly manufactured pans that are produced by welding have sides that are as much as 8 inches taller than comparable soldered pans. This allows for faster boiling without sap splashing out or foam overflowing the sides. Many new flue pans have an additional internal partition to help prevent mixing of partially boiled sap with the incoming sap. Another recent innovation is the electronic valve, which can replace either of the regulator boxes and floats. With this unit, sensors control the opening and closing of the valve to precisely maintain a predetermined level of sap in either pan. Although most electronic systems are simple on/off valves, a newer style of proportioning valve is just being introduced into the maple industry.

## The Syrup Pan

Syrup pans have flat bottoms and internal partitions to channel the boiling sap as it increases in density either from side-to-side (cross flow) or from front-to-back (reverse flow). Reverse flow pans (**Figure 7.6**) commonly have three or more partitions that divide the pan into compartments; cross flow pans normally have one partition to divide the pan into two compartments and are used in pairs, or a set of three in very large evaporators (**Figure 7.6**). Syrup pans can have either a single syrup draw-off valve or a draw-off on each side of the pan. Traditionally, reverse flow pans were designed to allow draw-off on either side; this configuration allows sugar sand build up to be minimized. Sugar sand or niter is produced anywhere in the evaporator during the boiling process, but normally the greatest amount accumulates where the sugar concentration is the highest—in the syrup pan channel nearest the draw-off. Reversing the flow in the syrup pan can clean off some of this accumulation and helps to balance the sugar sand on both sides of the pan and prolong the time the pan can be used before cleaning. Recent design changes in some reverse flow pans allow flow to be reversed while maintaining syrup take-off on a single side, which allows more efficient use of space in the sugarhouse (**Figure 7.6**).

Instead of using the reversing feature to minimize the build-up of sugar sand, cross flow pans are intended to be rotated frequently so that a clean pan is substituted for a niter-coated pan. The pans are normally supplied in sets of three; two are used on the evaporator at one time and the spare third pan is kept clean. This style of boiling requires shutting down the evaporator more frequently than with a reverse flow. It is more difficult to change cross-flow pans when the arch is fired with wood as opposed to oil, natural gas, or propane. In pans with the cross flow design the syrup pan is actually two separate pans connected by pipes that can be closed off with valves or plugs (**Figure 7.7**). An advantage to this design is that when the evaporator is shut down at the end of the run, the partially boiled syrup can be isolated in each front pan by plugging the pipes, instead of mixing throughout the whole syrup pan, as it does in reverse flow systems. Cross-flow pans have the syrup draw-off on one side only; the producer chooses the configuration at the time of placing the order.

Figure 7.7. Pipe connecting cross flow syrup pans.

## Syrup and Sap Pan Construction

Since the early 1990s a major shift in evaporator construction has occurred. Welding has almost entirely replaced solder for pan construction. Although it is possible to purchase a new soldered evaporator, for reasons of the appeal of traditional equipment or for the small cost saving compared to welded pans, most purchasers prefer the appearance, durability, and food safety aspects (see discussion on lead in the following section) of welded equipment. Stainless steel has replaced a variety of materials formerly used in evaporators, including rubber hose, English tin, and bronze valves. Most new pans are made using 304-stainless steel, a nickel-based alloy that is somewhat more corrosion resistant than 430-stainless steel used by most manufacturers a decade ago. In constructing the evaporator, parts are cut using computer controlled lasers and punches for a precise fit, and components are welded by machine or by hand. Welding requires somewhat thicker metal than soldering, and most welded pans use 20 or 22 gauge steel compared to 24 gauge steel that was commonly used in most soldered pans. Welded equipment is generally made from bright annealed stainless. This finish is the result of a chemical treatment that is incompatible with solder. Soldered equipment has a softer, brushed finish.

## Lead in Maple Equipment

Older equipment fabricated from materials that have a high lead content should not be used to process maple products. Evidence gathered over the past 30 years indicates that accumulation of lead in the human body can have significant health consequences. Most evaporators manufactured before 1995 were constructed using some lead-containing materials. Primary among these materials was 50:50 solder (50 percent tin and 50 percent lead). Galvanizing used in maple equipment constructed before 1994 contains lead, as do evaporators constructed of terneplate, a lead-containing alloy. In addition, most bronze or brass fittings manufactured around the same time period also contain some lead. Maple producers should consult with their equipment manufacturer to determine whether the evaporator being used was manufactured from materials that contained lead. Low-cost lead testing kits are also available from most maple equipment dealers and some hardware stores

The move to using only lead-free equipment in the production and storage of maple syrup and maple products and the phasing out of old galvanized and other leaded equipment is supported, promoted, and encouraged by all state and provincial regulatory departments. However, until such time that all lead-containing equipment has been replaced, maple syrup producers should minimize the time that sap and syrup are exposed to lead-containing materials. Any maple producer using equipment that contains lead should have the produced syrup tested for lead on a regular basis, preferably at the beginning, middle, and end of each season.

It is recommended that before any new or used maple equipment is purchased, the manufacturer or seller provide certification that it has been manufactured from lead-free materials.

## Evaporator Size and Rate of Evaporation

Modern evaporators are commonly available in sizes ranging from 2 feet wide by 4 feet long (referred to as a 2 x 4 evaporator) to 6 feet wide by 18 feet long (referred to as a 6 x 18). The larger the evaporator, the greater the evaporation rate per hour. **Table 7.1** provides estimates of the evaporating capacity of conventional evaporators

of different sizes. Evaporator capacities provided by several different manufacturing companies were averaged to develop these estimates. The capacity information should be used only as an approximate guide since there is considerable variation in evaporation capacities among units made by different manufacturers, and some manufacturers have incorporated efficiency improving modifications that substantially increase productivity above that reported in the table.

**Table 7.1. Estimates of conventional evaporator capacity in gallons and liters per hour.**

| Evaporator Size (width x length) feet or inches | Evaporation Capacity U.S. gal/hour | Evaporation Capacity liters/hour |
|---|---|---|
| 2' x 4' | 15 | 57 |
| 2' x 6' | 25 | 95 |
| 2' x 8' | 35 | 132 |
| 30" x 8' | 50 | 189 |
| 30" x 10' | 60 | 227 |
| 3' x 8' | 70 | 265 |
| 3' x 10’ | 85 | 322 |
| 3' x 12’ | 100 | 379 |
| 40" x 10' | 110 | 416 |
| 40" x 12' | 120 | 454 |
| 4' x 10' | 120 | 454 |
| 4' x 12' | 140 | 530 |
| 4' x 14' | 170 | 643 |
| 5' x 12' | 205 | 776 |
| 5' x 14' | 230 | 871 |
| 5' x 16' | 280 | 1060 |
| 6' x 14' | 310 | 1173 |
| 6' x 16' | 340 | 1287 |
| 6' x 18' | 380 | 1438 |

The size of evaporator appropriate for a particular maple operation depends on several factors including the number of taps or amount of sap to be processed, how quickly the sap will be processed, the amount of time available to process the sap, future plans, and the amount of capital available. Also important is whether sap will be processed with an evaporator alone, or whether a reverse osmosis unit and/or back pan addition such as a STEAM-AWAY® or Piggyback will be used. While it is probably not economical to purchase equipment that will process the "granddaddy" of all sap runs, the evaporator should process large runs in a reasonable time period. A good run may produce 4 to 5 quarts (3.8 to 4.75 liters) of sap per taphole (if different in your location, use the appropriate quantity).

If, for example, a producer has a 3000-tap sugarbush and wishes to process all of the sap the day it is collected, and has 9 hours available during the day to devote to boiling, and decides that 1 gallon (3.8 liters) of sap per tap is a large run, an estimate of the size of evaporator needed can be made as follows:

Number of Sap Gallons in Run =
3000 taps x 1 gallon/tap = 3000 gallons

Time Available for Boiling = 9 hours

Evaporating Capacity Required =
3000 gallons/9 hours = 333 gallons/hour

According to **Table 7.1** this would require a conventional evaporator that was 6' x 16'.

If a STEAM-AWAY® or Piggyback, capable of increasing the evaporation rate by an average of 65 percent, was used in combination with this evaporator, the same number of gallons of sap per hour could by processed using a 5' x 12' evaporator, with a capacity of 205 gallons per hour (from **Table** 7.**1**) x 1.65 = 338 gallons per hour.

If a reverse osmosis machine, capable of removing 75 percent of the water from the raw sap, the producer would only need to boil 1/4 as much sap per hour, or 83 gallons (314 liters) per hour. This could be accomplished with a 3' x 10' evaporator.

It is recommended that producers consult with equipment dealers to determine and select the appropriately sized evaporator. As the above example illustrates, there are several combinations of equipment that influence the amount of sap that can be processed per hour. By adding a reverse osmosis unit and/or a STEAM-AWAY® or Piggyback, yearly fuel costs are lowered in the above

examples, while the overall purchase price for the new equipment is only slightly higher due to the smaller evaporator needed. Another approach, which requires a larger initial investment, would be to purchase an evaporator as specified in **Table 7.1** and use a reverse osmosis unit or other equipment to reduce boiling time, thereby reducing both fuel and labor costs, as well as gaining capacity for future expansion. In any case, it is wise to heed the following precautions.

- First, do not be overly generous with the amount of time available for evaporating. It is easy to sit at a desk and commit to extra hours in the sugarhouse; it is far more difficult when those hours have to be worked because of the desire to save on the purchase of equipment. For most individuals, a 10-hour workday is probably the maximum that should be used in planning. Realistic time commitments also provide a "safety margin" for the exceptionally large run, as well as time necessary for preparation before boiling and cleaning up afterwards.
- Second, plan for at least ten years in the future. While the life of a carefully maintained evaporator is considerably more than ten years, it provides a meaningful planning horizon. If future plans call for an increase in the size of the operation, incorporate that growth in the planning and purchase of the initial equipment.

## Reverse Osmosis, Steam Hoods, Preheaters, Piggyback, STEAM-AWAY®, and Air Injection

To increase the efficiency of "standard evaporators," several different accessories have been developed that increase the concentration of sugar in sap before it is processed, or that utilize heat in the evaporated water or steam from the boiling sap. These units vary in design and degree of sophistication; however, all reduce the time necessary to evaporate a given quantity of sap. A description of the general design and principle of operation of each is provided.

**Reverse osmosis** units (RO) are technically not a part of the evaporation process that occurs in the evaporator. However, the use of a RO machine as part of the maple syrup production process will significantly affect the operating efficiency, as well as productivity of an evaporator. Thus, the reverse osmosis process and its applicability to maple syrup production are considered here. Some suggestions relating to operation and maintenance of RO systems are also included.

Figure 7.8. Two different reverse osmosis machines. Notice large cylinders that contain the semi-permeable membranes. (lower-Girard)

Originally designed and used for desalinating sea water, reverse osmosis as applied to maple syrup production is a process in which the water content of maple sap is reduced by forcing sap, under pressure, across membranes (the pores in the membrane are large enough to permit water molecules to pass through, but too small to allow the passage of sugar and other large molecules (**Figure 7.8**). As the water in the sap passes through these semi-permeable membranes, the sap becomes more concentrated. Passing sap through a RO unit can remove up to 75 percent or more of the water, although lower percentages are more common, especially as membranes age. The resulting concentration of sugar in the sap can be as high as 7 to 15 percent. When sap of

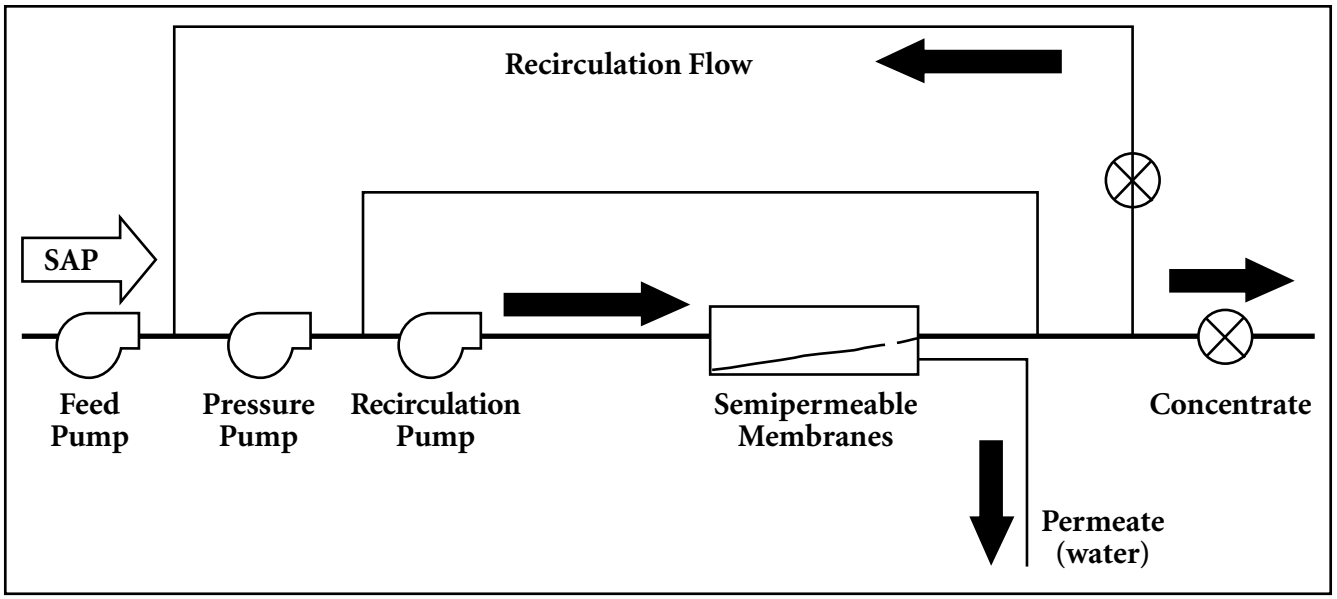



Figure 7.9. Schematic of operation of reverse osmosis machine.

this sugar concentration is placed in the evaporator a substantial reduction in boiling time as well as fuel cost is realized. For example, applying the Rule of 86 discussed on pages 141 and 142, sap with a 2 percent sugar requires the evaporation of 42 gallons of water for each gallon of finished syrup. Sap concentrate with 8 percent sugar requires the evaporation of less than 11 gallons of water for each gallon of finished syrup[42]. Other commonly cited advantages of reverse osmosis include reducing the holding time for unprocessed sap and shortening the time during which sap is processed at high temperatures. These benefits may easily translate into the production of higher quality syrup.

Sap is pumped into the RO machine, placed under pressure, and recirculated across semipermeable membranes (**Figure 7.9**). The concentrated sap (termed "concentrate") is drawn off to be processed through the evaporation, while the permeate (the water removed from the sap) is often stored for use in cleaning the RO and other equipment. The operation of an RO unit primarily involves the adjustment of valves to control the flow rate and concentration level of sap as it moves through the unit. It is critical to maintain proper pressures and flow rates at all times. The correct relationship between the amount of liquid flowing across the membrane (recirculation flow), the amount of water being removed (permeate), and the amount of concentrate being drawn off are also essential to the proper operation of an RO. Reverse osmosis units are available for a variety of sizes of maple operations, but generally are most cost effective for medium and large operations. Throughput capacities vary from about 150 gallons per hour to approximately 3200 gallons per hour.

Specifications for RO units usually provide feed rate in gallons per hour and sometimes an estimate of the number of taps the unit would serve. If the number of taps in the sugarbush is multiplied by the estimated yield per taphole for an average or good run, and this number is divided by the feed rate (gallons of sap processed per unit time) for the RO unit, the resulting number will be the number of hours the unit will require to process the run. For example, with a 2500 tap sugarbush, an estimated good run of 1 gallon per tap, and reverse osmosis unit with a feed rate of 200 gallons per hour, the RO would require 12.5 hours to process the run. If the specifications provide an estimate of the number of taps the unit should service, a similar calculation can be performed to determine how many hours it would take for the unit to handle a large or average size run. Producers should determine the desired processing time and match the ap-

[42] A gallon of 8 percent sap contains 0.688 pounds of sugar; a gallon of 66° Brix syrup 7.28 pounds of sugar. Therefore, 7.28/0.688 or 10.6 gallons of 8 percent sap are required to produce a gallon of 66° Brix syrup.

propriate sized RO unit to their needs. In general, producers should utilize an RO that matches, or just slightly exceeds the evaporation rate of their evaporator. This limits the requirement to store concentrate, which can spoil very quickly due to the high sugar content.

Maple equipment dealers will provide technical guidance regarding the proper operation of an RO unit and assist with the installation. Care must be taken to ensure that the RO unit is properly operated, maintained, and winterized.

Important operational guidelines for RO Units are:

1. Filter the sap with a fine filter before it is processed. The RO membranes are much easier to clean and will not plug up as easily if the sap is filtered. Some producers re-filter their sap several times before it enters the RO. Many producers change the prefilters on their RO units daily to ensure high sap quality.
2. Save all the permeate water possible, since this water is superior for cleaning RO units. It may be desirable to install a special holding tank for the permeate water.
3. Check the water supply for RO compatibility before using it in the RO cleaning process. Chlorinated water is not suitable for cleaning an RO.
4. Always keep sap as cool as possible to minimize microbial growth before it is processed. The growth of microorganisms is encouraged at higher temperatures. This growth can foul the RO membranes; this will slow down the rate of processing and contaminate the sap. The temperature of sap entering the RO unit should remain below 48°F.
5. Consider not using the RO when concentrate will be held for an extended period of time because not enough sap is available to start the evaporator (e.g. slow or weeping sap flows). If the concentrate is not promptly processed, microorganism populations will increase and contaminate the sap leading to the production of inferior quality syrup.
6. Do not concentrate poor quality sap since this can foul the RO membranes and shorten their life span.
7. Do not bring sap to a higher concentration than the manufacturer's specification for the RO unit.
8. Do not let RO sit idle during periods of little sap flow; most units should be operated every day. Bio-films (populations of microorganisms on surface of membranes) need to be washed out daily to protect the permeability of the membranes. Permeate water can be substituted for sap when sufficient sap is unavailable and when there is insufficient sap for continuous processing. Alternatively, the RO unit should be placed in semi-storage during periods of downtime.
9. Follow manufacturer recommendations and guidelines for operation, membrane rinsing and cleaning intervals, maintenance, chemical washes, membrane replacement, and winterization of the RO unit.
10. Consistent record-keeping of the performance of the RO machine on a daily basis is recommended. At a minimum, sap temperature, sap sugar content, operating pressure, permeate flow, and concentrate flow should be recorded.
11. Since the chemicals used for RO cleaning and membrane storage are concentrated, and may be hazardous, care should be taken in their handling, storage, and disposal. Make certain the equipment dealer provides proper instructions for the use of all chemicals needed for the RO, and be sure to acquire and read all Material Safety Data Sheets (MSDS). Improper use of cleaning chemicals can affect the quality of processed syrup. Chemicals are generally specific to the type of membrane used. Use of the wrong cleaner can destroy membranes very quickly.

**Steam hoods** facilitate the movement of water vapor (commonly referred to as steam) away from the evaporator. They are made to fit over the flue pan and syrup pan, and are available for different sized evaporators. The flue pan hood usually sits directly on the pan, while the syrup pan hood is normally suspended about 18 inches (0.46 m) above the pan so that the operator can observe and have access to the boiling sap. A hood with a stack that goes through the roof is an effective means of

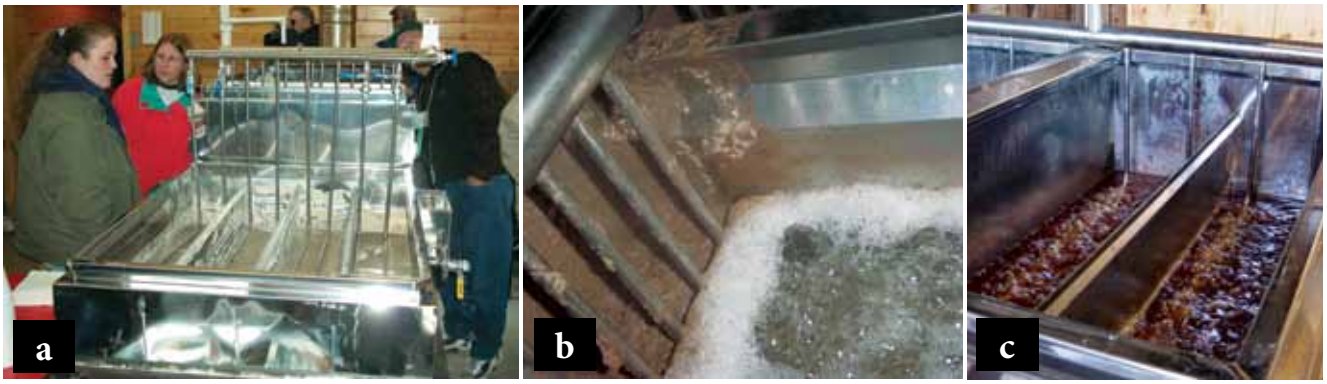



Figure 7.10. Air injection system in empty evaporator (a), and operating in a sap (b) and syrup (c) pan. (b and c - Girard)

removing water vapor from the sugarhouse, but alone will not add appreciably to the evaporation rate. In combination with a preheater, however, a tight-fitting hood over the flue pan will increase evaporator efficiency by about 15 percent.

**Preheaters** use the heat in the evaporated water vapor to increase the temperature of the incoming sap, thereby reducing the amount of fuel required to heat the sap in the evaporator. Most preheaters consist of a series of parallel tubes (usually copper) with a drip tray located below the tubes to collect and direct away the condensate that forms on the outside of the tubes. The outlet for the drip tray passes through the hood, and serves as a source of hot water for cleaning. Some producers choose to fabricate their own pre-heater; a useful reference is Garrett et al. (1977). Lead-free solder should be used in the manufacture of any preheater, as with all commercially manufactured or producer built units.

The **STEAM-AWAY®** and the **Piggyback** are enclosed, manufactured units that sit tightly over the flue pan and use the heat energy in the evaporated water vapor from the evaporator to heat and remove water from the sap before it enters the back or flue pan. These units use an energy recovery steam hood system, along with an air injection system, capturing heat from the evaporated water vapor that would normally be lost through the stack. A float box on the incoming sap line regulates the level of sap inside either unit. These units preheat incoming sap and actually begin the evaporation process. Sap enters the flue pan at a higher sugar concentration, thereby decreasing both boiling time and increasing the efficiency of the evaporator.

Heat is transferred to the sap via a flue pan inside the Piggyback, or by a combination of V-shaped trays suspended over the back pan with steam tubes that pass through sap trays in the STEAM-AWAY®. The heat from the evaporator causes the sap in the unit to approach 200°F (93°C). In both systems an external blower pushes air through perforated pipes that rest in the sap trays, creating air bubbles in the sap that increase the evaporation rate. With either unit, incoming sap at 2 percent sugar will be concentrated to between 3.2 to 3.5 percent before it enters the flue pan.

**Air injection devices** are relatively new (although technically the STEAM-AWAY® is an air injection device) and force filtered air through a series of small holes in stainless-steel tubes lowered into the pans (either the back pan or both pans) (**Figure 7.10**). Although there has been relatively little independent research conducted on these devices as of the publication date of this manual, anecdotal and unpublished research reports indicate that air injection units produce lighter colored syrup but with reduced flavor intensity. Their use is also reported to reduce the amount of sugar sand that forms in the flue and syrup pans. Air injection appears to foster chemical changes in the transformation from sap to syrup, probably through reductions in the carmelization process and alterations in the Maillard reactions[43] in sugar solutions, but little is known about specific effects on flavor development and syrup stability. On-going research on both the efficiency gains in the evaporator as well as the effect on syrup color and flavor can be expected over the next several years.

[43] Maillard reactions are reactions that take place between amino acids and sugars that affect the color and flavor of many food products.

## Increasing Evaporation Efficiency

There are several means of increasing the efficiency of the evaporation process so that a smaller evaporator can be used in combination with other units to achieve the boiling capacity of a larger evaporator, or to reduce the amount of time necessary to evaporate a given quantity of sap. Upgrading an older arch with forced draft and airtight doors, in the case of a wood-burning arch, or equipping an oil-burning arch with a more efficient burner can result not only in fuel savings but in more vigorous boiling and evaporation. Some arches are especially built to permit very rapid boiling; for example, commercial units are available that use a burner that operates at 300 pounds per square inch (21.2 kilograms per square centimeter) oil pressure and can achieve very high rates of evaporation for its size. Stack-on units, such as the STEAM-AWAY® or the Piggyback discussed previously, use steam produced by the flue pan to evaporate water from the sap before it reaches the evaporator. Finally, the use of the proper-sized reverse osmosis machine, that can remove one-half to three-quarters of the water in the sap before it enters the evaporator, will allow the producer to purchase a much smaller evaporator than would be possible without an reverse osmosis unit.

## The Gradient

The continual flow of sap through the evaporator along an ever-increasing sugar concentration gradient that reflects the process of changing maple sap to maple syrup can be a source of mystery to observers as well as to inexperienced producers **(Figure 7.11)**. What causes the gradient to occur? When starting the evaporator for the first time, there is no gradient, as all of the liquid in the pans has the same sugar concentration. However, as boiling occurs and a constant influx of sap is maintained, a density gradient is soon established. As water is evaporated from the sap the sugar concentration, and thus density, of the remaining liquid increases. Fresh sap is constantly entering the evaporator as the float valve opens to maintain the proper liquid level. The liquid farthest from the sap entry point is "pushed" toward the farthest end of the pathway, where the syrup drawoff is located. As boiling continues, and sap continues to enter the evaporator, the sap that has been in the pan for the longest time is located in the last channel of the syrup pan. In theory, since this liquid has been in the pan for the longest period of time, this is where it will reach the desired density for syrup. For theory to become reality, the flow must be unobstructed at all points in the evaporator, the pans must be level, and the heat source constant.

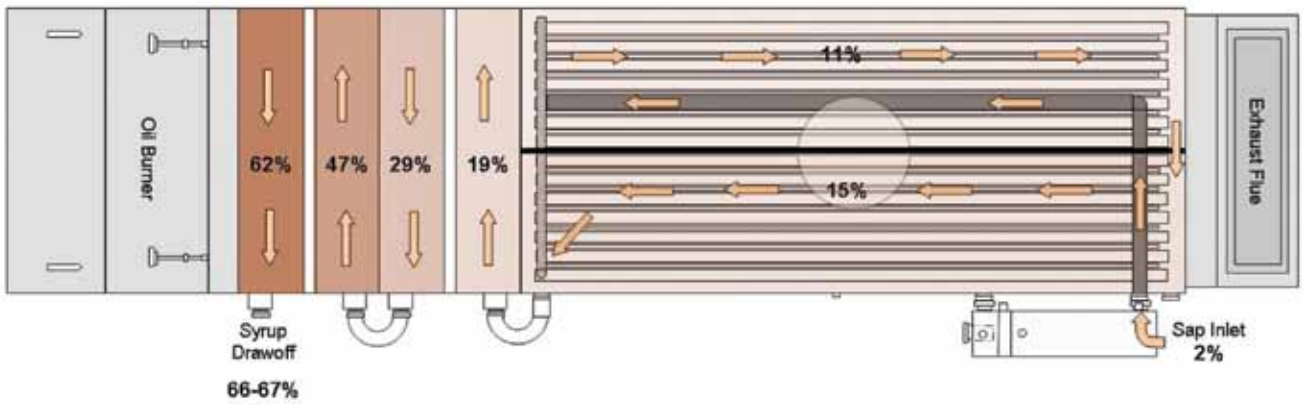



Figure 7.11. The development of the sap to syrup gradient in an evaporator is the result of the repeated addition of fresh sap into the sap pan and the continual evaporation of water from both the sap and syrup pans. In the diagram, 2 percent sap was introduced into the front of the upper sap channel. The numbers in each channel report the average Brix concentration for that channel. The Brix values reported in the diagram are for the purpose of illustrating the sap to syrup gradient. The measurements are from a specific evaporator, and are not meant to be representative of all evaporators.

## Arch Systems and Design

Arch design for evaporators reflects the fact that oil and wood burn differently. Wood burns with a luminous flame over essentially the entire length of the evaporator. Under the flue pan, much of this flame results from burning gases released from the wood and moving in the draft toward the stack. Since most of the heat (about 80 percent) transferred from the fire to the evaporator is radiant, an evaporator design that encourages movement of the flame along the bottom of the pans is desirable when burning wood. As a result, wood evaporators are designed with nearly vertical sidewalls and a relatively shallow depth to the arch floor beyond the firewall.

In contrast, fuel oil burns in a relatively compact ball; its flame does not move along the bottom of the pans. In traditionally designed oil-fired evaporators, to efficiently transfer heat from the oil fireball to the bottom of the evaporator pans, the burning ball must illuminate, by radiation, the entire area under the surface of the pans. This has been accomplished by tilting the firewall, at least the upper portion, back under the flue pan, essentially lowering the arch floor below the front of the flue pan. This provides a direct line for radiant heating from the fireball to the underside of the pans. However, a number of fairly new technologies deviate markedly from traditional designs, and appear to achieve comparatively high efficiencies. Among these are the use of relatively small V-shaped combustion chambers and the use of rear-mounted burners.

## Insulation and Firebrick

Modern arches are lined with highly efficient thermal insulation made of either ceramic wool or firebrick, or a combination of both. The temperature tolerance of each is rated at 3000° to 3200°F (1649° to 1760°C). Wood units must use the dense brick next to the fire to avoid damage to the insulation (**Figure 7.12**). Some units use an arch board to line the sidewalls and deck between the brick and the sheet metal. The high-density arch board withstands temperatures of 1900°F (1038°C) without breaking down. It reflects heat and is lightweight. Other fuel systems use a thicker ceramic blanket for maximum insulating properties providing for superior fuel energy efficiency (**Figure 7.13**).

Figure 7.12. Wood-burning evaporators must be lined with firebrick next to the fire to avoid damage to the insulation.

Figure 7.13. Oil and gas fired evaporators use a ceramic blanket to insulate the arch.

## Ceramic Insulation

Ceramic insulation and gasket material provide nearly perfect filler between the pans and arch wall, preventing cold air from leaking into the firebox under the pans (notice ceramic insulation between the reverse flow syrup pan and arch in **Figure 7.6**). Tests results provided by equipment manufacturers have indicated a 10 percent increase in the firebox temperature can be obtained when the arch is well insulated.

## Insulated Airtight Doors and Front

New, highly efficient wood burning arches feature an insulated front equipped with insulated, airtight doors. This feature is necessary to achieve maximum efficiency (**Figure 7.14**). Some of the newest designed doors also have forced air injectors built into the doors to increase combustion efficiency.

Figure 7.14. Insulated arch doors dramatically increase the efficiency of a wood-burning evaporator.

## Forced Draft

Using a blower to supply supplemental air to the fire to increase the rate and completeness of combustion of wood and wood gases can substantially improve efficiency. Specially designed forced draft systems can improve the efficiency of combustion, resulting in increased heat yield from each cord of wood. Most of these units are powered by electric motors equipped with a variable speed control rheostat that enables the fan speed to be regulated so the correct amount of air is forced through the grates, or in some units through inlets surrounding the firebox. This provides for more complete combustion of the wood and combustible gases (**Figure 7.15**). More heat means faster boiling and increased production. Claims by some manufacturers indicate the amount of heat recovered from a given quantity of wood may be increased by 10 to 20 percent, and total wood consumption can be reduced by 30 to 50 percent (assuming air dry wood).

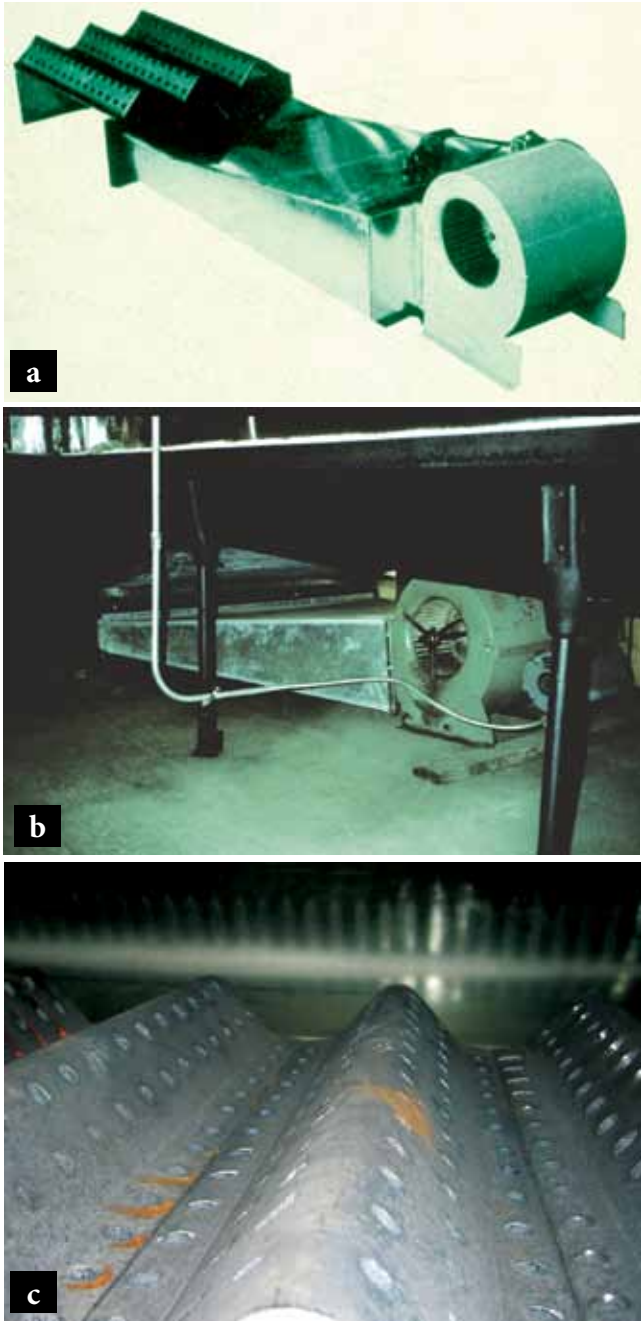



Figure 7.15. One form of forced draft assembly (a) to improve efficiency of wood-burning evaporator showing blower, plenum, and grates; blower and plenum under arch (b); and forced draft grates in firebox (c).

More efficient combustion also yields less ash, reducing the time necessary for clean-out. Forced draft systems are particularly effective when installed on arches with an insulated front and airtight doors. This combination allows faster boiling while using less wood. The result is an increase in the amount of sap that can be processed through the evaporator in a shorter time period. Some models feature graduated channels to equalize air distribution for improved heat flow, so wood burns at consistently higher temperatures. The boiling point of sap is stabilized more quickly following refueling since higher internal arch temperatures assure faster ignition of new wood.

## Fuel Options for Evaporators

If a new operation is being planned, the type of fuel used to heat the evaporator should be considered early in the planning process, and the entire heating system designed and assembled with components that enable it to operate effectively and efficiently. Wood and fuel oil are the two most commonly used fuels to provide heat for the evaporator. Natural gas and propane are also used but are less common. Some producers use steam as a heat source for the evaporator. Steam is generated using a wood, coal, oil, or gas-fired boiler. Other producers have explored less traditional heat sources such as coal or wood chips.

Many important factors affect how efficiently and effectively a fuel system will operate, including sugarhouse design and layout; evaporator arch design, size, and construction; stack size; and pan characteristics. Sugarmakers who are developing a new system are advised to thoroughly explore all options with respect to fuel type, evaporator manufacturer, model, features, accessories, etc. A system should be designed that meets the needs of an individual operation. New producers or those contemplating significant change are advised to work with equipment manufacturers or consultants to ensure that the fueling system is both efficient and cost effective.

### Wood

Wood is the traditional fuel for maple evaporators, and it is still used by a significant number of producers, especially in small- to medium-sized operations. A sugarhouse with a wood-fired evaporator can be easily recognized by its ample storage space for firewood near the evaporator doors, the tall smokestack (usually more than twice as tall as the length of the evaporator), and the characteristic wood-burning arch (much more vertical firewall and much shallower under the sap or flue pan than most oil-fired arches).

However, wood fuel has several advantages beyond the atmosphere it creates. One of the most important advantages is that it allows the producer to exchange labor for capital and operating expenses. Labor to produce the wood and "fire" the evaporator is exchanged for the increased capital and operating expenses that would be required for oil burners and fuel. Labor, of course, has a value but many producers find an investment of labor more desirable than short- or long-term investments of actual dollars for equipment and fuel.

Utilizing wood as a fuel provides an effective means of using the trees removed during thinning or other woodlot operations designed to improve the quality of the sugarbush. Cutting up the trees removed and using them for fuel eliminates disposal problems and has proven to be cost-effective, as compared to hiring someone to come in and remove them. Harvesting wood from dead trees and non-maple trees in the sugarbush is an effective means of maintaining healthy and vigorous sap-producing trees.

Wood fuel systems are generally simpler and easier to understand and maintain than other fuel systems, and while some producers thrive on learning new technologies and maintaining their equipment, others do not. Sugarmakers report producing up to 25 gallons (94.6 liters) of syrup from a standard cord[44] of firewood on conventional arches. Actual production will depend on the efficiency of the evaporator, the moisture content of the wood, as well as the species of wood burned.

[44] A cord of wood is a stack of wood occupying 128 cubic feet (3.62 cubic meters) of volume, often represented as a pile 4 feet high, 8 feet long, and 4 feet deep (1.22 meters high, 2.44 meters long, and 1.22 meters deep).

**Table 7.2. Heat equivalents of common firewood, by species.**

| WOOD 1 Standard Cord | Available BTUs/ cord Millions | Equivalent to | | Heat Value Rating | Splitting | Coals | Sparks |
|---|---|---|---|---|---|---|---|
| | | No. 2 Fuel Oil Gallons | Natural Gas 100 cu. ft. | | | | |
| Locust, Black | 24.6 | 251 | 307 | Best | Tough | Excellent | Few |
| Hickory, Shagbark | 24.6 | 251 | 308 | Best | Tough | Excellent | Few |
| Ironwood/Hardhack | 24.1 | 246 | 301 | Best | Tough | Excellent | Few |
| Apple | 23.9 | 244 | 298 | Best | Tough | Good | Few |
| Oak, White | 22.7 | 232 | 284 | Best | Tough | Good | Few |
| Beech, American | 21.8 | 222 | 273 | Best | Tough | Good | Few |
| Birch, Yellow | 21.3 | 217 | 286 | Best | Tough | Good | Moderate |
| Maple, Sugar/Hard | 21.3 | 217 | 286 | Best | Tough | Excellent | Few |
| Oak, Red | 21.3 | 217 | 286 | Best | Fair | Excellent | Few |
| Ash, White | 20.0 | 204 | 250 | Good | Fair | Good | Few |
| Walnut, Black | 19.5 | 198 | 244 | Good | Fair | Good | Few |
| Birch, White/Paper | 18.9 | 193 | 236 | Good | Fair | Good | Moderate |
| Cherry, Black | 18.8 | 191 | 235 | Good | Fair | Good | Few |
| Tamarack/Eastern Larch | 18.6 | 190 | 233 | Good | Fair | Fair | Moderate |
| Maple, Red/Soft | 18.6 | 190 | 232 | Good | Fair | Good | Few |
| Ash, Green | 18.4 | 187 | 229 | Good | Fair | Fair | Few |
| Sycamore, American | 18.0 | 183 | 224 | Good | Fair | Fair | Few |
| Ash, Black | 17.3 | 177 | 216 | Good | Fair | Fair | Few |
| Elm, American | 17.2 | 176 | 215 | Good | Tough | Fair | Few |
| Spruce, Red | 13.6 | 139 | 170 | Fair | Fair | Poor | Many |
| Hemlock | 13.5 | 138 | 169 | Fair | Fair | Poor | Many |
| Willow, Black | 13.2 | 135 | 165 | Fair | Tough | Poor | Moderate |
| Butternut | 12.8 | 131 | 160 | Poor | Tough | Poor | Few |
| Pine, Red | 12.8 | 130 | 160 | Poor | Easy | Poor | Many |
| Aspen/Poplar | 12.5 | 128 | 156 | Poor | Fair | Poor | Moderate |
| Pine, E. White | 12.0 | 123 | 150 | Poor | Easy | Poor | Many |
| Basswood | 11.7 | 119 | 146 | Poor | Easy | Poor | Few |
| Fir, Balsam | 11.3 | 115 | 141 | Poor | Easy | Poor | Many |

**Assumptions**
1 Standard Cord = 128 cu ft wood and air; 80 cubic feet solid wood; 20 percent moisture content. 1 lb. of this wood contains 5,780 BTU (British thermal unit). One BTU = amount of heat required to raise 1 lb. of water 1 degree Fahrenheit.
No. 2 Fuel Oil: 1 gallon contains 140,000 BTU, burned at 70 percent efficiency, providing 98,000 available BTU.
Natural Gas: 100 cubic feet = 1 therm = 100,000 BTU, burned at 80 percent efficiency providing 80,000 available BTU.

**Table 7.2** presents a comparison of the available heat in a standard cord of common firewood species and compares each with the energy obtained from equivalent amounts of fuel oil and natural gas. Most conventional wood-burning evaporators will use less than half of this heat for evaporation, depending on the dryness. Obviously, all species are not the same when it comes to providing heat. Other things being equal, the denser the wood the higher the available heat per unit of volume. Conifers, which contain gums and resins, offer a hot, flash fire, but lack the overall energy value of hardwoods when comparing equal volumes of fuel.

If a producer is using wood removed from the sugarbush for fuel, trees should not be removed according to their heat value, but according to the benefit their removal will provide the sugarbush in improving its health and productivity. However, if a producer is purchasing or trading for wood, the species obtained is important. If wood is being purchased by volume, such as by the cord, it pays to become familiar with the available wood species. Obviously a cord of a lighter, less dense species such as basswood or pine is not equal in heating value to a cord of the more dense species such as ironwood or hickory. When using the less dense species the evaporator has to be fired more frequently, requiring more labor. Wood cut to fill the length of the firebox works best for getting heat to the flue pan, since short pieces continually have to be pushed back and do not work as well as longer wood.

Wood used in an evaporator may be round or split, depending on its diameter, but should be thoroughly seasoned (dried). Most hardwood species will require from 9 to 12 months to thoroughly season. This means that wood used in the evaporator should be cut the previous spring or early summer. Wood cut later than this will have higher moisture content and will burn less efficiently because a portion of the heat will be used to evaporate the excess moisture in the wood. Firewood will dry most rapidly if it is stacked on runners or supports to keep it off the ground, and is placed in an open shed (under roof) in such a way to encourage air circulation (space within the stack for air to move across the cut ends and split sides of the wood). Producers should evaluate alternative ways to store and move firewood to minimize time and labor, such as using pallets or sleds, or by using bundled slab wood. Some have used trolleys on rails or racks suspended from old hay or manure-handling overhead tracks.

New, highly efficient wood burning arches (**Figure 7.16**) include:

- A totally insulated arch front.
- Positive door-latching systems with no air leakage.
- Double wall arch design with insulation between the walls.
- Forced draft with air injecting grates.
- Turbulence created in the firebox to ensure complete combustion.
- Some units are equipped with multiple draft controls for both the primary and secondary air, allowing for injection of air over, under, and behind the flames, making the flame burn stronger and more completely. This permits the maximum amount of heat energy to be extracted from the wood.

Figure 7.16. Modern, efficient wood-burning arch includes such features as insulated doors, positive door latch to prevent air leakage, double wall arch with insulation between walls, and forced draft with air injecting grates.

To improve the efficiency of older wood burning systems, consider the following:

- Insulate the inside of the arch with high-density arch board and full thickness firebrick. The arch board withstands 1900°F (1038°C) temperatures without breakdown. Producers can line the arch with the material before bricking, cutting to fit with a knife. It may also be used on the arch deck.
- Install a preheater.
- Add some form of forced draft system.
- Make certain the doors fit tightly. New airtight insulated doors and fronts are available for most models.
- Use ceramic pan gaskets under the pans and ceramic blankets between them to reduce cool air from leaking around the pans. This will improve combustion of the wood, increase the draft up the stack, and improve overall efficiency of the system.
- Minimize the amount of time the arch doors are open during firing or loading, and open and load only one side at a time.
- If forced draft is not used, be sure the stack is high enough to effectively create a strong draft. It is not uncommon for stack height to exceed 2 or even 2½ times the length of the evaporator. Without forced draft, too short a stack will result in an inadequate draft necessary to achieve a hot enough fire to maintain a rapid boil.

Most traditional wood burning evaporators are less than 50 percent efficient in recovering the available heat from each unit of wood and using it for evaporation. Conversion efficiency is largely dependent on the moisture content of the wood and the design of the evaporator. Some evaporators may be substantially less than 50 percent efficient. The importance of efficiency cannot be overemphasized. As an example, if a producer is using wood with 20,000,000 BTUs[45] available heat per cord, the efficiency of the evaporator is 30 percent, the sugar content of the sap is 2.5° Brix, the temperature of sap in the storage tank is 35°F (1.7°C), the boiling temperature of standard density syrup is 219°F (103.9°C), then approximately 19 gallons (72 liters) of syrup will be made per cord. If the efficiency of the evaporator can be increased to 40 percent, an easily attainable figure, approximately 25 gallons (95 liters) of syrup can be made from the same amount of wood.

## Fuel Oil

Oil burning units are also available for fueling the evaporator (**Figure 7.17**). Experiments with fuel oil (Number 2) as a source of heat for maple evaporators began in the early 1950s, with recommendations for installations available since the early 1960s. Interest in the development of oil-fired evaporators came, in part, from the growth in size of many operations during that period. This resulted in the need for more wood, which required more labor. Operating the evaporator also required more time as well as labor, therefore any increase in automating the fueling of the evaporator was viewed as positive**.** There is one additional factor that contributed to the rapid rise in popularity of oil-fired evaporators—fuel oil supplies were abundant and the price was relatively inexpensive.

As the popularity of oil-fired evaporators increased, improvements in oil burner design led to greater efficiency of the oil-fired arch.

Figure 7.17. Modern oil burner used to fire maple evaporator.

[45] BTU is the abbreviation for British Thermal Unit. One BTU is the amount of heat required to raise one pound of water one degree Fahrenheit.

Most modern oil burners operate at 150 pounds per square inch (psi) oil pressure, compared to 100 psi for older burners. Fan speed has been increased from 1750 revolutions per minute (rpm) to 3500 rpm; this results in better atomization and higher burning efficiency of the oil. A high retention head spins the flame; this feature eliminates the concentration of heat in the front of the evaporator, a problem which plagued earlier designs. Modern burners are available in both single stage and dual stage models; the latter are used to provide reduced heat when starting the evaporator under very cold conditions. In contrast to firebrick in the typical wood-fired evaporator, a ceramic blanket is used inside the arch to provide insulation without absorbing heat that can cause the sap to continue to boil after the flame is shut down. Efficiency is also improved in modern arches by preheating the oil, which is usually accomplished by running the oil line in the space between the double walled arch. Heating the oil to between 60°F (15.6°C) and 100°F (37.8°C) increases BTU extraction, although heating over 125°F (51.7°C) results in a loss of efficiency.

Upgrading an old wood-burning arch with an oil burner is possible. This requires substantial retrofitting of the arch to reduce the size of the combustion chamber and filling in or covering the pit under the burner.

To improve the efficiency of an oil-burning evaporator, consider the following:

- Insulate the inside of the arch with ceramic wool blanketing made for oil-burning arches.
- Use the proper size oil burner(s) and nozzle for the size evaporator and position them correctly within the combustion chamber (consult equipment dealer or manufacturer).
- Use pan gaskets and blankets to reduce cool air leakage under and between pans.
- Use one of the more recently developed evaporator systems, which incorporate efficiency enhancing design and equipment like a preheater or other heat reclaiming unit.
- Consider using one of the previously discussed commercially available units, which are especially designed to permit very rapid boiling.
- Note that lengthening the height of the stack beyond that specified by the manufacturer based on the oil burning rate will usually not affect evaporator efficiency since oil-fired burners operate on a forced draft. In fact, too much stack draft can be a problem leading to the loss of heat up the stack, particularly during periods of low barometric pressure. This is commonly remedied by installing a barometric damper in the stack.

Commonly cited advantages of using fuel oil as a heat source for evaporating maple sap include the following:

- Oil-fired evaporators require less labor to operate than wood fired units.
- No farm labor is required to harvest and process the fuel as is required with wood.
- With oil-fired evaporators, it is easier to maintain a constant, more uniform heat source than wood.
- Oil is generally considered cleaner since little or no soot or ashes are produced.
- Should trouble present itself, shutting off the burner is as easy as the flick of a switch.
- No wood storage space is needed.

Commonly cited disadvantages of using oil to fire evaporators include:

- Requires more capital investment in equipment—both oil burners and environmentally friendly tanks. Check with your local EPA (Environmental Protection Agency) office or water quality regulations concerning leak/contamination protection requirements.
- If switching from wood, it requires a different arch than wood-fired evaporators, although in new installations this is not necessarily more expensive.
- Fuel oil must be purchased rather than produced by labor, but wood can be produced by the owner/operator (sometimes wood is purchased).
- Does not use up wood material generated through proper management of the sugarbush.
- Accessibility for the delivery of fuel must be adequate, both out of season, and possibly

during sugaring. Many producers install a fuel tank with capacity to last a full season, purchasing during the summer when prices can be "locked in" and are usually most competitive.

- Dramatic yearly and seasonal fluctuations in the price of fuel oil, and upward long-term trend.
- For some, heating the sugarhouse may become a necessity, as little heat is lost from modern oil-fired arches. When this is a concern, heat-reclaiming units can be installed around the stack to warm the facility.

Conversion kits are sold by many manufacturers to convert wood-burning evaporators to oil burners. However, before undertaking such a conversion, it is recommended that all requirements necessary to make such a conversion efficient be considered. Conversion kits generally supply equipment necessary to convert the front of the arch to oil burning, including oil burner(s), mounting and supporting hardware, nozzle(s), and door plate. To convert to an efficient oil burner also requires substantial modification of the firewall and arch floor, lowering and gradually up sloping the arch floor so the entire underside of the pan is heated by direct radiant heating from burning oil. This type of modification should be discussed thoroughly with equipment manufacturers beforehand to determine how it should be done and whether it can be done effectively with a particular wood-burning arch. In the long run, it may be more time-efficient and cost-effective to replace the old unit with a new one designed specifically for use with oil.

Number 2 fuel oil is normally used to fire one or more oil burners in an oil-fired evaporator. It contains approximately 140,000 BTUs of available heat per gallon. Referring to the example considered previously with wood, if the evaporator were 100 percent efficient, it would require slightly more than 2.2 gallons of fuel oil to produce a gallon of syrup from 2.5° Brix sap, at 35°F (1.7°C) if standard density syrup boiled at 219°F (103.9°C). Traditional oil-fired evaporators are commonly 65 to 75 percent efficient; therefore, an excess of 3 gallons of fuel oil is required to produce a gallon of syrup. Currently, the most efficient evaporators available, in conjunction with other efficiency enhancing accessories like an reverse osmosis unit, STEAM-AWAY®, or Piggyback unit, require as little as 1 gallon of fuel oil per gallon of syrup produced.

Because fuel oil can sometimes freeze, resulting in a blockage of the fuel lines, kerosene is occasionally used as a substitute or mixed with fuel oil. Kerosene has a slightly lower energy content compared to fuel oil. Some producers and research stations are beginning to experiment with biodiesel, a mix of diesel oil and vegetable oil, as a substitute for fuel oil.

The storage tanks for fuel oil should be located separate from the evaporator room and away from the parking area. To prevent off-flavors due to fumes, fuel tanks should not be located near air inlets for STEAM-AWAY®s, air injectors, or other similar systems. A fuel containment system, equal to the size of the tank's capacity, should be constructed to capture any spilling oil in the event of a tank rupture or leak.

## Natural Gas and Propane

Natural gas (NG) and liquid petroleum gas (LPG, or propane) are clean and efficient fuels for firing evaporators (**Figure 7.18**). Natural gas may be particularly attractive to producers with access to an inexpensive supply, such as a well. Propane is sometimes the fuel of choice of hobby producers to fire small evaporators. Historically, wood-fired arches were converted to use natural gas. Today, gas-fired arches, similar in appearance to basic oil-fired arches, along with natural gas and propane burners, are available from maple equipment suppliers. The numerous firing ports located in the front wall of the arch indicate the presence of a gas-fired arch. Burner nozzles must be selected for either natural gas or propane. Considerations to improve the efficiency of gas-fired arches are similar to those for oil-fired arches.

Since gas heat can be easily adjusted and shut off when the desired temperature is reached, propane gas is commonly used to fire finishing pans and canning units. Its cleanliness also makes it an attractive fuel to use adjacent to canning or other maple product making locations in the sugarhouse.

Figure 7.18. Five natural gas burners in front wall of arch.

## Wood Chips

Wood chips may be an attractive fuel to producers who have access to large quantities of affordable wood chips or wood suitable for chipping. Commercial evaporators that use wood chips are available. Some units have automated chip loading that incorporates a chip hopper, an agitator to separate the chips, and an augering mechanism to load the chips into the evaporator firebox. Some wood-chip evaporators require forced-air draft both below and above the grate to support effective combustion. Fuel systems using a wood-chip evaporator require chip drying and storage facilities under cover to prevent moisture deterioration and freezing, as well as chip-handling equipment such as a blower, auger conveyer, or bucket loader. If wood is being converted to chips, chipping equipment will also be needed.

Wood chips can also be processed through gasification to a clean, efficiently burning fuel, with the added advantage that gasification units can burn green hardwood chips. Producers can purchase green chips, or buy or rent a chipper and produce their own.

## High-Pressure Steam

The use of high-pressure steam in the maple industry dates back to the nineteenth century when the first steam evaporators were made available (**Figure 7.19**). High-pressure steam systems involve specialized equipment and technology with which, until recently, most maple producers were not familiar. New research and information on its use for the production of maple products are two key reasons for an increase in interest by producers today. There is considerable potential for steam evaporation as a viable alternative processing method for producing high quality maple products.

Figure 7.19. Steam evaporators. Notice in the lower evaporator that the parallel steam pipes are visible in the bottom of the evaporator pan.

Producers recognizing the potential of using high-pressure steam for the production of maple products in their operation should seek information and advice on the subject[46]. This means carefully planning their steam systems with the aid of qualified assistance. Further, as with any system, proper installation, adequate operator training, and regular maintenance are critical. Because of operating and safety concerns, qualified individuals should do the installation of steam systems.

[46] Further information on evaporating with steam is available in Chapeskie (2003) and other related publications.

Advantages commonly cited for using steam include:

- Steam heat provides a steady, uniform heat for rapid boiling with minimal scorching or burning of syrup. These characteristics contribute to the production of high quality, light-colored syrup.
- Easy to control temperature through valve adjustments.
- Saves time; quick startup/shutdown. Boiling day is shorter, leaving time for other tasks.
- Requires comparatively small pans, lowering costs. Small volume of sap in boiling pans means easy draining for cleanup between runs.
- Some users of steam indicate that foaming is greatly reduced.
- The evaporator and boiler can be in different rooms, making cleanliness and sanitation easier.
- Steam may be used for other purposes such as heating the building, cleaning equipment, etc.
- One boiler can provide heat for several evaporators or heating units such as finishing pans and canning tanks.
- Efficiencies of fuel to syrup have been very promising. One producer with an oil-fired boiler steam unit used in conjunction with an RO reports using 0.5 gallons (1.9 l) of oil per gallon (3.8 l) of syrup produced.
- Saves labor in the sugarhouse; one person may be able to run the operation.
- Safety aspects—no open flames; fuel and stack are away from boiling pans.

Disadvantages or concerns commonly cited for using steam to boil sap include:

- A license may be required if a high-pressure system is used.
- Routine inspections and maintenance of the system are required.
- Installation can be complicated, requiring specialized knowledge.
- Boiler repairs can be expensive; proper maintenance is essential.
- A source of adequate quantities of water suitable for use in a steam system may not be available in some locations, although this may be only a minor problem as water to generate steam can be reused.
- Heat for the boiling room must be provided from an external heater.

The principle behind a steam evaporator is relatively simple. When water vaporizes into steam it requires energy (970 BTUs per pound). As steam condenses it releases this heat energy. Steam is formed in the boiler and transferred by tubes to the evaporator where it condenses in pipes in the evaporator pan. The energy that is released when the steam condenses boils the sap. A comparison between copper and stainless steel piping should be made in evaluating the costs and efficiencies of both systems.

The economics of evaporating with a steam system must be closely evaluated due to the initial cost of the boiler and other equipment. To reduce startup costs, most producers purchase used boilers when available. Considerations must include not only the initial capital investment, but the long-term cost of operation as well.

The use of steam involves not only all of the safety considerations associated with using any evaporator, but also those related specifically to steam. Because of this, maple producers must ensure the proper installation, operation, and maintenance of their steam systems. They must have knowledge of and adhere to rules and regulations governing its use in their own geographic area.

## Vapor Compression

Although from a technical perspective, vapor compression is not a type of fuel, it is considered because it is an alternative process for evaporating maple sap and producing maple syrup. Vapor compression techniques have been used for desalinating salt water since World War II; however, interest in evaluating and adapting the concept and technique to maple syrup production is much more recent. In the vapor compression pro-

cess, the water in maple sap is evaporated, but unlike open pan evaporators, the heat energy in the steam produced from the evaporating sap is captured and repeatedly reused. Evaporation takes place in an evaporation chamber in which hot sap is sprayed onto an even hotter surface. The result is the vaporization of some of the water molecules that are then pulled out of the evaporation chamber under negative pressure. This vapor is condensed, and the released heat is used to reheat the evaporating surface. Sap is recycled until the desired density is achieved. To increase efficiency, sap is preheated with heat exchangers that absorb heat from the evaporation chamber and finished syrup. External heat energy is required to start the evaporating process but only intermittently thereafter to maintain it.

While no vapor compression evaporators are available commercially, research using original and modified desalinating equipment has demonstrated the feasibility of using it to process maple sap to produce quality maple syrup. Limited research has been done on small-scale vapor compression units that remove about 90 percent of the water necessary to produce maple syrup. The resulting concentrate is then boiled to standard density syrup using conventional open pan evaporation equipment. Research studies on the applicability of vapor compression techniques to the production of maple syrup have been conducted in both New York and Ontario.

## How Much Sap…How Much Syrup—The Rule of 86

Because the conversion of sap to syrup is essentially a concentration process, the sugar content (°Brix) of the sap determines the amount of sap required to produce a gallon of syrup. This relationship, termed the "Rule of 86," may be used to estimate the number of gallons of sap of a specific density (sweetness) required to produce a gallon of syrup. The relationship is as follows:

**THE RULE OF 86**

**S = 86/X**

Where "S" is the number of gallons of sap required to produce one gallon of syrup, "X" is the Brix value of the sap, and 86 is a mathematical constant representing the percentage of solids (mostly sucrose) on a weight-volume basis that is in a gallon of syrup (see following discussion).

It follows then that the number of gallons of water that must be evaporated from sap to obtain one gallon of syrup can be calculated by subtracting "1" from the above equation:

**W = (86/X) – 1**

As an example, using sap with a density of 2° Brix requires 43 gallons of sap to produce 1 gallon of syrup:

***S* = 86/X = 86/2 = 43 gallons sap**

And 42 gallons of water must be evaporated to produce one gallon of syrup:

**W = (86/X) – 1 = (86/2) – 1 = 43 – 1 = 42 gallons water**

The "Rule of 86" calculates a good "working" estimate of the number of gallons of sap required and the number of gallons of water that must be evaporated to produce a gallon of syrup. It is not exact because the mathematical relationship was developed when "standard density syrup" had a density of 65.5° Brix[47]. Current "standard density syrup" has a density of 66° Brix. Furthermore, individual producers in different areas of the region where maple syrup is produced differ slightly as to what is the optimal desired density of finished syrup. Nonetheless, the "Rule of 86" is a tradition in the maple industry and gives a satisfactory estimate for practical purposes. It

[47] Note: the "Rule of 86" is calculated by dividing the weight of sugar in a gallon of 65.5° Brix syrup (7.2115 pounds) by the weight of sugar in a gallon of 1 percent sap (0.0836 pounds). The answer, 86.26, represents the number of gallons of 1 percent sap that must be evaporated to produce syrup with a density of 65.5° Brix. For current standard density syrup of 66.0° Brix, dividing the weight of sugar in a gallon (7.283 pounds) by the weight of sugar in a gallon of 1 percent sap (0.0836 pounds) produces the constant 87.1.

is suggested, however, that the "Rule of 86" not be applied when sugar concentration is above 8 percent because the "Rule" becomes progressively less accurate as sugar content increases.

## Operating the Evaporator

For new producers, starting the evaporator for the first time is a moment of both anticipation as well as some anxiety. Even for experienced producers, "firing up" the evaporator at the beginning of each season can yield some anxious moments associated with its operation. A few suggestions are offered that may be helpful to new producers, but which can also be reassuring to established and experienced producers as well. For most producers making maple syrup is enjoyable! If there is not a degree of personal satisfaction and plain "old-fashioned fun" in the syrup production process, it is unlikely the venture will be successful in the long-term. For the beginning and veteran producer who may have many years of experience, there is a tendency to become rather anxious when the first good sap run occurs. It is good to know that this is a normal response, but also to remember that maple syrup production is a time-honored process that has been undertaken each year for centuries. As equipment related to sap collection and evaporation has become more complex, it is easy to be intimidated by the several mechanical and electrical components. However, these are all designed to improve the efficiency of the production process and the quality of the syrup produced. When guidelines and instructions provided by the manufacturer are followed, everything "will work." At the end of the season the time-honored sugaring question that has been passed from generation to generation can be asked: How did we do this last year? Information is provided in this section that may be helpful in allaying some apprehensions related to operation of the evaporator.

### Sugarhouse Records

Keeping detailed records of sugarhouse activities during the sugaring season can be an invaluable tool in developing a successful operation. It is unlikely that too much information can be collected, so it is appropriate to record even the most mundane observations. Accurate descriptive information of what is and has happened, as well as experiences and problems that are encountered, may hold the answer to a future problem. Relying on memory may work for some, but individual sugaring seasons tend to become blurred with the passage of time. The best way to ensure good records is to make them convenient and simple to take. Make up data sheets with blocks where daily production and operating data can be recorded. Be sure to allow space for notes and other personal observations.

Examples of data include:

- Date tapped
- Amount of time spent tapping; the weather conditions
- Date of first run
- Sugar content of sap (measured daily or by the batch)
- Sap condition (clear/cloudy)
- Sap flow (light, moderate, heavy; gallons per hour or per day)
- Hours boiled
- Gallons of sap boiled
- Gallons of syrup produced (percent of each grade produced)
- Date, grade, and other pertinent information recorded for each batch of syrup
- Drums, if produced, individually identified with a code, and, if possible, a record of the drum in which each batch was packed
- Amount of fuel used (e.g. cords of wood, gallons of fuel oil, cubic feet of natural gas, etc.)
- Frequency of firing the evaporator
- Reverse osmosis unit use data and schedule information
- Vacuum pump hours
- Vacuum level
- Types and location of damage in the woods
- Time spent on repairs
- Frequency of switching sides (drawing-off from the evaporator)
- Float levels on the evaporator
- Depth of sap in the pans

- Amount of sugar sand and scale
- Amount and type of defoamer used
- Amount of filter aid used
- List the problems encountered and the solutions
- Other personal notes, observations, thoughts, ideas, etc.

Examination of the records permits evaluation of productivity and efficiency, and assists in making improvements related to operating practices, correction of mistakes, and charting progress as the operation progresses and changes over time. This information is helpful in avoiding repeat problems or mistakes. Good records also provide an overview of what kinds of activities and decisions must be made when responsibility for overseeing the operation is passed on to the next generation or to a new owner.

## Sap Supply to Evaporator

A properly functioning sap supply or feed line is critical to proper evaporator function. The pipeline between the storage tank (feed tank) and the evaporator must be large enough to deliver a constant supply of sap to the evaporator in sufficient quantity to maintain the desired sap level in the pans under full boil. If this pipeline is connected to an outside storage tank, it should be insulated to prevent freezing or drained when not in use. A frozen feed line could prevent sap from reaching the evaporator resulting in scorched pans. Many producers install an alarm or signaling device to indicate when sap movement is interrupted or when sap level is low. The sap supply line should be equipped with a valve that can be used to adjust flow rate and cut off the flow when the evaporator is shut down.

As a precaution, a secondary sap supply line should be installed with a flexible hose long enough to reach any part of the evaporator or finishing pan. This is an emergency line for use if there is a stoppage in the main supply line or for quickly supplying sap to any part of the evaporator where it may be needed to prevent burning of the pans. If a second supply line from the sap storage tank cannot be easily arranged, an adequate supply of water can be substituted; where a pressure water system is available, a garden hose connected to an operating faucet can be used to supply water to the pans in the event the sap level becomes dangerously low. At the very least, keeping a fresh bucket of sap or water close by can be a real pan saver when bad things start to happen fast.

## Level the Evaporator

Make sure that your evaporator and each pan is level before flooding the pans with sap. If the evaporator is not level, sap will not flow evenly and shallow spots may develop. The result could be a scorched or burned pan.

## Flooding the Rig

Before adding sap to an evaporator that has not been used recently, make certain it is clean and free of debris and surface deposits. Prior to filling the pans with sap, most producers will flush the pans with water to remove dirt and dust that has accumulated since last season. Run sap into the evaporator until the bottom of each pan is covered to a depth of approximately 1 inch (2.5 cm). This actual depth may vary depending on type of evaporator and skill and preference of the operator. Many experienced maple producers prefer to maintain a very shallow sap/syrup level believing this contributes to producing syrup of the lightest possible color. New producers should experiment with maintaining a sap level that produces high quality syrup and with which they are comfortable so burning or scorching of the pans does not occur. Once the proper sap level has been reached, heat can be applied.

## Firing the Evaporator

When firing with oil, gas, or propane, follow the directions for the use of the burners. When firing with wood, start with a layer of cardboard or newspaper placed over the grates in the firebox. The cardboard acts as a platform for kindling and as a wick if an accelerant is used. If accelerants are used to start the fire, caution is advised due to the increased risk of severe injury and property damage. If accelerants are used, avoid fuels such as gasoline or lantern fuel as these have a low flash point and produce large quantities of flammable vapors that might ignite explosively. Consult your local fire department for guidance and safety tips. Light the kindling with a long fireplace match or

starting device that puts some distance between you and the fire. Once the kindling is burning, add larger pieces of small or split wood, close the fire doors, and turn on the forced draft fan if one is present. Keep checking the fire and add larger sized pieces of wood until the desired mix of fuel and air is obtained that will maintain an optimal boiling rate.

Two of the most common methods of firing an arch with wood are the alternating door **(Figure 7.20)** and the double door methods. The alternating door method, as its name implies, means that firewood is added through one door during the first firing, then through the other door during the next firing, and so on. This method is believed to maintain the most even temperature in the pans due to the short duration of each firing resulting in less heat loss and less time with the fans off. The downside is that the firing interval will be very short (every 3 to 7 minutes) and more frequent firings are required. The double door method involves firing both sides of the firebox at the same time. To minimize heat loss and maintain boiling temperature, only one door is opened at a time. This method allows for a longer interval between firings (10 to 12 minutes), thus freeing up time to carry out other activities in the sugarhouse. Regardless of the method employed, the principal objective is to develop consistent firing in order to maintain a vigorous continuous boil, yet still have some time available for completing other tasks in the sugarhouse.

A few common "tools" needed with a wood-fired arch include a long-handled poker for moving burning pieces and ashes, a pair of insulated gloves, and heavy, insulated coveralls to provide personal protection from both heat and cold.

A firing schedule can maintain an even temperature and remove some of the guesswork of when to fire. The goal is to choose a consistent firing interval that maintains optimal temperature and also allows time for performing other sugarhouse duties. The interval will vary a great deal depending on the size of evaporator, the species and moisture content of the firewood, and the weather. It is suggested that operators experiment with different methods of firing to determine what works best for their operation. Having a kitchen timer or a reliable clock that is clearly visible will be helpful in maintaining a consistent firing schedule. If the rate of boiling decreases between firings, the firing interval is too long. Conversely, if the firebox is still relatively full when it is time to add more wood, the firing interval should be lengthened.

Figure 7.20. Alternating door method of firing wood-burning evaporator.

## Boiling

As the sap begins to boil and water is evaporated it is necessary to monitor the level of sap in the evaporator and make adjustments to the floats so a constant flow of sap at the desired level in the pans is maintained. Depending on the style of evaporator, varying the sap depth will change the evaporation rate. In general, the shallower the sap level, the faster the boil. However, a word of caution is appropriate; it should be remembered that when a shallow sap level is maintained in the pans, the margin for error is small. The likelihood for a scorched pan increases as the depth of sap in the pan is decreased. It is suggested that producers start with an inch of sap (or the level recommended by the pan manufacturer) and experiment with decreasing this level until a point is reached that the operator is comfortable with. Be aware that the desired sap level will vary with the sugar concentration of the sap. For example, if a reverse osmosis unit is used, the sugar content of the sap will be higher, and syrup production from the evaporator will be more rapid. Most producers with reverse osmosis machines maintain a slightly deeper level of sap in the evaporator to minimize the possibility of scorching. Syrup production per

hour will increase, and accordingly, the amount of syrup that must be drawn off the evaporator will also increase. Maintaining a deeper sap level reduces the likelihood of scorching when syrup is drawn off the evaporator.

It is important to monitor the operation of floats throughout the boiling process. When conditions change, it may be necessary to adjust the float to maintain an optimal sap level in the evaporator. Mechanical floats generally require more frequent adjustment while electronically controlled float valves are usually more reliable in maintaining the desired sap level as long as the sensors and probes are kept clean.

## Establishing and Maintaining the Sap/Syrup Density Gradient

As sap in the evaporator pans begins to boil and evaporation occurs, a desired sap/syrup density gradient develops from sap at the inlet valve to finished or near finished syrup at the draw-off valve. The development of this gradient can be hastened by adding some nearly finished syrup (often referred to as "sweet") to the final partition (the one from which finished syrup will be drawn). The temperature of syrup in the draw-off partition should be approximately 212°F (100°C) before adding the nearly finished syrup. If sweet is added too soon after starting your evaporator, it will mix with less concentrated sap, reducing its effectiveness. This nearly finished syrup can be added each time the evaporator is started, and each time the side from which finished syrup will be drawn off is changed. The amount will vary with the size of the evaporator. Be careful not to add too much, as this could result in the production of too much syrup at one time. At the end of each boil, before the evaporator cools down, draw off some nearly finished syrup and save it for use when the evaporator is started again.

## Controlling Foaming

Foam is an inevitable part of the syrup production process. In the past, many different products, mostly fatty substances such as animal fat, whole milk, cream, butter, vegetable shortening, and vegetable oil, have been used to reduce foaming. Increasingly there is a tendency to use commercially available defoamers. If substances other than commercial defoamers are used, producers should avoid strong-flavored substances (like peanut oil) and animal products, as they can impart a rancid or otherwise off-flavor to the syrup**.** Defoamers must be food-approved and not detract from the purity of maple syrup.

Commercial defoamers are readily available and are preferred over other materials. They are available in two main types—liquid and granular. Granular defoamers can be suspended over a pan at the maximum level that foam should reach**.** When the foam level touches the granules, it will drop back down. Liquid defoamer can be added manually from a bottle that delivers a small droplet, or automatically using an adjustable drip reservoir set over each pan.

Defoamer should be used sparingly. It only takes a drop or two of liquid commercial defoamer to bring a foaming mass under control. If excessive amounts are used it may impart an off-flavor to syrup or cause it to feel greasy. Spray-type bottles generally add much more defoamer than necessary. Producers desiring organic certification should check for permissible defoaming agents; some organic certifiers only allow the use of organic defoamers. Defoamer should also not be broadcast throughout the evaporator, and hardly ever be used in the center sections of the syrup pan, but instead should be used sparingly near the drawoff point or at entry points from one section of the evaporator to another. Wherever defoamer is used, foaming will cease rapidly, drawing liquid syrup into the area. This results in deeper sap/syrup levels, increased boiling time between draw-offs, and larger batches. All of these factors produce darker syrup and make evaporator management more problematic. If you find that you have very large draws, or a long time between draws, try to reduce defoamer as a possible solution.

## Managing Sugar Sand

Sugar sand, or niter, is a mineral deposit (mostly calcium malate) along with trapped sugar that forms on the bottoms and sides of pans as the sugar concentration increases due to evaporation (**Figure 7.21**). Excessive amounts of sugar sand

on the bottom of the pan can create a "hot spot" where burning or scorching occurs, giving the syrup an unpleasant, strong caramel, or bitter taste. In addition, the pan may be damaged due to the additional heat that will accumulate in the area of the deposit**.** The effects of small amounts of sugar sand in the syrup pan can be minimized in reverse flow pans by periodically reversing the direction of flow. This practice is known as switching sides. It works because the sugar concentration in sap coming out of the back pan is less than that present in nearly finished syrup and accordingly, some of the sugar sand accumulation may be dissolved. When the flow of sap is reversed in the syrup pan this unsaturated sap passes over the built-up sugar sand, dissolving and lifting it off the pan. Eventually sugar sand will build up on the new draw-off side, thus the need to switch sides again. Excessive accumulations of sugar sand should be removed by cleaning the bottom of the syrup pan with cold water and a brush or, if necessary, with commercial pan cleaners. Some producers purchase a second syrup pan, switch pans, and circulate permeate from a reverse osmosis machine or hot condensate from a preheater through the dirty pan. This method works well to remove sugar sand accumulations without excessive scrubbing or the use of cleaning chemicals.

Figure 7.21. Heavy sugar sand build-up.

As discussed previously, when cross-flow pans are used, sugar sand is commonly managed by having a third pan that is rotated onto the arch when sugar sand accumulations begin to form. The replaced pan is then cleaned and is available for use in the next rotation.

If a reverse osmosis unit is used to increase sugar concentration in the sap, be aware that sugar sand will tend to form throughout the evaporator and at a more rapid rate than when using sap that has not been passed through a reverse osmosis unit.

## Determining When to Draw Off

Removing syrup from the evaporator or finishing pan when the desired density has been obtained is one of the most exacting tasks in making maple syrup. Traditionally, finished density was identified by a number of imprecise, subjective methods including the "blow" test and the "apron" test. In the blow test, a small loop of wire was dipped into the boiling sap; syrup was determined to be finished when a "certain puff" of breath blew the sap off the loop. In the apron test, a scoop was dipped into the boiling sap and held upright; the formation of a large, thin sheet or apron with the right shape and other characteristics indicates finished syrup (**Figure 7.22**). Use of either of these methods requires knowledge and skill developed from long practice. The enviable title of "sugarmaker" was bestowed on those few who perfected the process.

Figure 7.22. Determining finished syrup using the apron test.

Currently a better understanding of the sap to syrup conversion process and the development of a number of precision instruments make the determination of finished syrup density easier and more accurate. Methods commonly used by producers to measure the density of boiling sap to determine when it has attained the correct

density include boiling temperature elevation and hydrometry. Drawing off syrup or concentrated sap based on boiling point elevation can be done manually, or with an automatic draw-off control.

## Boiling Point Elevation

Measuring boiling point elevation with a thermometer is the primary method for monitoring the density of actively boiling concentrated sap in an evaporator or finishing pan and determining when it has reached the correct density. As the sugar concentration of a sugar-water solution such as maple sap or syrup increases, the temperature at which the solution boils increases; thus this elevated boiling point can be used as a measure of density. **Table 7.3** presents the boiling temperature elevations above pure water for sugar solutions of different concentrations. Notice that at low sugar concentrations, changes in density produce relatively small changes in the boiling temperature (e.g. an increase in the sugar concentration from 7.5° to 13.8° Brix increases the boiling temperature only 0.2°F). In the vicinity of standard density (66° Brix), however, comparatively small changes in density result in relatively large changes in boiling temperature (e.g. an increase in the sugar concentration from 64.5° to 67.0° Brix raises the boiling temperature 1°F). Thus the boiling point elevation method of measuring sugar concentrations is well adapted to processing maple sap into maple syrup.

**Table 7.3. Boiling temperature above that of water for different concentrations of sugar solutions.**

| Temperature Elevation, °F | Temperature Elevation, °C | Sugar Solutions (%) |
|---|---|---|
| 0.0 | 0.0 | 0.0 |
| 0.2 | 0.1 | 7.5 |
| 0.4 | 0.2 | 13.8 |
| 0.6 | 0.3 | 19.0 |
| 0.8 | 0.4 | 23.4 |
| 1.0 | 0.6 | 27.1 |
| 1.2 | 0.7 | 30.3 |
| 1.4 | 0.8 | 33.4 |
| 1.6 | 0.9 | 36.0 |
| 1.8 | 1.0 | 38.4 |
| 2.0 | 1.1 | 40.5 |
| 2.2 | 1.2 | 42.5 |
| 2.4 | 1.3 | 44.3 |
| 2.6 | 1.4 | 46.0 |
| 2.8 | 1.6 | 47.7 |
| 3.0 | 1.7 | 49.0 |
| 3.2 | 1.8 | 50.4 |
| 3.4 | 1.9 | 51.6 |
| 3.6 | 2.0 | 52.8 |
| 3.8 | 2.1 | 53.9 |
| 4.0 | 2.2 | 54.9 |
| 4.2 | 2.3 | 55.9 |
| 4.4 | 3.4 | 56.9 |
| 4.6 | 2.6 | 57.8 |
| 4.8 | 2.7 | 58.8 |
| 5.0 | 2.8 | 59.7 |
| 5.2 | 2.9 | 60.4 |
| 5.5 | 3.1 | 61.5 |
| 5.6 | 3.1 | 62.0 |
| 5.8 | 3.2 | 62.5 |
| 5.9 | 3.3 | 62.9 |
| 6.1 | 3.4 | 63.4 |
| 6.4 | 3.6 | 64.4 |
| 6.6 | 3.7 | 64.9 |
| 6.9 | 3.8 | 65.5 |
| 7.1 | 3.9 | 66.0 |
| 7.3 | 4.1 | 66.5 |
| 7.5 | 4.2 | 67.0 |
| 8.0 | 4.4 | 68.0 |
| 8.2 | 4.6 | 68.5 |
| 8.5 | 4.7 | 69.0 |
| 8.8 | 4.9 | 69.5 |
| 9.1 | 5.1 | 70.0 |
| 9.5 | 5.2 | 70.5 |
| 9.9 | 5.5 | 71.0 |
| 10.4 | 5.8 | 71.6 |
| 10.7 | 5.9 | 72.1 |
| 11.1 | 6.2 | 72.5 |
| 11.5 | 6.4 | 73.0 |
| 12.0 | 6.7 | 73.5 |

From: Willits, C.O. 1965. *Maple Syrup Producers Handbook,* USDA Agriculture Handbook No. 134. Agricultural Research Service, Washington. 112 pp.

A thermometer calibrated in ° Fahrenheit is commonly used to measure boiling point elevation. Such a thermometer should have a range extending to at least 225°F (107.2°C). The thermometer should be calibrated in one-fourth degree or smaller intervals, the distance between calibration lines should be as great as possible, and the calibration lines should be marked clearly and in high contrast to the background.

## Thermometer Calibration

It is extremely important to remember that boiling temperature elevation refers to the elevation of boiling temperature relative to that of pure water at the time and place syrup is being made. Pure water boils at 212°F (100°C) only when the barometric pressure is 29.92 inches (760 millimeters) of mercury; normally this is referred to as the temperature at which water boils at sea level. Since the barometric pressure is seldom 29.92 inches when syrup is being made, and because it decreases with elevation above sea level, it is best not to associate 212°F with the temperature of pure boiling water. Instead, it is necessary to determine the temperature at which water boils at the time and place where syrup is being made before using the boiling temperature elevation method. Simply heating pure water to the point of boiling and measuring the temperature can do this[48]. The boiling temperature of standard density syrup is determined by adding 7.1°F (3.5°C) to the temperature of the boiling sap (**Table 7.3**). If syrup with a higher density is desired, the appropriate degree adjustment is added to the boiling point of water (e.g. for 66.5° Brix syrup add 7.3°F to the boiling point of water).

The boiling point of pure water should be determined each time the evaporator is started (e.g. at the start of each evaporation), and periodically throughout the evaporation period, particularly if weather changes occur suggesting changes in barometric pressure. Barometric changes resulting in boiling temperature changes of one or more degrees are not at all uncommon. A change of 1°F (0.5°C) in the boiling temperature of water will result in missing the desired syrup density by 2.5° Brix (**Table 7.3**), an amount that could result in syrup being produced that was significantly "off-density." Modern monitoring equipment is available that combines the features of thermometers and barometers, as well as automatic draw-off equipment that continually adjusts for barometric changes.

## Types of Thermometers

Any properly calibrated thermometer can be used to measure the temperature of boiling sap/syrup. A variety of thermometers are available from maple equipment suppliers including standard thermometers, dial thermometers, and digital thermometers. Standard and/or adjustable thermometers are lowered into the sap from the top of the pan by hand or in a mount. Dial thermometers are mounted in a hole in the lower side of the pan near the takeoff valve (**Figure 7.23**). Digital thermometers can be used in all of the above applications (**Figure 7.23**). Caution: mercury thermometers pose a contamination risk if broken, and should be replaced with other types of thermometers.

Because of possible changes in the boiling point of water during the day due to changes in barometric pressure, and because of the difficulty in reading manual thermometers accurately, the density of syrup finished with a manual thermometer should be verified with a hydrometer once the syrup temperature has reached room temperature.

Figure 7.23. Dial and digital thermometer.

## Hydrometer

Hydrometers are specially constructed glass tubes that contain a weighted bottom and a calibrated scale. When placed in a liquid solution, the depth at which the hydrometer floats is related to the

[48] Note that in practice many producers use the boiling temperature of unconcentrated sap in the back of the sap pan as an estimate of the boiling point of water. This can be done since there is very little temperature elevation at the sugar concentration of sap.

density of the solution (**Figure 7.24**). Hydrometers are used in many different applications. As applied to the maple industry, both sap and syrup hydrometers are available for use in determining the sugar concentration of maple sap and syrup. For many producers, the syrup hydrometer is the instrument of choice for determining when syrup has reached the desired finished density. Hydrometers are relatively inexpensive and when correctly calibrated are quite accurate.

Figure 7.24. Hot testing with a hydrometer to determine syrup density. (Girard)

As discussed in Chapter 8, hydrometers are calibrated to directly read the density of a liquid at a specific temperature. At temperatures other than the calibrated temperature the reading must be adjusted to compensate for temperature-related variations. Most hydrometers used in the maple industry to determine syrup density are calibrated at 60°F[49]. When used to "hot test" boiling syrup, the target density reading of the hydrometer must be adjusted to the temperature of the syrup being tested. While boiling syrup would be expected to have a temperature of 219°F to 221°F (103.9°C to 105°C), it begins to cool as soon as it is placed in the hydrometer cup. The target density readings for "hot testing" maple syrup are, therefore, commonly determined assuming that the temperature of the syrup in the cup is in the vicinity of 211°F (99.4°C).

The "hot test" target density depends on the desired density of the finished syrup. With hydrometers calibrated to read directly at 60°F (15.5°C), the general rule is to subtract 8° Brix (or 4 points Baume) from the desired density to obtain an accurate "hot test" density reading. Thus, if the desired density of finished syrup were the legal minimum of 66° Brix, the "hot test" density reading would be 58° Brix[50]. Most producers of retail syrup finish syrup so the density is slightly higher, usually 66.5° Brix. In that case, the "hot test" density reading would be 58.5° Brix.

Almost all of the hydrometers currently used in the maple industry have two red lines encircling the paper scale in the stem, one labeled "Cold Test 60°F" and one labeled "Hot Test 211°F". It should not necessarily be assumed that these lines are appropriate for each maple operation. In most hydrometers the lines are approximately 0.5° Brix wide (i.e. there is a half a degree Brix difference between reading the top and the bottom of the line). Further, most of the hydrometers are designed to be legal in Vermont where the minimum density allowed for maple syrup is 66.9° Brix[51]. The mid-point of the "cold test" line is, therefore, 66.9° Brix, and the mid-point of the "hot-test" line is 59° Brix, the hydrometer reading for 66.9° Brix syrup when the temperature is approximately 211°F (99.4°C). Furthermore, the position of the lines may vary slightly as they are not always located precisely at these positions. It

[49] Note that many of the long-stemmed hydrometers, which are sometimes used to very accurately measure the density of contest syrups and whose stems are calibrated in 0.1° Brix units, are usually calibrated to directly read density at 68°F. See Chapter 8 for discussion.

[50] Readers who note that these values are different from those presented in any of the previous manuals need not be concerned. Values presented in the previous manuals were based on a hydrometer calibrated to directly read density at 68°F rather than 60°F.

[51] At the time of the writing of this manual 66.9° Brix was also the legal minimum for New Hampshire.

is suggested that maple producers calibrate their syrup hydrometer with a known standard, and make appropriate adjustments when it is used, so syrup of the desired finish density is produced.

Additional information regarding hydrometers and their use is discussed and illustrated in Chapter 8. For "hot testing" it is important that the syrup not cool below 211°F (99.4°C) before the density reading is obtained. Generally, density measurements will be satisfactory if they are made within 30 seconds of filling the hydrometer cup with syrup. To slow the rate of syrup cooling, hydrometer cups can be filled several times with boiling syrup from the evaporator prior to taking the test batch. The temperature of the test syrup can be verified with a thermometer, and should be rechecked if there is any question about the indicated density reading.

Because hot test density readings taken when the temperature of the syrup is not stable are generally not as accurate as cold test readings taken when the syrup's temperature is stable, the finished density of all syrup whose finish point was determined by hydrometer hot test should be verified with a hydrometer cold test once the syrup has cooled.

## Hydrotherm

A hydrotherm is a special hydrometer that has a liquid thermometer built into it that automatically locates the point on the hydrometer (the top of the thermometer liquid column) for measuring standard density syrup. It is used as a hydrometer, with 30 to 40 seconds allowed for the thermometer column in the hydrotherm to warm or cool to the temperature of the syrup. The perceived advantage to using a hydrotherm is that it self-adjusts for the temperature of the syrup. However, there are two disadvantages when using a hydrotherm. First, the top of the thermometer liquid column of many currently available hydrotherms is calibrated at 65.8° Brix rather than 66° Brix. This means that the density scale in the hydrotherm cannot be directly read but an adjustment must be made; if this is not done the density of the finished syrup will be less than what is desired. Second, while the hydrotherm contains a scale, it is not calibrated, and only with practice and some difficulty can this scale be used to determine how close the syrup is to the desired density. For these reasons, hydrotherms are not widely used. If one is used its accuracy must be determined by comparing it with an accurate hydrometer, taking into consideration any temperature corrections that must be made.

## Refractometers

Optical refractometers offer another method of checking the density of the sap or syrup. While the use of an accurate hydrometer and thermometer combination remains the most accurate method, a properly calibrated refractometer provides a quick determination of density that requires only a drop of liquid. However, the use of most refractometers with boiling syrup is not advised, as the scale reading of the rapidly cooling syrup is often not accurate (it often appears as a blurred image on optical refractometer), and hot syrup can damage the glass in many refractometers. The use of refractometers is described and illustrated in Chapter 8.

## Automatic Draw-Off

An automatic draw-off is a unit that continually monitors the temperature in the syrup pan in the vicinity of the draw-off valve (**Figure 7.25**). It is equipped with a solenoid valve that automatically opens to draw-off concentrated sap or syrup when the desired density is achieved. The obvious advantage of this unit is that it frees the producer from constantly monitoring density. In its simplest form, it consists of a probe that is placed in the side of the evaporator near the draw-off valve, a thermo-regulator that can be adjusted to open and close when the probe senses a specific temperature, a solenoid or motor-controlled valve that is located in the draw-off line, and a power source to provide the electricity that activates the valve when the thermo-regulator closes. Contemporary automatic draw-off units, available from maple equipment suppliers, are sensitive to changes in temperature of 0.1°F (0.056°C), allowing them to be used to draw-off either finished syrup or concentrated sap for transfer to a finishing pan. Some commercial units automatically compensate for changes in barometric pressure once calibrated. These units need to be calibrated for each evaporator since the depth of sap, the rate of flow, and the distance of the probe from

the outlet all affect accuracy. It should be remembered that automatic draw-off units need to be frequently monitored and the production of high quality syrup of uniform density requires regular attention by the operator of the evaporator.

Figure 7.25. An automatic draw-off unit monitors the temperature in the syrup pan and automatically opens a solenoid valve to draw-off sap or syrup when the desired density is achieved.

## Finishing Methods

Sap may be processed to finished syrup in the evaporator or it may be removed before the desired density is achieved and the final evaporation completed in a finishing pan.

### Finishing Syrup in the Evaporator

Finishing syrup in the evaporator is the more traditional method. Except in very large evaporators, it is seldom possible to continuously remove finished syrup from a syrup pan. Instead, syrup is removed discontinuously or in batches, with the last channel of the syrup pan functioning as a finish pan. Although many producers finish syrup directly in the evaporator, this method has a few disadvantages. These include:

- The turbulence of boiling syrup causes a constant mixing with less concentrated sap. This lengthens processing time since heating is a critical factor in flavor and color development.
- When syrup is drawn off, some syrup is left in the last channel to prevent burning. This syrup mixes with the incoming batch of concentrated sap, prolonging the heating period, which may affect flavor and color.
- The chance of a scorch increases with the increasing density of the sap; i.e. drawing off a large batch of finished syrup has a greater potential to burn than drawing off less concentrated sap.

To finish syrup in the evaporator, syrup density must be carefully monitored near the takeoff valve. If boiling point elevation is used as a density guide and 66° Brix is the desired density, the draw-off valve is opened as soon as the temperature of the boiling syrup reaches 7.1°F (3.1°C) above boiling water. In a large evaporator the temperature of the boiling syrup is then watched for changes. If the temperature increases above 7.1°F (3.1°C) that of boiling water, the draw-off valve is opened slightly; if the temperature decreases below, the draw-off valve is closed slightly. In this way, finished syrup is continually drawn off. In smaller evaporators, continual draw-off may not be feasible and finished syrup must be removed in batches. Finished syrup drawn from the evaporator should immediately be hot-tested for density with a hydrometer. If a batch of syrup is too dense, it can be immediately blended with some sap from the evaporator to achieve the correct density.

### Finishing Syrup in a Finishing Pan

Because of the perceived difficulties of finishing syrup in an evaporator, many sugarmakers finish syrup in a separate finishing pan (**Figure 7.26**). Often cited advantages of using a finish pan include:

- Concentrated sap is removed from the evaporator before it becomes syrup. This eliminates the risk of syrup remaining in the evaporator where continued heating will darken it and alter its flavor.

- Higher quality syrup is produced through maximum control of finishing the syrup in a batch process.
- Finished syrup is completely removed from the pan. Finish pans are cleaned between batches so no residue is left to influence the next batch.
- Permits filtering the concentrated sap as it is being transferred from the evaporator to the finishing pan. Syrup at this density (45° to 60° Brix) has essentially all of its sugar sand precipitated yet has a viscosity (fluidity) only slightly higher than water, and is more easily filtered than finished syrup. Syrup must be refiltered when finished.
- The finishing pan allows syrup to be accumulated until there is enough to fill a storage drum.

Figure 7.26. A gas heated finishing pan.

A finishing pan is essentially a batch evaporator in which sap of a density between 45° and 60° Brix is evaporated to finished syrup. Note that the concentrated sap being transferred from the evaporator to the finishing pan need not all be exactly the same density. Furthermore, the higher the density of the concentrated sap withdrawn from the evaporator, the smaller the amount of water that has to be evaporated in the finishing pan. If boiling point elevation is being used to identify when the concentrated sap should be transferred from the evaporator to the finishing pan, **Table 7.3** indicates the boiling temperature that will give concentrated sap of the desired density. For example, if 50° Brix is the desired concentration at which sap is to be transferred to the finish pan, **Table 7.3** shows that the boiling point elevation is 3.2°F. If water is boiling at 211°F (99.4°C), then 211°F (99.4°C) plus 3.2°F (1.8°C), or 214.2°F (101.2°C) is the boiling temperature of 50° Brix concentrated sap. When concentrated sap in the evaporator reaches this temperature it is ready to be transferred to the finishing pan or stored for later finishing.

The density of the partially processed sap when it is transferred to the finish pan and the size (production rate) of the evaporator influence the appropriate size of a finishing pan. Depending on desired syrup density, slightly more than 1.6 gallons of 45° Brix sap or slightly more than 1.4 gallons of 50° Brix sap is required to produce a gallon of finished syrup[52]. An evaporator that produces 4 gallons of finished syrup in an hour would produce close to 6.5 gallons of 45° Brix sap per hour[53]. Similar calculations can be done for evaporators with different capacities or where more than one evaporator is used to produce partially processed sap. When purchasing finish pans, producers need to match the productive capacity of the finish pan to the amount of partially processed sap that will be produced by the evaporator(s) and the time available to finish it. Using the cited example as an illustration, if the finish pan is expected to process at the same rate as the evaporator, it must be capable of processing 6.5 gallons of 45° Brix sap to 4 gallons of finished syrup in one hour. Obviously, depending on the size of the operation and equipment, it is not necessary that the production rate of the evaporator and finish pan be the same. However, this type of calculation will allow the processing time of the finish pan to be accurately estimated.

[52] A gallon of syrup finished at 66° Brix contains 7.28 pounds of sugar; one finished at 67° Brix contains 7.43 pounds of sugar. A gallon of partially processed sap at 45° Brix contains 4.52 pounds of sugar; one at 50° Brix contains 5.13 pounds of sugar. To produce 1 gallon of syrup finished at 66° Brix from partially processed sap at 45° Brix requires 7.28/4.52 = 1.61 gallons of the 45° Brix sap.

[53] (4 gallons syrup/hour)(1.61 gallons 45° Brix sap/gallon finished syrup) = 6.44 gallons 45° Brix sap per hour.

Finishing pans should have handles and be equipped with a precision thermometer having a range of 200°F (93.3°C) to 230°F (110°C) in 0.25° or finer divisions and a syrup draw-off spigot. Oil, propane, and natural gas are all commonly used heat sources since the flame is easily adjusted and can be shut off immediately when the syrup reaches the desired temperature. For convenience, some producers use two finishing pans alternately, one of which can be cleaned while the other is in use.

In many installations, syrup is pumped from the finishing pan to the holding or canning tank. A canister or plate filter press can be placed in the transfer pipeline to "polish" the syrup and remove any remaining sugar sand in the finished syrup.

## Filtering Syrup

Refer to Chapter 8 for a complete discussion on filtering systems and procedures.

## Shutting the Evaporator Down

When it is time to shut down the evaporator, care must be taken to avoid damaging the pans. This is particularly important with wood- or oil-fired evaporators since some residual heat will be maintained in the arch for a period of time. Even though fuel is no longer being supplied to the evaporator, enough heat can remain in the firebox and arch to cause damage to the thin metal pans if the sap level is low and eventually "runs dry." This heat retention is especially true if firebricks are used to line the firebox as opposed to the blanket insulation. To prevent damage to the pans after the unit is "shut down," the pans should be filled with 3 to 5 inches (7.5 to 12.5 cm) of sap for wood-fired evaporators and slightly less with oil-fired rigs before the fire is extinguished. Some producers remove wood coals and unburned fuel from the arch, although this is not common.

If sufficient sap is not available, water can be used to flood the pans. If the sap tank runs dry at the end of a boil, use mineral-free water (permeate or condensate) to force the last of concentrated sap or sweet out of the evaporator to avoid burning the pan (this process is sometimes referred to as "chasing the sweet"). If a reverse osmosis unit is being used, this may be accomplished by switching the sap feed line over to the permeate tank.

To keep the sap in the pans from freezing during extreme cold temperatures that may occur during the season, many producers drain the pans and store the sap in containers until the next time the evaporator is used.

## Cleaning the Evaporator

A clean evaporator maximizes heat transfer and is essential to the production of high quality maple syrup. The evaporator should be clean at the beginning of the season, usually needs to be cleaned during the season, and must be thoroughly cleaned inside and underneath (wood-fired evaporator) at the end of the season.

If the evaporator is thoroughly cleaned at the end of the season, it is only necessary to wash it out at the beginning of the season, or alternatively to boil water vigorously in the evaporator before sap is allowed to enter the pans. This will remove dust, dirt, cobwebs, etc., that have accumulated during storage. Be sure to rinse the evaporator thoroughly before evaporation begins. Some producers store non-stainless steel evaporator pans without cleaning them at the end of the season, assuming that the deposits provide a protective coating and keep the evaporator surfaces from corroding. This procedure is not recommended in that it usually creates a much more difficult cleaning chore that must be done in late winter before processing can begin.

During the season, it may be necessary to clean evaporator pans between runs to prevent residual sap from spoiling fresh incoming sap, or to remove soot that has accumulated on the underside of the pans, and to remove any accumulations of niter or scale. The underside of the pans should be kept clean to provide maximum heat transfer. Particular attention should be given to removing soot accumulations from the flues of the back pan. Wood-fired evaporators will obviously have more soot accumulations than oil evaporators.

Scale deposits are precipitates that form on the sides and bottom of the evaporator pans during the evaporation process. One type of scale, a

protein-like material, typically forms in the back pan. The other type, also known as sugar-sand, is a mineral salt deposit that forms primarily in the syrup pan. Sugar-sand is the more troublesome of the two types, particularly if allowed to accumulate to any appreciable thickness along the bottom of the evaporator pans. Accumulations of sugar-sand can reduce heat transfer, thus slowing evaporation. This can contribute to the production of darker, stronger flavored syrup. Sugar-sand can also contain some entrapped sugar that caramelizes upon excessive heating and results in the production of stronger flavored syrup. Finally and perhaps most importantly, scale can form hot spots that result in warping or burning the bottom of the syrup pan. The amount of sugar-sand that forms in evaporator pans varies from year to year and even within a season. It should be noted that when using a reverse osmosis unit or a more advanced preheater, sugar-sand may form throughout the entire evaporator rather than just in the syrup pan.

Periodically reversing the direction of sap flow (switching sides) in an evaporator with a reverse flow syrup pan will reduce scale accumulations. When the flow of sap through the evaporator is reversed, less concentrated sap flows over surfaces with scale build-up. The less concentrated sap will dissolve or lift some or all of the deposited scale or niter. In evaporators with cross flow pans, exchanging and then cleaning the pan rotated off of the arch prevents significant scale build-up.

During the season it may be necessary to clean evaporator pans between runs to remove accumulations of scale. Occasionally, scale will accumulate to such an extent during a run that evaporation must be stopped and the scale removed.

## Cleaning Scale from Pans

During the season thin layers of scale can be removed by boiling water (soft if available) or R/O permeate in the pans. Boiling agitates and lifts scale deposits and is the preferred method of cleaning moderate deposits. When scale deposits are not removed by boiling water, the pans can be scrubbed with a stiff nylon brush, Teflon® cleaning pad, or similar equipment. Be careful not to mar or scratch the stainless surface as this can promote the formation of scale. Caution is suggested when cleaning evaporator pans that contain lead solder. Minimal scrubbing of soldered joints is recommended to decrease the risk of exposing lead-containing surfaces to the boiling sap and syrup. A thin coating of scale and niter over soldered seams can actually reduce the amount of leaching of lead from these surfaces.

Some producers will use a dilute water/vinegar[54] solution periodically to remove scale. The dilute water/vinegar solution is brought to a boil, allowed to cool and remain in the pan for 12 to 24 hours, and then scrubbed with a stiff nylon brush, Teflon® cleaning pad, or similar equipment if necessary. Never use wire brushes that can scratch surfaces, or steel wool that may leave tiny steel fragments.

Producers with cross-flow front pans have found that the commercially available rinse racks designed for these pans often do an acceptable job of removing scale without scrubbing or the use of chemical cleaners. These units spray water (best to use a mineral-free water such as preheater condensate or RO water) over the pans.

Removal of scale during the season is most effective when done on a regular basis before heavy deposits are allowed to build up. Some producers employ a second syrup pan, cleaning one pan while boiling with the second. Whenever possible, cleaning should be done without the use of chemicals. However, the removal of substantial sugar-sand deposits during the season and at the end of the season may require chemical cleaners.

If chemical pan cleaning agents are used, the recommendations of the manufacturer and adequate environmental and personal safety precautions should be followed[55]. Most pan cleaners are acids, with the more common and traditional

[54] Concentrations used by producers vary depending on the length of soaking period and the severity of the scale deposits. Some producers report adding 2 to 3 cups of food-grade vinegar to an evaporator pan filled with 1 to 2 inches of water (preferably softened or R/O permeate).

[55] See Chapter 13 in this manual, and A.K. van den Berg, T.D. Perkins, and H.J. Marckres. 2005. *Chemical Safety in Maple Sugaring Operations*. University of Vermont Miscellaneous Publication, Burlington, VT.

being phosphoric and gluconic acid. Gluconic acid cleaners were commonly recommended for galvanized-iron equipment because they were less corrosive on the zinc coating[56]. Presently most maple equipment dealers sell chemical pan cleaners specifically labeled for maple equipment. Whichever cleaner is used, be sure to follow the label recommendations for mixing and using, and follow all safety precautions and guidelines. By law, chemical manufacturers are required to provide a Material Safety Data Sheet (MSDS), which will outline safety precautions, handling procedures, and storage requirements for cleaners.

The procedures for cleaning either sap or syrup pans with acid cleaners are the same. A good supply of pressurized, potable water is needed with which to rinse the pans after cleaning. If pressurized water is not available at the evaporator house, take the pans to a location where it is. Thorough rinsing is essential. Observe all safety precautions when using chemical cleaners, including wearing appropriate protective clothing, and avoid breathing the vapors. When cleaning is completed rinse the pans thoroughly to remove any traces of pan cleaning materials. Traces of pan cleaner products that remain in the pans could impart off-flavors or otherwise contaminate syrup produced when the evaporator is operated again. It is appropriate to ask pan manufacturers if using acid cleaners has any impact on warranties related to the pans.

When using a chemical pan cleaner, follow the directions on the label. The following general guidelines for using chemical pan cleaners are provided; however, they are not meant to replace label recommendations for specific products.

1. Remove all loose scale and dirt from the pan using a brush or broom. Thoroughly rinse the pan with a strong stream of water from a hose or a pressure washer.
2. Plug the outlets of the pan. Use metal threaded plugs if the outlets have threaded fittings; otherwise, use cork or rubber stoppers.
3. Fill the pan with enough potable water to thoroughly cover the areas to be de-scaled.
4. Add the correct amount of acid to the water in the pan and thoroughly mix to dissolve the acid.
5. If possible, warm the solution in the pan to a temperature of 140°F to 160°F to hasten the rate at which the scale softens and dissolves. After the warm solution has been in the pan for a short time (usually 15 to 20 minutes), brush the sides and bottom of the evaporator with a stiff nylon brush to speed the removal of the scale. With soldered pans, avoid or minimize brushing of soldered joints. Wear rubber chemical gloves and avoid breathing vapors created during this process.
6. Continue soaking and repeat brushing until the scale is completely removed. If cleaner is to be left standing in the pan, follow label directions. Under most conditions the time required to remove a thin layer of scale with a sulfamic acid based cleaner is about 1/2 hour; to remove a thick layer usually requires from 1 to 1½ hours. About twice as much time is required when using a gluconic acid based cleaner. A phosphoric acid based cleaner usually requires 1 to 2 hours to remove scale.
7. When the evaporator is clean, drain the acid water from the pan. If desired, the acid solution can be stored and reused several times. Store the cleaning solution in a glass, earthenware, approved plastic, or similar containers; do not store in iron or galvanized containers. If the cleaning solution is to be discarded after use, dispose of it following local chemical disposal guidelines; if possible, neutralize the acid before disposal.
8. Turn the pan on its side and thoroughly rinse it with a stream of potable water and avoid splashing the cleaning solution. Recommendations suggest multiple rinses, allowing the pan to drain between rinses. Consider using a baking soda solution as the first rinse to neutralize the acid.

[56] Gluconic acid based cleaners can be used to remove mineral deposits from other metals but their cleaning rate is generally slower than sulfamic acid based cleaners.

**Note: In the past some equipment manufacturers have used muriatic (hydrochloric) acid to remove heavy incrustations of sugar-sand from evaporators returned to them by sugarmakers. This acid is highly corrosive and dangerous, and should not be used by producers to clean pans.**

## End of Season Cleaning With Fermented Sap

In the past it was not uncommon for some producers to use the more traditional end-of-season cleaning procedure of filling the pans with sap and allowing them to stand for several weeks to a month or longer. During this time the sap ferments forming acids that loosen the scale. At some point, the sap becomes ropy, jelly-like, and difficult to remove. However, if allowed to stand longer, it will again become liquid and can be easily removed. The pans must be thoroughly rinsed after the fermented sap treatment. Fermented sap left in pans too long may result in serious pan damage, especially to soldered pans. This method should not be used in older English tin pans. A couple of weeks are usually sufficient, depending on the temperature and the sugar concentration of the sap. Fermented sap may not remove heavy scale deposits. If this process is used, the pans should be filled with water that is boiled for a period of time at the beginning of the next sap season before sap is added.

## Repair of Evaporator Pan Seams

When pan seams require repair, welded seams should be welded and soldered seams should be soldered using lead-free solder. Be sure the solder used is lead-free and not low lead. Remember that most equipment manufacturers offer repair services for both soldered and welded equipment.

# Chapter 8 · Syrup Filtration, Grading, Packaging, and Storage

Maple syrup is produced by concentrating the naturally occurring sugars (principally sucrose) present in maple sap through evaporation by boiling. During the process of heating (boiling) and attendant evaporation, the characteristic color and flavor associated with pure maple syrup are produced. However, during the evaporation process not only is the sugar content of the boiling sap increased, but so also is the concentration of other compounds, some of which produce suspended solids in the syrup. These suspended solids must be removed to produce syrup of the highest possible quality. This chapter discusses ways to filter the suspended solids from the syrup, along with proper methods of grading, packaging, and storing syrup—all critically important activities in successfully producing and marketing maple syrup of the highest quality.

## Syrup Filtration

When finished maple syrup (with the correct density) is removed from the evaporator it contains suspended solids commonly referred to as niter or sugar sand. The composition of sugar sand includes calcium and magnesium salts of malic acid. These salts form during evaporation and precipitate out of the syrup solution as their concentration increases. Malic acid is one of the organic acids present in maple sap. Sugar sand can occur in various forms ranging from a nondescript oily substance that is dark in color to a fine-grained, crystalline material that is light in color similar to beach sand—hence the name "sugar sand." Sugar sand can cause syrup to appear cloudy or darker in color, and impart a gritty texture. If present in large amounts, sugar sand can also result in an off-flavor in finished syrup.

The amount of sugar sand in maple syrup varies from year to year, during the season, and from one sugarbush to the next. Factors responsible for the amount of mineral compounds in maple sap are not completely understood. Apparently soil and site factors in the sugarbush contribute to the formation of sugar sand. It is also probable, but not yet proven, that local weather may play a role.

Syrup that is marketed must have all suspended material and other precipitates removed. The removal or clarification process is necessary to meet the requirements of states and/or provinces that have mandatory syrup grading requirements. From a practical perspective, it is necessary to produce a quality product. Two methods of removing suspended materials are commonly used; these involve settling/sedimentation and filtration systems.

### Settling/Sedimentation

This process is the simplest method of removing suspended solids from syrup. It involves simply placing finished syrup (of the correct density) in a large container, waiting for the suspended particles to "settle out" of the syrup, and then decanting the clarified syrup without disturbing the sediment. Though relatively simple in concept, this process has several disadvantages and is not commonly used. One disadvantage is that the sedimentation process requires considerable time, ranging from a few days to a week or more. Further, even after settling, some fine particles may remain which can detract from the syrup's perceived quality. Also, considerable care is required to not disturb the sediment when decanting the clarified syrup.

### Clarification by Filtration

Most producers use some type of filtering process to clarify or remove suspended particles from finished syrup. Filtration involves pouring or forcing finished syrup through a filter or series of filters to remove suspended particles. Syrup may be filtered either through a gravity or a pressure system. When done correctly, either process will result in effective clarification.

## Gravity Systems

Gravity filters utilize the natural force of gravity to move hot, finished syrup through a filtering material that traps and removes the suspended particles. Cone filters and flat filters are two common types of gravity filtering systems.

The "felt-hat" (so called because the filters look like a peaked hat) system uses a cone-shaped wool or synthetic felt bag that is suspended over an appropriately sized and shaped container (**Figure 8.1**). Hot syrup from the evaporator is poured into the filter bag and flows through to the collection container below. Since the filtration process may be slow, especially if large amounts of suspended particles are present, two or three bags can be suspended side by side over a single collection container. Syrup is placed in each bag as space is available. Filtering tanks are frequently fitted with canning spigots so syrup can be directly packaged following filtering. When this is done some provision must be made to keep filtered syrup hot (180–185°F, 82–85°C) while it is being packaged.

Figure 8.1. Felt-hat filter system, showing filter tank, paper prefilter (left top), and "felt" cone filters.

Flat filters consist of a wool or synthetic felt sheet placed over a food-grade hardware cloth screen (**Figure 8.2**). As with filter bags, two or three adjacent filtering units may be constructed. Hot syrup is poured on the filter and allowed to pass through to the collection container below. Once in the collection tank, syrup may be packaged directly if it is kept hot (> 180°F, 82°C) and a packing-valve filling assembly is present.

As hot syrup passes through a gravity-type filter, suspended sugar sand and other particles in the syrup accumulate on the filter and are removed. This material reduces the rate of syrup flow through the filter, eventually requiring that the filter be cleaned. To prolong the period of use between washings, a pre-filter is often used. Paper or nylon pre-filters are available that can be placed on top of the felt filter (**Figures 8.1 and 8.2**). When accumulations of sugar sand build up, the pre-filter is either replaced or is removed, washed, and reinstalled. This process will extend the life of the felt filter and will increase the rate at which filtration occurs. Some producers use two or three pre-filters, removing the top pre-filter when it starts to clog, and gently pouring the syrup into the next pre-filter below. Some claim that this process results in a better and more rapid filtering operation.

Figure 8.2. Flat gravity filter/bottling system showing filter sheet, paper prefilter (on top of "felt" filter), and supporting screen.

While different techniques may be used to wash both pre-filters and felt filters, many producers use a system that attempts to keep the "syrup side" of the filter from coming in contact with the accumulated sugar sand. Before washing the sugar sand is carefully scraped off the filter. Then water[57] is forced through the filter from the

[57] Some producers pass hot sap through the filter to reclaim the syrup remaining in it, and then return the sap to the evaporator.

"syrup side" to the "sugar sand side." When all the sugar sand has been removed the filter is washed and allowed to dry. Use only hot water to wash. Do not use chlorine bleach, scented detergents, or other washing aids that might impart an off-flavor to finished syrup. Between seasons filters should be stored in a clean, dry place, protected from insects and other vermin. Filters should not be exposed to mothballs or other aromatic substances (e.g. scented soap, cleaning agents, etc.) as these odors may cause an off-flavor in the syrup.

It is also advisable to wash new filters before they are used as they may have a "chemical odor" that should be removed. Place them in boiling water followed by rinsing and drying. Putting the filters through a wringer, common to older washing machines, is an effective means of removing water. The filters should never be twisted as this may break some of the fibers thereby reducing the filter's effectiveness. Following washing the filters should be allowed to air dry.

## Pressure Filters

Pressure filters are of two types, plate and canister (**Figure 8.3**). In both types syrup is forced through the filtering medium under pressure from a pump. As a result, both process syrup more quickly than gravity filters, and provide excellent filtration. Both types use filter paper or filter cloth along with diatomaceous earth (commonly referred to as "DE" or filter aid) as the filtering medium. Syrup produced is free of detectable particles and has a "polished" or "sparkling" appearance. Another commonly cited benefit of pressure filters is that they provide a clean, convenient way to move syrup in the sugarhouse. Before using either type of pressure filter, be sure to obtain a complete set of directions on the assembly and use of your specific model. Assembly procedures and recommended methods of operation vary somewhat among different units. The following discussion is provided as an introduction to pressure filters, not as a step-by-step guide to their use.

Figure 8.3. Canister (top) and plate (bottom) pressure filters.

## Plate Pressure Filter or Filter Press

The major components of most plate filter presses include the filter press frame, end plates, filter plates (waffle or backer plates and frame or cake plates), a pump, some form of power for the pump, and appropriate connecting hardware including a pressure gauge if other than a hand-powered pump is used (**Figures 8.3 and 8.4**). Filter plates are of two types, frame or cake plates and backer or waffle plates. The frame or cake plates appear as picture frames, with an open area in the center in which a diatomaceous earth (filter aid) cake is formed. The backer or waffle plates are solid-appearing plates that have a waffle surface texture. In an assembled press, the backer plates alternate with the cake plates, dividing the press into a series of filtering compartments. A variety of pumps are used with plate-type filter presses. Pressure filters may utilize electric, air compressor, or hand-operated pumps to move the syrup through the apparatus.

The cake of diatomaceous earth that is formed in the center of each of the cake plates and the filter paper placed between each plate in the "stack" accomplish the filtering process in a plate-type press. The filter paper acts as a barrier against which the cake of diatomaceous earth forms.

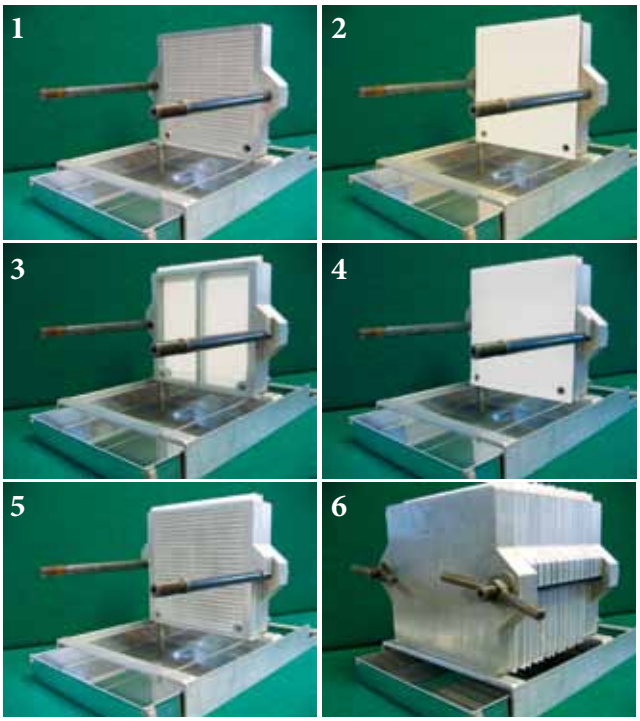



Figure 8.4. Components of most plate filter presses include the filter press frame (1–6), end plates (1, 6), filter paper (2–6), waffle or backer plates (5), and frame or cake plates (3).

When the plate-type filter press is in operation:

- Hot syrup containing diatomaceous earth (filter aid) is pumped into the press.
- Syrup flows into a diatomaceous earth cake through holes in the sides of the frame plates.
- Syrup then flows through the cakes of diatomaceous earth and the adjacent filter papers where suspended solids and diatomaceous earth are removed, gradually increasing the size of the filter cakes.
- Syrup then flows along the waffled surfaces of the adjacent backer plates.
- Syrup exits the compartments and the press through holes in the side of the backer plates.

Hot syrup to be filtered is typically mixed with the filter aid before being pumped through the filter press. The amount of filter aid required depends on a variety of factors. These include the size of the filter press (number and size of plates), the amount of syrup to be filtered, and the amount of dissolved solids to be removed. For example, 1 cup of filter aid for every 5 gallons of syrup to be filtered is a common recommendation for "average" quality syrup to be filtered in a standard 10-inch plate-type press. Therefore, 50 gallons of syrup would require 10 cups of filter aid.

While some recommendations suggest mixing the required amount of filter aid with the entire batch of syrup to be filtered, current recommendations are to "charge" the filter press with half the filter aid before actual filtering to produce superior results. To "charge" the filter press, mix half of the required filter aid with 3 to 5 gallons of hot syrup in a stainless container. Pump this mixture through the filter press, and collect the output in a second stainless container. This process deposits an initial layer of diatomaceous earth on the filter paper within each compartment of the press, creating the initial filter aid cake. As the last of this syrup/diatomaceous earth charging mixture exits the filter press, the output should be checked for clarity. If it is cloudy, the charging mixture should be run through the filter press repeatedly until it runs clear. Once it runs clear, the "charging mix" can be added to the syrup to be filtered, the remaining required amount of filter aid added, and the entire batch filtered. An alternative method is to mix the diatomaceous earth with the syrup and pump the first few gallons of syrup back into the container holding the syrup/diatomaceous earth mix in order to allow the filter aid cake to develop. Once the output from the filter is completely clear, the output hose can be moved to the appropriate storage container.

## Canister Pressure Filters

The major components of a canister pressure filter include a stainless steel outer canister, smaller stainless steel inner canister with perforated walls, gear pump and electrical motor, and appropriate connecting hardware and pressure gauge (**Figures 8.3 and 8.5**). When the canister filter is assembled, a reusable cloth filter is placed around the inner canister, which provides the support for the cloth filter and the diatomaceous earth

cake. As with the plate filter press, the canister press should be "charged" with about half of the required filter aid. Hot syrup containing filter aid is pumped into the outer canister. It then passes through the diatomaceous earth cake forming on the outer surface of the cloth filter, through the cloth filter and into the inner canister through the perforation in the wall, and out of the filter through an outlet in the top of the inner canister. Some producers successfully filter small batches of syrup through a canister pressure filter without using filter aid, depending solely on the filter cloth as the filtering medium.

Figure 8.5. Inner and outer canister of canister pressure filter showing filter cloth around inner canister.

## Suggestions for Using a Pressure Filter

When using a pressure filter the following suggestions are offered:

- Assemble, disassemble, and clean according to manufacturers recommendations. Be sure none of the plates are reversed.
- Filter the syrup hot—recommendations vary from a minimum of 180°F (82°C) to 200°F (93°C). Keeping the filter press itself hot will also aid in filtering syrup.
- Operate the filter press only within the recommended pressure range for safety and efficiency. Most pressure filters begin filtering at pressures below 20 psi (depending on the pump), and filtering should be discontinued when the pressure approaches 50 psi (consult individual instructions). At higher pressures filters become too clogged to function safely and effectively, and should be cleaned and recharged.
- Have a bypass (release) line and valve located between the pump and the press that can be used to divert some of the syrup before it enters the filter. If the pressure in the system is approaching the pressure limit with a small amount of syrup remaining to be filtered, some of the syrup coming from the pump can be diverted back to the tank of unfiltered syrup. This slows the filtering rate and reduces the pressure, thereby allowing a small additional amount of additional syrup to be filtered before shut-down is necessary.
- Use only food-grade diatomaceous earth filter aid. Non-food-grade can alter the composition, color, or flavor of syrup, destroying its quality and/or rendering it unfit for consumption. Do not use commonly available swimming pool filter grade diatomaceous earth.

The amount of syrup that can be filtered with a pressure filter before it has to be cleaned and recharged depends on the quality of the syrup and amount of suspended sediment. The more suspended sediment, the smaller the quantity that can be filtered per charge. Producers report filtering as much as a hundred gallons of very high quality syrup with little suspended solids to as little as 10 to 15 gallons of low quality syrup high in suspended solids. For a 7 or 10-inch plate filter press or 12-inch canister filter press, filtering 50 to 60 gallons (190–228 liters) of "average" syrup per charge is a reasonable expectation. It is worth noting, that very low quality syrup that quickly plugs a pressure filter could not be filtered at all with a gravity filter.

One common misconception is that it is the diatomaceous earth which causes the pressure to build in a pressure filter system. Actually, the suspended solids plug the minute holes formed by the filter aid and cause increased pressure. The more filter aid added, the more pores created in the filter aid cake. Therefore, if filtering is difficult, although the natural tendency is to reduce the amount of filter aid used, in fact the opposite

will do the most good. When filtering is hard, INCREASE the amount of filter aid for better results.

## Measuring and Adjusting Syrup Density

Although the grade of pure maple syrup is largely determined by color, it is absolutely essential that all grades of syrup meet minimum density standards. At the time of this writing the minimum legal density of pure maple syrup in all provinces and most states was 66.0 percent soluble solids by weight[58], commonly referred to as 66° Brix (discussed below). The density of syrup is commonly determined by using either a refractometer or a hydrometer. Weight per volume can also be used to determine syrup density, but because of the accuracy and precision required in measuring the temperature, volume, and weight of a syrup sample, the use of weight as a measure of syrup density is not a practical tool for producers.

While 66.0° Brix is the legal minimum density for maple syrup in most states and the provinces, the character and quality of maple syrup is strongly affected by its density. Producers need to become aware of these effects, and learn to correctly finish syrup at the desired density.

Viscosity, the measure of a fluid's resistance to flow (its apparent thickness), is an important characteristic of pure maple syrup. Until the sugar concentration of boiling maple sap exceeds 30° Brix, an increase in sugar percentage has relatively little effect on viscosity. However, as the sugar concentration increases toward standard density syrup, the increase in viscosity becomes pronounced. Maple syrup having a density of only 0.5° to 1.0° Brix below standard density syrup feels and tastes "thin" and "watery." Conversely, an increase of only 1.0° Brix above standard density causes the syrup to acquire a thick, pleasant feel to the tongue and the perception of considerable increased sweetness.

This explains why some producers finish their syrup at a density slightly above that of standard density syrup—customers can tell the difference between 66° and 67° Brix, and most prefer the taste of the thicker and somewhat heavier syrup.

Syrup density also affects how well product quality is maintained during storage. Syrup with a density of less than 66.0°Brix is likely to spoil more quickly, and syrup with a density greater than 67° Brix may precipitate sugar crystals when stored at room temperature for extended periods.

Finally, the higher the density at which syrup is finished, the less can be made from a given amount of sap. For example, a producer making 66 gallons of syrup finished at 67° Brix could make 67 gallons of syrup finished at 66° Brix from the same amount of sap.

### Syrup Density Scales

#### The Brix Scale

The Brix scale is the most commonly used density scale in the industry. The Brix scale relates the density of syrup to that of sugar solutions of the same density and known percentages of sugar. It does not express the true percentage of sugar in maple syrup; rather it is an indication of what the percentage of sugar would be if sugar was the only dissolved solid. The Brix scale is, however, particularly well suited for measuring the density of maple syrup because typically 98 percent of the dissolved solids in syrup are sugars. For practical purposes, the Brix value equals the percentage of sugar in the syrup. When using the Brix scale, density is expressed as "degrees Brix" or less commonly "percent Brix," and is written as ° Brix.

A good approximation of the weight of sugar in any lot of maple syrup, whether or not it is standard-density syrup, can be found by multiplying the weight of the syrup by its density (degrees Brix) and dividing by 100. This information is important to the producer who sells his/her syrup wholesale since the price is based on its solids (sugar) content or weight.

[58] At the time of this writing the only jurisdictions with a minimum legal density different from 66.0° Brix for pure maple syrup were Vermont and New Hampshire, which both have a minimum legal density of 66.9° Brix.

Thus, 100 pounds of syrup at 65° Brix contains 65.0 pounds of sugar, whereas 100 pounds of standard-density syrup (66° Brix) contains 66.0 pounds of sugar. Therefore, 100 pounds of the low-density syrup has a lesser value than 100 pounds of standard-density syrup. Likewise, 100 pounds of syrup with a density of 66.8° Brix contains 66.8 pounds of sugar, which is more than that contained in 100 pounds of standard-density syrup, and therefore it has greater value.

## The Baume Scale

The Baume scale is less widely known and used than the Brix scale, but it is firmly entrenched in some geographic areas and many producers use it exclusively. The Baume scale relates the density of a liquid to that of a salt solution. It does not directly express the solids content of maple syrup and therefore does not have the same utility for determining syrup sugar concentrations. Comparisons between the Brix and Baume scales are presented in **Table 8.1**. This table may be used to convert between the two scales. As an example, 66.0° Brix is equivalent to 35.6° Baume. When using the Baume scale, density is expressed as "degrees Baume" or less commonly "points Baume," and is written as ° Baume or °Bé.

**Table 8.1. Comparison of Brix with Baumé scales for values between 30° and 70° Brix.**

| °Brix °Baumé | °Brix °Baumé | °Brix °Baumé | °Brix °Baumé | °Brix °Baumé | °Brix °Baumé |
|---|---|---|---|---|---|
| 30.0.....16.6 | 43.5.....23.8 | 57.0.....30.9 | 62.0.....33.5 | 64.7.....34.9 | 67.4.....36.3 |
| 30.5.....16.8 | 44.0.....24.1 | 57.5.....31.2 | 62.1.....33.6 | 64.8.....34.9 | 67.5.....36.3 |
| 31.0.....17.1 | 44.5.....24.4 | 58.0.....31.5 | 62.2.....33.6 | 64.9.....35.0 | 67.6.....36.4 |
| 31.5.....17.4 | 45.0.....24.6 | 58.5.....31.7 | 62.3.....33.7 | 65.0.....35.0 | 67.7.....36.4 |
| 32.0.....17.7 | 45.5.....24.9 | 59.0.....32.0 | 62.4.....33.7 | 65.1.....35.1 | 67.8.....36.5 |
| 32.5.....17.9 | 46.0.....25.2 | 59.5.....32.2 | 62.5.....33.8 | 65.2.....35.2 | 67.9.....36.5 |
| 33.0.....18.2 | 46.5.....25.4 | 60.0.....32.5 | 62.6.....33.8 | 65.3.....35.2 | 68.0.....36.6 |
| 33.5.....18.5 | 47.0.....25.7 | 60.1.....32.5 | 62.7.....33.9 | 65.4.....35.2 | 68.1.....36.6 |
| 34.0.....18.7 | 47.5.....26.0 | 60.2…..32.6 | 62.8.....33.9 | 65.5.....35.3 | 68.2.....36.7 |
| 34.5.....19.0 | 48.0.....26.2 | 60.3.....32.6 | 62.9.....34.0 | 65.6.....35.3 | 68.3.....36.7 |
| 35.0.....19.3 | 48.5.....26.5 | 60.4.....32.7 | 63.0.....34.0 | 65.7.....35.4 | 68.4.....36.8 |
| 35.5.....19.6 | 49.0.....26.8 | 60.5.....32.7 | 63.1.....34.1 | 65.8.....35.5 | 68.5.....36.8 |
| 36.0.....19.8 | 49.5.....27.0 | 60.6.....32.8 | 63.2.....34.1 | 65.9.....35.5 | 68.6.....36.9 |
| 36.5.....20.1 | 50.0.....27.3 | 60.7.....32.9 | 63.3.....34.2 | 66.0.....35.6 | 68.7.....36.9 |
| 37.0.....20.4 | 50.5.....27.5 | 60.8.....32.9 | 63.4.....34.2 | 66.1.....35.6 | 68.8.....37.0 |
| 37.5.....20.6 | 51.0.....27.8 | 60.9.....33.0 | 63.5.....34.3 | 66.2.....35.7 | 68.9.....37.0 |
| 38.0.....20.9 | 51.5.....28.1 | 61.0.....33.0 | 63.6.....34.3 | 66.3.....35.7 | 69.0.....37.1 |
| 38.5.....21.2 | 52.0.....28.3 | 61.1.....33.1 | 63.7.....34.4 | 66.4.....35.8 | 69.1.....37.1 |
| 39.0.....21.4 | 52.5.....28.6 | 61.2.....33.1 | 63.8.....34.5 | 66.5.....35.8 | 69.2.....37.2 |
| 35.5.....21.7 | 53.0.....28.9 | 61.3.....33.2 | 63.9.....34.5 | 66.6.....35.9 | 69.3.....37.2 |
| 40.0.....22.0 | 53.5.....29.1 | 61.4.....33.2 | 64.0.....34.5 | 66.7.....35.9 | 69.4.....37.3 |
| 40.5.....22.2 | 54.0.....29.4 | 61.5.....33.3 | 64.1.....34.6 | 66.8.....36.0 | 69.5.....37.3 |
| 41.0.....22.5 | 54.5.....29.6 | 61.6.....33.3 | 64.2.....34.6 | 66.9.....36.0 | 69.6.....37.4 |
| 41.5.....22.8 | 55.0.....29.9 | 61.7.....33.4 | 64.3.....34.7 | 67.0.....36.1 | 69.7.....37.4 |
| 42.0.....23.0 | 55.5.....30.2 | 61.8.....33.4 | 64.4.....34.7 | 67.1.....36.1 | 69.8.....37.5 |
| 42.5.....23.3 | 56.0.....30.4 | 61.9.....33.5 | 64.5.....34.8 | 67.2.....36.2 | 69.9.....37.5 |
| 43.0.....23.6 | 56.5.....30.7 | | 64.6.....34.8 | 67.3.....36.2 | 70.0.....37.6 |

## Measuring Syrup Density

As indicated, syrup density is most commonly determined by using either a refractometer or a hydrometer. A properly calibrated hydrometer is the instrument of choice for most syrup producers, especially when finishing syrup directly from the evaporator or from a separate finishing pan.

### Using a Refractometer

A refractometer (**Figure 8.6**) measures the density of syrup by measuring the refractive index of a solution (syrup), which is directly related to the amount of dissolved solids (primarily sugar) present in the solution. When using a hand-held optical refractometer, a drop of syrup is placed on a small window at one end of the refractometer, and the density of the solution is indicated by a dark shadow appearing against a calibrated background scale when viewed through the eyepiece at the other end of the refractometer. When using a hand-held digital refractometer, a drop of syrup is placed on the testing window and the density of the solution is reported digitally in the window. Most modern refractometers automatically compensate for the temperature of the syrup, thus providing direct reading of the correct density. Be aware, however, that many older refractometers do not automatically compensate for temperature, and readings must be adjusted if the temperature of the syrup and refractometer differs from the instrument's calibrated temperature. Also, it is important to realize that syrup refractometers must be periodically calibrated with either a calibration oil of known density or a calibration glass (occasionally provided with a refractometer). If possible, the calibration oil or glass should have a value close to the density of syrup. Sap refractometers are calibrated to a zero value with distilled water.

Hand-held refractometers are reasonably precise instruments, relatively easy to use, but moderately expensive and most are not well suited to measuring the density of hot syrup. Accuracy and readability of hand-held instruments commonly used in the maple industry are approximately 0.2° Brix. Cost commonly ranges between $100 and $400, depending on construction and features (such as automatic temperature compensation).

More accurate bench models, with digital output, are available at considerably higher cost. Most hand-held refractometers currently on the market are not recommended for measuring the density of hot syrup (> 180°F, 82°C) for several reasons. First, liquids near the temperature of boiling syrup can permanently damage the glass in many refractometers. Second, as hot syrup cools rapidly it creates a blurred shadow in optical refractometers that is difficult, if not impossible, to read, rather than the sharp-edged shadow that appears when cooler syrup is tested. Also, significant water can evaporate from the tiny, hot syrup sample to affect the density reading.

Figure 8.6. Optical refractometer (left) and digital refractometers (center and right).

### Using a Hydrometer

Hydrometers are specially constructed glass tubes that contain a weighted bottom and a calibrated scale (Brix or Baume for maple use) in a glass stem which, when the hydrometer is floated in syrup, indicates the syrup's density (**Figure 8.7**). The use of a hydrometer (hydrometry) is based on a physics principle that the density of a liquid (syrup in this case) can be measured by evaluating the amount of the liquid displaced by a floating body (i.e. how high the hydrometer floats in the syrup). The less dense the liquid, the deeper the hydrometer floats; the more dense the liquid, the shallower the hydrometer floats. For the majority of producers, the hydrometer is the instrument of choice for determining syrup density. It is relatively inexpensive (a standard syrup hydrometer and cup costs less than $40 at this writing), relatively easy to use, and reasonably precise if used correctly.

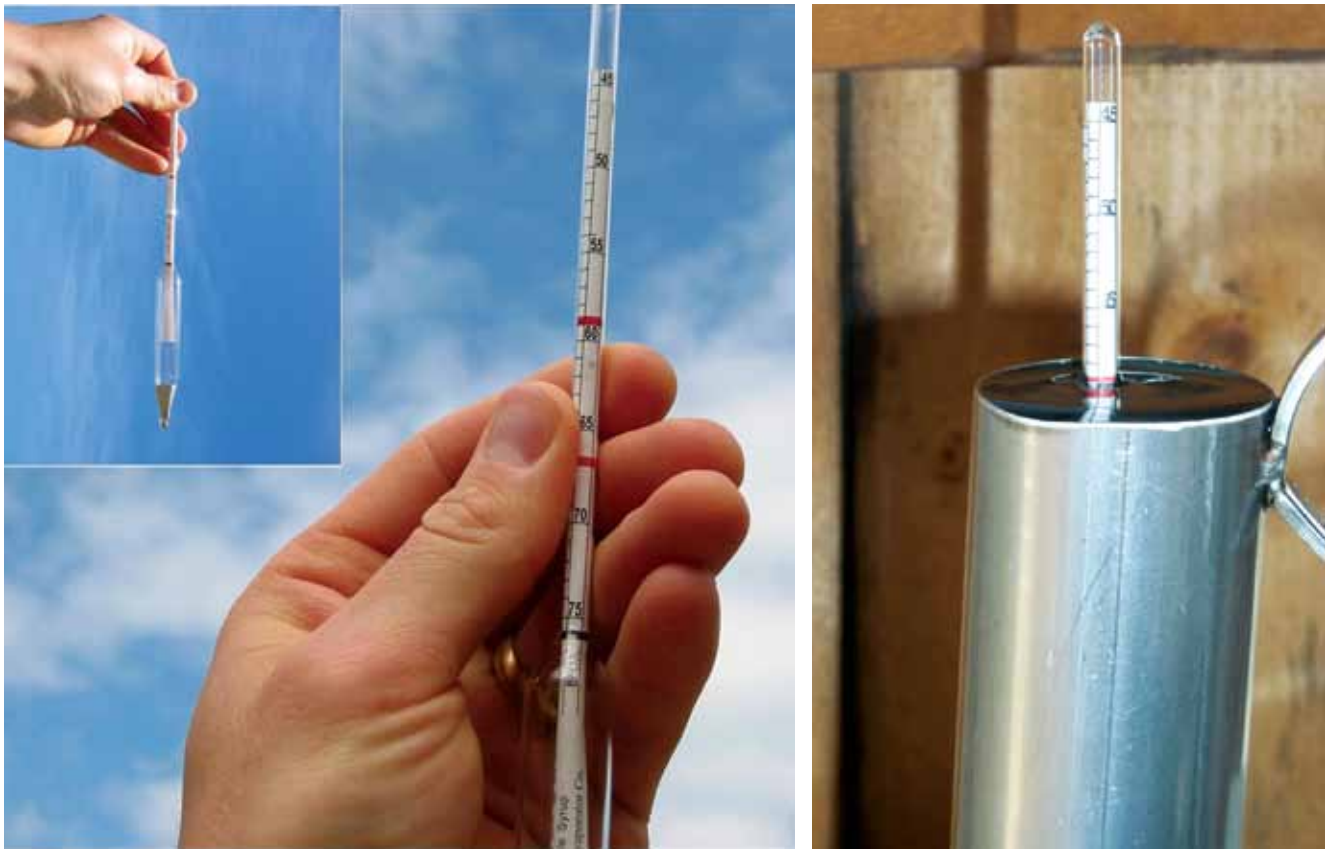


Figure 8.7. Hydrometer (insert, left), close-up of hydrometer scale (left), and hydrometer in use measuring density of syrup (in hydrometer cup).

Hydrometers are well adapted for use in the sugarhouse as they can be used to measure the density of syrup from well below room temperature to near boiling. However, the depth at which a hydrometer floats in syrup depends on the syrup's "thickness," which is a function of both syrup density and temperature. Hydrometers, therefore, are calibrated for use in syrup of a specific temperature. When the hydrometer is placed in syrup at the calibration temperature, the hydrometer reads the correct density. At all other temperatures the hydrometer reading must be corrected. Most hydrometers commonly used in the maple industry are calibrated at 60°F (15.6°C). **Table 8.2** presents the Brix and Baume density corrections for hydrometers calibrated for 60°F. For example, when using a hydrometer calibrated for 60°F, if the syrup density is determined to be 65.8° Brix and its temperature is 80°F (26.7°C), the actual density of the syrup would be 66.8° Brix. Note that producers sometimes use long-stemmed hydrometers to measure syrup density to the nearest 0.1° Brix (e.g. contest syrup). Most long-stemmed hydrometers are calibrated for 68°F (20°C) syrup, and require a different correction table (**Table 8.3**). It is important to determine the calibration temperature of the hydrometer being used. This information is usually printed on the scale paper in the stem.

**Table 8.2. Density corrections commonly used for Brix and Baume readings for hydrometers calibrated for 60°F. Add values preceded by a "+", subtract values preceded by a "-".**

| Temperature at Which Density Measured | Brix Adjustment[1] (+ or -) | Baume Adjustment[2] (+ or -) |
|---|---|---|
| 209+ | +8.0 | +4.0 |
| 202+ | +7.5 | +3.75 |
| 193+ | +7.0 | +3.5 |
| 185 | +6.5 | +3.25 |
| 176 | +6.0 | +3.0 |
| 167 | +5.5 | +2.75 |
| 158 | +5.0 | +2.5 |
| 149 | +4.5 | +2.25 |
| 140 | +4.0 | +2.0 |
| 130 | +3.5 | +1.75 |
| 120 | +3.0 | +1.5 |
| 110 | +2.5 | +1.25 |
| 100 | +2.0 | +1.0 |
| 90 | +1.5 | +.75 |
| 80 | +1.0 | +.5 |
| 70 | +.5 | +.25 |
| 60 | 0 | 0 |
| 50 | -0.5 | -.25 |
| 40 | -1.0 | -.5 |

[1]Brix adjustments calculated at 0.05° Brix for each 1° F.
[2]Baume adjustments calculated at 0.025° Baume for each 1° F. Note, the C. H. Jones rule states that the actual adjustment should be 0.0265° Baume for each 1° F, but that level of precision exceeds that achievable with commonly used hydrometers.

**Table 8.3. Density corrections commonly used for Brix readings for hydrometers calibrated for 68°F.**

| Temperature of syrup in hydrometer cup °F (°C) | Correction to subtract from (-) or add to (+) observed Brix reading of: | |
|---|---|---|
| | 60.0°-69.9° | 69.9° and higher |
| 32 (0.0) | -1.4 | -1.5 |
| 35 (1.7) | -1.3 | -1.4 |
| 40 (4.4) | -1.2 | -1.2 |
| 45 (7.2) | -1.0 | -1.0 |
| 50 (10.0) | -0.8 | -0.8 |
| 55 (12.8) | -0.5 | -0.5 |
| 60 (15.6) | -0.3 | -0.4 |
| 65 (18.3) | -0.1 | -0.1 |
| 68 (20.0) | 0.0 | 0.0 |
| 70 (21.1) | +0.1 | +0.1 |
| 75 (23.9) | +0.3 | +0.3 |
| 80 (26.7) | +0.5 | +0.5 |
| 85 (29.4) | +0.8 | +0.8 |
| 90 (32.2) | +1.0 | +1.0 |
| 95 (35.0) | +1.2 | +1.2 |
| 100 (37.8) | +1.5 | +1.5 |
| 105 (40.6) | +1.7 | +1.7 |
| 110 (43.3) | +1.9 | +1.9 |
| 115 (46.1) | +2.2 | +2.2 |
| 120 (48.9) | +2.4 | +2.4 |
| 125 (51.7) | +2.7 | +2.7 |
| 130 (54.4) | +3.0 | +2.9 |
| 135 (57.2) | +3.2 | +3.2 |
| 140 (60.0) | +3.5 | +3.4 |
| 145 (62.8) | +3.8 | +3.7 |
| 150 (65.6) | +4.1 | +4.0 |
| 155 (68.3) | +4.4 | +4.2 |
| 160 (71.1) | +4.7 | +4.5 |
| 165 (73.9) | +5.0 | +4.9 |
| 170 (76.7) | +5.5 | +5.2 |
| 176 (80.0) | +5.9 | +5.7 |

As briefly discussed in Chapter 7, most hydrometers used in the maple industry, with the exception of the long-stemmed hydrometers noted above, are marked with two red lines; one labeled "Cold Test 60°F" and one labeled "Hot Test 211°F", and most are "Vermont Approved"[59]. These two lines are placed on the scale paper to make it easier to identify the depth at which the hydrometer should float in syrup with a density of 66.9° Brix (36° Baume) when the syrup is at 60°F ("Cold Test") and near boiling ("Hot Test"). The finished density of 66.9° Brix (36° Baume) is highlighted because it is the legal minimum syrup density in Vermont. Before using such a hydrometer, producers should closely examine it and identify the positions of each line. Note the exact position of the lines as they are not always located precisely at the intended position. Furthermore, the lines are approximately 0.5° Brix (0.25° Baume) wide and can be read at the top, midpoint, or bottom of the line. Finally, producers should not assume that the lines are appropriate for their operation. If 66.9° Brix (36° Baume) is the desired finish point, the lines can provide a precise guide. However, if some other density is desired, the lines may be less useful. When this is the case, the density of the syrup is read and corrected for temperature, and the "Hot Test" density is determined by subtracting 8° Brix (4° Baume) from the desired density.

When using a hydrometer, consider the following suggestions:

- Make sure the hydrometer is clean and dry (a slight film of water on the hydrometer is acceptable and may actually help break surface tension, but it should not be dripping wet).
- Use a hydrometer cup that is nearly as long as or longer than the hydrometer, and one and a half times as wide.
- Fill the cup to the top, float foam off, and "hot test" (review the section in Chapter 7 on use of hydrometer for "hot testing" syrup from the evaporator or finish pan).
- Lower the hydrometer gently (slowly) into syrup. Do not allow any portion of the stem above the equilibrium point to dip into the syrup.
- Read the density as soon as the hydrometer "settles," and determine the temperature of the syrup if other than a "hot test." The temperature of the syrup can most conveniently be read with a small dial thermometer.
- If the syrup temperature is other than the calibration temperature, correct the density reading using the appropriate table.

Common sources of error when using a hydrometer include the following:

- Using a dirty hydrometer. Failure to clean a hydrometer after each use can result in the accumulation of a crusty coating of sugar sand on the hydrometer. This coating adds weight to the hydrometer, resulting in lower density readings, perhaps as much as 1° Brix. The use of such a hydrometer as a guide will result in the production of heavy syrup. Clean the hydrometer with warm water after each use. If a crusty coated hydrometer must be cleaned, first try warm water, then a mild acid such as vinegar. If scraping is required, use a Teflon pan cleaning pad to avoid scratching the glass. If the hydrometer cannot be cleaned it should be discarded. A new hydrometer that will provide accurate values is relatively inexpensive.
- Over time the paper with the density scale printed on it may move up or down in the hydrometer stem, resulting in erroneous density readings. This source of error is much more likely with a standard syrup hydrometer where the scale paper is tightly wedged into the stem. Most long-stemmed hydrometers have the scale attached to the hydrometer wall. With a standard syrup hydrometer, the movement of the scale paper ⅛ inch represents an error of 1° Brix or ½° Baume. The key to recognizing this source of error is being aware of where the scale paper should be positioned in each hydrometer that is used. If the hydrometer is stored in its original box, mark the position of the top of the scale paper on the inside bottom or side of the box to use as a reference. Alternatively, the hydrometer can be placed against a wall on a

[59] Vermont law requires all hydrometers used in the state to be tested, approved, and so marked by the Vermont Agency of Agriculture, Food & Marketing—most hydrometers sold by equipment dealers have been through this process.

counter surface and the top of the scale paper marked on the wall.

- Because hydrometers are easily dropped and broken, always have a spare hydrometer on hand.
- Having two hydrometers that initially read correctly can provide some assurance that both are accurate.

If problems occur when there is sap to be processed, valuable time or sap can be lost if a spare hydrometer is not available. When a new hydrometer is obtained check its accuracy against the one that is currently being used, or with a refractometer. Occasionally a hydrometer is sold with the scale paper in the wrong position.

In addition to instrument errors, procedural errors may also result in an erroneous reading. Technique errors include:

- Allowing the hydrometer stem to sink into syrup, picking up syrup on the surface of the stem. This will increase the weight of the hydrometer and cause it to read light.
- Allowing the hydrometer to "hang up" on the side of the hydrometer cup or other container.
- Reading the hydrometer scale at the wrong point.
- Allowing the syrup to cool too long when "hot testing."
- Failing to adjust for temperature.

### Using A Hydrotherm

A hydrotherm is a special hydrometer which has a liquid thermometer built into it that automatically locates the point on the hydrometer (the top of the thermometer liquid column) for measuring standard density syrup (**Figure 8.8**). It is used as a hydrometer, with 30 to 40 seconds allowed for the thermometer column in the hydrotherm to warm or cool to the temperature of the syrup.

The perceived advantage to using a hydrotherm is that it self-adjusts for the temperature of the syrup. There are, however, two disadvantages to using a hydrotherm. First, the top of the thermometer liquid column of many commonly available hydrotherms is calibrated to 65.8° Brix rather than 66° Brix. This means that the hydrotherm cannot be directly read and an adjustment must be made, or low-density syrup will be produced. Second, while the hydrotherm contains a scale, it is not calibrated. With practice and some difficulty the scale can be used to determine how far the syrup is from the desired density. For these reasons, hydrotherms are not commonly used. If one is used it is important to check its accuracy by comparing it with an accurate hydrometer; remembering to adjust the hydrometer for any necessary temperature corrections.

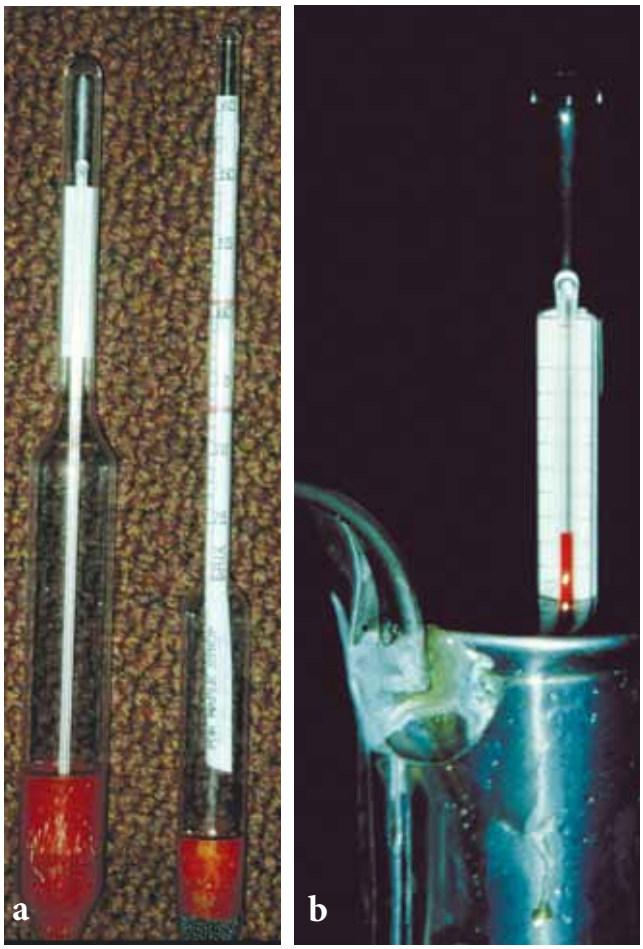



Figure 8.8. (a) Hydrotherm on left compared to hydrometer; (b) hydrotherm floating in syrup.

## Adjusting Syrup Density

No matter how skilled an individual producer may be at finishing syrup, most will occasionally produce syrup with an unacceptable density. Maple syrup with too low a density is not legal, will spoil more quickly, and is thin and runny. Syrup that is too thick will produce sugar crystals and costs the producer money in syrup not made.

**Table 8.4. The volume of water or sap of a known density that should be added to a gallon of syrup to lower its density a desired amount.**

| Density of Sap (°Brix) | Density Reduction of Syrup Desired (°Brix) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0.5° | 1° | 1.5° | 2° | 2.5° | 3° | 3.5° | 4° |
| | Fluid Ounces of Water/Sap Per Gallon of Syrup | | | | | | | |
| 0° (Water) | 1.26 | 2.52 | 3.80 | 5.08 | 6.38 | 7.68 | 8.99 | 10.32 |
| 1° | 1.28 | 2.56 | 3.86 | 5.16 | 6.47 | 7.80 | 9.13 | 10.48 |
| 1.5° | 1.29 | 2.58 | 3.89 | 5.20 | 6.52 | 7.86 | 9.20 | 10.56 |
| 1.75° | 1.29 | 2.59 | 3.90 | 5.22 | 6.55 | 7.89 | 9.24 | 10.60 |
| 2° | 1.30 | 2.60 | 3.92 | 5.24 | 6.57 | 7.92 | 9.27 | 10.64 |
| 2.25° | 1.30 | 2.61 | 3.93 | 5.26 | 6.60 | 7.95 | 9.31 | 10.68 |
| 2.5° | 1.31 | 2.62 | 3.95 | 5.28 | 6.63 | 7.98 | 9.35 | 10.72 |
| 2.75 | 1.31 | 2.63 | 3.96 | 5.30 | 6.65 | 8.01 | 9.38 | 10.77 |
| 3 | 1.32 | 2.64 | 3.98 | 5.32 | 6.68 | 8.04 | 9.42 | 10.81 |
| 3.25 | 1.32 | 2.65 | 3.99 | 5.34 | 6.70 | 8.08 | 9.46 | 10.85 |
| 3.5 | 1.33 | 2.66 | 4.01 | 5.36 | 6.73 | 8.11 | 9.50 | 10.90 |
| 3.75 | 1.33 | 2.67 | 4.02 | 5.38 | 6.76 | 8.14 | 9.53 | 10.94 |
| 4 | 1.34 | 2.68 | 4.04 | 5.41 | 6.78 | 8.17 | 9.57 | 10.98 |

If the syrup's density is too low, it can be reprocessed to a higher density or blended with another syrup. If the density is too high, it can be blended with another syrup, water, sap, or partially processed sap. The challenge when blending is to determine how much syrup, water, or sap to blend with the off-density syrup to produce the desired density.

Except for the most experienced among us, guessing the proportion of syrup, water, or sap to blend with off-density syrup can be a frustrating experience. The alternative is to calculate the proportions to blend to achieve the desired density. Certainly, those of us who are mathematically inclined can, and some probably have, used algebra to determine the proportions of two syrups to blend in order to achieve a desired density. There is, however, a quick and easy way using a Pearson's Square, which is explained and demonstrated in Appendix 3. A Pearson's Square can be used when working with large quantities of syrup to easily calculate the amount of another syrup, water, sap, or partially processed sap to combine to achieve the desired density.

Producers desiring to lower the density of small volumes of syrup with water or sap may find **Table 8.4** useful. This table provides the ounces of water or sap of a known density Brix that should be added to a gallon of syrup to lower its density by a desired amount.

**Table 8.5. Useful equivalents when measuring small volumes of syrup, sap, or water.**

| Volume in Ounces | Tablespoon Teaspoon Measurement |
|---|---|
| 1 ounce | 2 tablespoons |
| 0.5 ounce | 1 tablespoon |
| 0.33 ounce | 2 teaspoons |
| 0.17 ounce | 1 teaspoon |
| 0.08 ounce | ½ teaspoon |
| 0.04 ounce | ¼ teaspoon |
| 0.02 ounce | ⅛ teaspoon |

For example, suppose a producer had 1 gallon of 68.5° Brix syrup and wished to lower its density to 67.0° Brix using water. To use **Table 8.4**, locate water down the left hand column and follow that

row across to below 1.5° Brix, the desired reduction in density. According to the table, 3.8 fluid ounces of water are required to reduce the gallon of 68.5° Brix syrup to 67.0° Brix. Using **Table 8.5**, this can easily be accomplished by adding 3 ounces plus 1 tablespoon and 2 teaspoons of water to the gallon of syrup.

When using **Table 8.4**, if the density reduction desired in the syrup or the density of the sap falls between two adjacent table values, interpolate appropriately. For example, if 2° Brix sap was to be used and the desired density reduction was 1.25° Brix, the amount of water required per gallon of syrup would be 3.26 ounces [(2.60 + 3.92)/2] which would require 3 ounces plus 1½ teaspoons.

Whenever syrup is blended with another syrup, water, sap, or partially processed sap, the resulting blend should obviously be thoroughly mixed and reheated prior to packing for sanitary purposes. This reheating will also reduce the viscosity of the syrup, making it easier to complete the blending process.

## Blending Syrup to Achieve a Desired Color Grade

For a variety of reasons producers may contemplate blending two syrups to achieve a desired color grade in the blend. Certainly syrups can be combined to produce a blended color, but achieving the desired results is as much an art as a science. The best guideline is to first blend small trial amounts to evaluate the results of mixing various proportions. In general, it takes less dark syrup to darken light syrup and more light syrup to lighten dark syrup. For example, 5 or 6 gallons of moderately dark Light Amber syrup blended with 1 gallon of a medium Dark Amber may be required to produce a blend of Medium Amber syrup. Whether this or other blending decisions are good decisions depends on a producer's individual market demand and supply of the different color grades. Also, be sure to taste the blend as the delicate flavor of the lighter syrup is often overwhelmed by the stronger or off-flavors that may be present in the darker syrup. Finally, if color blending is to be done at some future time after the syrup has been packaged, each container must be color coded more precisely than simply noting the grade. One gallon of a Dark Amber on the low (dark) side of the transmittance range, for example, will often blend with 10 to 12 gallons of medium Light Amber to produce 11 to 13 gallons of Medium Amber, while 1 gallon of light Dark Amber may blend with only 5 or 6 gallons of medium Light Amber to produce 6 to 7 gallons of Medium Amber.

## Blending Syrup Flavors

Unfortunately, for a variety of reasons (see Appendix 4), syrup with an off-flavor is occasionally produced. When this happens, the temptation is to blend the offending syrup with another to dilute or "cover-up" the undesirable flavor. While this can be successful in a limited number of situations, it is more often unsuccessful with often costly results. High quality maple syrup has a relatively delicate flavor; the lighter the syrup the more delicate the flavor. A high proportion of offensive syrup flavors are relatively strong, often capable of destroying the flavor of many blended gallons of good syrup. The best guideline when contemplating blending two syrups for the purpose of diluting or "covering-up" an undesirable flavor is to first blend small trial amounts to evaluate the results of mixing various proportions. In general, blending to improve flavor is more likely to be successful when the offensive syrup is a light colored/flavored syrup and the syrup with which it is to be blended is a darker colored, more full-flavored syrup. It is also wise to have more than one person taste the blend to evaluate the success, and that taste trial should not occur immediately after tasting the offensive syrup. The final and perhaps most important rule is "if in doubt, don't blend." Over the years countless gallons of good syrup have been ruined trying to "save" a few gallons of bad flavored syrup.

## Syrup Grading

While all maple syrup sold must be finished to at least a legal minimum standard density[60],

[60] 66° Brix in all Canadian provinces and most states, 66.9° Brix in Vermont and New Hampshire as of this writing.

significant variation in other syrup characteristics, particularly color and flavor, occurs as a result of a variety of factors. These include method of production, year of production, and when during the season the syrup was produced. In both the United States and Canada, federal guidelines exist to communicate this variation to consumers and provide assurance that consumers (wholesale or retail) obtain maple syrup with desired characteristics. Additionally, several states and provinces have recognized grading standards applicable to some or all syrup sold in that state or province. And, while the grade names currently vary among the different jurisdictions (**Table 8.6**), the standards used wherever syrup is graded are essentially the same[61]. It is important to be aware that the requirement to grade maple syrup varies among different states and provincial jurisdictions. In some states and/or provinces grading of all syrup is mandatory while in others there is no legal requirement to grade. When producers are located within a jurisdiction with no legal requirement to grade maple syrup, the decision to grade or not is entirely their own—they may choose to grade all, part, or none of their production. Before using any grading standard, producers should acquaint themselves with the specific grading standard(s) and requirements appropriate to the area where the syrup is sold.

## Grading Standards

Traditionally, maple syrup grades have been established based primarily on color, with five to six different grades recognized (depending on the jurisdiction) ranging from very light to very dark syrup. A comparison of the different grades and grade names used in various jurisdictions at the time of this writing, along with the percent light transmittance requirement for each grade (discussed below) is presented in **Table 8.6**. For grading purposes, syrup color is evaluated using comparators or a spectrophotometer. In addition to color, other characteristics affecting syrup grade include clarity, density, and flavor.

Clarity is an expression of the clearness or lack of cloudiness (caused by suspended solids) of the syrup. In general, a high degree of clarity is required of all syrup packaged for consumer purchase (often termed table-grades), less for some syrup that is packaged for reprocessing. Note that the presence of suspended solids (lower clarity) may actually influence the perceived color of syrup. For grading purposes, clarity is commonly determined visually.

All maple syrup packaged for consumer purchase must meet the minimum density standards of the state or province in which it is sold. Some jurisdictions have different density requirements for syrup packaged for reprocessing, currently bearing such grade names as "Commercial" or "Substandard." Density is most commonly determined with either a refractometer or hydrometer.

Flavor is the most subjective characteristic associated with maple grades. There is currently no effective quantitative or qualitative method for maple producers to accurately describe the flavor of syrup. Instead, syrup color is used as a surrogate for flavor because the predominant flavors become stronger in darker syrups. To be sure, there is an expected flavor or range of flavors that experienced producers and consumers associate with specific grades. In fact, many grading standards express the expected grade flavor as the "flavor characteristic of the grade or class." These are often expressed as broad characterizations ranging from a light, delicate maple flavor for the lightest class to a more robust, full-bodied, even slightly caramelized flavor for the darkest class. The recent development of the "Flavour Wheel for Maple Products" by researchers in Quebec offers a methodology for researchers and professional tasters to more accurately characterize maple flavors, but it requires extensive training, therefore its use does not translate easily to the individual producer. In all grading standards, however, table-grade syrups must be free from any objectionable flavors or odors (see Appendix 4). For grading purposes flavor is evaluated by tasting.

[61] At the time of this writing an international effort has been initiated to standardize the grade names and standards throughout the maple producing region.

**Table 8.6. Maple syrup grade designations in effect in the United States and Canada at the time this manual was published.**

| Light Transmission[a] | United States and All States Not Individually Listed[b] | Canada All Provinces[c] | Vermont[h] and Ohio[d] | New Hampshire[h] | New York[f] | Maine |
|---|---|---|---|---|---|---|
| ≥ 75.0% | U.S. Grade A Light Amber | Canada No. 1 Extra Light (AA) | Vermont Fancy Ohio Grade A Light Amber | Grade A Light Amber | Grade A (Light Amber) | Grade A Light Amber |
| 60.5–74.9% | U.S. Grade A Medium Amber | Canada No. 1 Light (A) | Grade A Medium Amber | Grade A Medium Amber | Grade A (Medium Amber) | Grade A Medium Amber |
| 44.0–60.4% | U.S. Grade A Dark Amber | Canada No. 1 Medium (B) | Grade A Dark Amber | Grade A Dark Amber | Grade A (Dark Amber) | Grade A Dark Amber |
| 43.9–27.0% | U.S. Grade B for Reprocessing | Canada No. 2 Amber (B) | Grade B[e] | Grade B[e] | Extra Dark for Cooking or Grade B for Reprocessing | Grade A Extra Dark Amber |
| < 27.0% | U.S. Grade B for Reprocessing | Canada No. 3 Dark (C) | Commercial Grade[g] | Grade B[e] | Extra Dark for Cooking or Grade B for Reprocessing | Commercial Grade[g] |
| Fails Other Grade Requirements Due to Unacceptable Density, Color, or Flavor | Substandard | | Substandard | Substandard | Substandard | Substandard |

[a] Percent light transmission measured with a spectrophotometer using matched square optical cells having a 10 mm light path at a wavelength of 560 nm, with the color values expressed in percent of light transmission as compared to analytical reagent glycerol fixed at 100 percent transmission. Percent transmission determined in this way is symbolized "%Tc".

[b] Official reference standard for United States Standards is USDA permanent glass color standards. States that do not have a state grading requirement may sell syrup ungraded or may use the USDA grading standards.

[c] Canada's law technically sets the light transmission ranges as follows: No. 1 Extra Light > 75%; No. 1 Light less than 75.0% but not less than 60.5%; No. 1 Medium less than 60.5% but not less than 44.0%; No. 2 Amber less than 44.0% but not less than 27.0%; and No. 3 Dark < 27.0%. Canadian law specifies determination of light transmission by spectrophotometer or a visual glass comparator, the optical specifications of which correspond as closely as possible to the specification of the spectrophotometer.

[d] Grading is mandatory in Vermont, optional in Ohio. In Ohio, producers may sell syrup ungraded or graded with Ohio's or the USDA grading standards.

[e] Table grade syrup; may be packaged in consumer size containers.

[f] The official color reference standard for New York is the USDA permanent glass color standards. Technically, New York has only two table grades of syrup, Grade A and Extra Dark for Cooking, and syrup can be so labeled. Within Grade A, color can be classified as Light, Medium, or Dark Amber. Syrups darker than the USDA Dark Amber glass that are of suitable quality may be labeled Extra Dark for Cooking or Grade B for Reprocessing, depending on the intended use. Extra Dark for Cooking may be packaged in containers of one pint or larger; Grade B for Reprocessing shall not be packaged in consumer-sized containers.

[g] Container size restrictions.

[h] Vermont and New Hampshire require 66.9° Brix minimum density.

In any discussion on syrup grading it is important to note that it is perhaps unfortunate that present grading systems are so strongly based on color as a prime determinant, and that lighter grades are very often assumed or actually marketed as "higher quality" or "better" grades. To be sure there is a relationship between color and flavor. However, full-bodied syrups with stronger maple flavors should not be viewed as inferior. In fact, a significant proportion of consumers will choose medium or dark amber syrup over light amber syrup if given the choice. One of the strongest arguments for producers who market syrup by specific grade is that is allows consumers to purchase syrup with the characteristics they prefer.

## Grading Kits and Spectrophotometers

Color requirements for maple grades are specified against a known set of color standards, either a permanent glass comparator (in the case of USDA Standards) or as the percent of light that passes through the syrup as measured with a spectrophotometer following the specifications noted in the footnote of **Table 8.6**. In practice, most producers grade syrup using either a comparator grading kit or a relatively inexpensive spectrophotometer. In cases of dispute, an analytical lab grade spectrophotometer may be used.

Standardized grading kits for both U.S. and Canadian trades are available from maple equipment dealers. These grading kits are comparators, the grade of the syrup in question is determined by comparing its color to that of a set of standard colored glass or plastic plates or glycerin solutions (**Figure 8.9 and 8.10**). When using the comparators, the syrup to be graded is placed in the syrup container supplied with the kit, the container is placed correctly in the kit, and the color is compared with the colors of the standards. With all kits, the colored standards represent the darkest color a particular syrup sample can be and still be in that grade. For example, if the sample of syrup being evaluated is darker than the light amber standard and lighter than the medium amber standard, its correct grade based on color is medium amber. It is obviously incorrect to assign syrup grade based simply on the color closest to the syrup sample. When using comparators, use only the syrup container provided with the comparator, move the syrup adjacent to each standard for evaluation, and always work in a location well illuminated with direct, natural light (**Figure 8.10**). Using the kits with inadequate, reflected, or artificial light can result in inaccurate results, particularly with syrup the color of which is close to the boundary between two grade classes. An ideal background light for using visual grading kits is daylight from a clear, northern sky.

Figure 8.9. Permanent glass standard grading kits, such as the Lovibond (upper left) and the USDA kit (Figure 8.10), and temporary glycerine grading kits, such as the Vermont temporary kit (upper right), are available for color grading maple syrup.

Syrup grading kits are of two types, permanent kits containing glass or plastic colored plates as color standards, and temporary kits that contain colored glycerin solutions in bottles as color standards. The colors of the plates in the permanent kits do not fade (or fade much slower), hence the designation permanent. The color added to the glycerine solutions in the temporary kits does fade over time and become inaccurate, hence the "temporary" designation. Permanent kits are considerably more expensive than temporary kits, but will last for many years with care. Temporary kits need to be checked yearly against permanent glass standards, or routinely replaced every year or two. Because the color of the glycerine solutions fade over time, producers who use the temporary kits beyond their effective life will classify some lighter syrup into a darker grade. It is recommended that all grading kits be stored in a dark cool location when not in use. Producers also need to be aware that visual grading comparators from different manufacturers will produce

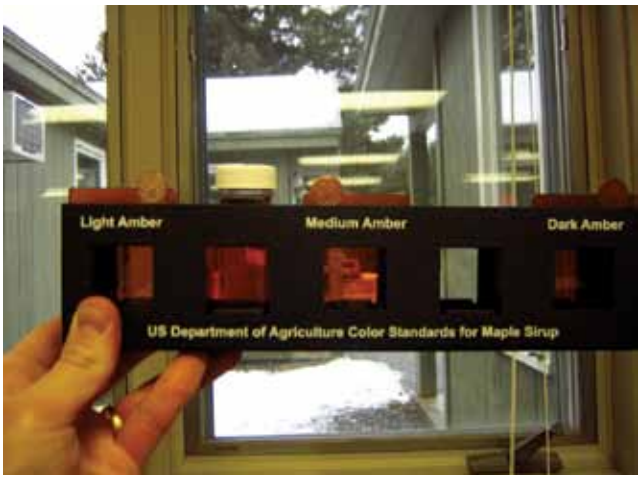



Figure 8.10. When using comparators, use only the syrup container provided with the comparator, move the syrup adjacent to each standard for evaluation, and always work in a location well illuminated with direct, natural light.

Figure 8.11. Relatively inexpensive spectrophotometer for determining the color of maple syrup based on light transmission.

slightly different results, especially when samples are close in color to the standards.

When used to evaluate the color of maple syrup, a spectrophotometer measures the amount of light of a specific wave length (560 nanometers) that passes through a cell within the unit in which the syrup sample is placed (footnote, **Table 8.6**). This reading, expressed as "percent light transmission," is then compared with a glycerine standard that has 100 percent transmission. It is these values that are reported in the left-hand column of **Table 8.6**. Until recently spectrophotometers were expensive optical instruments found only in research labs and sophisticated testing facilities. Recently, less expensive instruments have been marketed to the maple industry (**Figure 8.11**). With these units it is imperative that producers read and understand the instructions for use, including the requirement for periodic recalibration. In particular, be aware that variations of 2 percent in the readings (more with some samples) are not uncommon, due to the precision of the instrument and the condition of the cuvette (the provided syrup container). When the sample of syrup being evaluated is close to the boundary between two grades, two different spectrophotometers could produce different readings, thereby placing the syrup in different grades. Small bubbles in the sample, or dirt or fingerprints on the cuvette will also result in (sometimes very large) measurement errors. In almost all cases, errors made in spectrophotometers tend to grade a syrup lower than the same sample measured with a visual comparator.

### Closing Comment

When grading syrup, it is important to remember that packaged syrup often darkens with time, particularly if packaged in conventional plastic or ceramic containers. If the syrup being graded is toward the dark end of the color range within a grade, it may well darken to the next grade by the time the consumer (or an inspector) opens it. Also, it is appropriate for producers to refresh their grading skills and procedures by participating in grading schools and contests. Grading is more difficult than it appears and depends on good equipment and technique, a proper light source, as well as lots of practice.

## Syrup Packing and Handling

Once maple sap has been processed into maple syrup and the correct density obtained, it is ready for packing. It does not require further processing or treatment beyond the normal filtering.

### Hot Pack

Maple syrup should be hot packed to prevent the development of yeasts, mold, or bacteria in packaged syrup. Research and experience has demonstrated that the processing of maple sap to syrup

kills any microorganisms commonly present. The syrup must, however, be packaged before it cools below a critical temperature or, if it cools below the critical temperature, reheated in order to kill any microorganisms that may contaminate the syrup during filtering, transport, and canning.

The commonly accepted minimum temperature for hot packing maple syrup is 180°F (82°C), though some research suggests a temperature of 190°F (88°C) or higher may be more appropriate when filling small glass containers or when the producer has experienced persistent mold or spoilage problems when packaging at 180°F. The heating of most syrup to a temperature between 180°F (82°C) and 195°F (91°C) when packaging will generally not create problems. However, some syrup may begin to precipitate additional sugar sand at temperatures above 195°F (91°C), and can darken if held at that temperature or higher for an extended period of time. It is important that the entire inside of the container, including the cap be exposed to the 180°F temperature. This is commonly accomplished by inverting the container immediately after it is filled and sealed.

The method and equipment used to package maple syrup depends on a variety of factors including the size of the operation, volume of syrup produced, financial resources, and preferences of the producer. For larger producers, a variety of bottling equipment systems is available in a broad range of sizes, along with air-powered cappers, and metered syrup dispensers (**Figures 8.2 and 8.12**). In some operations producers will package syrup directly into containers from a heated filter tank. Others modify equipment such as commercial coffee makers to serve as canning units. Hobbyists and other producers, who package only a small quantity of syrup at any one time, may simply reheat filtered syrup and pour it directly into containers.

Syrup can be packed directly into containers intended for retail sale, or it can be placed in larger cans or drums (ranging from 5 to 55 gallons or more). These larger sized containers (referred to as bulk storage) may either be sold at wholesale or can be used as sources of syrup for filling retail containers later in the year. Most maple producers will find it advantageous to pack some syrup in retail containers during the producing season; however, it is recommended that at least part of the crop be packed in bulk containers for filling later orders. This allows individual orders to be filled on a customized basis while making certain that syrup quality at the time of filling is high. When syrup is to be stored for longer periods of time, storage in bulk as opposed to retail containers is preferred. It is helpful to keep a small container of syrup from each lot or batch in a freezer: this can be used to check the characteristics of the syrup batch without unsealing the drums.

Figure 8.12. Maple syrup bottling equipment is available in a wide range of sizes. (Girard, Ober)

## Considerations for Glass, Plastic, Metal, and Ceramic Retail Containers

All syrup offered for retail sale is packaged either in glass, plastic, metal, or ceramic containers. Many different types, styles, and sizes are available (**Figure 8.13**). The choice is largely dependent on producer as well as customer preference. Each has advantages as well as disadvantages associated with their use. While the handling and filling of each type is generally similar, there are some important guidelines and considerations related to the use and storage characteristics of each. It is advised that all containers be washed/rinsed with hot water before filling and dried as rapidly as possible. It is recommended that any containers that have been open and exposed for any length of time be washed/rinsed before filling.

Figure 8.13. Maple syrup is commonly packaged in a wide variety of commercially available glass, plastic, metal, or ceramic (insert) containers.

### Plastic Containers

Plastic containers are very popular for packaging maple syrup. They are readily available from dealers in a variety of sizes and shapes, can be custom lithographed with state or individual producer designs and information, and are highly resistant to breakage. Producers and packers report that syrup tends to darken after three to six months storage in conventional plastic containers, moving it to the next darker grade, and occasionally losing some of the characteristic flavor. For this reason when using traditional plastic containers, it is commonly recommended that syrup offered for sale in these types of containers not be packed for periods longer than three months before the anticipated sale date. These potential changes in color and flavor appear to be associated with the porosity of the plastic. Currently available coated plastic containers are much less porous to air, and are better adapted to longer storage periods. Whether or not their additional cost is justified depends on the individual producer and the nature of their market.

### Glass Containers

In recent years glass has increased in popularity as the container of choice for many producers. Glass containers are available in many different sizes and are very popular when maple syrup is purchased for gifts (commonly up to 1 pint/500 ml, although somewhat larger containers are available). An extensive variety of shapes and sizes are available, along with custom containers featuring painted or etched designs. An often-cited advantage of glass is that it allows the natural color and beauty of the syrup to be seen—a feature requiring syrup packaged in glass to be of the highest clarity. Syrup stored in glass maintains its quality very well, though some suggest that long-term storage should be in the dark. The fragility of glass containers used for maple syrup is quite variable, some are quite resistant to breakage, while other are less resistant. Fragility is a characteristic that should be considered when product is to be shipped.

It is recommended when filling glass containers that the fill temperature of the syrup be 190°F (88°C) to 195°F (91°C), with the higher temperature used for smaller containers. Hot syrup used to fill glass containers cools rapidly, and experience suggests that lower temperature syrup does not remain hot long enough to adequately kill some of the microorganisms present. Many producers also preheat glass containers to address this problem.

### Metal Containers

Historically, metal cans represent the most traditional maple syrup packaging container. They are

particularly well suited for packing in the one-quart to one-gallon size, although some unique, collectable cans, such as the traditional log cabin can, are available in smaller sizes. Metal containers are very effective in maintaining syrup grade (color) over long periods of time (years). Their effectiveness in maintaining flavor over an extended time period is not always as good. Many producers and packers have experienced excellent flavor in syrups stored in metal for months or even years, and many choose to package their best syrup in metal. In contrast, other producers and consumers have reported the presence of an off-flavor, often characterized as metallic or "tinny" (see Appendix 4), when syrup has been in a metal container for a year or more. Some of these unsatisfactory experiences with metal containers may have been the result of container quality—unquestionably today's metal containers are superior to those of years past. Some of the unsatisfactory experiences may have resulted from the use of an unclean container or one that was not made from food-grade materials. Irrespective of the cause, producers and packers using metal containers need to be aware of the potential for the development of an off-flavor when maple syrup is stored for longer periods.

Use only metal containers manufactured for food products. A wide variety of sizes and designs are available. Once metal containers are filled, securely install the cap insert, screw on the cap, and place the container on its side to sterilize the cap and inner top of the container. After opening, syrup should not be stored in metal containers for any length of time as it will sometimes acquire a metallic off-flavor.

### Ceramic Containers

Ceramic containers are occasionally used for retail syrup sales, although they are much less common than containers of other materials. If ceramic containers are used, it is critically important that they be "food grade" as not all ceramic materials are appropriate for food use. Always thoroughly wash/rinse ceramic containers, even if they appear clean. Ceramic containers are commonly sealed with natural cork, and only cork of the highest quality should be used. Experienced producers recommend not heating the corks in boiling water to sterilize them, but inserting them into the container dry and sterilizing the cork and top of the container by turning it on its side as is done with other maple containers. As with glass, the recommended fill temperature of syrup when using ceramic containers is 190°F (88°C) to 195°F (91°C), with the higher temperature used for smaller containers. Also, like glass, ceramic containers are more fragile than some other types of containers and may require more care in packing, handling, and shipping. Finally, as with conventional plastic containers, syrup stored in ceramic containers may darken over time, which needs to be taken into account when grading and packing.

### Avoiding Stack Burn

The color of pure maple syrup results partially from a browning (caramelization) reaction that occurs in the latter stages of evaporation. When syrup is packaged hot, this same browning reaction may continue in the container until the syrup has sufficiently cooled. This may result in a grade change after packaging, with, for example, a medium amber syrup changing to a dark amber or even darker grade. This darkening of color is known as stack burn. It is often less of a problem with syrup that is light amber in grade.

To avoid stack burn, it is recommended that filled containers be allowed to cool in an area where air can freely circulate around them before they are boxed or packed close together. Once the syrup and its container have reached room temperature, all containers can be stacked more closely. Some producers have hastened the cooling process by using a fan to cool the syrup after packing, and by packing syrup in a cool room. Larger syrup packers and processors may employ refrigerated cooling tunnels to rapidly reduce the temperature of syrup to storage room temperature.

## Storage of Packaged Syrup

Once containers filled with syrup have adequately cooled they are ready for storage if necessary. It is recommended that all packages of syrup from a particular lot be coded to distinguish them from

other lots. Coding will permit rapid identification if a problem develops or will quickly allow multiple packages of a specific lot to be located.

Time, temperature, and exposure are important factors to consider when storing maple syrup. It is natural for some lots of syrup to lose flavor when stored for long periods of time. For this reason many producers will package syrup in retail containers on an as-needed basis, usually accumulating no more than a two- to three-month supply. Filled containers should be stored in a darkened, relatively cool location where temperature fluctuations are minimized. To maintain constant temperatures and control humidity, it is recommended that syrup be stored in air conditioned storage rooms in the summer months. This will minimize temperature changes and reduce condensation that can occur on packaged syrup. Condensation on metallic containers can result in the formation of surface rust. Syrup in retail containers also can be stored at below freezing temperatures (though it never freezes solid). If this is done, quality will be maintained for an indefinite time period.

## Bulk Storage Considerations

Those conditions conducive to maintaining syrup quality in retail packages are also applicable to storage of bulk syrup. Control of temperature and minimum exposure to airborne contaminants are especially important. For small- to medium-sized operations, storage in 5-gallon containers that can be hot filled and sealed is preferable to drum storage. Their use will reduce the possibility of syrup spoilage or grade reduction due to microbial contamination since it is probable that all of the syrup in these containers will be re-packed at the same time. In contrast, repeated opening of larger drums to add or remove syrup increases the likelihood of bacteria, yeast, and mold contamination.

When syrup is removed from bulk containers for packaging into retail containers it must be reheated. If bacteria, mold, or yeast growth is present, all visible growth should be removed and the syrup evaluated for off-flavor. Following heating to a minimum of 180°F (82°C), the syrup should be filtered and packaged. When reheating has been completed the density of the syrup should be checked and necessary adjustments made to make certain the syrup is at the correct density when packaged. It is not uncommon for the density of syrup to increase slightly during the process of reheating and packaging. It is also advisable to taste each batch to verify acceptable flavor.

As with retail containers, there are different sizes and types of bulk storage containers available. Each producer must determine the types and sizes of containers appropriate to their own operation. The most commonly used types of bulk storage containers include:

### Stainless Steel

Some of the best containers for maintaining syrup quality during bulk storage are made of stainless steel (**Figure 8.14**). New storage containers are available, however, many used stainless steel drums in a variety of sizes are presently in use. It is important to remember, however, that not all drums have been used for food storage. Do not purchase any used bulk container that has been used for storage of non-food materials. Furthermore, it is advisable to determine what kind of contents were previously stored in the container as some foods may impart odors and flavors that are difficult to eliminate. Stainless steel will provide excellent long-term storage for maple syrup.

### Galvanized Metal

This has been the traditional type of bulk container used in the maple industry for many years (**Figure 8.14**). However, several concerns have been identified that discourage their use. Older galvanized drums often contain traces of lead, either in the metal itself or in the soldering of the seams. Long-term storage of syrup in galvanized containers containing lead may result in an increase in the amount of detectable lead in the syrup. Newer galvanized drums, produced after 1994, do not contain lead; however, they are prone to rusting if not dried completely following use. This is unsightly and may affect the quality of the syrup stored in them. As a generalization, the use of galvanized drums is no longer recommended for maple syrup storage.

Figure 8.14. The most common type of bulk containers used in the maple industry today include: stainless (a), galvanized (b), epoxy (c), and food-grade plastic (d). A fifth container, plastic with a food-grade, replaceable liner, is also available (e). Stainless containers or those made of food-grade plastic are recommended for maintaining the quality of maple syrup.

### Plastic

Various sizes and styles of bulk plastic containers are available (**Figure 8.14**). Many producers use five-gallon plastic containers for storing syrup that will be packed later in the year. Additionally, new types of plastic containers are being developed and may be available in the future. When using five-gallon plastic containers, place them on their side after filling to sterilize the air space in the top of the container. Several different styles of plastic drums are available, some of which utilize a food-grade disposable liner bag, but none have gained widespread acceptance.

### Epoxy-Lined Metal

This type of bulk storage container is the least expensive of the several alternatives available and when used properly can maintain syrup quality for long-term storage (**Figure 8.14**). Epoxy-lined containers are commonly referred to as "one-way" drums since they are designed to be used once and then discarded. However, if these containers are handled with care and used only at the producer's location, it is possible to reuse them. With prolonged use the epoxy lining may weaken and crack, thereby creating areas for microorganisms to grow; such microbial growth may affect syrup quality. Thoroughly inspect the interior of the drum before using. Drums with weakened, cracked, or chipped epoxy should be discarded.

## Some General Comments on Packing and Storing Maple Syrup

Regardless of whether bulk quantities or retail packaged syrup is being stored, all containers should be kept in a dark, cool, and dry area. Walk-in coolers represent ideal storage conditions and where available afford excellent conditions for maintaining syrup quality.

A packing date code should be used on retail containers to monitor the age and disposition of the product. If a problem arises, it is easy to check records to verify what was packed, and when. It is recommended that syrup be kept in bulk and only packed in retail containers for a two- to three-month supply. Not only will doing so allow greater control over retail inventory, it will also maintain greater control over the quality of the product. The absolute best way to store retail containers of syrup is in a freezer. Many producers advise their customers to refrigerate the amount that will be used in a two-week period and to freeze the remainder. Maple syrup will not freeze solid due to the high sugar content, and will maintain color and flavor for a long period of time.

In addition to properly storing syrup in bulk containers, it is important to keep all containers sealed until ready for use. Opening them exposes syrup to bacteria, yeast, and mold. Once opened, syrup stored in a bulk container should be used

or re-packaged as quickly as possible. For this reason, choosing the proper size bulk container appropriate for each operation is an important consideration.

When a bulk container is emptied, wash it thoroughly with hot water or steam and dry completely. Drying individual drums can be difficult, however, if the drum is inverted and a towel placed in the bung opening, moisture can be wicked out with the towel. Store empty bulk containers in a dry area free of any type of contamination. Wash the container thoroughly again just before use and examine it under well lighted conditions to ensure that the interior is in good condition.

# Chapter 9 · Maple Sugar, Maple Cream, Maple Candy, and Other Products

Pure maple syrup, in addition to being a high-value product on its own, also serves as the raw material for many other maple products. These additional products enable individual maple producers and processors to expand potential markets for maple syrup by manufacturing a variety of products that will have appeal to a broader section of consumers. Additionally, opportunity exists to obtain greater total returns from the maple crop because of the significant value-added component that results from producing secondary maple products. The increase in product value more than compensates for the additional cost of production. In comparison to the price of a gallon of syrup it is not unusual to double or even triple the return when maple syrup is converted into other maple confections. As a result, it is not surprising that some producers process the majority of their annual syrup crop into maple confections such as maple sugar, maple candy, maple cream, and other value-added maple products.

## Historical Perspective

During Colonial times the annual crop of maple syrup was mostly converted to maple sugar**.** Unlike liquid syrup, dry maple sugar was easy to store and transport. There were no problems associated with spoilage or broken containers. Blocks of maple sugar were used as a form of barter and exchange in the coin and currency starved early days of North American history. At that time almost every farm in the maple region produced their own syrup, with almost 100 percent of it being made into dry sugar. By the early twentieth century, only 30 percent of the maple syrup crop was further processed into dry maple sugar. Now at the start of the twenty-first century, over 90 percent of the maple crop is sold as liquid maple syrup, with less than 10 percent made into other products. Nonetheless, these value-added products are popular confections and are in high demand by tourists and other consumers seeking a tasty sweet or specialty food gift item.

## General Considerations

Pure maple syrup is a water-sugar solution of a specific density, obtained by concentrating (by heat-induced evaporation) the sugar present in maple sap. During the evaporation process the sugar concentration increases to at least 66.0° Brix (66 percent dissolved solids, 34 percent water by weight). Characteristic heat-induced color and flavor changes unique to maple syrup also occur and make for a special and unique sweetener. At 66.0° Brix, maple syrup is a stable solution. If evaporation continues, the concentration of sugar in the syrup continues to increase as boiling temperature increases (as water is lost) until there is more dissolved sugar in the solution than can be held at room temperature. When this solution is subsequently cooled to room temperature, the excess sugar (above that of the normal stable concentration) will precipitate or crystallize out of the solution.

It is this ability to increase the sugar concentration above the stable level that enables the production of other maple products. All secondary maple products depend on producing a syrup solution (made by additional evaporation) containing more sugar than can be retained in solution at room temperature and then controlling the subsequent sugar crystallization or precipitation process that occurs with cooling through such actions as regulating the rate and extent of cooling and the degree and timing of agitation or stirring.

### Crystallization and Graininess

The crystalline or grainy nature of the precipitated sugar is determined by a number of factors, all of which are influential in making the desired maple product. These factors include the amount of excess sugar in solution (which is a function of the boiling point achieved), seeding, the rate of cooling, and the amount and timing of agitation or stirring. Large crystals, often called rock candy, which represent one extreme, are formed when

a small amount of excess sugar is present (67° to 70° Brix) and the solution is cooled slowly and stored for a long time without agitation. A glass-like non-crystalline solid represents the other extreme. This is formed when a large amount of excess sugar is present (the boiling point is elevated 18°F or more above the boiling point of water) and the solution is cooled rapidly to well below room temperature without stirring. The syrup becomes so viscous that it solidifies before crystals can form and grow. If the hot concentrated sugar solution is stirred while it is cooling, the tendency to form crystals increases. The mechanical shock produced by stirring causes microscopic crystal nuclei to form. Continued stirring mixes the crystals throughout the thickened syrup and they increase in numbers as well as size. When the number of crystals is relatively small, stirring causes the largest crystals to grow larger at the expense of the smaller ones. Thus, a sugar with a grainy texture tends to become even grainer the longer it is stirred.

For maple cream, the desired sugar crystal size is very small, giving it a smooth, creamy feel. The highest quality maple cream is buttery-smooth with no perceptible graininess or crystals. Molded maple sugar candy has a small crystalline structure, not as smooth as maple cream, but also not gritty or grainy. Large rock-sugar crystals often form on the bottom of a syrup container that contains syrup that has been boiled to over 68° Brix and stored for a relatively long period of time. If small sugar crystals are added to a supersaturated sugar solution (this is referred to as seeding), the rate of crystal formation will be increased and the crystals formed will tend to be similar in size to the seed crystals.

## The Products

Maple producers have many names for products made from pure maple syrup. Some names vary from region to region, and some have a historical context such as *Indian Sugar*. All are basically made by boiling maple syrup to remove additional water, followed by cooling (fast or slow) with or without agitation.

*Maple cream* is sometimes called *maple butter* or *maple spread*. Although it is a pure maple product with no dairy product added, it gets it name from its creamy, buttery smoothness. *Maple sugar* can be in the form of *soft sugar, hard sugar, block sugar, molded sugar, or granulated (stirred) sugar.*

## The Process

When producing maple confections it is unreasonable to recommend a precise syrup boiling temperature. Rather, a close temperature "range" is suggested. Other factors, such as barometric pressure, air temperature, humidity, the amount of invert sugar in the syrup, and the elevation above sea level, all influence the results. The secret to successful confection making is not so much with equipment and temperature, but with the producer's ability to determine when the syrup looks "just right" during the processing. This requires some practice, because maple sugar products sometimes seem to have a mind of their own. It is suggested that maple producers experiment with conditions and processes to determine what works best for each operation. The "mistakes" are always good to eat or they can be "recycled" by adding water, reheating, and starting over once again.

## Safety Concerns

Most maple confections call for additional boiling to increase the sugar concentration of the syrup. Sugar solutions at elevated temperatures have a tendency to stick to the skin and can cause severe burns. Be careful when handling hot syrup and make sure that children are not nearby. It is suggested that the boiling syrup be watched very closely as the temperature increases; there is a tendency to boil over or scorch. Scorched syrup can actually burn if it gets hot enough. When using a mechanical candy or cream machine, follow the manufacturer's directions carefully and always be aware of moving parts. Remember that a food product is being prepared and all requirements and recommendations regarding food quality and sanitation should be observed. Obviously this includes using only clean sanitary molds, utensils, and equipment. Handle molded maple sugar pieces with plastic food service gloves and keep hair retained.

## Invert Sugar

Sucrose is the predominant sugar in sap when it comes from the tree; however, some of the sucrose can be converted to invert sugar as a result of microbial contamination during processing and storage of sap. This change occurs most commonly in syrup produced from sap that is collected late in the season when temperatures are warmer. Both sucrose and invert sugars are made up of two simple sugars, referred to in older literature as dextrose and levulose, and now more commonly as glucose and fructose. In sucrose, these sugars are united chemically as a single molecule; in invert sugar they occur as separate molecules[62].

A small amount of invert sugar is desirable in maple syrup that is to be made into maple sugar and maple confections. Invert sugars are more soluble in water than sucrose at room temperature meaning more total sugar can be held in solution before crystallization occurs. This helps keep the product moist, and it also encourages exceedingly small sugar crystals to form. Too little invert sugar in the syrup will cause the product to be grainy; too much may prevent formation of small crystals (creaming) as required for making maple cream. In general, all grades of maple syrup contain some invert sugar, and the amount varies among different grades. Lighter syrup (e.g. U.S. Light Amber or Canada No. 1 Extra Light), particularly that made early in the production season, generally has the least invert sugar; very dark syrup (e.g. U.S. Grade B or Canada No. 2 Amber), particularly that made late in the production season, has the most invert sugar. Thus the grade of syrup can be used as a guide in selecting syrup for making a specific confection. With experience, producers develop the ability to select the proper grade of syrup that will produce confections with the desired characteristics. Generally a lighter grade of syrup makes the best maple sugar and maple cream. It is recommended that producers do some experimentation to identify which syrup grade works best for the specific product that is being produced. When maple syrup is being produced many producers will identify and put aside specific lots of syrup to be used later when making confections.

It is sometimes desirable to test the amount of invert sugars in a particular lot of syrup, especially if maple cream is going to be made. A simple chemical test described at the end of this chapter can help to identify the relative amount of invert sugar present. If the amount of invert sugar in the syrup is too high for the confection to be made, other syrup should be used, or the syrup high in invert sugar can be blended with syrup lower in invert sugar. Be sure to test the blend as some lots of dark syrup high in invert sugars do not blend well with lighter syrup. An additive solution is required if the amount of invert sugar in the syrup is so small that a fine crystalline product cannot be made.

## Additive Solutions

The simplest additive solution and the one most commonly used is USDA Grade B or Canada No. 2 Amber maple syrup. This syrup generally contains a considerable amount of invert sugar (sometimes more than 6 percent). As a generalization, darker grades of syrup are made from sap collected when air temperatures are warmer. The addition of 1 pint (500 ml) of good flavored U.S. Grade B or Grade A Dark Amber (Canada No. 2 Amber or Canada No. 1 Medium) syrup to 6 gallons (23 liters) of maple syrup low in invert sugar (less than 1 percent invert sugar) usually will correct any invert deficiency. For smaller quantities, use 5 tablespoons per gallon, or 75 ml per 3.8 liters. Be especially careful of strong flavors in dark syrup if blending is necessary as these flavors will become more pronounced in the final product.

If syrup with a high content of invert sugar is not available, an additive solution can be prepared. To 1 gallon (3.8 liters) of standard-density maple syrup add 2½ liquid ounces (75 ml) of *Invertase* (an enzyme that causes the conversion of sucrose to invert sugar). Stir the mixture thoroughly and allow it to stand at room temperature or above

[62] Sucrose is a twelve carbon sugar having the chemical formula $C_{12}H_{22}O_{11}$. Invert sugars are six carbon sugars, glucose (dextrose) and fructose (levulose), which are structurally different, but both with the chemical formula $C_6H_{12}O_6$. Invert sugars are produced by the hydrolysis of sucrose, commonly by the action of microorganisms. The name invert comes from the fact that a solution of invert sugars rotates (inverts) the plane of polarized light.

(65°F or 18°C) for several days. During this time sufficient invert sugar will form so that 1 pint (473 ml) of this solution can be used to adjust 6 gallons (23 liters) of maple syrup low in invert sugar. Invertase may be purchased from many confection manufacturers.

Another convenient type of additive is an acid salt such as cream of tartar (potassium acid tartrate). Adding ½ teaspoon of cream of tartar to 1 gallon (3.8 liters) of low-invert syrup just before it is boiled for confection making will cause sufficient acid hydrolysis or inversion of the sucrose to form the desired amount of invert sugar. Cream of tarter is available in the spice section of most grocery stores.

**Be aware that some areas do not allow any amount of additives to maple products. Check with your local authorities to be certain**.

## Facility and Equipment Requirements

Producing maple products is easier and more efficient in a spacious, well-equipped kitchen or similar facility (**Figure 9.1**). The complexity of the facility depends on the size of the operation and the amount of product that will regularly be produced. It is not difficult to make maple products, and it does not normally require expensive or unusual equipment, however, a convenient layout and arrangement of necessary equipment makes the task much easier. Processors should check with local health departments or food production authorities concerning construction codes and applicable specific food processing regulations.

Necessary equipment and ingredients include the following:

- High quality maple syrup. To produce maple confections it is obvious that maple syrup is required. However, it should be emphasized that as a general rule, lighter colored syrup made earlier in the season (with low invert sugar content) will make the best secondary maple products. Remember that flavor will be intensified when syrup is boiled to a higher density. Therefore, any syrup with even a hint of an off-flavor should not be used, as this flavor will be intensified in the final product. As it is drawn off the evaporator, some producers will identify syrup with an excellent flavor and put it in marked storage containers so it can be used later for making maple candy, cream, or other confections.
- An efficient heat source. High-pressure steam is considered ideal for secondary processing of maple syrup because heat can be precisely controlled and there is little or no likelihood of scorching. For producers who do not have a steam heat source such as a steam kettle, gas heat is preferable to electric, because it is more easily controlled and usually more economical.

Figure 9.1. A spacious, clean, ordered, well-equipped area is desirable for making maple products. Equipment visible includes container and basket for crystal coating candy (left front), soft sugar candy machine with molds (left middle), maple cream machine (left rear), syrup barrel (rear center), propane-fired syrup reheating pan (right rear), canister pressure filter (right middle on floor), and syrup canning equipment (right front). (Ober)

- A collection of appropriately sized pans, kettles, mixers, stirring machines, ladles, spoons, scrapers, measuring cups, etc. Most of these are not unique to the maple products industry and can be obtained from conventional kitchen or restaurant supply sources. Utensils should be good quality and food-grade in order to facilitate long wear and transmit heat uniformly. Food-grade stainless steel equipment is recommended. Boiling pans should be deep and large enough to hold four to six times the volume of syrup being heated since boiling syrup has a tendency to foam up substantially. Generally, boiling syrup will foam up to four times its actual depth compared to when it is not boiling. Hence, 2 inches (5 cm) of non-boiling syrup should be placed in a pan that is a minimum of 8 inches (20 cm) deep to prevent boil-over. A spray mist bottle is handy to disperse bubbles and prevent crystal formation on the surface of cooling syrup solutions.
- Thermometers with a temperature range of 200° to 300°F (90° to 150°C) (**Figure 9.2**). Durable high-range thermometers calibrated to indicate 0.5 to 1.0 degree differences are essential. Either dial units or standard stem-type candy thermometers can be used. Digital thermometers are especially convenient when accurate to 1 degree or better. Suitable candy thermometers are available from kitchen and restaurant supply sources and from maple equipment suppliers.
- A mechanism for rapidly cooling cooked products. Several specialty maple confections require rapid cooling after reaching the desired boiling temperature. Some type of water bath or similar cooling facility must be available (**Figure 9.3**). While large refrigeration units can be used, many producers prefer to use a large shallow container or pan through which cold water is circulated. Containers of cooked syrup are placed on a rack in the water-bath pan where rapid cooling occurs as cold water flows into the cooling pan, around the container of hot syrup, and overflows to a drain. In lieu of a circulating cold-water bath a large pan containing ice water can be used. When a container of hot syrup is placed in the ice water, it may be necessary to add ice to maintain a cold temperature. Depending on the location, pans can also be covered and set in snow when it is present. Commercial restaurant supply stores are a good source for large shallow pans.

Figure 9.2. Digital, dial, or stem-type candy thermometers can all successfully be used to make maple confections.

- Sugar molds. These are required for making hard block maple sugar, soft molded maple candies, or maple lollipops. Rubber candy molds are available from maple equipment suppliers or confectionery suppliers. New molds should be treated before use by washing carefully in hot water and lightly coating each one with a thin layer of glycerin, or spray lightly with a food-grade vegetable oil pan coating. After this initial treatment it is only necessary to wash rubber molds in very hot water. Do not use soap on rubber candy molds because the soap may impart an undesirable flavor to the sugar. Racks of metal molds are usually used to make blocks of sugar; individual metal candy molds can also be used.

Figure 9.3. A water bath provides the rapid cooling required for several maple products during processing. Depending on the size of the batches and the frequency they are made, a small tub (a), a stainless sink (b), or a trough specifically designed as a cooling bath (c) might be most appropriate. (Douglass, Freeman, Ober)

Figure 9.4. Commercial candy machine (left) and two styles of cream machine (center, right). (Douglass, Ober)

- Defoaming agent. A few drops of vegetable oil added to syrup before boiling or a small amount of butter rubbed lightly around the inner rim of the boiling pan will help keep the boiling foam under control. Be aware that some consumers cannot consume any dairy products because of allergies or for personal reasons. The use of food-grade and kosher certified maple syrup defoamer is highly recommended. These products are available from maple equipment suppliers.

- Maple candy and maple cream machines. These mechanical devices represent a costly investment, however, they are necessary when making large batches of some maple confections (**Figure 9.4**). Either machine is capable of making many pounds of product at one time. It is possible to construct your own maple cream machine from readily available materials (**Figure 9.5**)

Figure 9.5. It is possible to construct your own maple cream machine from readily available materials.

## Some Common Maple Products

### Maple Sugar Cakes or Blocks

Maple sugar in its various forms (molded soft candies, hard blocks, loose granulated) has always been the most common product produced from maple syrup. In 1860, one maple producing state in New England produced over 5000 tons (4.5 million kg) of maple sugar. This form allowed easier transport and storage while also providing a source of sugar that was used in cooking and baking. Maple syrup could be reconstituted by adding water to maple sugar.

Hard maple sugar is produced by heating maple syrup to a temperature of 34° to 38°F (19° to 21°C) above the boiling point of water. The lower boiling temperature will make a softer product such as the common small maple sugar pieces, while boiling to the higher temperature is best for making larger blocks of hard sugar. The boiling point of water varies depending on the weather, barometric pressure, and elevation above sea level, so determine the exact boiling point of water before making any maple confections. Observe carefully as the syrup temperature begins to increase; it can get too hot very quickly as the desired temperature is approached. The froth that forms as the syrup boils should be skimmed off as necessary. As soon as the boiling syrup reaches the proper temperature remove it from the heat source and stir (**Figure 9.6**). Some maple producers allow the syrup to cool to 210°F (99°C) before stirring, although this is not necessary. Stirring continues until the solution begins to crystallize, stiffen, and become slightly opaque in appearance. At this time it can be poured into molds, commonly small or large blocks. The sugar will solidify in the cooking container if stirring continues for too long or the contents of the cooking container are not promptly transferred to molds. If this occurs, the addition of some hot water and re-heating to the proper temperature will allow re-use of the hardened sugar. Maple sugar is very sensitive to atmospheric humidity levels as it is hygroscopic (absorbs moisture) by nature and will absorb moisture when humidity levels are high. When atmospheric humidity is very low, maple sugar can dry out, become hard, and will tend to have occasional white spots appearing on its surface. Maple sugar should be stored in dry, airtight containers or other appropriate packages once the production process is complete.

Figure 9.6. As soon as the boiling syrup reaches the proper temperature, remove it from the heat and stir.

## Loose Granulated Maple Sugar

Granulated maple sugar (sometimes called stirred sugar or Indian sugar) is prepared by heating maple syrup until the temperature is 45° to 50°F (25° to 28°C) above the boiling point of water. It is then allowed to cool to about 200°F (93°C), and stirred either in the cooking vessel or in an appropriately sized container until granulation is achieved. Stirring can be done by hand or by using a mechanical stirring machine (**Figure 9.7**). Granulated sugar will "breathe" and ride up high in the pan as it is stirred. A pause in stirring will cause it to drop back down again; after which stirring can be resumed. Stirring continues until all moisture is essentially removed from the cooked syrup and crumbly, granulated sugar remains, similar to commercially packaged brown sugar. At this point the sugar is sifted through a coarse screen (1/8-inch or 3 mm hardware cloth is commonly used) to make a uniformly sized product. Stainless steel sieves with handles are available at restaurant supply stores. Granular sugar absorbs moisture and should quickly be stored in dry, airtight containers. A quart of syrup will yield about 2 pounds of granulated sugar; a liter of syrup about 1 kg of granulated sugar. Lighter colored (lower invert) syrup tends to make a "drier" finished product than if darker syrup is used.

## Maple Cream (Maple Spread, Maple Butter)

Maple cream, also called maple spread or maple butter, is an increasingly popular product. Though commonly known as maple cream in the United States and maple butter in Canada, it actually contains no dairy product; the name is derived from the creamy-smooth texture. When properly prepared maple cream has the consistency of soft peanut butter. Some producers believe the cream and butter terms should be discouraged to avoid confusion with dairy products, however, many producers have developed extensive markets for this product and now process much of their annual maple syrup crop into maple cream.

Maple cream is prepared by boiling maple syrup to 22° to 24°F (12° to 13°C) above the boiling point of water, then rapidly cooling the cooked syrup, followed by slow stirring. This procedure results in the formation of very small sugar crystals and forms a product with a consistency similar to peanut butter. Maple cream is a delectable topping for toast, muffins, fruit, or other similar products and can be used anywhere as a substitute for jam or jelly. For best results, the syrup from which maple cream is prepared should be U.S. Grade A Medium Amber (Canadian No. 1 Light) or lighter. However, other grades of syrup can be used if they contain less than 4 percent invert sugar. Darker grades will produce a darker, stronger-flavored finished product. A gallon of maple syrup will produce about 7½ pounds (3.4 kg) of maple cream.

Figure 9.7. The difficult job of stirring maple sugar can be made a lot easier with a heavy-duty mixer. (Freeman)

The amount of invert sugar in the syrup selected for making cream can be determined by the simple chemical test described at the end of this chapter. Syrup that contains from 0.5 to 2

percent of invert sugar will make a fine-textured cream that feels velvety-smooth to the tongue. Syrup containing 2 to 4 percent invert sugar can be made into cream by heating it to 25°F (14°C) above the boiling point of water instead of the usual 22° to 24°F (12° to 13°C). Syrup with more than 4 percent invert sugar is not suitable for making cream, as it will not crystallize, or will crystallize only if heated to a much higher than normal temperature. When this is done, the cream is commonly too fluid and often separates within a few days.

To prepare maple cream, heat syrup to a temperature of 22° to 24°F (12° to 13°C) above the boiling point of water. Boil to the higher temperature on rainy or humid days. Remember to establish the exact temperature at which water boils at the time the maple cream is prepared since the exact temperature at which water boils depends on weather (atmospheric pressure) conditions. Always skim off the froth that forms on the surface of the boiling syrup. Watch the boiling syrup carefully as the temperature increases, as it can get too hot very quickly, especially as the desired finish temperature is approached. As soon as the syrup reaches the desired temperature it should be removed from the heat and rapidly cooled. Cool the syrup in the pan that will be used for stirring. If a maple cream machine is used it contains its own pan; otherwise the syrup can be chilled and stirred in the boiling pan. Rapid cooling prevents premature crystallization. Cooling the cooked syrup in large shallow pans will facilitate quick cooling. Place the pans in refrigeration units or in troughs with circulating cold water and elevate the pans slightly off the bottom. Small batches can be efficiently cooled in a sink of cold water (**Figure 9.3**). Ice can be added to the water to speed the process. For best results, the syrup should be cooled to 75°F (24°C) or below before stirring. Be sure that the cooling syrup solution is kept absolutely still. Do not move or stir it as crystals will begin to form due to the agitation. If this occurs the final product will be maple cream with a distinctly grainy texture. It is sufficiently cooled when the surface of the cooked syrup is slightly firm to the touch. If crystals begin to form on the surface of the cooling solution, mist the surface lightly with clean water. This creates a very thin layer of low-density syrup on the surface and tends to dissolve the surface crystals and disperse any bubbles of foam.

After cooling, stir the chilled syrup under room-temperature conditions. Stirring can be done by hand or by a mechanical stirring machine. Several different types of commercial stirring machines are available, or they can be locally constructed (**Figures 9.4 and 9.5**). If using a machine with paddles, adjust the paddles so that one gently scrapes the side of the revolving pan while the other is positioned about a third of the way from the edge of the pan. When the cream reaches the proper consistency, it can easily be scooped out as the pan turns by using a thumb-operated, 2-ounce portion-control scoop.

Stirring by hand must be done slowly—don't beat or whip the syrup. The objective is to slowly stir the solution until crystals start to form. This will require some time and strength, especially if the syrup is cooled below room temperature. Under some conditions this may be a two-person operation—one to hold the bowl and one to stir. While being stirred, the cooled syrup first tends to become more fluid (less stiff). Later it will gradually become thicker, lighter in color, and most importantly will lose its glossy appearance and become opaque (**Figure 9.8**). Eventually it will become a smooth paste, with the consistency of soft peanut butter. When this occurs, the crystallization process is complete and the cream can be transferred to appropriate containers. If stirring is stopped too soon, the final product may become somewhat grainy due to the formation of larger crystals. Likewise, if the cooking process did not reach the correct temperature, some separation (presence of liquid syrup on top of the crystallized cream) may occur while in storage. If the cream separates, stirring will bring it back together.

Stirring the mixture too long may cause it to start to harden in the pan. If this occurs, add a small amount of hot water or mist some water into the pan and stir it in to soften. If the syrup solution does harden in the pan, it can be immersed into a pan of hot water or placed into a warm oven until it can be easily stirred again. If using a

mechanical cream machine and the syrup solution starts to get too stiff, it is also possible to soften it by applying a gentle heat source to the outside of the revolving pan. Never re-heat maple cream above 140°F (60°C).

Figure 9.8. As maple cream is stirred, it will gradually become thicker and lighter in color and then will lose its glossy appearance and become opaque (from a to b)

To hasten crystallization, add a small amount of "seed" crystal (previously made maple cream) to the chilled syrup just before stirring. The addition of one teaspoonful of "seed" for each gallon (5 ml per 4 liters) of cooked syrup provides small particles to serve as nuclei so crystals will form more rapidly. For best results use "seed" from the best and smoothest cream available. The entire stirring and crystallization process may require an hour or longer, depending on the size of the batch, but the use of seeding may shorten the time by half. Pausing for a minute or two while stirring, and then stirring again will speed up the crystallization process. Be extra cautious with this technique, because pausing too long allows the syrup to set up into one large chunk. If this occurs, the batch can be softened by gently heating to no more than 140°F (60°C), then stirring can resume.

Maple cream can be packaged in food-grade glass or plastic cups or jars. Containers with wide mouths are best for easy filling. The use of a portion control scoop makes this task much easier. Care must be taken to prevent air bubbles from forming, especially when the maple cream is packaged in glass. Air bubbles are not only unpleasing in appearance but also create the impression that the package is short in weight. Furthermore, separated syrup can collect in air pockets, further adding to a poor appearance.

If the cream is packaged in glass or other moisture-proof containers, it can be stored in the refrigerator for a month or two with little likelihood of the saturated syrup in the cream separating. Because maple cream, like maple syrup, contains no preservatives, it is susceptible to mold forming on the surface. For long-term storage (up to a year) it should be stored in a freezer where it will not mold and will show little or no separation.

## Extending the Shelf Life of Maple Cream

During production of maple cream, maple syrup is heated to a high temperature that kills any microorganisms present. However, after boiling the subsequent production steps involve rapid cooling to produce fine crystals, and transfer of the finished product to individual containers. These operations occur at room temperatures in an open environment where exposure to the atmosphere provides an opportunity for contamination by airborne molds and yeast. At the high sugar concentration level of the cream microorganisms cannot grow in the finished product, however, some molds and yeast can grow on the surface of the cream. For this reason maple cream is stored under refrigerated conditions where the growth of microorganisms is reduced. This limits marketing in some locations and affects distribution as well. These storage and handling requirements also increase the final cost to the consumer.

Unless kept refrigerated or frozen, maple cream has a limited shelf life. Over time at room temperature some separation of the product is likely to occur and mold growth on the surface is probable. To prevent separation of maple cream during storage some producers add a small amount of "invert syrup" to the syrup used to make the cream.

The "invert syrup" is made by adding 0.1 percent to 0.25 percent by volume of the enzyme Invertase to the maple syrup used for making maple cream. Invertase is available from confectionary and baking supply sources. For a gallon (3.8 liters) of syrup to be converted to invert syrup add 1.5 teaspoons of Invertase. This mixture is heated to 120°F (49°C) for 24 to 48 hours and then stored under refrigeration. The use of an oven or crock-pot is ideal for this purpose. This invert syrup solution is added to the maple syrup to be used for boiling to the higher temperatures needed to make maple cream. The invert syrup should represent 10 percent of the final quantity of syrup to be boiled to the normal temperature required of maple cream.

To prevent mold growth on the surface of maple cream, powdered potassium sorbate can be added after the boiling stage. Potassium sorbate is a commonly used food preservative available at most stores that supply materials for wine making. Add potassium sorbate at the rate of 500 parts per million based on volume to the concentrated cooled product prior to stirring. If the cooled product is a result of 1 gallon (3.8 liters) of syrup prior to cooking add 0.3 teaspoons of potassium sorbate to the surface of the concentrated syrup.

*Check with the appropriate state or provincial authority before using either Invertase or potassium sorbate to extend the shelf-life of maple cream to determine how, if at all, the use of these products will affect labeling.* In some areas, for example, Invertase is considered to be a processing aide and need not be declared on the product label, while in other areas it cannot be used and still label the product as pure maple cream.

Extended-shelf-life maple cream will not mold or separate for six months when held at room temperature. However, for the benefit of consumers it is recommended that containers in which maple cream is placed be labeled "Best if used by _____" (dated six months after production) and "Refrigerate after opening."

## Fondant Style Maple Candy (Heavy Maple Cream)

Maple fondant is a nougat-type candy produced in some areas of the maple region. While it is called "maple cream" in some locations because of its very fine crystalline structure, it should not be confused with what is commonly called "maple cream" or "maple butter." Maple fondant (heavy maple cream) is made in the same manner as maple cream except that the syrup is heated to 27° to 29°F (15° to 16°C) above the boiling point of water. The thickened syrup is then cooled to 100°F (38°C) and stirred as when making maple cream. Because there is less syrup left in the fondant, it will set up much more quickly to a soft solid similar to cool butter at room temperature. Remove the stiff cream from the pan in large chunks and knead it like heavy dough until it can be formed and cut into pieces of the desired size. Small amounts can be dropped onto a clean, hard surface such as a marble slab, metal sheet, or other similar surface. It can also be packed into molds or dipped in chocolate.

## Molded Sugar Candy (Soft Sugar Candy)

Like maple cream, the popularity of molded sugar candy has increased (**Figure 9.9**). Most consumers recognize this product as molded pieces of candy, often in the shape of a maple leaf. It is a popular confection with a concentrated maple flavor. Like maple cream, approximately 7½ pounds (3.4 kg) of molded sugar can be prepared from 1 gallon (3.8 liters) of maple syrup.

Molded maple sugar contains little or no free syrup, thus it is stiffer than maple cream or the fondant style confection. The crystals in molded sugar are larger than in maple cream and can be sensed on the tongue, but they should not be so large as to have an unpleasant sandy or gritty texture. Molded sugar can be made from any of the top three grades of syrup, but fresh U.S. Grade A

Light Amber syrup usually yields the most desirable candy in terms of flavor, color, and texture. Unlike maple cream, a small amount of invert sugar reduces the tendency to produce large crystals that give the sugar a grainy texture. The invert sugar content can be increased by adding a small amount of dark amber syrup or ½ teaspoon (2.5 ml) of cream of tartar to 1 gallon (4.4 liters) of low invert syrup.

Figure 9.9. Soft sugar candy shown top in the mold and bottom boxed for sale (without cellophane covering). (Freeman)

To prepare molded sugar, heat syrup to 32° to 34°F (18° to 19°C) above the boiling point of water. Then cool the pan of cooked syrup to at least 200°F (93°C) but not below 160°F (71°C). The thick syrup should then be stirred, either by hand with a large spoon or with a commercial maple sugar machine. The lower the temperature to which the syrup is cooled before stirring, the finer (smaller) will be the sugar crystals formed in the candy. However, large batches of candy are commonly cooled only to approximately 200°F (93°C) or higher, because when cooled to lower temperatures it becomes almost impossible to mold the entire batch before it becomes too stiff.

When stirring, the syrup solution must be watched carefully as it becomes lighter in color, somewhat thicker, and eventually has a creamy opaque appearance. At this critical stage the syrup has lost some of its gloss and appears paste-like. This is the result of the formation of many tiny sugar crystals that form and increase in size in response to the agitation of the syrup. Stirring will only take a few minutes, usually less than five. It is important to determine the exact moment to pour the syrup into the molds. If the mixture is stirred too long the thickened syrup will "set up" (harden) in the pan. It's best to err on the early side.

While the sugar is still soft and plastic, pour or pack it into rubber or metal molds of different shapes. If packing the molds is necessary, use a wide-blade putty knife or spatula. When using a maple candy machine, the semi-liquid sugar can be poured directly into molds without packing or leveling. Use a rigid support under rubber molds to prevent them from flexing. Place molds on a rack to cool; the individual pieces can be removed within 10 to 30 minutes. Sugar formed by pouring rather than packing has an attractive glazed surface. Fresh maple candies can be stored in cool dry conditions for a few months.

## Making Molded Sugar Candy with a Candy Machine

A candy machine is a good investment if large batches of candy are made on a regular basis (**Figure 9.4**). Most commercial candy machines can make up to 18 pounds (8.2 kg) of candy at one time. The metal pan that holds the boiled syrup on a candy maker is called a "pig," because of its shape and the pouring snout at the front. Immediately after the boiling syrup has reached the proper temperature the syrup is poured into the pig. The syrup can also be boiled directly in the pig. Place the pig on the candy machine shelf and tip it up into the locked position, first making certain the nose valve is completely shut. It is not necessary to let the syrup cool much when

using a candy machine; experiment to see what works best. Make sure the trough valve is closed before adding any syrup to the trough. Open the pig nose valve slightly and allow a half-inch or less of syrup to flow into the trough. Close the valve, turn on the motor, and the stirring coil will slowly rotate. Watch carefully at the front of the trough by the valve. After a few minutes the syrup will become lighter in color, somewhat thicker, and have a creamy, paste-like, opaque appearance. At this critical stage the syrup has lost some of its gloss because many tiny sugar crystals have formed to cause this change in appearance. Stirring will only take a few minutes, usually less than three.

Open the trough valve and allow the opaque, partially crystallized syrup to flow out into your mold. Don't wait too long to complete this step, or else the sugar may harden in the nose of the trough. It's better to open the trough valve a bit too soon and have only semi-crystallized sugar flow out for the first few molds. They will harden in time. At the same time, slightly open the nose valve of the pig to allow more syrup to flow into the trough. A slight steady stream about the diameter of a pencil lead works best. The objective is to have a small continuous flow of fresh hot syrup from the pig into the trough, while the stirring coil is crystallizing the syrup, but is still allowing liquid crystallized syrup to flow out from the trough into the molds. An extra set of hands is helpful at this stage, particularly when this equipment is being used for the first time.

Try to keep ¼ to ½ inch (6 to 12 mm) of syrup turning in the trough. If the syrup crystallizes in the trough valve and stops the flow, a small knife can be used to reach into the valve and clear out the clog. Be careful of the turning coil. After little experience it will be possible to make perfect candy in a continuous operation.

## Crystal Coating Molded Sugar Candy

Over time individual pieces of maple sugar have a tendency to dry out. Coating them with a moisture-resistant shell made from crystalline sucrose can prevent this. To make the crystallizing syrup, heat low-invert sugar maple syrup to 9.5° to 11°F (5° to 6°C) above the boiling point of water. This syrup should have a Brix value of 70.5° to 72.5° or 62.5° to 64.5° at 210°F (99°C)[63]. One gallon (3.8 liters) of standard-density syrup (66° Brix) will make slightly more than 7 pints (3.8 liters) of crystallizing syrup (70.5° to 72.5° Brix). Sugar candy should not be crystal coated on humid or rainy days because it will not dry properly. If the sugar is not thoroughly dried, the coating will dissolve when it is packaged.

Set the hot, heavy syrup aside to cool where it will not be jarred or shaken or transfer it immediately to large pans that will be used to treat the maple sugar. To retard surface crystallization (caused by rapid cooling of the surface), the syrup can be covered with a piece of damp cheesecloth or paper (preferably the same kind used as a syrup pre-filter, because it has a high wet strength). The cloth or paper must be in contact with the entire surface of the syrup. If crystals form, they attach to this cover and can be removed along with the covering. The sugar crystals can be recovered by rinsing the cover in hot water, or the cover can be allowed to dry for a few days and the sugar crystals will peel off easily. Some producers have success without covering the coating solution.

The sugar pieces to be coated should be dry (24 hours old). Pack the pieces loosely in a mesh basket (**Figure 9.10**) or other container that will allow them to be completely submerged in the coating solution. The covering is removed from the cool (70° to 80°F or 21° to 27°C) crystallizing syrup solution, and any crystals not removed with the cover are skimmed off. Submerge the sugar pieces completely in the coating solution; place a fresh cover directly on, and in contact with, the entire surface of the coating solution. Leave the candies in the coating solution at a temperature of 65° to 80°F (18° to 27°C) for 6 to 12 hours or overnight.

Most of the crystal coating forms on the molded sugar pieces during the first few hours. Therefore, the time the sugar pieces are left in the crystallizing syrup beyond a six-hour period is not critical. The more times the same batch of dipping solution is used, the more rapidly it will coat the

[63] Hot test temperature.

Figure 9.10. Molded soft sugar pieces that are to be sugar coated are placed in a wire basket or heavily perforated container that will allow them to be completely submersed in a coating solution. (Ober)

candy pieces. Sometimes it may only take two to three hours.

The most important factor related to crystal coating is the Brix value of the coating solution; if it is too high, coarse crystals will result. Sugar precipitates out of the thick syrup and is deposited and crystals form on the surface of the maple sugar pieces. The ideal density of the syrup is determined by trial and error. Remove the paper or cloth cover when sufficient sugar coating has been deposited on the candy and lift the wire baskets of coated sugar out of the coating solution and support them above the trays of coating solution until the candy pieces have drained. The outside of the candy should feel like fine sandpaper when it is sufficiently coated. A single batch of sugar coating solution can be used about three times before it gets too low in density to sufficiently coat the candy pieces. The used solution can be boiled again to make maple cream. Some producers have success without using a covering on the dipping solution. It is suggested that different approaches be tried to determine what will work best for each individual situation.

After the syrup has drained for about one-half hour, dry the candy pieces by manually removing all remaining drops of syrup. Failure to do this will result in areas having a glazed (non-crystalline) surface that is not a water barrier, thus permitting the sugar to dry out during storage. The dried areas will appear as unattractive white spots on the candy.

There are two ways of removing excess crystallizing syrup. The sugar pieces may be spread out in a single layer on a clean sheet of paper turning each piece over at intervals of one to two hours; or each piece of sugar can be wiped with a clean, slightly damp sponge or cloth to remove any moist areas. Place the sugar pieces on screen trays to dry. Set the trays in racks to complete the air-drying process at room temperature. This usually requires from four to seven days, but the process can be hastened by using a fan and/or a dehumidifier. After drying, the sugar is ready for packaging.

Crystal-coated maple sugar has a relatively long shelf life of up to a few months, and it tends not to absorb moisture or dry out. Sugar that is not crystal coated may do either, depending on the humidity of the room in which it is stored. In a dry environment it will lose moisture and the dried-out areas will appear as white spots becoming stone-like in hardness. If the humidity is high the sugar will absorb moisture and moist areas or droplets of water will appear on the surface. The droplets become dilute sugar solutions and are good sites for mold growth. The humidity of the packaging room and the candy storage area should be kept relatively low. Use a dehumidifier or air conditioner when the situation warrants.

The packages for molded maple sugar candies have two functions: to make the sugar as attractive as possible and to keep them in good condition. Boxes, individual wrappings, and paper candy cups can be purchased from a confectioner's supply house or a maple equipment supplier. The net weight of the sugar pieces must be stated

on the outside of the package. Consult local health officials or food production authorities for specific regulations about package requirements.

The best type of wrapper for the outside of the sugar package should not be 100 percent moisture proof but should allow the sugar to breathe slightly and not totally dry out. Consider that the emulsion applied to cellophane to make it heat seal with a hot iron also makes the cellophane moisture proof. Some packers of maple confections obtain longer storage by puncturing the moisture-proof wrapper with some pinholes to permit limited air exchange between the inside and outside of the package. Humidity and temperature will affect length of storage time. A cool storage temperature with 50 to 60 percent humidity works best.

## Other Maple Products

### Sugar-on-Snow

This is a perennial favorite of guests at maple camps during the sugaring season. As in making maple cream, syrup is heated to 22° to 27°F (12° to 15°C) above the boiling point of water. As soon as the syrup reaches the desired temperature, pour it immediately, without stirring, onto snow or crushed ice. Before the container is completely emptied, test by spooning a narrow stream of hot syrup onto the snow. The syrup should stay on the surface and form a chewy layer. Because it cools so quickly, there is not sufficient time for the concentrated solution to crystallize, and instead a thin, glassy, taffy-like sheet is formed. The final syrup temperature for making sugar-on-snow depends on individual preference. To make a stiffer product, boil the syrup a few degrees hotter, less for a chewy, softer product.

### Rock Candy

Making rock candy is usually unintentional as it tends to form in syrup that has been finished at a higher than standard density. Although it should not be considered a product of maple syrup since it is pure sucrose with no maple flavor, this form of "maple sugar" is easy to make. When maple syrup is finished at a density between 67.5° and 70° Brix (heated to 8°F or 3°C above the boiling point of water) and the syrup is stored for a considerable length of time at room temperature or lower, a few well-defined crystals of sucrose (rock candy) appear. These continue to increase in size if the syrup is left undisturbed for a long time. A length of string suspended in the supersaturated syrup solution will act as a base structure for the rock sugar crystals, which can then be "harvested" by pulling out the string and hanging until dry.

### Maple Snow-Cones

This product is easy to prepare and is a favorite at many country fairs and festivals. Pour 1 ounce of dark amber maple syrup on a cupful of ground or crushed ice (resembling snow) that has been compressed with a scoop and placed in a paper cone. A hand operated syrup pump (available at a restaurant supply source) that can be attached directly into the top of a standard syrup jug works best for consistent, easy syrup dispensing.

### Maple Cotton Candy

This confection, also popular at fairs, is prepared using a standard cotton candy machine. The normal sugar mixture is modified to contain a mix of granulated maple sugar and fine granulated white sugar. Proportions vary according to personal preference. A mix of one part maple sugar and three to four parts cane or beet sugar is commonly used. If the humidity is high, use slightly less maple sugar. A higher proportion of maple sugar will not make as fluffy a product. Follow the manufacturer's instructions for operating the cotton candy machine.

### Coated Nuts

It is possible to coat almost any nut with pure maple sugar to make a delicious product that is very popular with consumers. Dark syrup with a robust flavor works best with the intense flavor of most nuts. Before heating the syrup, make sure the nuts are very dry or they will absorb moisture and become stale when stirred into the hot syrup solution. Dry the nuts by heating them in a low-heat but warm oven. Heat syrup to 40° to 45°F (22° to 25°C) above the boiling point of water;

remove from heat and immediately stir in the nuts. Continue stirring until the mixture crystallizes and coats the nuts. Spread the coated nuts on a tray one layer thick and allow them to cool and dry. Once cooled, package them into airtight containers. A quart of syrup will be sufficient for coating about 4 pounds of nuts.

### Maple Lollipops

Use equal parts maple syrup, white corn syrup, and cane sugar. Stir together and heat to 295°F. Allow the mix to cool to about 250°F (146°C) and pour into molds. If the mix is poured hotter than 250°F (146°C), the syrup will boil out of the molds. Sticks should be inserted before pouring. U.S. Grade A Medium Amber or U.S. Grade A Dark Amber syrup (Canada No. 1 Light or Canada No. 1 Medium) works best. Molds must be made from materials that will withstand high temperatures. After the lollipops cool to room temperature they are easily removed from the molds. They should be wrapped immediately or they will become sticky, especially when the humidity is high.

### Maple Taffy

Taffy is a non-crystallized form of maple sugar. Heat the syrup to a temperature of 23° to 26°F (13° to 14°C) above the boiling point of water. Allow the syrup to cool for a few minutes without disturbance, and then pour immediately into containers. A very light misting of water helps eliminate bubbles on the surface. Cool as quickly as possible by placing containers gently into a freezer; being careful not to agitate the syrup or crystals will form. Once allowed to warm up to room temperature, maple taffy can be eaten with a fork or wooden taffy spoon. Individual servings can be packaged in small plastic cups with snap-on covers. The taffy will last indefinitely when frozen.

### Maple Jelly

Jelly can be made with the addition of a jelling agent such as *Genugel© CP Kelco,* which is available from maple equipment dealers. Regular pectin normally used for other jellies will not work with maple syrup. Genugel is a food-grade, natural product, derived from ocean grown plants. A tablespoon or less of Genugel is sufficient for a half gallon (1.9 liters) of syrup, which will yield seven 8-ounce (1/4 liter) jars of jelly. Whisk the Genugel into 2 cups (1/2 liter) or more of cool water. When completely dissolved, add to hot (but not boiling) maple syrup. Be sure to use a container with at least three times the volume of the amount of syrup used since it will foam extensively while boiling. Boil the mixture to 6 to 7°F (4°C) above the boiling point of water, reduce heat, gently skim the surface, and ladle immediately into containers. Fill containers gently to prevent the formation of air bubbles in the jelly. A single pouring from a large cup works best. The need to skim will be reduced if the cooking container is kept covered with a lid as much as possible. The jelly sets quickly as it cools, so it is helpful to keep the heat low under the pan while bottling. Cap the filled containers and process in a hot water bath for ten minutes at 180°F (82°C). Experiment to find the right proportion for the desired thickness of jelly.

### Others, Limited Only by Imagination, Including Maple Ice Cream, Maple-Covered Popcorn, Maple Fudge, Maple Vinegar…

Most maple cookbooks offer a wide variety of suggestions and recipes for other value-added maple products. Darker syrup with a strong flavor is usually preferred for many other products. Experiment and remember there are no failures; even the mistakes can be eaten…and they taste good!

## Some General Tips for Success with Maple Confections

- Always check the boiling point of water before starting to make any confection. Water boils at a different temperature depending on the specific location above sea level and current weather conditions. The boiling point of water will be lower at higher elevations and it will be lower on days with lower atmospheric pressure.
- Use caution—boiling syrup is very hot and can cause severe burns to yourself as well as others.

- Watch the boiling syrup closely as the temperature increases. It can get too hot very quickly as it nears the proper temperature. If it cooks too long over direct heat it can scorch and even catch fire.
- When using a mechanical candy or cream machine, follow the manufacturer's instructions carefully; always be aware of moving parts.
- Always use the best quality, freshest, and lightest grade of syrup available.
- Follow recommended food sanitation procedures using clean molds, pans, and utensils.
- Clear, sunny days with high atmospheric pressure are best for making confections. On rainy or humid days, try boiling the syrup about one degree hotter. Experiment to see what works best.
- After syrup has reached its proper temperature and is cooling, do not disturb it. Any movement may cause large crystals to form. Don't even remove the thermometer at this stage.
- Boiling maple syrup will foam extensively. Watch the pan closely when it first begins to boil and be prepared to remove it from the heat or stir it to keep the foam down. Be sure to add a defoamer. It is important that the boiling pan should have a minimum capacity of four times the volume of syrup being boiled.
- Failed batches of sugar or candy can be used for a sweetener or added to more boiling syrup for another batch.
- Never use soap to wash rubber candy molds because the soap can cause off-flavors.
- Don't be afraid to experiment with temperatures. Experienced producers can make good candy and cream in any weather. A difference of a degree or two in temperature can determine whether or not a particular confection can successfully be produced under a particular set of weather conditions.
- Likewise, different syrup lots may produce the identical desired result when boiled to different temperatures. The key to success is to experiment to find out what temperature results in producing the best product.
- When candy making with a machine, place each rubber mold on a small tray or small sheet of plywood, and stack them next to the candy machine. By doing so the time delay in filling the molds will be minimized and candy can be produced in a smooth continuous manner.
- A spray bottle of water is very useful to help prevent crystals from forming on the surface of the cooling syrup and the sides of the cooling pan when making maple cream. Lightly mist the surface of the syrup and the edges of the pan when the cream pan is first placed into the cold-water bath.
- As experience is gained in making maple cream with a machine, carefully watch the thickness of the mixture as it is stirred. If it starts to get too thick, a bit of hot water can be added to the syrup, or medium heat to the edge of the pan as it turns. A heat lamp suspended over the rotating pan can be used to soften the cream. If this technique is used, be sure to use a shatterproof bulb in the heat lamp. Such bulbs are available from a restaurant supply business. Other producers have successfully used an electric paint stripper as a heat source.
- If maple cream has been stirred for a long time and hasn't started to set-up, turn off the machine for about two minutes and allow the contents to set undisturbed. Then turn the machine back on and it will usually start to set-up quickly. Use this technique very carefully because too much time at rest may cause the cream to set quickly into one firm mass.

**Summary table of maple confections, boiling points and characteristics.**

| Product Name | Other Names | Cook to Boiling Point of Water Plus: | Process | Characteristics |
|---|---|---|---|---|
| Rock Candy | | 8-10° F (4-6° C) | boil, allow to set for weeks | hard, clear sucrose crystals |
| Maple Cream | Maple Spread Maple Butter | 22-24° F (12-14° C) | boil, cool, and stir | creamy smooth, paste-like |
| Sugar-on-Snow | Jack Wax Leather Aprons | 22-27° F (12-15° C) | boil, pour over packed snow | chewy to brittle, depending on boiling temperature, no crystals |
| Taffy | Tiré (fr.) | 23-26° F (13-14° C) | freeze immediately | thick and chewy, no crystals |
| Fondant Type Candy | Maple Cream Heavy Maple Cream | 27-29° F (15-16° C) | boil, cool, stir, and mold | smooth, putty-like |
| Molded Sugar | Soft Sugar, Maple Candy | 32-34° F (18-19° C) | boil, stir hot, pour into molds | firm, but not rock solid, very small crystals |
| Hard Sugar | Block Sugar | 34-38° F (19-21° C) | boil, stir hot, pour into molds | harder than molded sugar candies, in block form |
| Granulated Sugar | Indian Sugar Stirred Sugar | 45-50° F (25-28° C) | boil, stir until granulated, sift | loose granulated, like brown (cane) sugar |

## Testing for Invert Sugar

Because the amount of invert sugar in maple syrup affects its suitability for making maple cream, it is sometimes desirable to evaluate the invert sugar content of syrup. There is no simple test to accurately measure the exact amount of invert sugar in a sample of syrup. For years, however, maple producers have used a modification of the Clinitest® urine sugar test to classify syrups into two categories, those containing less than 2 percent invert sugar and those containing more than 3 percent invert sugar. The test is made by first preparing a syrup-water mixture (1 part of syrup to 20 parts of water) and then color testing the diluted syrup. It can be performed in three or four minutes. The few pieces of equipment necessary to make the test can be obtained from a local pharmacy. The following items are required:

1. Clinitest® tablets obtainable at a pharmacy.
2. Two medicine droppers.
3. A test tube, about ½ inch in diameter and 3 or 4 inches long.
4. A sample of the syrup to be tested (a cupful).
5. One medicine glass, calibrated in ounces.
6. One glass measuring cup, calibrated in ounces.
7. Test tube holder.
8. Two, 8-ounce, clean and dry drinking glasses.
9. One, 1-quart glass fruit jar and cover.
10. Water (20 fluid ounces).

### Making the Test

1. Carefully pour enough of the test syrup into a medicine glass to bring the level of the syrup exactly to the 1-ounce (2 tablespoons) mark. If too much (more than 1 ounce) is added, empty the syrup out of the medicine glass, wash and dry it and start over.
2. Measure 2½ cups of water and transfer it to the quart jar.
3. Make the 1 to 20 dilution by pouring the fluid ounce of syrup into the jar containing the 2½ cups (20 fluid ounces) of water.
4. Pour some of the water-syrup mixture into the medicine glass and return it to the jar.

Repeat this three or four times to be sure that all the syrup has been transferred to the water in the jar. Mix the contents of the jar thoroughly by stirring with a spoon or with a portable electric mixer.

5. Place the test tube upright in the holder. (The holder can be a 1-inch-thick block of wood, 2 inches square with a 7/16-inch hole 3/4-inch deep.
6. Fill a clear, dry medicine dropper with the diluted (1:20) syrup in the fruit jar. Hold the dropper upright above the test tube and let 5 drops of the diluted syrup fall into the test tube.
7. Fill another clean and dry medicine dropper with water and add 10 drops of water to the test tube.
8. Place a Clinitest® tablet, freshly removed from the bottle or wrapper, in the test tube. As the tablet dissolves, it causes the contents of the tube to boil. Do not remove the tube from the holder while the solution is boiling.
9. Fifteen seconds after the boiling stops, add water to the test tube until it is two-thirds full.
10. Observe the color of the solution in a room illuminated with an incandescent bulb. The colors are not easily judged by fluorescent light or direct sunlight. Disregard the colored chart values provided with the test. For this test, blue indicates the syrup contains less than 2 percent of invert sugar and can be used to make cream; yellow or yellow green indicates the syrup contains more than 3 percent of invert sugar and may not be suitable for making cream.

# Chapter 10 · Marketing Maple Products

Maple syrup is one of the oldest agricultural products produced in North America. In the years following European settlement it was produced on the family farm, primarily for personal consumption. Over time the production and processing of maple syrup and derived maple products has become a nearly full-time business endeavor for many producers. As production surpassed what was needed for personal consumption, marketing became a necessary component of the production process. Originally, most maple syrup was processed to maple sugar and this product, principally in block form, was the primary product bartered or sold to wholesale and retail markets. Today the demand for pure maple syrup, maple sugar, and other maple products continues. Maple syrup has many attributes that make it an attractive and profitable product for the marketplace. It is natural, great tasting, versatile, and represents a wholesome North American tradition.

The commercial production of maple syrup is limited to the northeastern United States and the eastern provinces of Canada. Traditionally and historically, marketing efforts have, for the most part, been concentrated within the maple production region where competition among producers for market share has often been intense. However, opportunities exist for expanded marketing outside this region and indeed outside both the United States and Canada. Promotional efforts to increase consumer awareness and knowledge of maple products are an essential part of the marketing process for pure maple products, especially outside of the areas of production. Consumer education is a critical step in development and expansion of maple product markets.

Marketing strategies are most effective when customized to each maple producing operation and the targeted consumer. This chapter contains information intended to help producers increase the profitability of their maple operation by establishing goals and effective marketing plans.

## Establishing Goals

The priorities of maple producers can be quite varied. For many small producers, the most important goal is to enjoy the experience of making maple products and the opportunity to involve family and friends. The production of small quantities of maple syrup for their own use and as gifts for family and friends tends to outweigh financial considerations that are generally viewed as being a bonus rather than the principal objective. For others, income from production is a high priority and directly influences the amount of effort put into promotion as well as the manner of marketing. The goals of different producers are influenced by the amount of time available to devote to the maple operation, personal preferences, the location and availability of the maple resource, as well as labor, financial resources, and the size of the operation.

### Time Constraints

Most maple producers have a number of demands on their time in addition to the production of maple syrup. These include other employment, family commitments, and social obligations that often make it difficult to dedicate the time necessary for extensive promotion and marketing efforts. For larger producers this may result in more syrup being sold in bulk because of the lack of time required for retail packaging and marketing.

Although more time and effort are required to package and market maple products for the retail market, the potential for greater profits is dramatically increased by a well planned and executed marketing strategy. A producer may choose to take the time necessary for wholesale or retail sales if they can be confident of a significant increase in profits.

## Personal Preferences

The personal preferences of maple producers will be reflected in the goals and structure of their business. Producers who enjoy meeting and working with others may be well suited to retail sales or dealing with wholesale customers. Producers who prefer limited distractions during production or who have less desire to interact with people may choose to focus on wholesale, bulk, or mail order retail sales rather than attracting customers to their sugarhouse or sales location. It is important to acknowledge that financial returns may be significantly lower where bulk sales are emphasized. An alternative may be to incorporate a person into your business who will complement your production interest, but who has the skills to develop more effective retail and wholesale sale procedures.

## Location

Location is an important consideration when establishing a new maple operation. Producers who are situated close to large population centers or on well-traveled routes have an advantage with respect to promoting their operation and attracting customers to their business (**Figure 10.1**). A few well-placed signs and targeted advertising can produce significant results. Little additional effort may be required to inform potential consumers of your location and what products are available for purchase. However, those producers in rural areas that are distant from population centers may have to rely on more intensive advertising or other creative marketing strategies to attract customers. In some instances it may require establishing a separate retail location to develop a retail clientele and business. The success of carrying out a wholesale business will also be influenced by the distance to wholesale markets and availability of transportation alternatives for transporting bulk maple products.

In addition to location, other aspects such as quality of roads, availability of adequate parking, and attractiveness of production and sales facilities are important considerations when contemplating the establishment of either a retail or wholesale maple business. One other aspect should be mentioned—make certain that local zoning regulations related to type of business, method of sales, traffic concerns, and conformity of signs have been checked and appropriate permits have been obtained to insure that requirements have been met.

## Size of Operation

Marketing methods and strategies are directly related to the size of the operation. If only small quantities of syrup are produced it is probable that most of it will be sold locally to neighbors and others who visit the operation during the maple season. However, if larger quantities are produced a method of marketing must be developed at the same time the operation is established. As with many other agricultural commodities, simply having a quantity of product available does

Figure 10.1. Producers located close to large population centers or on well-traveled routes have an advantage with respect to attracting customers to their business.

not ensure a ready market. For producers who intend to sell the majority of their crop wholesale, contacts and even pre-season contracts with wholesale buyers should be obtained.

Additionally, it is important to be able to continually supply the demand a developed market requires. If substantial efforts are put into developing and establishing a retail market, it is essential that adequate supplies of maple products be available to meet the demand. This may require the outside purchase of syrup and other maple products during poor maple seasons or when seasonal demand is strong.

## Marketing and Promotion—What Are the Differences?

By definition, marketing consists of all the activities carried out by a business to promote and sell its products. As identified in the following table it encompasses all aspects of the selling process.

| Aspect of Marketing | Purpose |
|---|---|
| Market Research | Evaluate consumers' needs and preferences |
| Product Presentation | Tailor products to correspond with marketing objectives and consumer preferences (e.g. value-added products, types of containers and packaging) |
| Promotion | Increase awareness of the product and likelihood of purchase |
| Pricing | Ensure profits for producer and meet with consumer perceptions of value |
| Distribution | Select and choose manner in which the product is made available to customers (e.g. retail location, Internet, wholesale, bulk) |

Promotion is an important component of marketing. The primary objective of promotion is to communicate information about a product in such a manner that consumers are persuaded to purchase it. Four different types of promotion strategies that could be adopted by maple producers to promote their business are described in the following table.

| Promotion Strategy | Description |
|---|---|
| Advertising | Purchased presentation of information in a public medium (e.g. newspaper ad) to draw favorable attention to the product or business |
| Sales Promotions | Direct encouragement to customers to make a purchase (e.g. coupons or special deals) |
| Personal Selling | Direct personal interaction between salesperson and customer in which product information is conveyed |
| Publicity | Non-purchased communication that draws attention to the business or product (e.g. coverage on local television of an event at a sugarbush) |

## Need for Promotion and Marketing

Effective promotion and marketing are among the most important keys in operating a successful business. Obviously, producing and having available a high valued product that appeals to consumers is fundamental. However, if these products are not effectively marketed the business is not likely to succeed. Promotion and marketing are useful as tools to ensure that the product can be sold in a reasonable length of time for a profit that will justify the effort and expenses incurred. A producer who enjoys making syrup but chooses to avoid the business side of the operation may be realizing only a portion of the potential profit.

The effort put into promotion and marketing should be proportional to the need. Greater effort may be required by a new business to attract new customers. Promoting maple products is beneficial not only to the individual producer but also to the entire industry if an increase in consumer purchases is achieved. Cooperative efforts and the pooling of resources by associations or groups of producers may make it easier to reach more people. Promotion efforts by state, provincial, and local maple syrup producers associations can also be very effective.

# Market Research

## Value of Market Research

Customers are essential to any successful business. In developing an effective marketing plan the producer/seller should attempt to understand potential consumers and what aspects and or characteristics influence their decision to purchase. The principal purposes of market research are to identify:

- potential customers
- effective methods that make potential customers aware of the product
- how the desires of customers can be satisfied most effectively

Market research is particularly important when new businesses are being contemplated and established. By identifying some of the characteristics and locations of potential customers, dollars allocated to marketing efforts can be spent most effectively. One component of market research is observing the competition and attempting to identify what is—and is not—effective in their advertising strategies. Where local competition is intense it may be necessary to promote your products in less saturated markets or to create a new niche market for the specific products available for sale.

Market research can also be helpful to a well-established business. The current customer base may be characterized by informal observations and conversations with customers or by conducting a simple survey. This information can be used to assess the effectiveness of existing marketing strategies and to identify new target markets that could prove profitable.

## Consumer Surveys and Trends

Conducting a consumer survey may be a very helpful component of market research. If a survey is to be conducted, consider the following suggestions that have often proven successful. The survey instrument should be designed so meaningful information will be obtained, and questions presented so they are clearly understood by the consumer. Response will be better if the survey is brief and easy to complete (multiple-choice as opposed to written responses). Offering an incentive (e.g. discount coupon) for people to participate may also be helpful. Sometimes entering the names of all respondents in a drawing for a significant "prize" can also be helpful in obtaining participation. Collecting the names and addresses of surveyed individuals is an efficient way to begin creating mailing list.

A basic consumer survey may include questions pertaining to the following type of information:

- age group
- where do they live
- how did they find out about you
- family status
- reasons for purchase
- amount and frequency of purchases
- products purchased
- suggestions
- other

After collecting a significant number of survey responses, the information obtained can be studied for characteristics and desires of customers. This will be helpful in making decisions related to future product production, promotion, and marketing activities. Results from industry and/or government-sponsored surveys may also be available in some areas. These results can also provide useful information for future marketing strategies.

## Market Segments

A market segment is a group of consumers that have some common characteristic or attribute that makes them unique. The grouping may be made based on age, income level, gender, interests, or purchasing criteria and trends. A market segment could be a group of people who are health conscious, traveling, retired, own large businesses, have young families, or share any other common characteristic. By focusing marketing efforts on specific market segments, strategies can be adapted accordingly. For example, if the decision is made to focus on individuals who are particularly health conscious, it may be advantageous to emphasize the natural, additive-free characteristics of pure maple products. If the decision is made to target the tourist market, attractive, souvenir-type containers may be more

appropriate. Once the specific market segments have been identified, appropriate promotion, marketing, and packaging strategies for the products that are offered can be adopted.

It is possible to develop market segments unique to the products that are produced and available. As an example, if a significant amount of high quality dark syrup is produced, its use as an ingredient in cooking and baking could be promoted. Identifying a group of individual consumers as well as commercial accounts (i.e. bakeries and/or restaurants) that would be interested in purchasing and using this particular product could be pursued.

## Product Presentation

Packaging is an important component in marketing pure maple syrup and related maple products. For maple syrup, containers are available in a variety of different styles, sizes, and materials. Each type, style, and size of container has attributes that are used to identify and enhance the appearance and appeal of the product. A savvy maple retailer will offer maple syrup in a variety of different sizes and styles of containers. It is a mistake to package and offer maple syrup in only a few containers that do not vary significantly in size.

Containers should be chosen that present the product most favorably and in a manner suiting the needs of the customer. Large, simple containers such as half-gallon or gallon cans or jugs are preferred by customers who buy larger amounts of syrup for personal consumption. However, smaller, attractive plastic or glass containers are well suited for gift giving and souvenirs. Consumers will sometimes buy an attractive bottle simply because of the appeal of the container (**Figure 10.2**). Offering a variety of containers will allow the desires and demands of consumers to be met (See discussion of containers in Chapter 8). Additionally, some types of packaging are better suited for mail order and commercial shipments due to their weight and resistance to breakage. Recyclable containers are becoming more important to many because of increasing environmental concerns.

Finally, some people enjoy the comfort of familiarity. By maintaining some unique and traditional packaging it is easier for consumers to quickly find your product on the shelf, thus facilitating repeat business.

Figure 10.2. Consumers will sometimes buy an attractive bottle simply because of the appeal of the container.

## Benefit of Value-added Products

Maple syrup is a very desirable and salable product, and much is sold directly to consumers. Since the desires of consumers vary, most producers offer syrup in a variety of different sized and shaped containers. Obviously the price charged to consumers reflects not only the quantity of syrup (smaller-sized containers are priced proportionally higher than larger containers on a per unit of syrup volume basis), but also the style and type of container or package. By packaging syrup in smaller containers producers are able to receive a higher total price for a given quantity of syrup than if it were sold only in a larger size such as a one-gallon container.

Processing maple syrup into secondary products such as maple sugar, maple candy, maple butter

or crème, or other products can also significantly increase total returns. While additional facilities, equipment, and labor are required, the increase in total value received for the additional effort required is significant and adds to total income received from the maple enterprise. Refer to Chapter 9 of this manual for information regarding the production and handling of a variety of "value-added" maple products.

## Promotion

The objective of promotion is to increase awareness among potential consumers of a business and the products offered in order to increase sales. There are many marketing strategies that may be effective in accomplishing this. Each business is unique. Who the customers are and what is important to them will influence what marketing techniques will be successful. Take advantage of what each location has to offer. Accessibility and tourism in the area will affect marketing strategies.

### Developing Effective Marketing and Promotional Strategies

The following are examples of some factors that have been identified as significant, and should be considered when developing effective marketing strategies for promotion of maple products.

- Continuity of Supply—To be identified as a dependable source of pure maple products it is necessary that a complete inventory of all products offered for sale be maintained on a year-round basis. This may require the purchase of additional syrup if a "short season" occurs. Some producers may object to this, preferring to sell only what they produce, and when that is sold out, sales for the year cease. Ideally, many producers would like to sell out of their crop of syrup just before the following sugar season begins and not have to purchase syrup to maintain their product inventory. However, the professional image of a successful retail establishment will be enhanced when a complete product inventory is available throughout the year and consumers associate both quality and dependability with the business.
- Environmental Awareness—In the past several years many consumers have become more environmentally conscious. This is reflected in different ways, from an increased desire to maintain forests and other features of the landscape in as natural a condition as possible, to using products that can be readily recycled, and purchasing "natural food" products such as those that have been "organically" produced. Maple producers are in a good position to identify themselves and their operation as "environmentally friendly." Pure maple syrup is a completely natural product; it is produced by simply processing, by boiling, maple sap into maple syrup. The tree is minimally harmed. No preservatives are added to the sap, and aside from boiling, subsequent evaporation, and filtering, no other processing is necessary to produce the final product. These attributes and characteristics can be used in the promotion of pure maple products to environmentally conscious consumers.

  To further increase consumer awareness of the positive environmental aspects of pure maple products, some producers may wish to consider joining appropriate organizations that identify and promote environmentally friendly and organically produced products. These include, but are not limited to: seal of quality programs, organic certification programs, and forest certification programs. Producers are reminded of the importance of verifying the authenticity of such organizations before committing to membership.

  Some producers may wish to incorporate eco-tourism into the business. The establishment of walking trails through the sugarbush and the hosting and conducting of ecology-focused seminars may attract certain groups of consumers, while promoting environmental awareness and a favorable business image.
- Maple Syrup Grades—Although production processes are the same, the grade of maple syrup produced throughout the season varies. The emphasis placed on grading is different throughout the maple region, with grading being mandatory in some areas and voluntary in others. In areas where grading is widely

recognized and promoted (even if grading is not mandatory), it is recommended that producers grade at least a portion of the syrup that is offered for sale. Preferences among consumers for lighter or darker colored syrup vary since flavor is usually more intense in syrup that is darker in color. Offering syrup that is graded allows customers to consistently purchase syrup that matches their preference, resulting in a satisfied customer. Although it is common practice to charge less for darker syrup in some regions, in actuality there is no justification for this price differential since the production practices and costs for all syrup are essentially the same for the producer.

- Food Safety—Pure maple syrup and derived maple products are food products. As such it is essential that all production practices, processing facilities, and packaging, storage, and display areas be designed and maintained to not compromise any aspect of quality, cleanliness, or safety. It is crucial that consumers have no cause for concern regarding the safety of maple products offered for sale. All production facilities and sales areas must be cleaned on a regular basis and maintained in an attractive condition. All potential sources of contamination should be identified and efforts undertaken to minimize or eliminate any facility or production practice that could result in compromising quality and/or safety.
- Emotions/Traditions—Pure maple syrup is a very "traditional" product. The production of maple syrup is one of the oldest agricultural enterprises in North America. It is one of the few agricultural endeavors that was not brought to the continent by Europeans or others. Although the methods and equipment used for sap collection and processing have changed, the process used for transforming sap into syrup remains the same. The "maple syrup tradition" can be used in the promotion and marketing of pure maple products as a "comfort" food. Many adults, especially those who reside in the maple production region of North America, have fond memories of sugarbushes and "sugaring" when they were younger. Appealing to the nostalgic aspects of maple syrup production is an excellent approach to attracting customers, and to introducing younger potential customers to pure maple products. Maple syrup is still the same product it has always been, and to many it remains a symbol of simpler times, family involvement, and hard work. Establishing and promoting a family atmosphere at the sugarbush or sugarhouse with traditional activities such as sugar-on-snow parties, sleigh-rides, and weekend tours may help attract potential people to the business and encourage purchases of maple products.
- Aging Population—Current population trends indicate the number of older individuals in society is increasing. This segment of the population may represent a potential market segment to which targeted promotion and marketing activities can be directed. Following retirement, many of these individuals have adequate resources for travel and non-essential purchases. Promotional efforts directed toward older individuals may focus on tours and/or other types of visits to the sugarhouse. Fall foliage or color tours have become popular with many touring agencies and coordinating visits to maple production/sales facility during the fall is a possibility that should increase the sales of maple products. Working through a travel agency to develop visits to the sugarhouse as a destination or as part of a local tour is another possibility.
- Involvement—Becoming a member of a local, regional, or national maple syrup association, tourism association, or local business association can be very beneficial to a business. These organizations represent a good source of information for current research information, equipment innovations and/or improvements, trends in consumer markets, marketing techniques, and other educational programs. Attending annual meetings of these groups can help individual producers remain current about what is going on in the maple industry as well as become more knowledgeable about promotion and marketing methods. Membership and participation also provides opportunities to include the business in collective advertising campaigns, and allow input on issues that may be important to local businesses.

## Consumer Education

Education of the public is a valuable component of marketing maple products. In contrast to pure maple syrup and maple sugar, alternative pancake syrups and cane sugars are inexpensive and readily available. The higher prices charged for pure maple products have made them more of a specialty product than a primary source for syrup and sugar. However, consumers who value the unique flavor and wholesomeness of pure maple products continue to make regular purchases when they are assured of a dependable supply of a high quality product. The authentic taste may be enough to maintain some consumers as repeat purchasers, however, additional information may be helpful in persuading others to purchase maple products. The following represent some areas where additional information can be offered in an attempt to further promote and market pure maple syrup and related products.

### Uses

As a generalization, consumers prefer to buy only a small quantity of maple syrup at a time, even when price is not an issue. The primary reason for this is the perception that maple syrup has limited use; the most important of which is as a topping for pancakes and/or waffles. However, as we all know, this is not the only use that can be made of maple syrup. It is important for consumers to understand that maple syrup can be used as a substitute for sugar in nearly every situation where sugar is used. The addition of maple syrup to meat or vegetable dishes adds an attractive flavor. As a sweetening agent for coffee, tea, and cereal, maple syrup is a good substitute for sugar. To acquaint consumers with the many uses of pure maple products, some producers find it helpful to hand out recipe cards that include maple syrup as an ingredient, or sell cookbooks that offer suggestions for using maple products in the preparation of many different kinds of food. Making available these kinds of materials can be helpful in promoting increased use of maple products and in encouraging sales.

### Health

Many consumers have become increasingly conscious of what they eat and implications related to diet and health. For those individuals concerned about food additives or other aspects of food purity and/or quality, pure maple syrup is an attractive product since it contains no additives and is an entirely natural product. Some of the nutritional values and chemical composition of pure maple syrup are presented in Appendix 2 of this manual.

### Grades and Handling

Some consumers are not aware that different grades exist for maple syrup. Federal and state grading guidelines are available and are rigidly adhered to in some areas of the maple-producing region. However, grades do not imply any differences in composition, density, or purity; the primary differences are color and flavor. Darker grades of syrup usually have a more intense or stronger flavor than lighter grades, and are preferred by many for use in cooking. Retailers who want their products to appeal to the many different preferences of consumers may want to establish tasting opportunities in their retail sales area.

To maintain quality, maple syrup must be handled properly following purchase. Purchases of larger quantities of syrup are more likely if consumers realize there are storage methods that will maintain syrup in a fresh condition for a prolonged period of time. Storing maple syrup in a freezer is an excellent method of keeping syrup until it is used. A smaller jug may be kept in the refrigerator and refilled as necessary from a large bottle of maple syrup kept in the freezer. Once a syrup container has been opened it should be stored under refrigerated conditions. Storing opened containers in a pantry provides opportunity for the growth of mold or possible fermentation.

Basic handling guidelines should be a part of the label on each container. Additionally, brochures containing storage and handling information are helpful in increasing consumer awareness.

### Nutritional Labeling

Labels containing information about the nutritional value of a particular food product are common for most processed and packaged food (**Figure 10.3**). Many containers in which maple syrup is packaged contain such information, however, their use on all maple products is recommended. Providing basic nutritional information on the package label may encourage the purchase of maple products, and is required by law in many instances.

Figure 10.3. Nutritional information printed as part of a maple syrup container label.

### Organic Maple Syrup

Interest among consumers in the purchase and use of organic products has increased. Some consumers will purchase food products with an organic label in preference to products that are not so labeled. For some producers, it may be worth the effort to obtain organic certification, particularly if syrup is to be marketed in health food type stores, or if one is seeking to gain a competitive edge in a well-saturated market. Maple syrup production is a naturally sustainable practice that produces an entirely natural product. Both the production process and the product lend themselves well to being organically produced. However, although the product is truly organic, *organic certification* (*which is what consumers look for)* requires that all aspects of the production process be certified according to the methods of the organic certifying agency. Certification guidelines focus on the sugarbush and its management, the methods of sap collection and processing, as well as procedures involved with packaging and handling. If maple syrup is purchased to supplement production, it must also be certified as organic for it to be sold as such.

## Advertising

Advertising is the most visible form of promotion. Advertising is a paid-for presentation of information about an individual business or product presented in a public medium. Well-designed and placed advertisements can be effective in creating a positive awareness of the business and the products offered. Among the many objectives of advertising are: maintaining an awareness of the existence of the business among current customers, presenting a message in order to attract new customers, and establishing and/or maintaining a favorable competitive position among other businesses selling similar products.

The quality of the advertising message and the medium in which it is placed should reflect the quality of products being sold. Pure maple syrup and other maple products are by nature high in quality. Advertising that promotes these products should likewise be of high quality. Important considerations when developing an advertising strategy include identifying advertising goals, establishing a budget, and selecting the most effective media.

### Advertising Goals

In order to develop an effective advertising plan, goals need to be clearly identified. The primary objective of advertising is to get the right message to the right audience at the right time. A secondary objective is to develop and establish a desirable image of the business in the minds

of consumers. Uniformity and consistency in all types and methods of advertising help to continuously reinforce this image.

Specific advertising goals can be identified in several different ways. While the overall objective is to increase the awareness of an individual business among consumers, this message may assume several different forms. For example, in some locations advertising may focus on messages to make potential customers aware of where the business is located. Another goal may be to seasonally inform consumers that the "sap is running" and fresh maple products are now available. Still others may focus on the diverse array of maple products that are available, and advertising that conveys images and uses of pure maple products may be helpful in creating a demand. Advertising can also appeal to the nostalgia and tradition associated with maple, creating a desire to visit a sugarhouse where "history" can be re-lived. It is up to each producer to establish specific advertising goals and to select the appropriate advertising medium to most effectively accomplish these goals.

## Advertising Budget

Because significant costs are involved in effective advertising, it is wise to establish an advertising budget and make decisions that obtain the greatest value for dollars spent. The necessity for advertising may be based on need; for example how well a particular business is established within a particular area. If the business is new, the need for advertising that focuses on the location of the business and the products and/or services that are offered will be greater than for businesses that have been established for some time. Advertising guidelines suggest that a reasonable advertising budget for new businesses should be between 5 and 10 percent of projected gross income per year. For well-established businesses this amount may be reduced to as little as 3 percent or less per year. Some maple producers have found it effective to develop a detailed advertising plan for the entire year so that advertising dollars can be allocated monthly, or to correspond with anticipated sales. Maintaining a record of response to advertising is an effective means of determining where placements of advertisements are most effective as well as what messages were responsible for promoting sales.

## The Advertising Medium

After establishing advertising goals that are specific in terms of both the message and the target audience, an appropriate medium can be selected. To ensure greater exposure it is recommended that a variety of different media be used. Not all potential consumers will respond to the same type of medium—advertising that uses a variety of media is likely to be most effective. Important forms of advertising media appropriate to maple producers and retailers are:

### Road Signs

Many producers find that well-placed, attractive signs are among the most essential and cost effective form of advertising, and often reduce the need for more extensive advertising (**Figure 10.4**). Ordinances relating to signs exist in many municipalities and all permits and guidelines relating to size, position, and location must be observed. In some locations it is possible to place directional signs close to highway that may help consumers locate your business. The effectiveness of signs is largely dependent on their appearance, content, visibility, and location.

- Appearance—Signs should be bright, clean, and neatly painted. Originality and attractiveness help. The area around the sign should be kept well groomed and tidy. Shabby, poorly maintained signs convey the impression that the business may also be untidy and not well managed.
- Content—All advertising, including signs, should be consistent so they can easily be associated with the business. When placed on a sign, a logo or trademark can be very effective, especially if its identity has already been established in other forms of advertising. Use as few words as possible to avoid confusion. Simple words are preferable to larger, compound ones. Use left or right for turning directions rather than north or south to eliminate confusion. Be sure to include the specific location of the business on the sign (i.e. the address).

- Visibility—To be effective, the message on a sign must be clear, uncluttered, and easy to read. Remember the target audience for the sign is someone driving by at a fairly fast speed. For example, a sign must be visible for 225 feet in order for a driver going 50 mph to see it for 3 seconds. The height and line thickness of the letters of a sign influence the distance at which it can be read. The table at the bottom of this page illustrates this point and provides guidance in selecting suitable sign lettering[64]. Signs at a 45° angle to the road are much easier for motorists to read than signs at right angles. (**Figure 10.4**).

- Location—Choose locations for signs that will be seen by numerous potential customers and from which it will be easy to find the business. Locate signs at turns in the road as well as placing a prominent sign close to the entrance to the business. For maximum visibility, select sign locations that are in the open and uncluttered.

Figure 10.4. Many producers find that well-placed, attractive signs are among the most essential and cost-effective form of advertising.

## Radio

Radio is one of the more expensive forms of advertising. It is well suited for operations that want to reach a large number of potential customers. The number of potential customers reached will depend on the selection of the radio station and time of day the advertising messages are placed. By design, radio stations conduct programming that will be attractive to different types of listeners. Discussions with managers or the marketing department of local radio stations about the objectives of the advertising message as well as the desired target audience can be helpful in determining the content of the advertising message and when it should be aired. To be most effective, it is recommended that radio ads be professionally designed and presented.

## Television

Television advertisements have the potential to reach a large audience, however, they are the most costly of all advertising options. For many small producers, the costs may outweigh the potential benefits. Larger operations that offer many products and services may consider television as an effective advertising option. Professional guidance should be sought concerning the appropriateness and cost effectiveness of television advertising. To make television advertising as effective as possible, it is essential that the advertising message be professionally prepared.

## Newspaper or Magazine

Advertising in local newspapers is one of the most common forms of advertising used by

| Distance from which sign must be visible to be fully read (in feet) | Minimum letter height (inches) | Line thickness of letter (inches) | Number of words which can be read by the average motorist traveling at various speeds | | | |
|---|---|---|---|---|---|---|
| | | | 30 mph | 40 mph | 50 mph | 60 mph |
| 50 | 1¾ | ⅓ | 4 | 2 | 1 | 0 |
| 100 | 3½ | ¾ | 8 | 5 | 4 | 3 |
| 200 | 7 | 1.5 | 15 | 11 | 8 | 6 |
| 300 | 11 | 2¼ | 22 | 16 | 13 | 10 |
| 400 | 14 | 2¾ | 30 | 22 | 17 | 14 |
| 500 | 17½ | 3.5 | 38 | 28 | 22 | 18 |

[64] Adapted from Blakely, R. 1964.

maple syrup producers. Seasonally placed ads can generate interest and be very effective in promoting increased sales of maple products, especially at certain times of the year such as during the maple season when "fresh syrup" is available, or at Christmas when consumers are looking for unique gift ideas. To be most effective, the content of printed advertisements should be characterized by a clear, eye-catching message that provokes interest, creates desire, and suggests action. Advertising that is distinctive and tastefully done is most effective. The use of borders, illustrations, the business logo, or trademarks can help make the ad attractive and distinctive. An attractive business logo that is prominently displayed in advertising assists consumers in recognizing the business. Generally, it is not recommended that prices be listed in advertising unless a special promotion or product is offered. The listing of prices for all products in advertisements has a tendency to only attract price conscious consumers. Make certain the name of the business, telephone number, products available, and location are clearly included in all ads. In some areas, newspapers publish directories or guides to local maple syrup operations. Participating and advertising in such cooperative advertising can be effective, however, it may be difficult to distinguish an individual operation from others. Smaller local or regional newspapers and periodicals will also often feature stories about local maple operations during the sugaring season. Being the featured operation provides excellent advertising.

### Brochures

An attractive, informative flyer or brochure can be a very effective advertising tool. A well-designed brochure should include the following:

- Brief background of the business
- Listing of available products
- What to expect in a visit
- Photos/illustrations
- Location, including a map and specific directions
- Contact information

Brochures can be placed in tourist information booths, hotels and/or motels, grocery stores, restaurants, service stations, or other facilities frequented by the public. It is often useful to make brochures available at any location where products produced by the business are sold. This will permit customers who purchase maple products to become better informed about the business as well as informing other potential customers regarding products that are available.

### Internet

Many maple producers have developed web pages to promote their business and advertise their products on the Internet. The Internet has become an increasingly valuable source of information for many. Individual businesses that take advantage of this promotion/marketing opportunity have discovered they are able to reach many potential customers at a relatively low cost. Creating and maintaining an attractive and informative web site is very effective in establishing the identity of an individual business as well as informing customers of the facilities and products available. Effective web sites need to be attractively designed and maintained on a regular basis. In addition to identifying and describing a business, the web site can also be designed to market products directly from the business to individual consumers. If this is done it is essential that the site be monitored on a daily basis and facilities established to respond to marketing inquires and sales.

A well-designed web site should contain the following information:

- Name and description of the business
- Location and directions
- Services offered and products available
- Hours of operation
- Photos of the business
- Upcoming activities or events

Some of the several options available for businesses that want to take advantage of using the Internet for promotion and advertising are summarized in the following table:

| Option | Description |
|---|---|
| Listing | Advertise or post a listing on an existing web site (i.e. Maple Association web site). |
| Host Page | Establish a host page on an existing domain—many Internet accounts allow for free web space. Drawbacks to this option are that the URL* may be lengthy and most service providers will not allow free space for business purposes. |
| Web Site | Create a personal web site. This involves registering a unique URL (i.e. http://www.maplefarm.com). This requires payment of a yearly domain hosting fee as well as a monthly service fee to maintain the server that hosts the page or pages. Individual web site pages can be personally or professionally designed. If the pages are professionally designed (this is recommended) a design fee must also be paid. |

* URL is the abbreviation for Uniform Resource Locator, the address of a resource on the Internet. World Wide Web URLs begin with http://

To ensure that your web site will be found by potential customers, be sure it is registered with two or three commonly used "search engines." This can be done by the individual or company who created and maintains your web site, or you can do it yourself through the search engine home page.

## Label Advertising

Containers in which maple products are packaged should be neat and attractive and should reflect the quality of the products contained. The container/package should contain an attractive label that identifies the product and the quantity present as well as providing additional information such as origin of maple syrup production, suggested uses, nutritional information (if appropriate), and the name and address of the producer (or other legal entity such as the packer or seller as defined by the governing agency). Containers of several different styles and sizes that are attractively designed are available from commercial sources and contain much pre-printed helpful information. There is also the option of having containers or labels printed with a producer's own design. There is greater cost for custom printing, but the benefits may outweigh the additional cost. Simple name stickers can also be obtained for use with generic labels or printed containers. If a business logo has been developed it is recommended that it be incorporated into the label.

An attractive label as a method of advertising is not limited to only those consumers who purchase maple products for their own use, but is informative to those who receive maple products as gifts, increasing awareness of the products available from an individual business.

## Setting

An excellent form of advertisement associated with the production of pure maple products is the nostalgic image of a traditional sugarhouse and the cloud of water vapor rising from the sugarhouse. The billows of steam are helpful in attracting consumers to the sugarhouse resulting in increased potential sales. The image of a traditional sugarhouse appeals to many, and may be particularly effective in attracting consumers who have never visited a maple sap processing facility, or those who visited as a childhood experience.

The appearance of buildings and surroundings are also important factors that influence sales. Buildings that are open to the public must be clean, tidy, and attractive, with orderly surroundings. The size of a building does not influence the volume of sales, however, appearance most certainly can.

## Sales Promotion

The objective of a sales promotion is to directly encourage consumers to make a purchase. Free samples are among the most common type of sales promotion used by maple producers. Sampling engages the consumer and increases the likelihood of purchase. Coupons or special offers are other types of sales promotions that may be used. For example, coupons that offer a free item or a price break on purchase may be included in a newspaper advertisement as part of a sales promotion. As an example, a coupon could be redeemed for a free piece of maple sugar with any purchase. Some producers offer a reduced per

unit price if a customer purchases several items such as a case of maple syrup. This encourages larger purchases and the use of maple syrup for gift-giving purposes.

### Personal Selling

Personal selling is the direct personal interaction between a salesperson and a potential customer in which product information is conveyed. It can be a very effective form of promotion since the salesperson can respond directly to the individual needs and interests of the customer with the result being an increase in sales. The maple business lends itself well to personal interactions since it is often the producer who is directly involved in sales. The producer is in a position to know more about the products that are offered for sale than anyone else, thus he/she is able to answer questions as well as offer suggestions related to various maple products, their characteristics, and use. Most consumers like to make purchases directly from the producer. Many consumers believe that products purchased directly from the producer are fresher and higher in quality than similar products bought elsewhere. Personal selling can also be involved when producers sell maple products directly to retailers. The image, knowledge, tact, and interest of the individual involved in direct interaction with either the consumer or retailer can contribute to the likelihood that a sale will occur. Additional information regarding personal selling is contained in the Distribution Options section of this chapter.

## Publicity

Publicity is any unpaid communication in a public medium regarding a product or business. In some instances it can be equal to or even more effective than purchased advertising. Since publicity is not presented directly by the business its credibility is enhanced in the minds of many consumers. Publicity can be difficult to manage and although it is usually positive it can be negative if some unfortunate situation or circumstance is described and publicized. Innovative, progressive maple producers can encourage the opportunity for positive publicity. The following are a few ideas that have been proven to be helpful:

- Invite local newspapers to a special event at the sugarhouse or sugarbush. Encourage the taking of photographs and provide printed information that describes activities that occur in the operation.
- Donate maple syrup or maple products to a local radio station for contest prizes.
- Send prepared press releases to local television stations, radio stations, and newspapers for any event or special activity that is being held at the sugarbush. A well-designed and composed press release can be very useful. It is most effective if it is kept short and simple. It should contain the following information:
  - —The five W's (who, what, when, where, why) and how
  - —Accurate, unique, and interesting information about the operation
  - —Contact information

## Pricing

Pricing is an important aspect of a successful marketing plan. It is important to determine a price that is fair to both the producer and the consumer. Since not many consumers purchase a particular product based solely on price, the concept of quality and uniqueness are product attributes that can encourage purchase. Consumers are often willing to pay more for a product that is of higher quality or can be considered as special or unique. Often there is hesitancy among some consumers to purchase lower priced products because of the assumption that low prices are associated with low quality.

Maple producers are advised to refrain from lowering prices below those of your competitors simply to increase sales. Any increase in sales is most likely to be short-lived as competitors are apt to also reduce prices; when this occurs increased sales will decline. When producers compete for customers by lowering prices, profits continually decline, causing harm to the entire maple industry. It is more beneficial to establish a fair price and develop a positive reputation for your business. By establishing a reputation for fair prices, high product quality, and personalized service, a

good customer base will be established. There is often a tendency for family operated businesses to set prices too low simply because lower labor costs are involved in production and processing (either because family members are not paid or are paid less). This is a mistake; lower expenses associated with labor should be seen as a benefit that allows for a greater profit potential rather than a reason to reduce the price of products that are sold.

A common method of pricing used by many maple producers is to establish prices for smaller containers of maple syrup that are based on percentages of the price of a 1-gallon or 4-liter container. Once the price has been established for this sized container, prices for smaller sized containers are established according to the percentages suggested in the following table[65]:

| Size of Container | Percentage of Gallon (4 Liter) |
|---|---|
| Gallon (4 liter) | 100% |
| 1/2 Gallon (2 liter) | 60% |
| Quart (l liter) | 35% |
| (Pint) (500 ml) | 20% |
| (1/2 Pint) (250 ml) | 15% |

For example, the price for a 1-pint or 500-ml container, based on a 4-liter (1-gallon) price of $50 would be $10.00 ($50 x 0.20). This system of pricing only applies to simple, basic containers. Maple syrup in more elaborate or otherwise unique and thus more expensive containers would be priced correspondingly higher.

## Balancing Production and Marketing Costs

The production costs associated with producing pure maple syrup and related maple products are substantial. Specialized equipment that is used for only a small portion of the year is required, as are significant amounts of mechanized and hand labor.

[65] Adapted from Myott, 1995.

Various amounts of capital and labor are required for sugarbush management, tapping, sap collection, processing, and packaging. These many inputs necessary for production require that the total crop be sold at the best possible price if maximum profit is to be realized. A more complete discussion of all economic aspects associated with maple syrup enterprises is contained in Chapter 11 of this manual.

A relatively small percentage of effort and funds put into marketing can make a huge difference in profitability. The amount of marketing required is related to the quantity of syrup and related products produced, and the unique or individual characteristics of the operation. More marketing is required in some situations than in others, particularly for large or relatively remote operations, as well as those in competitive markets. Improved marketing of maple products can help to offset increases in wages and equipment costs.

Care must be taken to not overspend on marketing. It is a waste of time and money to conduct large marketing campaigns and not put similar efforts into improving production. Producing adequate quantities of products of the highest quality is necessary for meeting all demands resulting from promotion and marketing efforts.

## Distribution Options

For the majority of maple producers, maple syrup and related maple products are sold through one or more of three principal market types: retail sales directly to consumers, wholesale to other businesses for subsequent retail sales, and in bulk to processors and/or packers. The percentage of syrup sold by an individual producer via retail, wholesale, or bulk sales will depend on the amount and quality of syrup produced and the objectives of the producer. Some maple syrup may be bartered locally to equipment or other maple syrup suppliers. Retail sales are important to many individual producers. However, as desirable and important as this method of sales may be, only a small percentage of the total annual crop of maple syrup is sold directly to consumers. The majority of syrup is sold wholesale to other

retailers and processors or packers who market most of the annual production. This is because most producers are able to produce more syrup than what can be marketed directly to consumers, either because of insufficient retail marketing facilities or the need for immediate income. Selling syrup wholesale reduces the profit potential for the producer; however, it is necessary to supply the needs of large processors who provide syrup to a much larger market. It is important for producers to make a profit but it is also important for processors since their presence increases the total volume of maple products sold annually. Two additional sales opportunities that may be important to a limited number of producers are cooperatives and the export market.

## Retail (Direct) Sales

Retail sales directly to consumers represents the greatest opportunity to maximize profits from the sale of maple syrup and related products (**Figure 10.5**). However, significant amounts of time and labor are required. An attractive sales facility with appropriate display cases and proper handling and storage facilities and procedures are essential to success. For example, producers should make certain that containers displayed in the sugarhouse or other retail sales facility, including roadside stands, are clean and free from rust or other defects. Furthermore, maple products such as maple sugar, maple candy, and maple cream, should be fresh and displayed under conditions that will maintain freshness and an attractive appearance. Dirty or otherwise soiled containers do not present a favorable image of the product, neither do aged products that may be discolored, separated, moldy, or are otherwise unattractive. Attractive display cases, including some that are refrigerated, are necessary components of any retail establishment that desires to offer, display, and maintain high product quality.

Sales will be greater if maple syrup is available in containers of different sizes and styles. Likewise, offering other maple products such as maple sugar, maple candy, and maple cream will result in increased total sales. Sales of less well-known maple products, such as maple butter, will be greatly increased if samples are available to consumers.

To help maintain freshness and quality in maple syrup it is recommended that not all syrup be packaged into retail-sized containers as it is produced. Rather, syrup should be stored in larger bulk containers and later packaged in retail-sized containers as necessary to maintain retail supplies. It is also recommended that a system of batch coding be used for all maple syrup that is produced during a given season. All of the containers containing syrup from a particular batch are coded with the same code. If a there is a problem with a particular batch of syrup, such as off-flavor, incorrect density, or microbial contamination, or if a particular batch has a desired set of characteristics, all of the containers containing that batch can be identified. Some producers will, in fact, freeze small samples of each batch for future reference.

Retail sales will also be enhanced if specialty items such as prepared gift packages or baskets are available. Attractively packaged gift baskets that contain a variety of maple products as well as other items such as pancake or waffle mixes are popular items, especially during the Christmas season. Some producers have marketed gift packages to local businesses for gifts to employees in recognition of special achievements or as birthday or Christmas gifts. Promoting such packages at Christmas can be very profitable and sales at this season of the year will often surpass those during the maple season.

In addition to retail sales on the farm, several other options are available. These include a well-situated retail outlet, a roadside stand, local farmer's markets, festivals, mail order, or Internet. Suggestions of desirable attributes related to specific outlets follow.

Figure 10.5. Maple products can be effectively displayed in a variety of attractive and eye-catching ways.

## Sugarhouse

Producers who want to sell as much of their annual production as possible directly from the sugarhouse have found it advantageous to offer activities or special events that will attract potential consumers to the farm. This may include scheduling an "open-house weekend" where the public is invited to view syrup production during the season. Other activities such as tours for school children or other visitor tours (e.g. fall foliage visits, sugar-on-snow parties, etc.) are all possibilities. When these events are scheduled it is important to have an attractive display area where the variety of maple products offered for sale are prominently displayed. The sales area at the sugarhouse does not have to be devoted strictly to maple syrup and maple products. Items made from maple syrup such as maple jelly, maple mustard, maple-coated nuts or popcorn, and maple vinegar may be of interest to customers.

Selling directly from the sugarhouse is an excellent means of encouraging sales since the customer can become more familiar with the production process involved in producing pure maple products. Most consumers will enjoy seeing the sugarhouse in operation; the sights, smells, sounds, and atmosphere are effective in promoting increased sales of pure maple products. Direct consumer selling at the sugarhouse is well suited for businesses that have addressed the following issues:

- Are the facilities suitable for dealing with the public (e.g. size, parking, accessibility, restrooms, safety [see Chapter 13], other)?
- Is adequate help available to monitor guests and/or schedule events or activities?
- Is someone available for selling at the same time syrup is being produced?
- Will consumer demand be sufficient to justify the time and expense involved?

- Is skilled labor available to produce and package maple products other than syrup?
- Are adequate supplies of maple syrup and related products available to meet demand?

It is important that the activities and responsibilities related to selling directly at the sugarhouse be identified and addressed thoroughly before a decision is made to promote sales at this location. A facility that does not accommodate the needs, wants, and safety of consumers may not be suitable. It is important that consumers who visit a production facility are not disappointed by their experience.

## Retail Outlet

Some producers either have or may consider establishing a retail location apart from their production facilities. Oftentimes this is an appropriate solution for a producer who wants to sell retail but has difficulties attracting consumers to a remote location or has a production facility that does not accommodate retail sales. Separate remote sales facilities also allow producers to sell other products or commodities such as fresh vegetables, fruit, crafts, and other items that are produced locally or are seasonal in nature. Location is an important consideration in making the decision to establish a separate retail outlet. Other considerations should include traffic patterns, zoning regulations, parking requirements, design and size of the sales facility, availability of labor, anticipated sales volume, and availability of other products to sell.

## Roadside Stands

Fruit and vegetable roadside stands are considered to be good marketing outlets for maple syrup and related maple product sales. Consumers have the general perception that the freshness and quality of produce and products offered for sale are usually higher than of similar items present in grocery stores. Consumers are often inclined to make larger purchases of specialty items when they are offered in such locations. As with all sales outlets, the location and convenience associated with purchasing contribute greatly to the success of roadside stands.

## Festivals and Farmers' Markets

Maple syrup festivals are common in some areas of the maple syrup producing region. These festivals effectively promote pure maple products and also provide an opportunity for local producers to display and offer for sale the products they have produced. Well-organized festivals that offer a variety of activities attractive to the general public can be very effective in promoting the sales of maple products. Marketing success for individual producers is often dependent on location of the sales booth, attractiveness of the product display, reputation of the producer in the community, quality and variety of maple products offered, and friendliness of the sales staff. Producers may offer other products for sale such as maple cotton candy, maple popcorn, maple ice cream, and maple taffy. These products lend themselves well to a festival-type setting and can be effective in promoting sales of other pure maple products.

Local farmers' markets also provide an excellent outlet for retail sales of maple products. Many consumers are attracted to local markets where they purchase locally grown produce, flowers, and other fresh fruits and vegetables. Locally produced maple syrup and other maple products complement the many types of products available at these markets. High quality products offered in attractive displays promote sales and help in establishing repeat business.

## Catalog and/or Mail Order

Maple syrup has long been available through catalog companies. Catalogs designed to present products suitable for gifts and those containing specialty products or otherwise unique merchandise are well suited for the sale of maple syrup and maple products. Maple producers who are interested may want to contact publishers of individual catalogs and indicate what type of products they have available. Producers can also develop and/or purchase mailing lists from companies and send a direct mail flyer and order form to those on the list. Mailing lists can be purchased for many different types of potential consumers or clients. It is essential that appropriate packaging is available and that orders are promptly prepared and shipped if repeat orders

are to be received. Selling via mail order can be a convenient way for producers to access a retail market without having to establish a separate retail sales facility on the farm. Producers who sell and ship maple products in response to catalog or other mail order inquiries must be able to package the product in such a manner that it will withstand rough handling during shipping. Some types of containers such as those made of plastic are better adapted than containers made from other materials.

### Internet

In recent years the Internet has become an increasingly important sales outlet. Furthermore, use of the Internet is continuing to increase and is likely to become a dominant sales outlet in the future. In many ways Internet sales are similar to catalog or mail order. However, there is no need to prepare and distribute a formal catalog; instead what is required is a well-designed and attractive web site that identifies, promotes, and facilitates purchase. The advantages are many, including eliminating the need for preparing a catalog, eliminating mailing costs for distribution of either a catalog or other order form, simple presentation of an individual business and the products available to an unlimited audience, and faster service in responding to inquiries and/or orders. Potential customers have the convenience of shopping from home while still being able to purchase what they want. Additionally, e-mail permits a means of rapidly responding to consumer inquiries or questions. The importance of the Internet as a sales outlet can be expected to dramatically increase in the future. Maple producers who want to maximize sales of maple syrup and related products should make this a priority sales method. The only disadvantage to Internet sales is at present not all consumers have Internet access, but this situation can be expected to decrease over time.

### Wholesale Sales

Selling maple syrup and related maple products wholesale allows some producers to expand their total sales. By definition, wholesale sales in the context used here, are those sales of packaged syrup and related products to retailers who subsequently sell directly to consumers. Some examples include grocery stores, specialty food or health-food stores, local gift shops, restaurants, and candy shops. Selling wholesale does not preclude the direct sales of small bulk quantities of maple syrup to bakeries, candy shops, catering services, and others for use in various food products, although this is not the primary interest of most producers. While the total price received by the producer is less than what would be obtained from direct consumer retail sales, wholesale sales can be an important means of increasing total product sales. It is important for producers who want to establish a wholesale market to remain sensitive to the needs of the wholesale purchaser. Attractively packaged, quality products that are delivered in a timely manner are essential for developing a long-term relationship. It is also important that the producer be able to sustain a wholesale market once it has been established. Producers are advised to begin with a small wholesale order and "work their way up" once they have become familiar with the demands. In years when below-average crops of syrup are produced it may be necessary to purchase syrup from other producers to sustain an established market.

Finally, since many retail stores use UPC bar codes for inventory control and pricing, it is suggested that maple producers work with the retailer to include appropriate coding on the package to facilitate scanning at the time of sale.

### Bulk Sales

Bulk sales are sales of maple syrup to packers or processors. These firms may package syrup for distribution and sale to larger wholesale accounts or provide syrup to other accounts for use in syrup blends, candy, or as an ingredient in the preparation of other food products, or sell to producers seeking drums of syrup to supplement their own crop. Additionally, some processors will convert large quantities of syrup to maple sugar and other confection products. Large packers are an important component of the maple industry. They provide a market for large quantities of maple syrup, including darker and less desirable syrup that generally could not be sold in the

retail market. Bulk sales are a good alternative for producers who lack the time, resources, or desire to develop a sufficient retail or wholesale market. It is better to sell in bulk than to end up not being able to effectively package, market, and sell the annual crop of syrup.

In some portions of the maple region many producers may sell their entire crop to bulk processors. Some of the advantages of selling syrup in this manner include eliminating the need and cost of packaging in small containers, eliminating the need for a storage or retail sales facility and associated staff, and the income for the entire crop is received shortly after the syrup season is over. The primary disadvantage is that a lower per unit price is received for all syrup that is sold. Producers who sell the majority of their annual production via retail or small wholesale accounts may also sell a portion of their crop to processors. This is an effective way to sell annual production in excess of retail or wholesale needs or lower grade syrup that may not be suitable for other markets.

### Selling Through Cooperatives

Maple cooperatives exist in a couple of areas within the maple-producing region of North America. These have been established primarily for the purpose of more efficiently marketing maple syrup produced by members of the cooperative. By joining together, producers increase the ability to obtain better prices for the syrup they produce and to direct and/or influence the industry in their area. Members of the cooperative pay a membership fee that enables the cooperative to operate and develop markets for the jointly produced products.

### Selling in the Export Market

In some years the total Canadian-U.S. production of maple syrup has exceeded the demand, resulting in a surplus. To reduce the surplus individual producers, processors and packers, and cooperatives have intensified marketing efforts, particularly efforts to increase exports of maple syrup and related products. Larger packers and cooperatives in particular have realized some success in marketing maple syrup through increased exports. A few individual producers have also developed limited export markets, though this has required considerable effort.

The development of export markets is most appropriate for larger producers who can supply large quantities of syrup on a continual basis, and who can negotiate the regulations, permits, licenses, and other requirements. Aside from Internet sales that may be made internationally, most individual producers are advised to expand promotion and marketing to increase domestic sales, rather than developing an export market where the costs and difficulties in sustaining the market may not be justified.

## Customer Satisfaction and Loyalty

There is no better advertising than a satisfied customer. Satisfied customers not only provide repeat business but also generate new business by word of mouth referrals to friends and families. Word of mouth advertising is not only free but is one of the most effective forms of advertising. Potential consumers are more attentive to and trusting of what is recommended by family and friends than any other form of advertisement. Offering products of the highest quality, attractively packaged, and which are sold by friendly, knowledgeable sales personnel will help develop a loyal customer base. It is important to believe in the products that are being sold and to guarantee customer satisfaction.

Providing opportunity for customers to taste some of the products offered for sale may also increase customer satisfaction. Free samples are popular and increase the likelihood of purchase as well as reducing the risk involved in making a purchase because the customer is not always familiar with what they are purchasing.

The unique flavor of pure maple syrup is a primary characteristic that distinguishes it from imitation maple syrups. For this reason it is very important to closely monitor the flavor of all syrup produced and offered for sale. During production, processing, and packaging make certain procedures are followed that will minimize any

likelihood that off-flavored syrup is offered to customers. It is of utmost importance to provide customers with a consistently high quality product and excellent service because word of mouth advertising can also be negative. A bad experience by a customer, either because of a low quality product or because of an unsatisfactory sales experience, can generate a lot of very negative advertising.

## Future Consideration

Finally, the creation of an effective marketing strategy is not a one-time effort, but a continuing process. Producers need to be open to new ideas, and to be quick to adapt marketing techniques that reflect changing consumer attitudes, lifestyles, and wants. Change is inevitable, even in the maple syrup business, and those producers who are innovative and adapt quickly to emerging and growing market opportunities can expect to have the greatest success.

# Chapter 11 · Economics of Maple Syrup Production

From a historical perspective the production of maple syrup and maple sugar was one of a number of activities carried out on family farms throughout the northeastern United States and adjacent Canada (**Figure 11.1**). The principal objective in syrup production was self-sufficiency. Maple syrup and maple sugar represented a local source of sugar and provided the primary sweetening component used in food preparation. Quantities of both maple sugar and maple syrup were often traded to local merchants for other food commodities that could not be produced on the farm, or for supplies and equipment necessary for the farm operation. Eventually, surplus quantities were sold as a means of obtaining cash for other products and services.

The production of maple syrup and other maple products assumed more importance in the local farm economy when larger cash markets developed. In addition to supplying their own needs for sugar and syrup, some producers began to produce syrup and sugar in larger quantities to supply the demands of a growing and expanding retail market. Sales of maple products thus became a cash crop, augmenting other farm income. Today, while some individuals produce small quantities of syrup for personal use, most maple producers are in business to generate income.

Figure 11.1. The production of maple syrup and sugar was an important activity on many family farms throughout much of the northeastern United States and eastern Canada.

Markets for pure maple products are generally good not only in local production areas but also in domestic and international markets. As consumers are made aware of these uniquely North American products, opportunities exist to expand markets outside the region of production. It is important to produce and market high quality maple products to consumers so the well-established reputation of pure maple products is maintained. Maple syrup and related maple products are recognized by most as specialty food items and are valued because of their purity and natural qualities.

The economics of maple syrup production, including expected cash revenues, are dependent on a number of factors. These include size of the operation, equipment costs, labor inputs, production efficiency, marketing strategies, and price. Annual *return on investment* will be much greater for individuals who pay close attention to dollar and labor inputs, manage their physical and financial resources efficiently, and price their products competitively. Like most agricultural endeavors, this is not a "get-rich enterprise" that rewards poor planning and minimal financial management. Over the years many individuals have developed plans for elaborate production and processing facilities, yet failed in their attempt to obtain anticipated product yields, production of products of the highest quality, and expected revenues. Development of a full business plan that recognizes the importance of both production and marketing components is recommended for anyone contemplating a substantial investment in the maple industry.

Profitability of an individual business venture occurs when *all* costs of producing and marketing a particular product are less than the selling price. The difference between these two values represents profit. Profit can be expressed as a direct dollar amount, however, it is more informative to compute it as a return on the investment represented in the maple facility and its operation. Profitability

is influenced not only by minimizing those out-of-pocket costs associated with production, but also by the efficiency of production and selling of the final product. Although packaging costs are higher and time investment is greater, producers generally find the retail market for maple syrup more profitable than the wholesale or bulk market. Similarly, retail syrup packaged in small containers tends to yield higher returns than syrup packaged in the more traditional 1-gallon or 4-liter size. If the packaging and labeling are attractive and marketing is promoted in off-the-farm locations, such as specialty product businesses or those catering to specific consumer groups such as tourists, the returns will be increased.

Economic analysis has shown that producing and marketing one-third or more of the total maple syrup crop as value added products (i.e. maple sugar or other maple confections) will significantly increase profitability of a maple operation. These same analyses indicate profitability is very sensitive to total yields as well as prices charged for the products produced. It is important that producers continually strive for high yields of good quality syrup and price it competitively.

In recent years several changes have occurred in the maple industry. Many of these relate to equipment innovations designed to improve evaporative efficiency while reducing energy costs. In order to recognize economies of scale, many operations have increased in size and complexity. Voluntary quality assurance programs have been established to assure consumers of consistently high quality products. Significant effort has been made to expand both domestic and international markets. Some of the economic implications of these changes are discussed in two recent studies: *Report on the Economics of Maple Syrup Production*[66] and *A Business Plan for the Profitable Production of Maple Syrup, Maple Sugar, and Maple Cream in New York State*[67].

[66] *Report on Economics of Maple Syrup Production*. 2000. Canadian Farm Business Management Council and the Ontario Ministry of Agriculture, Food and Rural Affairs. 45 pp.

[67] Winchip, C.E. 1999. *A Business Plan for the Profitable Production of Maple Syrup, Maple Sugar, and Maple Cream in New York State.* 25 pp.

It is important to remember that production of maple syrup is a seasonal activity that occurs in a four- to six-week period during late winter and early spring. The seasonal nature of the business must be taken into account when determining labor requirements and appropriate levels of capital investment. The timing and intensity of the sap run can vary dramatically from one year to the next as can the yield and quality of sap produced per tap. Sap flows and resultant sap yields are strongly influenced by seasonal weather patterns, in particular daytime and nighttime air temperatures. Over a period of a few years, it is common to have low, average, and above average yields.

It is extremely important to acknowledge that there is no "master production plan" that will assure success and profitability in the pure maple syrup business. Each operation is unique and production plans, profitability, and ultimately success greatly depend on individual innovation and management style.

## Some Characteristics of Maple Operations that Have Economic Implications

While there are similarities between a maple sap/syrup operation and other agricultural activities, there are several aspects of maple syrup production that are unique, and as such influence or contribute to the economic success of the venture. The producer can control some of these variables while others are affected by factors or characteristics beyond the influence of the producer. Weather patterns, most notably temperature fluctuations during the "sap season," are perhaps the most prominent example of a factor that has great influence on the economic success realized in any particular season, yet the producer can do little if anything to modify the effects of unfavorable temperatures. Several characteristics and/or factors that contribute to the profitability of a maple operation are identified and discussed below.

## The Maple Resource

The production of maple sap, and eventually maple syrup, requires maple trees. Most commonly these are located in a woodland or forested area, although maple trees growing along roadsides, in lawn areas, or other isolated areas can also be tapped. While sugar maple and black maple are the preferred species for sap production, maple sap can also be collected from red and silver maple as well. Even boxelder *(Acer negundo)* will produce sap although it is not commonly tapped where other maple species are present. Depending on the part of the maple region under consideration, the composition of woodlands is variable with respect to species, number of trees per unit area, tree size, as well as tree health and productivity. In natural woodlands it is desirable that between 50 and 100 taps per acre (120 to 240 taps/hectare) be present. This number should be calculated based on the application of recommended tapping guidelines that consider tree vigor and diameter. Woodlands (sugarbushes) with a lower number of taps per unit area may be economically viable where sap sugar concentrations are high (3 percent or above), or in circumstances where other sources of revenue such as fuelwood or timber products are produced. In these instances there may be some economic trade-off between revenues derived from syrup production and wood and/or timber production.

## Building Facilities and Equipment

To produce maple syrup on a commercial scale specialized and dedicated equipment is necessary. This equipment includes but is not limited to a complete evaporator unit, steam hood, sap preheating or other evaporation enhancing equipment, storage tanks, canning and packaging equipment, sap collection equipment, pumps, etc. Additionally, a separate production facility (sugarhouse) is necessary, as is a fuel storage facility, the nature and size of which will depend on the type of fuel used and the size of the operation. If maple products such as maple sugar or various maple confections are produced, a dedicated kitchen area is usually necessary as well. All production facilities must meet minimum local, state, or provincial standards appropriate to food preparation and processing plants.

The majority of equipment and facilities necessary for producing pure maple syrup are "unique" to the industry, and as such have limited use for other purposes. There may be some exceptions to certain components such as the kitchen area if other food products such as jams, jellies, etc., are produced at different times of the year. However, in most maple syrup operations the equipment and facilities necessary are only used for a few weeks each year during the maple season.

## The Production Season

The production season for collecting maple sap and producing maple syrup is a short four- to six-week period in late winter-early spring each year. Sap flow occurs mainly in response to temperature changes, and depending on location, this may begin as early as late January or as late as mid-March. Sap flow does not occur in response to a calendar date; the exact starting date each year varies in response to local and regional weather patterns. For a producer to maximize the profit potential of producing maple syrup it is essential that as much sap as possible be collected. This means tapping must begin as soon as there is an indication of favorable temperatures so the "first run" is not missed. If a "sap run" is missed, there is no opportunity to "catch up" as subsequent sap flows will not be larger simply because the first run was not collected. The fixed costs associated with sap collection are essentially the same whether large or small amounts of sap are collected, thus every effort should be made to collect as much sap each season as possible. It should also be noted that syrup produced from sap collected early in the sap season is usually of a higher grade and accordingly higher value than that collected towards the end of the season.

In addition to uncertainty concerning the beginning date of the season, there is also uncertainty as to season length. Again, this is a function of temperature fluctuations and patterns. In an "average season" most producers expect that approximately 1 quart (1 liter) of syrup can be

produced from each tap. This reflects an average per tap sap yield of approximately 10 US gallons (approximately 40 liters). However, this amount can and does vary considerably. In some years a smaller amount is produced while in a "good year" per taphole yield may be larger by a factor of up to 50 percent or more. When planning for annual projected revenues from syrup production it is advisable to plan conservatively. The 1 quart (1 liter) value is appropriate and larger planned annual yields should not be expected.

### The Production Process

The production process for high quality pure maple syrup requires considerable skill. While the development of automated and efficient production equipment has made the process easier, in the minds of many, making high quality syrup is an art. The production process begins with the prompt processing of high quality sap. Sap collection systems should be efficiently designed so deterioration of sap does not occur in the collection system, nor does it become contaminated during storage in unclean holding tanks. It is commonly understood that sap flow does not occur on an "8 to 5" basis; rather sap flow can and does occur at all hours of the day and on all days of the week. This means that evaporation must be done whenever sufficient quantities of sap are present. Evaporation often involves working at night and on weekends; "all-nighter" evaporation sessions are common during some days of the maple season. Equipment such as reverse osmosis units and other sap-sugar concentration systems can reduce the length of evaporation time, however, prompt processing is essential. From an economic perspective, operation of the evaporator at other than "normal working hours" may contribute to increased production costs, particularly if hired labor is involved.

### Income Potential

Certain aspects of maple syrup production, particularly the relatively short production season, and some characteristics of the production process (necessity of large sap volumes, prolonged evaporation periods, the unpredictability of weather patterns and accompanying sap flows, etc.), make it highly unlikely that sufficient income can be generated during the production season to support a family unit on an annual basis. This does not mean that maple syrup production cannot be an excellent source of supplemental income. It is also an excellent crop to consider as one of several other "seasonal crops"; the combined revenues of which can sustain an individual or family. Recent economic studies suggest that about 10,000 taps are required to provide adequate income for a family unit[68]. An operation of this size requires labor beyond that which can be provided by one individual. Most maple operations are considerably smaller than this. In smaller operations, although the income potential can be augmented through the making of other maple products and confections, it is still likely to be insufficient to provide an adequate annual income. Some smaller production operations have developed larger markets, and purchase syrup from other producers in order to have adequate quantities available.

## Some Economic Cost Components

In most business endeavors, including maple syrup production, there are two components of costs. These are identified as *fixed* costs and *variable* costs.

### Fixed Costs

Fixed costs are those that do not vary with the level of production and include costs associated with facilities, equipment, and other overhead or management. In a maple production operation components commonly identified as fixed cost sources include the following:

**The Maple Resource**—Although it is obvious, it must be stated that maple trees are necessary to produce maple sap, and thus maple syrup. The number of trees required will vary depending on the objectives of the producer and the size of the evaporator and other processing equipment. If the trees are owned they represent an investment since the land where they are growing has

[68] *Report on the Economics of Maple Syrup Production*. 2000. Canadian Farm Business Management Council and the Ontario Ministry of Agriculture, Food and Rural Affairs. First Edition. 45 pp.

a real estate cash value. Theoretically, the annual return on the land and tree investment can be represented by a cash value equal to the annual rental for similar land in the local area. This value represents a fixed cost that is present regardless of whether or not the trees are tapped, and is not affected by the amount of syrup produced.

**The Sugarhouse or Processing Facility**—Although this facility may be a part of another structure on the farm, it is dedicated to maple syrup production and thus represents an investment that must be charged to the cost of syrup production. Usually the cost of the sugarhouse is depreciated over time; the annual depreciation amount may be one method of assigning a per-year fixed cost value to this facility. Like the maple tree resource, the cost component represented by the sugarhouse is not affected by the amount of product produced.

**The Evaporator and Related Equipment**—The majority of maple syrup production facilities include a commercial evaporator and several pieces of related equipment including forced draft units, steam hoods, reverse osmosis units, various types of preheating devices, automatic draw-offs, filters, storage tanks, canning units and/or bottling units, etc. Additionally, some operations have separate processing kitchens complete with standard kitchen appliances as well as specialized processing and packaging equipment. For the majority of operations this equipment is dedicated to maple syrup and related product processing, and represents a fixed investment necessary for the operation to function.

**Sap Collection Equipment**—The type of equipment used for sap collection varies considerably among different operations. Typically sap is collected using spiles or spouts, buckets, pails, plastic bags, or plastic tubing. Equipment required for the actual tapping includes a drill, drill bits, hammers, tubing cutting equipment and necessary fittings, connectors, clamps, etc. Other necessary collection equipment includes sap transfer pumps, vacuum pumps (tubing systems), sap collection and holding tanks, a wagon or trailer, a tractor, horses (some operations), and possibly a generator. The amount and specific type of equipment required reflects the size and layout of the sap collection system as well as topography, proximity to the sugarhouse, and availability of electricity. Like most of the equipment necessary for evaporation, sap collection equipment is quite specialized and has limited use outside the maple operation, thus it represents a fixed cost component of the operation. The exception to this generalization would be tractors and a trailer or wagon that are used in other farming operations; when this situation occurs only a portion of the equipment value is charged to the maple operation.

**Storage Tanks—**Adequate storage capacity for sap that accumulates during a sap run must be available. Large capacity storage tanks are usually located at the sugarhouse. The capacity required will vary depending on the number of taps and the size of the evaporator. Normally producers will plan on 2 to 4 gallons (4 to 8 liters) of storage capacity for each tap. Storage tanks are of several designs and configurations. New equipment is available although many producers have used tanks obtained from dairies or other food processing facilities.

**Insurance—**The facilities and equipment necessary for a maple operation to be efficient and successful represent a significant investment. Furthermore, the liability risk associated with the operation is also substantial. To protect the physical assets and to prevent loss in the event of a claim related to a personal liability concern, maple producers carry both property and liability insurance. Producers are also advised to carry a product liability policy. The amount of coverage can change from one year to the next; however, the cost of insurance reflects a fixed cost that is not necessarily influenced by annual production.

## Variable Costs

Variable costs are those costs associated with annual sap and syrup production. These are directly related to the amount of syrup and processed products that are produced each year. Costs commonly identified as variable costs include:

**Labor**—By definition, maple syrup operations are labor intensive. Labor is required for all aspects of the operation, from sap collection to

evaporation to canning and secondary processing. Some mechanization of the production process is available; however, substantial amounts of manual labor are necessary. In the process of sap collection, labor is necessary to tap the trees, install spouts and collection containers (where used), install and maintain tubing systems, fuel and maintain sap pumps and vacuum pumping units, operate tractors, empty pails (if present), wash storage tanks, and clean up of the entire system when the season is over for the year. In the evaporation process labor is necessary to fuel the evaporator, maintain and monitor sap levels in storage and feed tanks, draw-off finished syrup from the evaporator, transfer syrup to filtering units, package filtered syrup in containers of various sizes, and finally clean up all equipment at the end of the season. Pumps, automatic draw-off units, pressure filters, etc., can reduce the amount of labor required, however, these units require monitoring and regular cleaning and maintenance. By far the largest labor requirements aside from operating the evaporator are for tapping and end-of-season clean up.

For a successful maple syrup venture, management of the operation is required through the syrup season as well as at other times of the year. Prior to the season, decisions must be made with respect to fuel production and/or purchase, ordering appropriate production and canning supplies, repair and maintenance of equipment, and arranging for labor to tap and install the type of collection system used. Labor is also necessary to stock, maintain, and operate a retail sales facility if one is part of the operation. Labor is required to maintain records relating to production and sales, as well as annual tax accounting and computation.

It is essential that the cost of all labor inputs required to operate a maple business be identified and accurately valued. Too many producers incorrectly believe that labor provided by family or friends who are not paid should not be charged as a labor cost. This philosophy is wrong, and will lead to substantially undervaluing the cost of producing maple products and exaggerating the amount of profit being made. Unpaid family or friends labor can be valued at the cost of hiring comparable workers.

**Fuel—**The cost for fuel represents a significant expenditure for maple syrup producers. Fuel is used for gasoline-powered tapping machines, operation of gasoline-powered pumps, fueling of generators (if present), operation of tractors or other powered collection equipment, and of course for the evaporator. Obviously, the cost of fuel for the evaporator is the largest component of fuel costs. Additionally, fuel is also required to heat a finishing pan if it is a part of the operation. Evaporator fuel may be oil, natural gas or propane, coal, or wood. There is a common perception that wood is a less expensive fuel. In comparison with purchased natural gas, propane, or fuel oil this may be true. However, if wood is produced on the farm there is a labor and equipment cost associated with production that must be charged against the maple operation.

**Utilities**—Charges are incurred for the cost of ordinary utilities necessary for the operation to function efficiently. Common utilities include electricity, telephone, water and sewer (some installations), natural gas and/or propane, and increasingly, Internet and monthly cell phone charges. Those utility charges that relate directly to the maple syrup operation should be identified and accounted for as a variable expense.

**Packaging and Storage—**Following production, maple syrup is packaged in various sized containers, depending on the marketing strategy of the operator. Some syrup is directly packaged into containers appropriate for retail sales (including syrup containers of various sizes and packaging for value-added products such as cream jars, candy cups, candy boxes, etc.), while other producers will package syrup into larger containers for later repackaging or further processing. A few large firms will package syrup in drums for sale to processors or other producers. With the exception of bulk containers that may be reusable, all other containers represent an annual cost, the specific amount of which depends on the quantity of product produced. Storage of the packaged product also represents a variable cost reflecting the amount produced and the conditions under which it is stored.

**Marketing**—Expenditures for annual advertising, promotion, and other publicity relating to promoting maple products are examples of annual marketing costs. This amount will vary depending on the quantity and diversity of product produced. For a producer who desires to market large volumes of maple products directly to the public, and who undertakes an extensive advertising program, marketing costs may be substantial. Delivery costs associated with supplying retail outlets are also considered marketing costs.

**Insurance**—It is required that employees be covered by appropriate insurance programs. In the United States these include Workers Compensation Insurance, FICA, and Medicare; in Canada required insurance includes Employment Insurance and the Canadian Pension Plan. The premium amounts are directly related to the cost of labor and most likely can be expected to vary from one year to the next.

When evaluating the economic profitability of a maple operation it is important not to confuse the value of one's own labor with profit. From an economic perspective, all labor used in a maple operation has value. If not associated with the maple operation, this labor could potentially be used in other ways to produce income. Giving up this alternative income to work in the maple operation is income foregone, and as such represents a significant component of variable costs. Failure to include a cost for the labor provided by one's self and other family members can lead to inflated and unrealistic profit margins and misleading analyses. While many maple producers love their work and are not driven entirely by financial motivations, it is still important to earn a reasonable return on the time and money invested. Failure to recognize the value of labor inputs obscures an accurate evaluation of this objective.

## Past Studies Related to Maple Syrup Economics

Over the past several years a number of studies relating to different economic aspects of maple syrup production have been conducted. References to many of these are listed in the bibliography at the end of this manual. A majority of the investigations cited have focused on providing basic cost information related to production costs or to comparisons between different processes such as equipment and methods of sap collection, alternative fuels, and accessories to improve evaporator efficiency. A summary of some of the findings by individual topics follows.

**Cost of Production**—It is important to producers that the actual cost of production for maple products is known. This information is used to form the basis for pricing individual products, allocating different quantities of product to wholesale or retail markets, identifying opportunities for decreasing individual cost components, and determining the level of profitability of the operation. Some generalizations from these studies indicate production costs vary significantly among different operations. Large, integrated operations tend to be more profitable than smaller businesses that focus on producing only one or two products. Similarly, there are economies of scale with production costs per production unit less for larger operations (3,000 taps or more) than for smaller operations. Increases in cost for fixed cost components have been the largest for processing equipment (new evaporators, sap preheating/evaporation equipment, etc.) and for acquisition of a maple resource, if one is not available. For costs identified as variable, increases have been greatest for fuel, labor, and sap collection equipment (vacuum pumping units, tubing washing units, etc.).

**Sap Collection System Comparisons**—Maple sap is collected using pails, buckets, bags, or a tubing system that can be of different design and/or size. Vacuum extraction units may or may not be a part of the installation. Cost comparisons have been made between the initial cost of the components in each system, as well as the amount of labor required in installation, sap collection, maintenance and/or repair, cleaning, etc. While variations exist among operations, a couple of generalizations have been established. The initial cost of components for each system can vary dramatically, depending on size of the system, distance of transport, and whether or not used equipment is used. Initial installation costs for tubing systems are greater than for non-tubing systems, however,

in subsequent years the installation cost of a tubing system is substantially less if, following cleaning, it is left in the woodlot throughout the year. However, once each system has been installed, sap collection costs for non-tubing systems are substantially higher than for tubing installations.

Another component of sap collection systems that has been studied is the relationship between total seasonal sap yield and vacuum extraction. Conclusions reached from several studies indicate that a significant increase in total sap yield (usually averaging a 50 percent increase in sap volume) is possible from a well designed and maintained vacuum tubing system when compared to a traditional bucket/bag collection system. Yield increases will vary from year to year and are dependent on maintaining a relatively high vacuum level at the taphole throughout the season. Tubing systems equipped with vacuum pumps have been determined to be cost-effective when operated for more than one sap season.

**Comparisons of Alternative Evaporator Fuels**—The cost of fuel for the evaporator is a significant component of total production costs for maple syrup. Wood has long been the traditional fuel, however, the availability, convenience, and application of efficient oil burners have resulted in their increased use in maple operations. Improved natural gas burners are also available, although they are less common than oil units. The increased convenience and less work required to operate the oil (gas) burner has many advantages over the work necessary for cutting, processing, and storing wood. However, as fuel costs for so-called fossil fuels have increased significantly over the past few years, renewed interest has focused on wood. Results from studies that have investigated the advantages and disadvantages, including cost, of wood versus oil (gas), indicate that wood costs per unit of product produced are less than for oil or natural gas. However, there are several other convenience factors that result from oil (gas) use such as less labor required during evaporation, better control of heat levels, ability to automate the evaporator fueling process, and elimination of need for a wood storage facility. On the other hand, wood production can result in reduced out-of-pocket expenses since it can often be produced simply by using one's own labor, provided of course that a wood supply is available. Additionally, producing fuel wood from the sugarbush can provide several silvicultural benefits to the remaining stand (see Chapter 5).

**Economies of Scale**—The influence of size of operation and the relationship with cost of production has been studied. As might be expected there are definite economies of scale. In general larger operations (3,000 taps and more) are more efficient with respect to utilization of collection and processing equipment, and accordingly have a lower per unit production cost than smaller operations. There are some exceptions to this generalization, particularly if used equipment is available and self-labor is the primary labor source.

**Diversity of Products Produced and Marketed**—For maple syrup producers who package and market maple syrup in a variety of different sized and styled containers, or who process maple syrup into sugar, maple cream, and other maple confections, the value received per gallon of syrup used is significantly higher than if syrup is only sold in a few different sized containers. Although processing and packaging costs are higher, the total value increase may range from 35 to 100 percent or more. Results from research studies related to packaging and producing secondary products indicate that total profit from a maple operation will be considerably greater for producers who take the time to manufacture other products and offer them for sale. Additional processing equipment and labor is necessary, however the returns for producing and marketing quality products typically justify the costs involved.

**Marketing Studies**—Where and how pure maple products are marketed has an influence on the total price received per unit volume of product sold. Marketing all maple products only at the point of production will usually result in a lower return than if specialty marketing outlets are located and developed. Returns from marketing maple products in "tourist areas" or specialty food stores, including "organic" food outlets, will generally be greater than if all products are

marketed from the sugarhouse. Likewise, those producers who develop catalog sales outlets, or who have developed an attractive Internet website with provision for direct consumer sales will realize larger total returns than if their products are offered only through local sales outlets. A few producers have developed profitable markets by providing maple syrup to local candy or confection manufacturers, local restaurants, or by developing attractive gift packages suitable for use by local businesses as customer appreciation gifts, Christmas gifts, or others. Opportunities for creativity in marketing are many and those producers who are successful in developing niche markets will be rewarded for their efforts.

## Worksheet for Determining Cost-Return Relationship

Because facility, equipment, and labor costs are subject to annual change and tend to vary widely among producers and throughout the maple region, it is difficult to develop an "average production" cost that is applicable to all operations. Any cost figure has only local application and is soon outdated. Previous cost studies tend to be snapshots of individual operations at a specific point in time. While production costs can be estimated as a percentage of average sale price (85 percent has been suggested[69]), this is only an approximation and may lead to erroneous estimates, especially in years of poor production.

A suggested simple approach that individual producers can use to arrive at an estimate of their own production cost is provided by the worksheet in **Table 11.1**. This worksheet identifies the principal cost components, both fixed and variable, associated with maple syrup production. It permits individual operators to use their own costs for various necessary components. If new equipment has been purchased, the appropriate costs can be entered. If used or modified equipment is available, its actual cost can likewise be entered. The worksheet requires some assumptions related to the useful life of the maple resource as well as facilities and equipment used in sap collection and processing.

Use of this worksheet permits an individual cost-of-production accounting that reflects the actual cost or a best-cost estimate associated with an individual operation. The worksheet, along with the analysis presented in **Table 11.2**, provides one measure of the profitability of the maple operation.

This approach presents a relatively simple cash flow analysis. It does not include the concept that money invested in an enterprise should earn interest (return to the investor). In the worksheet a $13,000 evaporator with a life expectancy of 20 years would be calculated as costing the producer $650 per year[70]. If the interest earning ability of the $13,000 was recognized, and the producer's alternative was to invest the $13,000 in an investment earning 4 percent compound interest, the total cost at the end of 20 years would be estimated as the $13,000 purchase price plus the interest it would have earned over the 20 years of $15,484.60[71]. By this method, the total cost of the evaporator over the 20 years is $28,484.60, and the annual cost of the evaporator is $956.66[72]. For those willing to do the math, this latter approach is financially more accurate and revealing, particularly for calculating the true cost of producing a gallon of syrup. For others, the simple cash flow analysis presented will provide considerable insight.

[69] Sendak, P.E., and J.P. Bennink. 1985. *The Cost of Maple Sugaring in Vermont*. USFS Research Paper NE-565. 14 pp.

[70] $13,000/20yr = $650 per year.

[71] The value after 20 years of $13,000 invested at an effective annual interest rate of 4 percent is calculated as $(\$13{,}000)(1.04)^{20} = \$28{,}484.60$. Interest earned during that time is, therefore, the value after 20 years ($28,484.60) minus the initial value ($13,000) or 15,484.60.

[72] The annual deposit required in an account earning interest rate "i" to accumulate in "n" years to a value "$V_n$" is calculated by the formula: Annual Deposit = $(V_n)(i)/(1+i)^n - 1$. In this case, the formula becomes: $[(28{,}484.60)(.04)] \div [(1.04)^{20} - 1]$

**Table 11.1. Worksheet for determining maple syrup production costs and profitability.**

| Cost Components | | | |
|---|---|---|---|
| **Fixed Cost** | **Initial Cost** | **Life Expectancy** | **Yearly Cost** |
| Sugarbush | | | |
| Sugarhouse | | | |
| • Evaporator | | | |
| • Steam Hood | | | |
| • Preheater | | | |
| • Forced Draft Unit | | | |
| • Reverse Osmosis Unit | | | |
| • Draw Off Accessories | | | |
| • Filter press/Canning Unit | | | |
| • Storage Tanks (Sap) | | | |
| • Evaporator Feed Tank | | | |
| • Miscellaneous Utensils | | | |
| • Other | | | |
| **Sap Collection Equipment** | | | |
| • Bucket/Bags | | | |
| • Tubing System | | | |
| • Transfer Pumps | | | |
| • Vacuum Pumps | | | |
| • Tractor & Trailer | | | |
| • Gathering Tank | | | |
| • Sap Storage Tank | | | |
| • Tapping Unit | | | |
| • Miscellaneous Equipment | | | |
| • Other | | | |
| **Overhead Management Costs** | | | |
| • Land Taxes | | | |
| • Land Rental | | | |
| • Insurance | | | |
| • Management/Record Keeping | | | |
| **Total** | | | |

| **Variable Cost** | **Quantity Used** | **Unit Cost** | **Total Cost** |
|---|---|---|---|
| **Labor** | | | |
| • Management | | | |
| • Sugarhouse Operations | | | |
| • Tapping and Set Up | | | |
| • Sap Collection | | | |
| • Fuel Production | | | |
| • Maintenance/Clean Up | | | |
| **Fuel** | | | |
| • Evaporator | | | |
| • Finishing/Canning | | | |
| • Tapping & Sap Collection | | | |
| • Utilities | | | |
| **Marketing** | | | |
| • Advertising (Yearly Cost) | | | |
| • Sales Costs (Yearly Cost) | | | |
| • Containers (Assorted Sizes) | | | |
| **Total** | | | |

| | |
|---|---|
| **Expected Revenues** | |
| • Amount of Syrup Produced (gal) | |
| **Anticipated Sales** | |
| • Retail (gallons sold ____ x average sales price per gallon ____) = | |
| • Wholesale (gallons sold ____ x average sales price per gallon ____) = | |
| • Other Products (equivalent gallons sold _____ x average sales price per gallon _____) = | |
| **Total Revenue** = | |

**Table 11.2. Determination of unit production costs for maple syrup enterprise.**

| Profit Summary | |
|---|---|
| Average Fixed Cost per Gallon of Syrup Produced (total fixed yearly costs divided by gallons of syrup produced) | = |
| Average Variable Cost per Gallon of Syrup Produced (total variable yearly costs divided by gallons of syrup produced) | = |
| Total Costs per Gallon of Syrup Produced (sum of average fixed and average annual variable costs) | = |
| Total Value of All Syrup Produced and Sold (sum of all sales revenue) | = |
| Total of Yearly Fixed and Yearly Variable Costs | = |
| Total Profit from Production and Sales of Maple Products (difference between total sales and total costs) | = |
| Profit per Gallon of Syrup Produced (total profit from production and sales divided by number of gallons of syrup produced) | = |

An explanation of each component in the worksheet was discussed in a previous section of this chapter. Enter values as indicated using actual or anticipated costs and revenues. Enter the new or used cost of equipment or materials as appropriate. Labor costs should include self and family labor as well as that which is hired. Revenue expectations are expressed in gallons; however, worksheet entries should reflect revenue obtained from different sized containers that have been converted to a gallon (4-liter) basis.

### Worksheet Example

To assist producers in applying this worksheet to their own operation, an example is presented (**Table 11.3**). This example is for a hypothetical operation consisting of 1000 taps in a 20-acre sugarbush. Several assumptions have been made. A separate sugarhouse building is located on the property. Sap is collected with a vacuum tubing system. The evaporator is wood fired and a reverse osmosis unit is not used. Three hundred gallons of finished syrup are produced per year. All syrup is sold in retail containers at the farm. Both new and used equipment were purchased for the operation. In the example, yearly costs for components lasting more than one year were determined by simply dividing the initial cost by life expectancy, rather than the more informative compound interest calculations demonstrated.

**Table 11.3. Sample worksheet for determining maple syrup production costs and profitability.**

| Cost Components | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Fixed Cost** | **Initial Cost** | **Life Expectancy** | **Yearly Cost** | **Variable Cost** | **Quantity Used** | **Unit Cost** | **Total Cost** |
| Sugarbush | 30000 | 50 yrs. | $ 600 | **Labor** | | | |
| Sugarhouse | 5000 | 25 | 200 | • Management | 30 hrs. | $12.00 | $ 360.00 |
| • Evaporator | 13000 | 20 | 650 | • Sugarhouse Operations | 125 hrs. | 8.00 | 1000.00 |
| • Steam Hood | 800 | 20 | 40 | • Tapping and Set Up | 50 hrs. | 8.00 | 400.00 |
| • Preheater | 1400 | 20 | 70 | • Sap Collection | 30 hrs. | 8.00 | 240.00 |
| • Forced Draft Unit | 1200 | 20 | 60 | • Fuel Production (12 Cords) | 35 hrs. | 8.00 | 280.00 |
| • Reverse Osmosis Unit | — | — | — | • Maintenance/Clean Up | 50 hrs. | 8.00 | 400.00 |
| • Draw Off Accessories | 200 | 20 | 10 | **Fuel** | | | |
| • Filter press/Canning Unit | 600 | 20 | 30 | • Evaporator (Self Produced) | — | — | — |
| • Storage Tanks (Sap) | 1500 | 20 | 75 | • Finishing/Canning | — | — | 50.00 |
| • Evaporator Feed Tank | 300 | 20 | 15 | • Tapping & Sap Collection | — | — | 100.00 |
| • Miscellaneous Utensils | 200 | 20 | 10 | • Utilities | — | — | 150.00 |
| • Other | — | — | — | **Marketing** | | | |
| **Sap Collection Equipment** | | | | • Advertising (Yearly Cost) | — | — | 250.00 |
| • Bucket/Bags | — | — | — | • Sales Costs (Yearly Cost) | — | — | 200.00 |
| • Tubing System | 5000 | 20 | 250 | • Containers (Assorted Sizes) | 300 gallons | — | 1000.00 |
| • Transfer Pumps | 300 | 10 | 30 | **Total** | | | **4430.00** |
| • Vacuum Pumps | 1000 | 10 | 100 | | | | |
| • Tractor & Trailer | 4500 | 15 | 300 | | | | |
| • Gathering Tank | — | — | — | | | | |
| • Sap Storage Tank | 300 | 10 | 30 | | | | |
| • Tapping Unit | 400 | 10 | 40 | | | | |
| • Miscellaneous Equipment | 200 | 10 | 20 | | | | |
| • Other | — | — | — | | | | |
| **Overhead Management Costs** | | | | | | | |
| • Land Taxes | — | — | 600 | | | | |
| • Land Rental | — | | — | | | | |
| • Insurance | — | — | 400 | | | | |
| • Management/Record Keeping | — | — | — | | | | |
| **Total** | | | **$3730.00** | | | | |

| **Expected Revenues** | |
|---|---|
| • Amount of Syrup Produced (gal) 300 | |
| **Anticipated Sales** | |
| • Retail (gallons sold 275 x average sales price per gallon $32 ) = | $8800.00 |
| • Wholesale (gallons sold 0 x average sales price per gallon) = | 0 |
| • Other Products (equivalent gallons sold 25 x average sales price per gallon $ 55 ) = | 1375.00 |
| **Total Revenue =** | **$10175.00** |

Comparison of production costs per gallon equivalent of syrup produced and total sales revenue permits the computation of anticipated profit for the enterprise (**Table 11.4**). Following the format presented, the profit margin is expressed on a per gallon basis.

**Table 11.4. Determination of unit production costs for maple syrup enterprise.**

| **Profit Summary** | |
|---|---|
| Average Fixed Cost per Gallon of Syrup Produced (total fixed yearly costs divided by gallons of syrup produced, e.g. $3,730.00/300) | = $12.43 |
| Average Variable Cost per Gallon of Syrup Produced (total variable yearly costs divided by gallons of syrup produced, e.g. $4,430.00/300) | = $14.77 |
| Total Costs per Gallon of Syrup Produced (sum of average fixed and average annual variable costs, e.g. $12.43 + $13.97) | = $27.20 |
| Total Value of All Syrup Produced and Sold (sum of all sales revenue) | =$10,175.00 |
| Total of Yearly Fixed and Yearly Variable Costs (e.g. $3730.00 + $4430.00) | =$8,160.00 |
| Total Profit from Production and Sales of Maple Products (difference between total sales and total costs, e.g. $10,175.00 – $8,160.00) | =$2,015.00 |
| Profit per Gallon of Syrup Produced (total profit from production and sales divided by number of gallons of syrup produced, e.g. $2,015.00/300) | = $6.71 |

## Other Aspects of Maple Syrup with Economic Implications

Most maple syrup producers have their own sugarbush and obtain sap by tapping trees that are appropriate in size and are conveniently located for sap collection. However, sap supplies may be supplemented by purchasing sap from others, or by renting or leasing trees (tapholes) from neighbors. In some locations maple trees on public lands are leased for tapping. Additionally, many maple producers do not have adequate quantities of syrup to supply market demand, and will purchase finished syrup from other producers or bulk markets to augment their own production.

**Taphole Rental**—A commonly accepted practice or standard for determination of the value of a rented taphole does not exist within the maple industry. Rather several different approaches are used including bartering for other services, providing syrup in exchange for tapping privileges, annual rental on a per taphole basis, and annual rental of the sugarbush on a per acre basis. Any method that results in satisfaction for both parties is acceptable, however, the most equitable method is probably one that provides payment on a mutually agreed upon price per taphole. Current taphole rental rates vary throughout the region ranging from $0.20 to $0.65 or more (U.S. currency). Variation in rates reflects accessibility, number of tapholes per acre, availability of local electric service (to power pumps), size of the trees present, and sugar content of the sap. Generally, trees along roadsides or other "open grown" trees receive a higher value per tap than woods trees due to their larger crowns and usually sweeter sap.

For trees in sugarbushes, a suggested taphole rental rate can be determined based on the average agricultural land rental rate present in the local area. To use this approach it is necessary to know this value as well as the total size (acres) of the sugarbush and the total number of tapholes per acre (divide total number of tapholes by number of acres in sugarbush). Finally the average taphole rental rate is determined by dividing the land rental rate by the average number of tapholes per acre present in the sugarbush. This per taphole value is then multiplied by the number of tapholes present to determine the total rental amount. These computations are illustrated in the following example:

| | |
|---|---|
| Average local agricultural land rental per acre | $50.00 |
| Number of acres in sugarbush | 20 |
| Total number of tapholes in sugarbush | 1760 |
| Average number of tapholes per acre (1760/20) | 88 |
| Average taphole rental rate ($50.00/88) | $0.57 |
| Total sugarbush rental value (1760 x $0.57) | $1,003.20 |

This approach should work satisfactorily for adequately stocked maple stands (more than 60 taps per acre). In stands of lower stocking, the tap rental may actually need to be lowered because of the increased costs of tapping and gathering.

Whatever the method for determining sugarbush leasing or rental rates, it is recommended that a written agreement that identifies the obligations and expectations of both the landowner and the lessee be prepared and signed (see Appendix 5).

**Sap Purchase—**Purchase of sap from neighboring farms or other individuals is a common practice throughout the maple syrup producing region. Tapping trees and selling sap to producers with evaporators is done by individuals who for various reasons choose not to process their own sap, but still wish to obtain some income from the maple resource.

Sap purchase can be mutually beneficial to both producer and processor if jointly developed guidelines for collection and quality control are stipulated and agreed to, and if an equitable purchase price schedule or arrangement is in effect. It is essential that purchasers receive sap in good condition so quality syrup can be produced. Likewise, the producer must receive a fair price that provides adequate compensation for the tapping and collection efforts expended. Suggestions for components of sap purchase agreement guidelines include the following:

1. Sap collection, gathering, and transportation equipment must be thoroughly clean.
2. Sap collection and delivery should be done on a daily basis.
3. Sap sugar content will be determined at the time of delivery to the processing facility.
4. It is expected all sap will be handled in a manner that will maintain quality.
5. Payment for sap will be made following a mutually acceptable rate and time schedule.

The price paid for purchased sap varies throughout the maple region. However, nearly all payment methods relate to sap sugar content since smaller volumes of higher sugar content sap are required to produce a similar amount of syrup in contrast to sap with a lower sugar content. Additionally, less evaporation time is necessary to process sap with a higher sugar content.

Because of changing production costs and prices received for maple syrup products, a uniformly accepted price schedule for sap of varying sugar content does not exist in the maple region. However, since research studies indicate sap collection costs represent approximately 50 percent of the total cost of syrup production, it is suggested a payment schedule be developed which reflects this percentage. As an example, if the average cost of syrup production from 2.0 percent sugar sap is $20.00 per gallon[73], then the 43 gallons of sap necessary for producing one gallon of syrup would have a total value of $10.00, or $0.23 per gallon. Value for sap of other sugar concentrations would vary accordingly.

**Purchasing Finished Syrup—**In addition to renting trees (tapholes) and purchasing sap, some producers find it necessary to purchase finished syrup to augment their own production. For most producers this is not done on an annual basis but rather is necessary when a "short crop" is produced or when an unexpected marketing opportunity is present and available supplies of syrup or other finished products are insufficient. Purchase price is usually determined by wholesale prices applicable to the local area or region. This may vary from year to year reflecting available supplies.

For producers who purchase finished syrup and market it as their own, it is important that syrup quality and grading be consistent with what the established customer base has come to expect, and that it be labeled consistent with applicable regulations. Purchasing finished syrup may not be profitable if the syrup quality is lower than what the established customer base has come to expect, or is significantly lower than that produced locally.

[73] U.S. dollars.

## Suggestions to Improve Economic Profitability of the Maple Operation

The primary factors that influence the sap flow process are largely beyond the control of the maple producer. For this reason the predictability of any maple season is uncertain and, accordingly, so is the amount of production that can be expected. Favorable weather patterns and temperature fluctuations are critical as the amount of sap produced is directly dependent on temperature changes. Since variations in weather patterns occur from year to year, consistent sap and syrup production should not be expected. While maple producers hope for an average or above average crop each year, they realize that averages are made up of extremes, and occasional below average seasons are in fact "normal."

Because of the uncertainties in annual production many maple producers attempt to maintain a syrup inventory from one year to another to help meet market demands when below average production years occur. Others operate with the expectation that additional syrup will be purchased when a short crop is produced.

Uncertainties in annual production have a direct relationship to profitability of the operation. Even when an average annual crop is produced profit margins are not necessarily high. This is especially true for operations that sell large quantities of syrup to wholesalers or for those that only operate local retail markets where sales opportunities are often limited.

The following suggestions are offered as possibilities for increasing total revenue and thereby the profitability of a maple operation. Several of these have been identified in other chapters in this manual, however, because of their relationship to economic success, they are listed here and discussed briefly.

**Efficiency of Operation**—Efficiency is a key component of increasing profitability in a maple syrup operation. Opportunities for increasing efficiency exist in all aspects of maple syrup production. Since two of the principal cost components of producing maple syrup are labor (time) and fuel, any change that reduces the amount of either will reduce total production costs. In sap collection the use of tubing in contrast to buckets requires less total labor when installation, collection, and cleanup are considered. For vacuum tubing systems it is important to maintain a relatively high level of vacuum throughout the system if significant increases in sap yields are to be realized. This requires designing and installing a system so that sap movement occurs unimpeded. It also dictates that the vacuum pump be properly sized to serve the entire system. Less labor and maintenance will be necessary if electrically powered pumps with thermostat controls are used as opposed to gasoline-powered units.

When transferring sap through pumps, less time will be required if larger as opposed to smaller diameter lines or hoses are used. Likewise, larger capacity pumps require less time to transfer sap than those with a smaller capability. Where possible, pumps with electric motors will require less maintenance than those with gasoline motors. A smaller number of storage tanks with larger capacities will require less time for cleaning than will several smaller capacity tanks.

There are several opportunities to improve efficiency in the sugarhouse. These include developing a mechanical delivery system for bringing wood to the evaporator, proper sizing of the evaporator consistent with the amount of sap to be processed, use of forced draft units for wood-fired evaporators, using a preheater or other heat capturing device before sap enters the evaporator, and use of condensate water for other purposes including heating the syrup canning tank and general cleanup of the facility.

**Used Equipment**—Many producers began their maple operation with used sap collection equipment, a used evaporator, and other used syrup storage and canning equipment. Others have modified and adapted equipment originally designed for another industry. The use of dairy equipment, such as storage tanks and pumps as well as pails and other containers, is common in many maple operations. Still other producers

have fabricated sap handling and syrup canning equipment that meets the needs of their own operation. As long as the quality and food safety aspects of the finished product are not affected, the use of used equipment is appropriate and desirable, and can result in substantial savings. Individual innovation and ingenuity have permitted many producers to remain profitable in an industry that characteristically has a low profit margin.

**Use of Family Labor**—Labor is a principal cost in producing maple products. The use of self or family labor is common in such activities as cutting and storage of fuelwood, tapping trees and collecting sap, operation of the evaporator, canning of syrup, and preparation and packaging of other maple products. While the use of family labor does not eliminate labor costs from an economic accounting perspective, it can significantly reduce out-of-pocket expenditures for labor.

**Location and Method of Sales**—Most maple producers sell the majority of their maple syrup at the farm gate or at local farm markets or similar outlets. Marketing maple products at sales outlets specifically designed for tourists or through outlets such as organic food stores can result in higher prices for the producer. There is an expectation among consumers who frequent these facilities that prices will be higher than for similar products purchased at larger volume retailers, discount outlets, or even at the farm. Producers who identify specialty product marketing outlets can expect to receive higher prices for products that are marketed there.

It is also an established marketing fact that prices per unit volume of product are higher when the product is sold in a smaller sized container, or in a unique or different style container. Container size, style, and attractiveness all have a significant influence on appeal to consumers and their purchases. Several aspects related to packaging are considered in Chapter 10, however, it is important to re-emphasize the importance of packaging and its effect on total returns from the sales of maple products.

**Product Diversification**—Traditionally maple syrup has been the principal maple product offered for sale. However, several other consumer products can be derived from maple syrup through further processing. Maple cream, maple sugar, and various forms of maple candy are among the most common. Additionally, other products such as maple-flavored popcorn, maple cotton candy, and maple-flavored ice cream are possibilities. When maple syrup is processed into other maple products, or added as a component to other food or confection products, the total value received for the syrup used to produce such foodstuffs is increased. Savvy producers are aware of the potential for additional profits and will adapt their operation and facilities to accommodate both production and marketing. Successful marketing may require that additional marketing outlets be located, including establishing concession outlets such as local county and/or state fairs, festivals, regional expositions, shopping malls, or any other location where large numbers of potential customers are present.

**Production of Other Compatible Products**—Some maple syrup producers operate retail sales outlets that offer other farm-raised products to the consumer. These may include seasonally available fresh vegetables, including sweet corn, locally produced fruits of various types, homemade jams and jellies, honey, apple cider, pumpkins, and even firewood for campground use. A few operators also include a bakery that specializes in high quality baked goods, including fresh bread. When strategically located, established farm markets with high quality products can become a convenient food source for consumers. Such sales outlets have a strong appeal to summer vacationers, weekend campers, seasonal cottage residents, and local residents who appreciate the convenience and value associated with establishments that feature local products of high quality.

**Operation of Additional Farm Production Activities—**Dairy production is the agricultural activity most commonly associated with maple, but there are certainly other possibilities. Cash crops, cow-calf beef operations, fruit orchards, wholesale vegetable production, logging and/or other forest product production, Christmas tree and/or nursery stock production, are all activities compatible with the production of pure

maple products. Some of these permit the utilization of equipment such as tractors, wagons, trailers, and possibly pumps that are used in the maple operation to be used in one or more of these ventures as well. The addition of other income-producing ventures is limited only by the imagination, resourcefulness, management competency, creativity, marketing skills, and energy of the operator. When combined with other production activities the incorporation of maple syrup production can be a significant additional source of income to the total farming enterprise.

## Conclusions

The production of pure maple syrup and related maple products is an activity that can result in significant economic gain for the producer. However, careful planning is a prerequisite with respect to managing production costs and product marketing. The demand for maple products is excellent; however, both the fixed and annual variable costs of production are relatively high. Annual production is unpredictable and can be quite variable. This is primarily a reflection of weather/temperature patterns that tend to be somewhat changeable from one year to the next. Successful operators are those who minimize fixed costs, develop and operate production facilities that are highly efficient, and use imagination and creativity in marketing their pure maple products. Marketing is a key component in making a maple syrup production profitable. Success in the maple business is related to producing products of the highest quality and in identifying and developing markets that appeal to consumers who appreciate the unique aspects of pure maple products and who are willing to pay a fair price.

# Chapter 12 · Maple Production Facilities[74]

To produce pure maple syrup and related products it is necessary to have production facilities that will accommodate the activities involved, provide a safe and efficient workspace, and are consistent with the requirements and expectations associated with producing a pure food product. At a minimum, the maple production facility, commonly known as a sugarhouse, provides protection from weather for sap storage and sanitary processing of sap into syrup. In addition, parts of the sugarhouse are commonly used for canning, packaging, and warehousing maple syrup; the production of candy and other secondary products; and retail sales.

Maple production facilities should be designed for efficiency of operation, provide adequate space necessary to complete all planned operations, and present an image consistent with the products produced. Ease of cleaning and maintenance of sanitary facilities associated with the production of a high quality food product is also essential. The cleanliness of the production and storage facilities can impact both the consumer's perception of quality and the actual purity of the finished product (**Figure 12.1**). This chapter is designed to help sugarmakers in the planning of a new sugarhouse or upgrading an existing operation. Chapter 13 on safety is also a valuable resource and reference.

Certain "minimum" elements should be included in any newly constructed sugarhouse. A concrete floor with adequate drains, ample ventilation for steam, sufficient lighting, and doors large enough to allow the movement of equipment are just a few considerations. The location of the sugarhouse will be determined by several factors including: location of property, location of the trees to be tapped, topography, soil drainage, nearness to utilities, and road location. If the sugarmaker is planning on selling syrup in a retail setting, an attractive facility in a location that is close to a well-maintained road may help increase sales.

[74] Portions of this chapter were adapted from work originally done by Grant D. Wells, University of Vermont Extension Agriculture Engineer.

## Location of Sugarhouse

Some basic considerations are necessary whenever a new sugarhouse is being planned or upgrades to an existing sugarhouse are made. A good site for building will include good soil drainage, good accessibility from an all-weather road, and electrical utilities in close proximity to the sugarhouse. Some sugarmakers plan on selling their entire crop wholesale or bulk while others incorporate retail space into their sugarhouse design. If a new structure and site are planned, take time to consider soil and surface water drainage, accessibility, utilities, space, and general air movement around the site. The specific location of the sugarbush on the site can be very important. Will sap flow by gravity into the sugarhouse or will it be pumped or trucked? Will the sugarhouse be used for retail sales, in which case it will need to be easily accessible from a paved road and parking space will be needed. If tubing is used, some locations will be far more efficient (operationally and financially) than others. Is there sufficient grade (slope) for tubing? Where is the nearest electrical service access? Now step back and look to see if

Figure 12.1. The cleanliness of the production and storage facilities can impact both the consumer's perception of quality and the actual purity of the finished product.

all aspects of the operation have been considered. When a suitable site has been chosen, stake out the dimensions of the proposed structure. How much earthmoving or drainage pipe/ditch installation will be necessary to minimize the effects of soil moisture? If wood will be the fuel, is there room to handle the wood supply necessary to operate the evaporator for the entire season? Can trucks or tractors with trailers turn around and maneuver readily?

## Drainage

The soil type and topography of a proposed sugarhouse site is important. If the land is wet some or most of the year, drainage issues will need to be factored into the plans. Take time to walk the area in late winter and early spring. This will likely be the time of highest ground moisture, but also the time when having access is essential. The earth should be graded away from the base of the sugarhouse. Ditches can be used to direct surface water away from the building. To make efficient use of earthmoving equipment, coordinate these activities with other jobs that need to be accomplished on the site (e.g. foundation excavation, electrical service, culvert installations, or road work).

## Design and Construction

At the heart of every sugarhouse is the evaporator. The size, type, and configuration of evaporator will have significant influence on the design of the sugarhouse. Beginning sugarmakers may be tempted to undersize the sugarhouse. When this

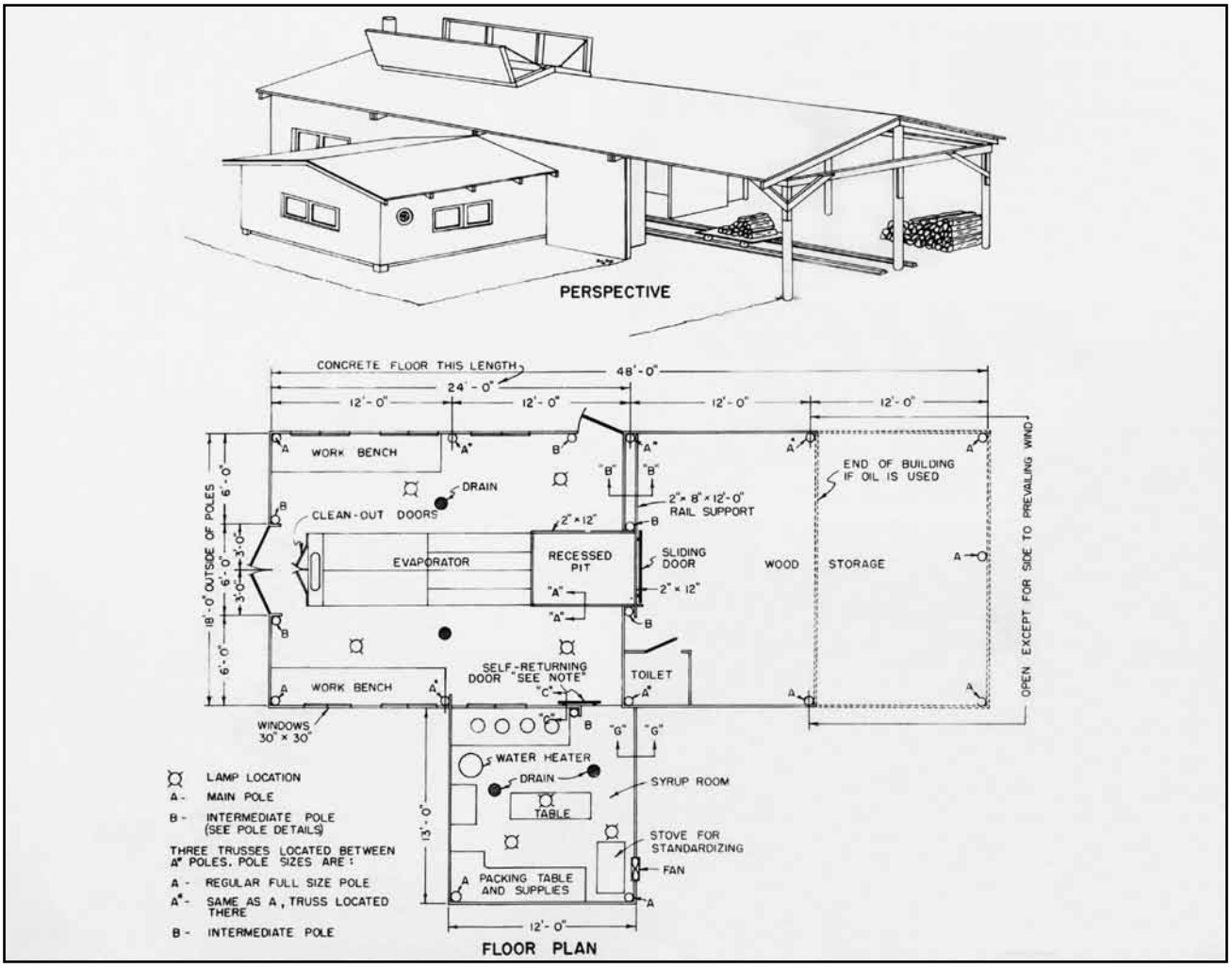



Figure 12.2. An elaborate set of blueprints is not necessary, but a simple, well-drawn diagram will be very helpful as you plan and construct a sugarhouse.

occurs it is not uncommon for the sugarmaker to be faced with the need to expand after only a few years. The need for and costs of future expansion should be anticipated when designing a new sugarhouse. If financial resources permit, build a larger structure than what is presently necessary as expansion within a maple operation is seemingly inevitable.

There are almost as many different sugarhouse designs as there are maple syrup producers working in them. Before any sugarhouse is constructed, it should be designed using drawn plans. An elaborate set of blueprints is not necessary, but a simple, well-drawn diagram will be very helpful (**Figure 12.2**). Working out details on paper can prevent mistakes in construction later on. The basic building should include room for the evaporator with a minimum of 4 feet of working space around the evaporator, and at least 4 feet of room for workbench space. A wood-fired evaporator will need at least 6 to 10 feet of space in front to fuel the evaporator.

If a new sugarhouse is being constructed, consider visiting several sugarhouses while they are operating. Visiting other sugarhouses will help make the decision as to what size and type of structure will best meet the needs of the planned operation. There is no substitute for listening to the suggestions and advice of other sugarmakers and learning from their experiences. Ask other sugarhouse owners what works best for them and what they would change in their own design. Always ask "what's wrong" with a design as well as "what's right." Consider using native building materials whenever possible. Buying lumber from your area supports local businesses, and will usually be less expensive than purchasing construction lumber from conventional building supply outlets.

The use of pressure-treated, decay resistant lumber should be minimized. Although effective for delaying rot, some of the chemicals used in the treatment process may be potential sources of contamination to the finished products. This is especially true where condensate from the evaporation process may find its way back into the evaporator or other processing operation. An exception to this suggestion is the use of pressure treated dimensional lumber for the foundation sill; the life expectancy of the building will be prolonged if decay in the foundation area is minimized.

There are several construction methods from which to choose (**Figure 12.3**). The least expensive is the post-frame construction method also known as pole barn construction. Post-frame involves sinking posts into the ground, then connecting them horizontally with lumber. The poles serve as foundation, bracing, and framework. Excavation is needed for the poles and prepping the site for a concrete slab.

Figure 12.3. Construction methods commonly used when building a sugarhouse include post-frame or pole barn (upper left), post-and-beam (upper right), and light frame (bottom).

Another type of sugarhouse construction is the traditional light-frame building. This is the most common residential construction method. Frames of "two-by" lumber (2 inches by 4 inches, 2 inches by 6 inches) are built and attached to a foundation. This type of construction is more

costly than post-frame because it requires more lumber and can be more complicated.

A third type of construction is post-and-beam, also known as timber frame. Post-and-beam makes use of large timbers cut from logs. Vertical posts and horizontal beams are assembled into sections called bents, then raised and attached to a sill beam on a foundation. Timber-frame sugarhouses are the most expensive type of construction because it takes a specialized contractor to cut and fit the timbers. Several companies offer kits that can be assembled and raised by the producer. Timber-frame sugarhouses can be small or large.

## Foundations

Ground movement resulting from freezing and thawing of the soil can result in significant damage to concrete floors and foundations in some areas of the maple-producing region. This usually occurs during the winter and early spring. This movement, commonly called "frost heaving," can cause concrete to crack, tilt, and/or sink from its original position. If the amount of soil moisture in the ground can be minimized, the effects of frost heaving will be lessened. Soil grading before construction to ensure that water drains away from the sugarhouse will be helpful as well as installing footing drains, especially if soil drainage is not good. Placing the footings for foundation walls below the frost line (this may be 4 to 5 feet in northern locations) will also minimize damage from frost heaving. Insulation of the foundation and other devices such as gutters with downspouts that direct water away from the foundation are also recommended. Consultation with a building expert for advice about insulating shallow foundations is recommended.

It is possible to locate small buildings on many well-drained soils without using foundation walls provided the slabs are steel reinforced. Increasing the amount of gravel and adding perforated pipe and curtain drains to control ground and surface moisture will help to prevent frost damage to the slab (**Figure 12.4**). If the concrete is not allowed to cure properly or if it is poured when the temperatures are below freezing without the addition of calcium chloride, cracks may develop that would not otherwise have occurred. Proper curing delays the drying until the concrete is strong enough to resist shrinkage cracking. Concrete that is moist-cured for seven days is about 50 percent stronger than concrete exposed to dry air for the same period.

Figure 12.4. Increasing the amount of gravel and adding perforated pipe and curtain drains to control ground and surface moisture will help to prevent frost damage to the slab.

## Slabs

A 4-inch concrete slab meets the minimum needs of the sugarhouse provided the slab is poured on a properly prepared surface. If vehicles will have access to the sugarhouse, slab thickness should be increased. The slab must be poured on at least 8 inches of well-compacted gravel and reinforced with steel. Never pour a concrete slab on frozen ground. Any area under the slab that will not be filled with concrete (this would include water diversion structures such as drain pipes) should be brought to a uniform level in stages or "lifts."

The area around pipes or trenches should be filled with 6 inches of soil at a time and compacted between each "lift." Most equipment rental companies have compacting equipment available and it is worth the cost to use it. If the ground is not compacted the loose soil will settle, leaving the finished slab with air pockets under it. A channel can form and become a route for water. The uneven surface of the slab combined with frozen groundwater can also result in cracking and movement of the slab (**Figure 12.5**).

Figure 12.5. Pouring concrete on an inadequately prepared base can result in cracking.

Construction tubes are available and can be used as a substitute for foundation walls in pole-frame construction; however, attention should be paid to prevent impact from frost heaving. Some type of footing must be used with construction tubes. Plastic forms or "bigfoots" are available and can be used to establish a large footing that can resist the effects of frost heaving. It is important to secure the concrete in the footing to the concrete in the construction tube with reinforcing steel. Metal brackets are available to connect the concrete to the vertical posts.

## Floors

Sugarhouse floors should be made of concrete. Some state health departments or other regulatory agencies require a concrete floor for sanitary reasons. Floors made of dirt, unpainted wood, or other porous material make it difficult or impossible to keep clean and represent an unnecessary risk to the quality of the product. Concrete floor surfaces can be finished many ways. A fine broom finish will provide enough traction while allowing for easy cleanup. Another method would be a smooth finish followed by several coats of floor paint containing anti-slip additives. A concrete floor that is too smooth is a serious risk for slipping and injury. A floor that can be cleaned easily will probably be cleaned more often. A clean floor is safer, more attractive to visitors, and is less likely to contaminate your syrup.

The entire floor should be graded toward floor drains. A pitch of 1/8 inch per foot is suggested as the minimum grade. There should be adequate drainage receptacles put in place prior to pouring the floor. The most common floor drain is the 4-inch circle drain**.** It can be difficult to slope an entire floor to a single point. Adding more drains can help. Some sugarmakers prefer a grate drain. The drain can be a single channel running the length of the evaporator or a trench that runs around the perimeter of the evaporator (**Figures 12.1 and 12.6**). These structures make cleaning around the evaporator easier and represent a larger target toward which to grade the freshly poured concrete. Grates are available commercially in many different shapes, styles, and materials. Particular attention should be given to the outlet of the drain. Water leaving the sugarhouse should not flow directly into a watercourse or otherwise contribute to erosion of the site.

Some evaporator accessories generate a large amount of very hot water. While this is convenient for cleaning, excess hot water will have to be drained away from the building. Hot water run through drains under the building can melt ice in the soil under the building, exacerbating frost heaving problems. Care should be taken when incorporating hot water drainage systems under concrete floors and slabs.

Figure 12.6. Adequate floor drainage in the sugarhouse might include a drain running the length of the evaporator or one running around the perimeter of the evaporator.

Figure 12.7. Incorporating a recessed pit in the floor in front of the firebox is a convenient feature in a wood-fired operation.

Incorporating a recessed pit in the floor in front of the firebox is a convenient element in a wood-fired operation (**Figure 12.7**). Standing 8 to 12 inches below the floor will ease back strain when firing the evaporator and make cleaning the ashes from the firebox less tedious. Adding this component to the floor requires some additional engineering but has proven to be worth the extra effort. This pit should also include a drain.

## Electricity

Most sugarhouses need reliable and sufficient power service. Vacuum pumps, reverse osmosis units, sap transfer pumps, filter presses, blower fans, UV lights, canning equipment and lighting all add to the electrical demand of the operation. When power service is interrupted to an operation that relies on electrical equipment for boiling efficiency, the rate of syrup production and syrup quality are adversely impacted. Before new equipment is added to the sugarhouse attention must be paid to the limits of the electrical system. An electrician should be consulted during the planning process and only qualified electricians should install electrical service in your sugarhouse.

The following are questions that will help determine the correct size electrical service for each operation.

1. What are the electrical loads and duty cycles of pumps, blowers, and lighting that will be used? What is the start-up load of major equipment (pumps, Reverse Osmosis)?
2. Is sugarbush expansion expected (adding a vacuum pump and R/O for example) and if so, how will it impact Question #1?
3. What is the distance of the sugarhouse to the source of power and will the lines be buried or aerial?

An example of computation necessary to determine the correct size of the electrical system for four hypothetical sugaring operations is presented in **Table 12.1**. As the size of operation increases, the pumps and equipment needed to handle larger volumes of sap also increase. Each successively larger pump in the sample operations doubles in electrical load. Ultimately it will be

necessary to select a suitable size amp service to fit the operation.

If a generator is used as a power source, the National Electrical Code and voltage drop calculations should be used to determine the appropriate generator size that will be necessary to provide power for the operation. A qualified electrician should be used to properly install a generator. Keep in mind that a gasoline-powered generator will produce exhaust that obviously is not desirable inside the sugarhouse. Be sure to keep generators away from the evaporator, sap tanks, or other food-handling equipment.

Energy is a significant expense in a contemporary maple syrup operation and actions that can be taken to reduce power demands should be undertaken. This includes using properly sized pumps for sap collection, transfer of sap from tanks, and operation of filtering and canning equipment. Doing so permits energy savings by requiring a smaller electrical service. If a sugarhouse is some distance from the electrical utility, power line extension will be an issue. This can be a very expensive proposition and the costs should be explored before advancing too far into the design and construction process. The local utility company will have information about line extension requirements and costs.

## Walls

Modern evaporators can range in height from 4 to 8 feet, depending on whether additional equipment such as a steam hood or preheater is being used. The height of sugarhouse walls should be designed with this in mind. Construction costs associated with increasing sidewall height a few feet are not usually large (an extra 5 to 10 percent generally). A finished total wall height between 9 and 10 feet is recommended. This height will help prevent the building trusses or collar ties from interfering with the location of the evaporator.

The purpose of exterior siding is to keep wind and weather out of the sugarhouse and not necessarily to insulate the building. Most exterior siding materials are satisfactory, assuming proper installation. Many sugarhouses are sided using rough sawn lumber installed as board and batten or shiplap siding. These relatively inexpensive materials provide adequate protection and have the traditional "look" of a sugarhouse. Such lumber can be usually be obtained from local sawmills present in most areas where maple syrup is produced.

The interior walls of a sugarhouse are exposed to significant changes in temperature and humidity. The often-remote location and seasonal use and location of sugarhouses become a disadvantage when trying to keep the structure free of pests. Some sugarmakers choose not to cover the interior walls. This results in more locations for dust and debris to accumulate. An ideal interior wall surface can be easily wiped or hosed down and is constructed tight enough to discourage rodents from entering. Several materials can be used for covering the walls in a sugarhouse. Plastic milk house paneling, painted shiplap or plywood, and painted metal roofing all provide a smooth cleanable surface. Milk house paneling is the most expensive material, although its use might be advisable in areas where sanitation is critical, such as in a syrup canning area.

## Potable Water[75]

Where possible, sugarhouses should be constructed with access to a source of clean, potable running water. Processing equipment should be cleaned after every use. Maple equipment cleaned away from the sugarhouse has the potential for cross-contamination from non-maple materials. An available source of clean water will help with personal hygiene, washing equipment used in processing and packaging, and in keeping the facility as clean as possible. Sugarhouses that do not have running water have successfully used large plastic water coolers to store a day's supply of water, or larger tanks periodically filled from a truck to hold a longer supply[76]. When this is done the tanks should be constructed of food-grade or potable (suitable for human consumption) water material and cleaned and sanitized as required.

[75] Water that is safe to drink.

[76] Some local, state, or provincial regulations permit this, others do not.

**Table 12.1. Estimated electrical demands for four sample vacuum sugaring operations[77].**

| 750 Taps | Watts | Equipment | |
|---|---|---|---|
| | 1,680 | 1Hp vacuum pump | |
| | 480 | 1/4 Hp transfer pump | |
| | 720 | Blower or burner for evaporator | |
| | 840 | Blower (small) for STEAM-AWAY® | |
| | 720 | 1/3 Hp filter press motor | |
| | 315 | Lighting for 210 sq. feet | |
| | **4,755** | **Total Watts** | |
| | **40** | **Amps*** | ***4,755 watts/240 volts = 19.8 amps X 1.25 for continuous duty = 25 amps. Because it is impossible to balance the loads on phase A and B of a 24 amp panel and leave room for an occasional hand tool the minimum service for the sugarhouse is 40 amps.** |
| **1,500 Taps** | 2,400 | 1 1/2 Hp vacuum pump | |
| | 1,200 | 3/4 Hp transfer pump | |
| | 960 | Blower or burner for evaporator | |
| | 1,680 | Blower (small) for STEAM-AWAY® | |
| | 720 | 1/3 Hp filter press motor | |
| | 1,920 | General outlet circuit | |
| | 600 | Lighting for 300 sq. feet | |
| | **9,480** | **Total Watts** | |
| | **60** | **Amps**** | ****9,480 watts/240 volts = 39.5 X 1.25 for continuous duty = 49.4 amps. This operation would run on 60 amps but 100 amps is recommended.** |
| **3,000 Taps** | 5,520 | 3 Hp vacuum pump | |
| | 8,880 | Reverse osmosis unit | |
| | 1,200 | 3/4 Hp transfer pump | |
| | 960 | Blower for burner for evaporator | |
| | 1,680 | Blower for STEAM-AWAY® | |
| | 720 | 1/3 Hp filter press motor | |
| | 600 | Lighting for 390 sq. foot sugarhouse | |
| | 3,840 | Separate canning room lighting and power | |
| | 1,920 | General outlet circuit | |
| | **25,320** | **Total Watts** | |
| | **150** | **Amps***** | *****25,320/240 volts = 105.5 amps X 1.25 continuous duty = 131.87 amps. With the variables offered by the canning room and the general outlet loads a conservative person could run on a 150 amp service. The larger service will allow for future expansion and the existing equipment will run cooler.** |
| **10,000 Taps** | 12,000 | 10 Hp vacuum pump | |
| | 28,800 | Reverse osmosis unit | |
| | 1,200 | 3/4 Hp transfer pump | |
| | 1,920 | Blowers or burners for evaporator (2) | |
| | 1,680 | 1 Hp blower for STEAM-AWAY® | |
| | 720 | 1/3 Hp filter press motor | |
| | 1,764 | Lighting for 1,176 sq. foot sugarhouse | |
| | 5,760 | Separate canning room lighting and power | |
| | 3,840 | General outlet circuits (2) | |
| | 2,400 | 3/4 Hp electrical releasers | |
| | **60,084** | **Total watts** | |
| | **400** | **Amps****** | ******60,084/240 volts = 250.4 amps X 1.25 continuous duty = 313 amps. A 400 amp service would be the right size for an operation with these loads. The next frame size for service gear is 600 amps.** |

[77] Provided by Donald Schroeder, Master Electrician.

It is important that the water originates from a high quality source. Untreated water sources (such as from a stream or brook) can contain microbiological, chemical, and physical contaminants. Regular testing of untreated water can help prevent humans from becoming sick or contaminating otherwise good quality syrup. Sugarmakers should check with local county health departments to obtain information about having water tested.

## Bathroom Facilities

Any sugarhouse that is open to the public should provide bathroom facilities. Some state or provincial health and local zoning require these facilities. Check with the appropriate county, state, or provincial agency health departments concerning requirements. Installing bathroom facilities, especially necessary plumbing, at the time of sugarhouse construction will save time and expense as compared to adding them later.

## Work Spaces and General Storage

Work surfaces that are difficult to clean increase the opportunity for contaminating syrup or processing equipment. Contaminants could be chemical or biological. Chemical contaminants include cleaning solutions, fuel residues, or pest control materials. Biological contaminants include bacteria, yeasts, molds, and pest urine and droppings. To help reduce possible contamination of either product or equipment, work surfaces should be smooth, nonporous, and free of cracks. Stainless steel or food-grade plastic are preferred materials, however, wood surfaces, when properly painted or treated, may also be satisfactory (check local requirements).

Many sugarmakers choose to build vertical shelving to store various supplies. If year-round storage is planned, consider the need to rodent/pest proof any sugaring supplies. If syrup containers are stored in the sugarhouse keep boxes off the ground and sealed to discourage infestations.

Arranging the sugarhouse to work efficiently can save time and improve your product. Keeping several aspects of the operation visible from one location can help save time and improve efficiency. In most operations the location of syrup draw-off on the evaporator should be thought of as the focal point that is located centrally. If the operation has several pieces of equipment (vacuum pump, reverse osmosis unit, mechanical releaser, filter press, etc.) arrange them in a way that allows for a rapid visual check of their status from this position.

## Evaporator Fuel Storage

For most sugarmakers fuel storage will involve either building a covered area to stack firewood or installation of an oil tank near the sugarhouse. The amount of fuel storage space needed will depend on how much sap is collected, the sugar content of the sap, the length of the season, and the efficiency of the evaporator. The old rule of thumb of 1 cord of dry hardwood for each 75–100 taps is acceptable for efficient evaporators. An area that is 8 by 16 feet stacked 5 feet high will hold 5 cords of firewood[78].

Good air circulation is needed for effective drying. Firewood should be protected from rain but not sealed in a tight structure. Split firewood should be air dried for nine months to a year; unsplit for at least one year before use. Try to reduce the number of times firewood must be handled. Many sugarmakers add wood storage onto the end of the sugarhouse nearest to the arch (**Figure 12.8**). This location allows the stacking of wood near the evaporator instead of moving it from a second location. Protection from drifting snow is also recommended.

Sugarmakers have found many inventive ways to transport firewood to the arch including overhead rails and a carriage that is strong enough to hold a load of wood, ground rails that allow pallets of firewood on small carts to be winched towards the arch, and stacking wood on pallets and using a small forklift to move wood to the evaporator (**Figure 12.9**).

[78] A cord of wood is a stack of tightly packed wood that occupies 128 cubic feet of volume, often represented as a stack of wood 4 feet high, 8 feet long, and 4 feet deep.

12.8. Many sugarmakers add wood storage onto the end of the sugarhouse nearest to the arch.

The price of fuel oil can fluctuate quickly. Some sugarmakers prepay for oil in an attempt to lock in a lower price. For operations that pre-purchase fuel oil before the sugaring season begins, larger oil storage facilities will be needed. A rule of thumb for determining oil storage requirements is to have 1 gallon (3.8 liters) of storage for each 10 tapholes if fuel delivery during the season is dependable and quick; otherwise plan on 3–5 gallons (11.5–19 liters) per 10 taps. The use of a reverse osmosis unit or other efficiency-increasing device will change the fuel per tap requirement. Make sure the oil tank can feed by gravity to the burners. Securely position the oil tank on a concrete slab or some other sound footing and locate the tank so it readily accessible by delivery trucks. Burying conduit in the sugarhouse's foundation will provide protection for fuel lines.

## Syrup Processing Room

Sugaring operations that plan to sell syrup in retail containers must devote some space to canning their product. Some sugarmakers fill containers in a corner of the sugarhouse; others bring bulk syrup into a residential kitchen for canning. Canning in a home kitchen involves more work and has the potential for contaminating syrup with non-maple materials[79]. Canning in the same room as the evaporator also presents a potential risk to the product. A processing room that is separate from the syrup production area is an ideal way to control the quality of syrup entering retail containers. In order to make this room more useful, consider installing a heater, vent fan, smooth light-colored walls that can be easily wiped clean, a stove for canning or making confections, and a water heater. This room can also be designed as a small retail space. Providing a separate entrance from the outside and an attractive display can improve sales.

## Roof

Roofing can be any fireproof material provided that it can handle potential snow loads and is installed correctly. Asphalt shingles are not ideal for use on a sugarhouse. They have the potential to hold snow and are less durable than metal roofing. Corrugated metal sheets can be easily installed and have a design that will effectively shed rain and snow. Standing seam roofs are durable; however, custom-fitted installations are about 25–30% more expensive then sheet metal roofing. Regardless of the material chosen, the roof should be carefully installed. Fasteners with a sealing washer for corrugated sheets and properly installed clips for standing seam roofs will prevent leaking or roof damage in the future.

[79] If this is planned, check local regulations. It is not permitted in all jurisdictions.

Figure 12.9. Sugarmakers have found many inventive ways to transport firewood, including ground rails, pallets, and a carriage suspended from an overhead rail.

## Steam Ventilation

The water vapor generated during boiling must be vented outside to keep the inside of the sugarhouse relatively dry and clean. Water vapor that is allowed to condense inside the sugarhouse will cause water to drip over equipment and supplies in the sugarhouse. This "raining" effect should be avoided as it can cause contamination of syrup, containers, and equipment, as well as create an unpleasant and unsafe workspace. Placing a layer of wood or hard foam insulation under metal roofing can help minimize the condensation. Tightly fitting steam hoods and steam stacks (**Figure 12.10**) are available which direct water vapor out of the sugarhouse. The cost of the steam hood and stack is not insignificant, but should be weighed against the potential problems caused by condensation within the sugarhouse.

Figure 12.10. Steam stacks venting water vapor from evaporator.

Several styles of roof ventilators exist, but the traditional sugarhouse cupola remains the most popular (**Figure 12.11**). A cupola allows for sufficient ventilation while providing protection from inclement weather. The opening in the roof above the evaporator should be as long as the evaporator and at least 75 percent as wide. The size of the cupola doors will also impact the ability to vent steam from the sugarhouse. Make cupola doors at least 75 percent as long as the evaporator and a minimum of 24 inches (61 cm) high. Cupola doors should be large enough so that on windy days one door can handle all the steam generated from boiling. The doors on a cupola should be made to open and close from the floor using ropes and pulleys. Evaporators with steam hoods and steam stacks can be vented directly through the roof of the sugarhouse, although some sugarmakers prefer to keep the traditional design but reduce the size of the cupola. Provision should be made so the doors of the cupola can be securely locked during the off-season.

Figure 12.11. Cupola to vent steam from sugarhouse.

## Stacks

Wood-fueled evaporators have different stack size requirements than oil-fired evaporators. A rule of thumb for wood-fired evaporators states that the stack should be two to two and one-half times as high as the arch is long. Oil-fired evaporators need only a stack equal to the length of the arch. Added technology and equipment may change the optimal stack height. The stack diameter within each fuel type also depends on the size of the evaporator. Check with the evaporator manufacturer for recommendations about stack diameter and height.

It is possible for live embers to be emitted through the stack to the atmosphere when wood is used as a fuel source for the evaporator. Forced draft systems increase the amount of burning material that is sent through the stack. A spark arrester is useful in preventing release of these potential fire starters (**Figure 12.12**). Spark arresters are constructed of strong metal screen or mesh that is fine enough to catch burning embers. A spark arrester must not restrict the draft of the stack. The arrester must be sturdy enough to withstand high winds and be fitted with a metal cover for rain protection. Equipment manufacturers have models available for stacks of many different sizes.

Wood-fired arches generate a tremendous amount of heat. Working stack temperatures commonly exceed 500°F (260°C). Care must be taken to avoid exposing combustible material, including the walls of the sugarhouse, to these extreme temperatures. Be sure to provide plenty of open air space between the back of the stack and any combustible materials. Follow the manufacturer's recommendations regarding installation of the smoke stack. A "roof jack" is used to make a watertight seal where the stack comes through the roof. Guy wires should be used to protect the stack from wind damage.

Figure 12.12. A spark arrester is useful in preventing release of these potential fire starters.

## Chemical Storage

The evaporator room should not be used for chemical or gasoline/oil fuel storage. There are many potentially dangerous cleaning chemicals currently available to the maple industry. Some of these chemicals are concentrated acids or detergents and should be stored, handled, used, and disposed of with caution. These chemicals should be stored with a Material Safety Data Sheet (MSDS) that covers the proper storage, use, and handling of each product. Contact the equipment dealer or supplier from which the material was purchased or the local Extension agent for additional information. To avoid inadvertent contamination, chemical products must be placed in a secure location that is out of reach of children and visitors and separate from syrup storage areas. Additionally, fuel for gas or diesel powered equipment should not be stored in the sugarhouse. The potential for contaminated syrup exists if these materials are not used or stored correctly.

## Sap Storage

Maple sap is highly perishable. Prior to processing, sap should be stored in a cool, clean environment. Tanks located in a well-lighted area that allows for easy access are more likely to be kept clean. Sap tanks should be kept out of direct sunlight to minimize accelerated spoilage due to heating. The north side of the sugarhouse receives the least amount of sun and is, therefore, a good place to locate sap storage tanks if practical. Sap stored outside the sugarhouse with minimal cover and near roadsides can be exposed to vehicle exhaust, road dust, and other airborne contaminants. Sap tanks need to be covered to avoid contamination but sufficiently ventilated to prevent the sap from heating. Sap tanks located next to a poorly insulated evaporator may be exposed to radiant heat from the arch.

Sugarmakers with buckets should plan on a minimum of 1 gallon (3.8 liters) of storage per tap. When tubing is used, plan on 1½ gallons of storage per tap for gravity systems and 2 gallons (7.6 liters) of storage per tap for vacuum systems. Extra sap storage will help prevent unnecessary loss during large sap runs or an unplanned rest day. Note that these recommendations are minimums and do not account for an increased need for storage due to a reduced production rate caused by a broken-down reverse osmosis machine, non-functioning preheater, or inoperative forced draft unit.

The location of the evaporator feed tank is particularly important. The outlet from this tank must be above the inlet point on the evaporator. If a preheater will be use, the inlet point must be higher, 18 inches (46 cm) or more above the evaporator. The more head pressure from the feed tank, the better the evaporator will function. Often this requires putting the feed tank in a loft or second story of the sugarhouse. Even a moderately sized evaporator requires several hundred gallons of sap for continuous operation. The location of all sap tanks must also allow for easy access for cleaning. It should also be remembered that a full sap tank is heavy, with sap weighing 8⅓ pounds per gallon (3.78 kilograms). Depending on the construction of the sugarhouse, extra structural support may be required to support the feed tank.

## Finished Syrup Storage

If syrup and other finished maple products are to be stored in the sugarhouse, a separate storage area is needed. Finished maple products need to be stored in a clean, cool, dry environment with minimal temperature fluctuations and little or no sunlight. The storage area should be of tight enough construction so cleanliness can be easily maintained, and insect or rodent problems kept to a minimum (e.g. concrete floor; tight walls, ceilings, doors, etc.). For safety purposes, the storage area should be lockable, and located a safe distance from fuel, chemical storage, or any other sources of contamination. If possible, the area should be insulated and air-conditioned. Location and size of the area should be considered carefully, anticipating future expansion, the need to sort inventory within the area, and the potential need for refrigerated or freezer units.

## Lighting

Good lighting is essential in an efficient operation. A well-lit sugarhouse allows for effective cleaning of the sugarhouse and production equipment, accurate grading of syrup, and a safe work environment. Sugarhouses with plenty of windows can take advantage of lengthening spring days. Windows do not need to be expensive or complicated units; simple barn sash windows are suitable.

Some form of electrical lighting is necessary for overcast days and during evening hours. Fluorescent light bulbs are energy efficient and can be used throughout the sugarhouse. These light bulbs contain mercury and should be shielded with a cover to prevent possible contamination of syrup or other maple products should any bulbs break. Fluorescent lighting fixtures are available that include safety covers designed to operate under humid or moist conditions. As a minimum, plan on 1/2 watt per square foot for fluorescent lighting and 2 watts per square foot for incandescent lighting.

## Entrances

Consideration should be given to the movement of people, supplies, fuel, and product into and out of the sugarhouse. Doors must provide enough room to move equipment, easily bring in fuel, and make it possible to take syrup out of the sugarhouse (**Figure 12.9b**). Doors that are large enough for a vehicle should satisfy these needs. Consider the flow of people in and out of the sugarhouse. If the public is going to be invited to the sugarhouse plan to have enough space for visitors while not disrupting the operation of the evaporator. Sugarmakers that sell their crop in bulk containers should have a plan for getting the syrup out the door. A full, 40-gallon (152 liter) barrel of syrup weighs 440 pounds (200 kg). A loading dock can make moving barrels of syrup easier. A door large enough to drive a vehicle in can facilitate moving large pieces of equipment in and out of the sugarhouse.

In case of fire, a sugarhouse should have at least two doors, one located at each end of the building. These exits must not be blocked when the sugarhouse is occupied.

## Maintenance

Careful construction will pay off in reduced maintenance costs in the future. The basic structure of a sugarhouse should require minimal maintenance. Leaks in the roof, walls, or floor should be dealt with before serious damage can occur. Keeping the interior clean will have many benefits including a more attractive workplace and reducing the chance of contaminated syrup.

## Pest Control

Rodents are one of the most common pests in the sugarhouse. Droppings and urine from mice can contaminate sap and syrup and pose a health threat to anyone working in the building. Simple preventative measures taken during construction can help avoid infestations. The most obvious is keeping the structure as tight as possible. Take the time during construction to caulk between joints and panels. Setting boards into fresh sealant is much more effective then covering gaps later. Avoid storing food in the sugarhouse.

## Expansion

The need for sugarhouse expansion can be the result of access to more taps or the addition of more processing equipment. The costs of expansion can be lessened with some prior planning. The foundation for a separate syrup canning room can be poured at the same time as the sugarhouse. The cost of the extra concrete and prep work is small compared to starting over. Furthermore, having a foundation is an incentive to completing the project in the future.

If changing from a wood to an oil-burning evaporator is a future possibility, place plastic conduit for fuel lines under the foundation when it is poured. It is also appropriate to consider installing extra drains for the possibility of adding a reverse osmosis machine in the future.

## Recycled Building Materials

Using recycled building materials can help reduce construction costs. Generally, the use of old windows, doors, and painted wood should be avoided unless it is certain they can be thoroughly cleaned to eliminate or cover any lead-based paint or other hazardous material that may be present. Used utility poles, railroad ties, or other chemically treated wood should generally not be used in the sugarhouse; additionally, such wood should not be used as fuel for wood-fired evaporators.

## Additional Features

Sap preheaters such as “Piggybacks” and “STEAM-AWAY®s” are filled with many gallons of sap. This additional weight requires support to prevent damage to the back pan and arch. Cables attached to collar ties can be used to relieve stress on the evaporator (**Figure 12.13**). The collar ties should be designed to handle the additional weight. Some sugarmakers have incorporated a system of rails or I-beams and winches to support and lift the back pan. These rails and winches can be attached to a wheeled carriage. This system makes the job of removing evaporator pans and ancillary equipment much safer.

Figure 12.13. Cables attached to collar ties can be used to relieve stress on the evaporator from the weight of a "Piggyback" or "STEAM-AWAY®."

Some maple producers also construct a shelf at eye level that is illuminated by a fluorescent light that can hold a grading kit. It is recommended that a diffuser screen be present between the fluorescent light and the grading kit. This simple setup provides even, consistent light behind the syrup samples and can contribute to more accurate grading.

# Chapter 13 · Safety in the Sugaring Operation

Safety must be a primary concern in all aspects of the maple syrup producing operation, from the sugarbush to the sugarhouse and to the processing-packaging facility. Practical means of addressing safety issues are identified and considered in this chapter. Chapter 12, which addresses the safe and effective design and construction of maple production facilities, is also a valuable resource and reference on safety concerns.

While some of the recommendations in this chapter may seem extreme, time and experience have proven them effective in preventing injuries and keeping workers safe. Many farm operators and enterprises have learned, sometimes the hard way, that a proactive safety and health program is necessary to reduce injury costs, control insurance rates, provide a healthier work environment, and reduce liability. All of these benefits result in increased operational efficiency and profit potential. These same management principles apply to maple operations, regardless of size.

## General Safety Concerns and Practices

### Safety and Health Principles

Most injuries have identifiable causes that are either preventable or avoidable. An incident involving an injury normally results from multiple causes, rather than from an isolated situation. Throughout life and in all agricultural operations risk is inherent. Understanding the risks involved in maple production is the key to minimizing injuries. To be human is to err and individual perceptions of risks are frequently not very accurate. When misperceptions are identified, human behavior can be changed to reduce risks. Occupational health and safety is largely a function of management, of the decisions made on a day-to-day basis, and the consequences of those decisions.

Many activities within the agricultural industry are among the most dangerous of all industries in North America. The agricultural, construction, and mining industries represent the top three industries with respect to occupational worker death rates. In the United States, the Occupational Safety and Health Administration (OSHA) regulates these industries. Generally, agricultural businesses like maple syrup production are family operated and fall below the minimum number of 10 employees to be under the jurisdiction of OSHA. In Canada, the Occupational Health and Safety Act of 1993, regulates workplace safety and health, and is the principal vehicle regulating workplaces having 10 or more workers. In smaller operations, it is the responsibility of producers to manage their business in such a manner that safety standards and practices are observed that will provide for the maximum safety of their family, their employees, and themselves.

Research has identified several steps that can ensure personal safety in the completion of any task. These include:

- Identify and eliminate all hazards associated with the job.
- Apply safeguarding technology. This involves the use of guards, shields, or other barriers, and keeping them in place and in good repair.
- Use warning signs and continually enforce their message.
- Provide training and instruction to all persons involved with the activity or task, teaching the proper procedures and operation of all machinery and equipment. Test for knowledge and understanding of safe operation before allowing anyone to perform the desired tasks.
- Prescribe the use of personal protective equipment (PPE) as appropriate for the task to be completed and the equipment to be operated.

One of the best ways to ensure that these steps are followed is to establish a "Safety Plan," an injury prevention program for the maple operation, and

assigning an individual to carry out needed procedures. This should be a written plan, perhaps kept in a notebook at a convenient location with a copy given to each worker. The following items should be part of the injury prevention program:

- Safety and Health Policy Statement (what is the objective or purpose of the plan)
- Safety Officer (who is the responsible individual)
- Training for Employees (schedule of training sessions and subjects taught)
- Inspection of Work Areas (frequency of checks and who is responsible)
- Recognition of Hazards and Corrective Measures (what to look for and how to minimize risks)
- Emergency Preparedness and Procedures (who to notify, emergency phone numbers)
- Record-Keeping System (for training, hazards identified, corrective measures followed, injuries and treatment with outcome)

A crucial part of any safety plan is hazard control, or the minimization of potential risks and problems. Not only will effective hazard control reduce or eliminate potential injury, it will also reduce potential liability exposure, assure compliance with regulations, and make employees feel good about working for you. Toward this end, the following should be inspected regularly:

- Chemical Storage and Disposal Procedures
- Electrical Systems
- Equipment Guarding and Shielding
- Fire Extinguishers
- First Aid and Emergency Equipment
- Housekeeping Procedures
- Personal Protective Equipment

The key to an effective hazard control program is to not only identifying the hazard, but taking steps to assure that appropriate corrective actions are taken.

"Telling someone *to be safe doesn't go far when* we're not setting the proper example *ourselves.*"

## Accident or Incident?

By definition, an accident is an event that cannot be prevented. In reality most occupational injuries and illnesses are preventable. The National Institute for Farm Safety (NIFS), a group made up of farm safety professionals from the United States and Canada, has considered recommending to the National Safety Council that the word "accident" be replaced with the word "incident." Reducing the number of incidents requires having a positive attitude toward safety, or stated in another way, making an informed choice at the right time.

A positive attitude begins with the leadership of the business. It must start with the owner, operator, manager, or other "team leader," and be transferred throughout the operation. Individuals learn by example and if a proper example is established by following safe operational procedures, employees and family members will quickly develop safe working habits.

## Communication

It is important to know the general location of all employees while working. If someone is headed into the woods or off to the sugarhouse they should leave word as to where they are going and at what approximate time they expect to return. Everyone involved in the operation needs to know who is working where, what activities are being conducted, and when workers are actually in the woods.

"Don't go out alone" is sound advice. From a practical point of view, this is not always possible. However, it is recommended that a "trail" be left when this is necessary. Make it easy for others to locate you if something unforeseen happens. A bulletin board mounted in the sugarhouse provides an easy way to let others know where you are going and when you plan to return. When no one is at home, perhaps a close neighbor will be willing to be a contact person. Make sure someone always knows where you are.

Communication is essential in an emergency. Post emergency telephone numbers by each phone on the property. Cell phones may provide

a means of communicating, although in some remote locations there may be a lack of adequate signal. Pre-program emergency numbers into cell phones. For "local" communication many producers rely on Citizen Band (CB) radios or other two-way radio systems. Establishing a "base station" at the house facilitates use.

### Making an Emergency Phone Call

If an emergency situation occurs maintain a sense of calmness so that the situation can be effectively communicated. To facilitate reporting an emergency situation, post critical information beside each phone, including the emergency phone number to call (911 or other); the number of the phone being used; and a brief, clear set of directions to guide emergency crews to the location. Anyone, even a visitor, can then read the information to the dispatcher and ensure that help is on the way. Instruct all employees on procedures to follow in the event of an emergency.

In general, when reporting an emergency, the following information must be conveyed to the dispatcher:

- Your name and the telephone number from which you are calling
- Nature of the problem and what help you need
- How many people are injured
- Age of the injured
- What care is being provided
- Clear directions to the location
- Additional pertinent information about the situation

At the conclusion of the call allow the dispatcher to hang up first.

## Some Common Sources of Injury for Maple Sugar Producers

There are many possible sources and types of injuries that can occur in maple syrup operations, however, some common types of injuries that can be avoided by observing recognized safety practices are identified and discussed below.

### Back Injuries and Lifting

Lower back pain is the number one musculoskeletal problem in North America. Eight out of ten North Americans have back pain at some point in their life. Problems with the lower back are the leading cause of Worker's Compensation claims, accounting for one-third of all work-related injuries. This equates to billions of dollars a year in medical and rehabilitation costs, in addition to the pain, discomfort, and lost production.

Maintaining good physical health, eating a proper diet, and getting appropriate exercise are essential to reducing the potential for injury and the need for medical intervention. Although some individuals who work outdoors may believe they get sufficient exercise, it is important to remember that not all physical activity provides the proper exercise necessary to maintain a strong and healthy back.

Observing proper lifting techniques can be helpful in minimizing problems. Recommendations for correct methods of lifting include:

- Establish firm footing, keep your feet apart for a stable base and point the toes slightly outward.
- When lifting and lowering, get a good grip on the object and keep it close to your body; place your feet close to the load and lift slowly, smoothly, and mostly by straightening the legs. NEVER use "jerking" or twisting motions while lifting or carrying anything, no matter how heavy it is.
- Keep the load close; the closer it is to your spine, the less force it exerts on your back. Minimize reaching; even relatively light loads lifted away from the body can create injurious stress levels on the spine. Move objects out of the way in order to get close to the item to be lifted.
- Bend your knees, not your waist, keeping your back upright. Keep "leverage" in mind at all times. Don't do more work than necessary. Lifting while bent at the waist means not only is the weight of the object being lifted; so is about one-half of your own body weight.
- Tighten stomach muscles. Abdominal muscles support the spine when lifting, thereby offset-

ting the force of the load. Train muscle groups to work together.

- Lift with your legs. Let the stronger leg muscles do the work, not the weaker back muscles.
- Keep the load as light and compact as possible.
- Lift only loads that can be handled safely. Test the weight of the load before attempting to lift it; if it is unmanageable, get help.
- Do not lift or lower an object with the arms extended.
- While lifting, always rotate the body by moving the feet, rather than twisting or bending the trunk.
- Avoid repetitive lifting; alternate the task with other tasks.
- Use mechanical assistance such as lift tables, hoists, and conveyors whenever possible.
- Maintain flexibility in the workplace to accommodate individuals of different sizes, weights, and strengths.

Good practical advice for preventing back injuries unrelated to lifting include:

- When operating motor vehicles use good seat positioning and lumbar support.
- Reduce whole-body vibrations when operating vehicles by using suspension seats that have appropriate vibration-dampening characteristics.

## Falls

Falls are responsible for approximately 25 percent of all work injuries. It is a common human characteristic to be in a hurry. Unfortunately, in too many cases the risk of a fall increases with an increasing pace of activity. In agriculture operations falls are commonly associated with mounting or dismounting tractors or other pieces of equipment. Conditions and actions that increase your chance for falling from the tractor or other equipment include:

- Missing the step
- Not using the grab bar
- Not watching what you're doing
- Mud, snow, or other debris coating the foot tread
- Individuals other than the driver riding on the drawbar, fender, or any location on the tractor other than the operator's seat. There is only one seat on most farm tractors, and only one person should be on a tractor.
- Jumping onto or off moving equipment. This is often a common practice during sap gathering.

Falls occur in other situations as well:

- Walking in the woods can pose increased risk of falls. During the sap season the forest floor is often icy, snow covered, wet, and/or muddy, all of which can increase the risk of falling. Running under such conditions further increases the risk of falling.
- Poor housekeeping or messy conditions add to the possibility of falls. Do not leave supplies laying around the sugarhouse or sugarbush. Maintaining an orderly facility and storing supplies and unused equipment in a proper manner will reduce the risk of falling as the result of tripping.
- Maintain a clear walkway around the evaporator and arch. For obvious reasons supplies and/or equipment should not be stored near the evaporator when it is in operation.

Good lighting will help to reduce the likelihood of falls. Steps with railings should be in good repair and kept free of ice, snow, and other debris.

## Ladder Safety

Ladders are a very common source of falls. Most falls occur as the result of using a ladder that is not in good repair, or by failing to place the ladder on a firm footing and observing good ladder handling techniques. Be sure to set the ladder on a solid footing. Remember to keep the base of the ladder 1 foot away from the building for every 4 to 5 feet of height. This 4:1 ratio will provide a stable angle that is safe and easy to climb. Individual safety and well-being on a ladder depend on observing common sense precautions. This often includes having someone steadying the base of the ladder when it is being used.

The National Fire Protection Association (NFPA) provides the following recommendations for ladder use:

- Always wear appropriate footwear and clothing when working with ladders.

- Only use a ladder in good repair.
- Use leg muscles, not back or arm muscles, when lifting ladders below the waist.
- Make sure that ladders are not raised into electrical wires.
- Check the ladder for proper angle.
- If using an extension ladder, check the hooks to be sure that they are properly seated over the rungs.
- Make sure the ladder is secure at both the top and the bottom before climbing.
- Climb smoothly and rhythmically.
- It is often necessary to carry equipment up or down a ladder. If a tool is carried in one hand, it is desirable to slide the free hand under the beam of the ladder while making the climb.
- Do not overload the ladder; check the ladder's working load limit.
- Always tie into ground ladders with a fireman's leg lock (**Figure 13.1**) when working from the ladder.
- Inspect ladders for damage and wear.
- When laddering a building, the ladder should extend a few feet (5 rungs) beyond the roof edge to provide both a footing and a handhold for persons stepping on or off the ladder.

Buy and use the right ladder for the job. When selecting a ladder the following NFPA guidelines should be observed. For a first-story roof, use a ladder that is 16 to 20 feet in length. To ladder a two-story building, select one that is 28 to 35 feet in length.

## Other Important Safety Considerations

### First Aid Training

First aid training pays off. Everyone should take a class in basic first aid and cardiopulmonary resuscitation (CPR). Refresher courses should be taken to maintain skills. Even Emergency Medical Technicians (EMTs) are required to complete on-going training and be recertified every two years.

Figure 13.1. Always tie into ground ladders with a fireman's leg lock. Leg is wrapped over and around ladder rung.

### First Aid Kit

Well-stocked first aid kits should be placed in convenient locations around the home, farm, and sugarhouse. Having one back at the house when someone is severely injured at the sugarhouse or in the woods will not be a great deal of help. Also, every tractor and motor vehicle should have a first aid kit (**Figure 13.2**).

Basic supplies for a First Aid kit for the sugarhouse include:

- Band-Aids
- Bandages and dressings
- CPR mask
- Cravats—for bandaging or making a sling
- Rubber gloves
- Splinting materials
- Sterile burn sheets

Figure 13.2. Every tractor and motor vehicle should have a first aid kit, and tractors should be equipped with a roll-over protective structure.

## Keep Rested

Fatigue can play a vital role in the ability to perform a job in a safe manner. Long hours are a given during the spring boiling season; however, long hours can also contribute to conditions where injury is more likely. As fatigue increases an individual tends to become careless, take shortcuts, pay less attention to the job at hand, and often make poorer decisions. Because not everyone responds to fatigue in the same way, each individual needs to understand how their body reacts to fatigue, and should take steps to minimize the effects of fatigue including rotating job responsibilities as available help and time allow.

Individuals who are well rested are more likely to make safe choices and sound decisions—it is important to recognize when it is time to stop!

## Youth Safety

According to the National Institute for Occupational Safety and Health (NIOSH), more than 100 children are killed and 33,000 are seriously injured on farms and ranches in the United States each year. Another 20 children are killed in agricultural-related fatalities in Canada each year.

Unintentional injury can occur when adults and children mistake a youngster's physical size and age for ability, and also underestimate the hazard and level of risk.

Children love to help, especially when it involves going out to the sugarhouse, to the woods, or to unusual destinations or locations. As experienced adults who are aware of potential risks, it is our responsibility to ensure that the tasks assigned to youngsters are appropriate for their age and capabilities (**Figure 13.3**). Many times they will want to pitch in and tackle jobs that are beyond their abilities. Remember that much of the time they just want to be there and to enjoy the companionship, fun, and excitement. They may have little or no awareness of potential dangers.

Figure 13.3. Assign children responsibilities they can safely and effectively perform, and that are appropriate for their age and maturity.

In non-agricultural industries there are federal and state/provincial regulations and work standards that indicate appropriate work tasks for both adults and children. In agriculture there are often no such standards, and children may be assigned farm jobs based on the parents' past practices, the need for "extra hands" to get the job done, and preferences of the child and/or parent. The North American Guidelines for Children's Agricultural Tasks was developed under the direction of the National Children's Center for Rural and Agricultural Health and Safety to assist adults in assigning farm jobs to children 7 to 16 years living or working on farms. This guide is available through Gempler's mail order web site (www.gemplers.com). Additional information and suggestions can be found at: http://research.marshfieldclinic.org/children.

### Liability Insurance

How much liability insurance should the maple producer carry? The answer of course will vary depending on the size, complexity, activity, and nature of the operation. However, it is important that each operation be insured to cover the risks associated with the business. Certainly coverage adequate for employee activities is a minimum. Specific needs are influenced by a variety of factors, including whether workers are family or paid employees. Additional insurance will be necessary if visitors come to the sugarhouse or sugarbush, even when appropriate precautions (signage, railings, and restraining barriers) are followed. It is recommended that each producer contact their insurance provider and inform them of the specific operation and/or situation. As has been noted, many aspects of a sugaring operation present risks and hazards often unfamiliar to guests and customers. Producers should also consider product liability insurance to provide protection in case someone who purchases maple products becomes ill or is otherwise injured by purchased maple products.

## Safety in the Sugarbush

### Use Only Food-Grade Equipment

Throughout this manual it has been repeatedly emphasized that maple producers are in the business of producing a food product. For this reason, all activities from tapping to the production of the final packaged maple product should be conducted following recognized and acceptable food handling and processing procedures. This fact is being re-emphasized since it directly affects the health and safety of all who purchase and consume maple products. In the sugarbush, all equipment related to sap collection (e.g. spouts, pails, tubing, pumps, collecting containers, transfer tanks, storage tanks, etc.) should be made of materials approved for food production. It is not recommended that producers use any materials such as tin pails, galvanized containers made with lead solder, or other collecting and sap storage containers that were not originally designed for food processing, storage, or related uses. Chemicals employed within the maple industry should be suitable for intended use and used in accordance with manufacturer instructions and accepted industry practices.

It is strongly recommended that all within the maple syrup industry continue efforts to phase-out and eliminate the use of galvanized metal containers for sap storage. Lead-free stainless steel tanks or containers made of food-grade polyethylene or fiberglass should be the containers of choice. If polyethylene containers are used, it is critical that they be approved for use with food. Much of the polyethylene used in the manufacture of plastic containers such as garbage cans and other similar storage containers is made from re-ground, non-virgin plastic and may contain ingredients that could pose a health threat.

### Be Alert to Natural Hazards

While maple producers enjoy the setting and atmosphere associated with the sugarbush and sugarhouse, it nonetheless does contain a variety of hazards that require all who work or visit there to be constantly alert. When working in the woods always make it a practice to look up from time to time to identify potential hazards that may be present. For example, the presence of barbed wire along fence lines can be a source of serious injury, whether walking or traveling at high speeds with ATVs or snow machines. "Widow-makers" or dead, hanging limbs that occur naturally or after major events such as intense summer thunderstorms, heavy snowfalls, or ice storms are especially dangerous on windy days (**Figure 13.4**). It is not recommended that anyone work in the sugarbush or woodlot on windy days; leave the woods work for a calmer and less hazardous day. Bent-over trees and saplings can hold a great deal of stored energy. When cutting them, think about the reaction that will occur when they are cut and what kinds of cutting techniques should be followed, as well as what escape path will be followed when the tree is falling. Traveling or walking on deep snow and/or ice is another obvious natural hazard during late winter and early spring.

Figure 13.4. Use extreme care when working around "widow-makers," and remove this hazard from the sugarbush as soon as possible.

## Dress Properly

Dressing appropriately means:

- Wearing clothing appropriate for the task or activity. Shorts and short-sleeved shirts increase exposure to brambles, insects, poison ivy, sunburn, and other hazards. Wear long pants and long-sleeved shirts whenever possible.
- Wearing multiple layers of clothes in cold and windy weather.
- Wearing steel-toed boots with effective sole and heel grips.
- Wearing gloves appropriate for the job to be done.
- Wearing a hardhat when working in areas with overhead hazards, especially in storm-damaged woods.
- Using chainsaw personal protective equipment, including a helmet with ear and face protection, chainsaw chaps, and cut-resistant boots.
- Using sunscreen as appropriate.

Make certain that children who are present in the sugarbush are also appropriately dressed.

## Machinery Safety

Safe tractor operation begins with trained operators. Even trained operators become tired and may fail to observe safety precautions at all times. For a maple operation, appropriate training includes familiarization with handling equipment on snow-covered, slippery roads and slopes. It may also include guidelines related to log skidding. Use tractors or other heavy equipment with roll-over protective structures (ROPS) (**Figure 13.2**), and always use seatbelts. Remember that most agricultural tractors were not designed as log skidders. Use the right machinery for the job and remember to keep all guards and shields in place, and make certain warning signs and symbols are visible. It is particularly important to make certain that all braking equipment on the tractor is operable and properly maintained.

Trailers or sleds are necessary pieces of equipment in most maple operations. Make certain the hitches are adequate for the job, and if a ball-hitch is present be sure to use the correct size ball. Draw or hitch pins should be safety clipped to prevent them from coming out while in use. Safety chains can prevent a run-away sled or trailer, and trailer brakes provide added control for sap gathering or transport trailers. Do not permit anyone to stand on the tongue or sled runners when the unit is moving. Guardrails or fenders placed around the trailer will help keep legs and feet away from the wheels.

## All Terrain Vehicle (ATV) Safety

ATVs have become a common utility vehicle around the sugarbush. When used with caution and operated properly and safely, they are a very handy, versatile piece of equipment. Three-wheel models are more dangerous due to reduced stability than four-wheel models. Most ATVs used on the farm or in the sugarbush are designed

for operators at least 16 years old. The following guidelines should be observed when they are used:

- Helmets are effective in reducing head injuries; their use is strongly recommended.
- Wear protective equipment appropriate for the conditions and job being done. This includes boots with heels, and long pants and long-sleeved shirts when working in the woods.
- Require that all new operators be properly trained.
- Always operate the vehicle at a safe speed.
- Do not operate ATVs on paved roads.
- Never drink alcohol while using an ATV!
- ATVs are not designed to carry passengers—do not ride double!
- NEVER allow visitors to use your ATV, no matter how experienced they claim to be. Adults can be as equally inexperienced as youths.
- Operate ATVs responsibly; don't show off!

## Chainsaw Safety

A chainsaw is an essential tool in most maple operations. In fact, most maple producers are so familiar with chainsaws and use them so frequently that it is easy to forget how dangerous this tool can be. Improper use of a chainsaw can result in painful, costly, debilitating, and sometimes fatal injuries. According to a recently conducted Wisconsin study, the most common injuries resulting from chainsaw accidents occur to the arms and hands (42 percent) and legs (38 percent). The remaining injuries involve the head, feet, and the upper body.

Anyone using a chainsaw should be properly trained. For most maple producers this means participating in a chainsaw use and maintenance workshop. Simply because someone has used a chainsaw for years does not necessarily mean they are using it correctly or safely. It is also recommended that periodically a refresher workshop be completed to resharpen skills, increase sensitivity to safety issues, and become familiar with new techniques. Some basic suggestions regarding the use of chainsaws include:

- Properly maintain the chainsaw. A properly running, sharp saw will be easier to use, create less fatigue, and allow more work to be done in less time in a safe manner.
- Read the owner's manual; become familiar with all features of the saw and make certain the operator is familiar with how to properly operate the saw before it is used.
- If possible, have a spare saw available. It can be used if the first saw develops problems or becomes bound in a log or tree.
- Always observe safe and effective techniques when starting and using a chainsaw (see below).
- Be alert, and don't use a chainsaw when tired. A high proportion of chainsaw accidents happen when the operator is fatigued.
- Wear protective clothing and use personal protective equipment.
- Don't work alone; when others are present remember to always maintain a safe distance.
- Don't take chances; work within your own experience, ability, and comfort limits.
- Always remember that the operator is the most important factor in chainsaw safety.

### Proper Clothing and Personal Protective Equipment (PPE)

Wearing proper clothing and using personal protective equipment are two of the most effective safeguards for reducing the possibility of serious injury when using a chainsaw (**Figure 13.5**). Proper clothing and protective gear includes wearing:

- Sturdy, snug-fitting clothing that provides complete freedom of movement. Do not wear loose clothing that could easily be caught in the moving chain, such as shirts with large cuffs, cuffed pants, baggy or loose fitting clothing, long hair, or jewelry.
- Heavy-duty, non-slip gloves to securely hold the saw and protect hands from abrasions, cuts, and splinters. Look for chainsaw safety gloves, which are specifically designed to protect hands from chainsaw injuries.

Figure 13.5. Always wear proper personal protective equipment for the job being performed.

- Steel-toe, cut-resistant boots with non-slip soles to ensure good footing.
- Approved woodcutters safety helmet with eye protection, a face screen, and ear muffs. A properly fitted helmet will be cool, comfortable, and provide protection from falling limbs. Ear muffs or ear plugs are essential to reduce potential hearing loss from loud chainsaw noise.
- Safety pants/chaps that contain pads of cut-retardant material designed to reduce the risk or severity of injury in the event of contact with a rotating chain. Safety pants/chaps do NOT prevent penetration by the chain saw, but will give the operator protection during reaction time (human reaction time is about 0.75 seconds). They are not intended as a substitute for good safety procedures when using chain saws. Follow manufacturer's instructions with regard to cleaning and replacement of safety pants and chaps.

## Some General Rules for Safe Chainsaw Use

The following rules are presented as a reminder of some important guidelines for safe chainsaw use. The list is not intended to be all-inclusive, and certainly is not adequate instruction to prepare someone to operate a chainsaw.

- Before starting the engine, make sure the chain is not contacting anything; always engage chain brake before starting.
- Do not let the saw rest on your leg or knee when starting the engine.
- Do not drop-start the chainsaw; start the saw when it is setting on the ground. An alternate method is to stand in an upright position, lock the saw between the thighs, maintain a stiff left arm and hand on saw handle, and pull starter with the right hand (or reverse if left-handed).
- Never work alone! At least be within yelling distance of help. But remember to not allow other people to be near the chainsaw when starting or cutting. When felling trees it is recommended that a two-tree height separation be maintained between workers.
- Always maintain control by standing securely, holding the saw firmly, and idling the engine between successive cuts.
- Engage the chain brake when taking more than two steps with a running saw.
- Do not work when fatigued.
- Keep saw handles dry, clean, and free from grease or oil and fuel mixtures.
- When cutting, be sure the body is clear of the natural path the saw will follow when the cut is complete.
- Never straddle a log to make a cut.
- Always shut off the engine before setting it down, even when retreating from a falling tree.
- Carry the saw with the engine stopped, the guide bar and chain to the rear, and the muffler away from the body.
- Make sure the saw is off and the chain has stopped before making any adjustments or repairs.
- Do not run the saw indoors.

- Only fuel the engine when it is cool. Do not smoke during fueling.
- Each time the saw is refueled, check the air filter, chain tension, and all nuts, bolts, and screws for tightness.
- When felling trees, know which way the tree will fall before it is cut.
- Always plan an escape route before the tree is cut.

**Kickback** is one of the greatest hazards when using a chainsaw. It occurs when the upper quadrant of the bar nose contacts a solid object or is pinched. The force produced from the moving chain throws the saw rapidly and sometimes uncontrollably up and back toward the operator. This very violent and sudden motion can result in severe injury to the operator. Kickback may occur when the nose of the guide bar is pinched unexpectedly, and contacts more solid material in the wood (e.g. knots, metal), or is incorrectly used to begin a plunge or boring cut. It may also occur when cutting limbs off the main tree trunk. The risk of kickback is increased by:

- an abrupt change in wood character (e.g. hitting a knot)
- running the chain too slowly
- twisting the saw in the cut so the chain binds or grabs
- using a dull or loose chain
- having a loose grip on the saw or cutting with only one hand
- not paying attention to movements of the saw when cutting

Kickback can be prevented or controlled with a few steps and precautions. These do not prevent kickback completely, but will reduce the likelihood of significant kickback occurring.

- Always hold the saw firmly with a both hands and keep the left arm as straight as possible.
- Use a firm grip with the thumbs and fingers encircling the chainsaw handles.
- Use a well-balanced saw equipped with a chain brake, an anti-kickback chain, a throttle interlock, and a hand guard.
- When activated the chain brake will stop the chain within a fraction of a second. This can mean the difference between a speed of 45 mph and 0 mph if the chain actually contacts the body. It is recommended that older model saws without a chain brake be replaced with new saws equipped with a chain brake.
- An anti-kickback chain reduces the forces on the chain that cause kickback. Replace worn chains with anti-kickback safety chains to reduce kickback.
- Make certain the correct tension of the chain is maintained and that the chain has been sharpened following instructions of the manufacturer.
- A throttle interlock prevents the throttle from accidentally advancing or inadvertently moving by automatically returning the throttle and chain to idle when the trigger button is released.
- The hand guard keeps the left hand from slipping forward into the chain.
- A well-balanced saw is more comfortable when operated, and is easy to control and handle under all conditions, including when kickback occurs.
- The chain brake should be checked frequently to ensure it is working properly.
- Do not rely exclusively upon safety devices; practice safety techniques when using the saw.
- During operation do not let the nose (kickback or danger zone) of the guide bar contact other objects such as a log, branch, the ground, or other obstruction.
- Watch for branches or small saplings that could snag the chain. The area in the vicinity of the chainsaw bar should be free from branches or small saplings before felling, limbing, or bucking cuts are made.
- Avoid cutting brush or shrubbery.
- Do not cut with the upper quarter of the bar tip.
- Maintain a high saw speed when entering, cutting, and exiting wood.
- Keep the chain sharp and the saw well maintained.

- Do not overreach. Do not cut at a distance away from the body that requires relinquishing a safe grip on the saw.
- Do not cut above midchest height—the saw is too close to the face and is more difficult to control.
- Use only replacement chains and bars specified by the manufacturer of the saw.

## Using Power Tapping Machines

Commercially available power tapping machines are light-weight gasoline engines appropriately geared and modified to power a tapping bit. Since some of the original power tapping machines were modified chainsaws, or used chainsaw engines, many of the maintenance and safety precautions identified in the chainsaw section are also appropriate for power tappers. As with any power tool, the operator must become familiar with the instruction manual. In addition, make sure the engine of the tapping machine is properly tuned so the bit will stop turning when the throttle is released. Keep the bit away from clothing while the machine is idling and be aware of where other individuals in the sugarbush are located when using these tools. Do not wear loose fitting clothing or clothing such as hooded sweatshirts with drawstrings as they can easily become entangled with the bit.

Newer, lightweight portable electric drills may be a safer alternative, particularly in smaller operations. Battery life is an issue in larger operations with more taps, but can be addressed by carrying multiple battery packs.

## Hearing Protection

Hearing loss is a common condition in many agricultural operations and has been called the silent epidemic. Noise-induced hearing loss affects many individuals. Loss of hearing is a slow process and usually increases gradually until the time it is recognized as a significant problem. Some early warnings signs include a ringing in the ears that doesn't go away; feeling a sense of confusion in large, loud groups; or constantly having to ask people to repeat themselves. Consult with a physician if any of these symptoms are experienced. Always use personal protective equipment (PPE) such as ear muffs or ear plugs. Wearing PPE must become a habit and be required of all workers, especially children. There are many areas of excessive noise in a sugaring operation including electric motors, vacuum pumps, tractors, snowmobiles, All Terrain Vehicles (ATVs), chainsaws, and others. (**Figure 13.5 and 13.6**).

Figure 13.6. Appropriate hearing protection should be worn whenever working around excessive noise; eye protection should be worn whenever there is potential for eye injury.

## Eye Protection

Eye injuries can cause pain, lost time and money, and even the loss of sight. Even a slight impairment in vision is a tremendous price to pay for a moment of carelessness. Wear proper eye protection (goggles, face screens, safety glasses) where potential eye injury hazards are apparent and remember to always use common sense. Common causes of eye injury in maple producers include:

- Blunt injuries to the eye from flying objects such as when splitting wood or from hitting foreign objects while walking, especially in low light situations
- Burns from flying sparks when firing the arch
- Injuries from welding, both hot materials and dangerous bright arcs or flames

- Chemical burns from being splashed during cleaning procedures.

Protective eyewear should be durable, reasonably comfortable, and fit snugly without interfering with head movement or vision of the wearer (**Figure 13.5 and 13.6**). It should be easily cleaned, capable of being disinfected, and maintained in a clean condition and in good repair. Store eyewear in clean, dust-proof containers. To shield eyes from flying particles and objects, wear industrial-rated glasses or sunglasses, or flexible or cushion-fitting ventilated plastic goggles that fit over ordinary eyeglasses. Adding side shields increases protection. Always wear splash goggles when handling and using chemicals (e.g. pan cleaners), and never wear contact lenses when handling chemicals. Full-face shields are another option for eye protection and can be worn comfortably. Maple producers should also wear appropriate welding goggles to protect the eyes from intense light and sparks during metal repair operations.

Basic eye protection for those who wear glasses or sunglasses is a necessity. Wearing ordinary glasses or sunglasses offers little or no protection from serious hazards; they may even splinter or shatter on impact. Individuals who wear glasses should wear a face shield, goggles, or safety glasses with protective lenses. All safety glasses should be of industrial-quality with flame-resistant frames.

Everyone working in the sugaring operation should become familiar with first aid treatment for eye injuries. The appropriate actions will depend on the type of injury. Some common suggestions include:

- For small foreign objects in the eye, let natural tears wash out the object. Do not rub the eye. Consult a physician if natural tearing does not remove the object. Do not remove any object that has penetrated into the eye, but stabilize the person and transport to a physician.
- For blows to the eye, apply cold compresses for 15 minutes and again each hour as needed to reduce pain and swelling. Consult a physician if the blow was hard enough to cause discoloration as internal damage may have occurred.
- For cuts and punctures to the eye, do nothing to the eye but bandage it lightly and consult a physician immediately.
- For chemical burns to the eye, irrigate the eye with fresh water for at least 15 minutes. Do not put any substance in the eye to "counteract" the chemical. Consult a physician immediately and have available the label or container of the chemical involved.

## Safety Around Livestock

Teams of horses and oxen may be used to haul sleds or wagons in some maple operations. Any experienced team handler knows to use only a "well-broke" team. However, all animals do not have the same temperament. Furthermore, individuals (guests, workers) who have not grown up with or worked around livestock may not be familiar with basic handling guidelines. If livestock are part of the maple operation, all family members and workers must be taught fundamental "livestock etiquette," or the basic "dos and don'ts" of working around livestock. It is preferable that visitors not be permitted to come into direct contact with livestock; all viewing should be done from a distance. If visitors are allowed to come into direct contact with livestock, including livestock-drawn wagon rides, instruction regarding basic characteristics and handling procedures is necessary, as well as an awareness by the producer of the implications for liability and insurance.

## Install Caution Signs

Install caution signs strategically to safeguard family, workers, and visitors. The hazards identified and the cautions addressed as well as the number of signs required will depend on the character of the operation. In operations where visitors are welcome, caution signs need to be more numerous and address hazards understood by family and workers but unfamiliar to visitors. All exits should be clearly marked.

## Cold Temperature Injuries

Injury from cold temperature is a very distinct possibility when working outdoors during the winter. Before going outside during wet or stormy conditions, make certain to dress warmly, as

becoming both cold and wet increases the risk for cold temperature injury. Minimize exposed areas of the body as injuries from cold temperatures are more likely on noncovered areas such as hands, ears, and face.

Hypothermia, or low body temperature, can be a life-threatening condition. Hypothermia occurs when the body loses heat faster than it can be maintained, thereby resulting in the body's inner core temperature dropping to below normal. Normal body temperature is at or near 98.6°F (37°C), however, when the core body temperature drops below 95°F (35°C), hypothermia develops. Most commonly hypothermia occurs after prolonged exposure to freezing or near freezing temperatures. Because hypothermia may develop slowly, often the victim may not realize it is happening. If the cooling process is not reversed death may occur. Symptoms of hypothermia include:

- Uncontrollable shivering
- Bluish tint to skin
- Poor coordination
- Slowing pace in walking or other activities
- Increasing numbness and loss of dexterity
- Dazed or confused look and actions, drowsiness
- Slurred and slow speech and slow to respond to questions
- Dilated pupils
- Hallucinations
- Decreased attention span and changes in personality

### Field Treatment for the Victim of Hypothermia

- First, if the person is unable to communicate or is no longer shivering, immediately call for an ambulance to transport the person to an Emergency Department.
- Seek professional treatment as soon as possible even if signs of hypothermia are no longer evident. Serious health problems or death can arise from even slight hypothermia.
- Get the victim into a shelter or area that can be heated slowly. Do not set the victim too close to a fire or heat source as a slow warm-up is better.
- If in an open area, block the victim from wind with a sleeping bag, tree limbs, etc. If no shelter or heat source is available, congregate as many people into as small an area as possible to allow their body heat to warm the victim's environment.
- Encourage movement of the victim, but do not make movements for them.
- If the victim is conscious and alert, slowly feed them warm (approximately 110°F/43°C), sugary liquids like hot chocolate, bouillon, or plain hot water. Do not give them alcoholic beverages.
- Wrap the victim in warm blankets or sleeping bags.
- If using people to warm a victim, remove wet clothes as they draw heat from the body. The warmer (person aiding the victim) and the victim should be nude (underwear can be left on), as body-to-body contact is needed to start warming the victim. Each warmer should exercise vigorously before and after contact with the victim to maintain his or her own body temperature. The warmers should rotate every 30 minutes to allow them time to get their body temperature up to normal.
- Keep the victim's head level with body, with slight elevation of legs and feet.

### When Helping a Victim of Hypothermia

- Never leave them alone
- Never apply ice
- Never rub, massage, or force movement of victim's body
- Never apply heat directly to the victim's skin
- Never give alcoholic or caffeinated beverages as these may provide a false sense of warming when they actually work against the body's efforts to warm the blood
- Never allow smoking as it curtails blood circulation
- Never give medications like painkillers, sedatives, or aspirin as they may mask the real condition of the individual

**Frostbite** is perhaps the most common cold weather injury, and also one of the most serious because affected tissues are actually frozen. Freezing permanently damages human cells. Areas most likely to be affected by frostbite include the ears, nose, cheeks, feet, fingers, and toes. Learn to recognize the following early symptoms:

- Tingling (pins-and-needles) feeling in area
- Numbness and loss of sensation to touch
- Affected area may feel cold, hard to the touch
- Blisters may appear on the skin
- Skin of affected area may take on a white tint or pale, even marbled look that can appear waxy
- Absence of pain in affected area
- Slurred speech and memory loss

### Treatment for Frost Bite Is Similar to Hypothermia

- Move victim indoors or to a sheltered, preferably warm location.
- Get medical attention as soon as possible.
- Never rub the affected areas as it causes damage to frozen tissue.
- Warm affected area slowly.
- Do not place direct heat on affected areas.
- Immerse frozen parts in warm water or wrap in a warm compress (100°F or 38°C) for 20 to 30 minutes. Do not let the victim control water temperature or heat source as they may not be able to feel the effects of water too hot and can suffer burns.
- Keep affected area elevated.
- Wrap area in warm blankets once pink or reddish color returns.
- Do not let affected area be exposed to the cold again.
- Serving a warm beverage is good, but not alcoholic beverages.

The severity of frostbite increases with the depth of the frozen tissue. Deep frostbite is the freezing of tissue, blood vessels, veins, muscles, tendons, nerves, and even bones. Any frozen tissue or organ can suffer irreversible damage in a short time period, or lead to further complications including infection, blood clots, and gangrene. Victims of frostbite are often more susceptible to future frostbite injury.

### Snowshoes

When the depth of snow on the ground exceeds a foot or more, snowshoes can save time and energy, and provide access to otherwise inaccessible areas. However, as with any tool, efficient and safe use requires care and practice. Beyond mastering the use of snowshoes, be careful not to get bogged down in deep, soft snow. The effort to get out can rapidly drain energy from an already tired body resulting in overexertion. In addition to contributing to excess fatigue, this overexertion could result in a heart attack or overheating, followed by rapid cooling in sweaty and wet clothes, leading to hypothermia.

Use extra care when working on slopes. Ice grippers are very useful when icy, crusty conditions are present. Be especially careful when crossing a stream, as the snow or snow and ice covering may not support your weight. As with most woods activities, from a safety perspective, snowshoeing is best done when accompanied by another person.

## Safety at the Sugarhouse

### Use Only Food-Grade Equipment

In discussing safety in the sugarbush it has been repeatedly emphasized that maple syrup producers are in the business of making a food product, and that all activities and equipment, from the tap to the finished and packaged maple product must be completed in a manner appropriate to food preparation, processing, and storage. This guiding principle is equally important in the sugarhouse. It is strongly recommended that equipment specifically manufactured for maple production be used. When using non-maple equipment, make certain it is of food grade quality.

It is not recommended to use tin pails or galvanized containers, particularly those made with lead solder, for collecting and storage of sap and syrup. Also containers that at any time contained oil, pesticides, plaster, or other harmful materials

should not be used as well as plastic transfer lines or containers not specifically intended for use with food. Lead-free stainless steel, food-grade polyethylene, and fiberglass containers should be the containers of choice. If polyethylene containers are used, it is essential that they be approved for use with food.

Old milk or cream cans and older galvanized drums once were common in many sugarhouses. Use of these containers is not recommended, either for sap or syrup storage, since they are fabricated from materials that may have a high lead content.

## Sap Storage

Make sure that the sap storage tank framing is structurally sound, and strong enough to support the weight of the tank(s) when filled with sap. Remember, sap weighs approximately 8⅓ pounds per gallon. Before any tank is filled, it should be inspected to ensure the tank framing support is sufficiently strong enough to handle the weight of the tank(s) and its contents when filled. If changes are made in tank capacity or fill level (e.g. more taps are added to the system so the tank can be expected to hold more sap), re-evaluate the tank framing to ensure that it is adequate. If unsure, contact a carpenter or structural contractor for an onsite analysis of the current design, materials, and workmanship.

## Fuel System Safety

### Wood

Wood is the traditional fuel for the sugarhouse. Wood should be carefully stacked in the woodshed to ensure that the stack is stable and not likely to fall. When wood is used during the sugaring season, remove wood from the top down, rather than from the face of the pile. This will ensure the pile does not become top-heavy. Sparks are always a threat when burning wood; care must be taken, especially late in the season after the snow has melted, to safeguard against sparks that may ignite dry combustibles, leaves, stored wood, and other tinder. Windy conditions can increase the danger from sparks. There is also an increased chance of back draft when the fire doors of the arch are opened, blowing hot burning embers out onto the sugarhouse floor. Keeping paper, wood, and other combustible materials picked up can prevent a potential fire, especially around the front of the arch. Prior to the beginning of the season, consider hiring an independent inspector to conduct a thorough check of the arch, stack, and all joints to be sure that they are in safe operating condition. If holes, perforated metal, or rusted and weak areas are found, replace the defective sections with new equipment.

Maple producers have developed various forms of spark arresters to be attached to the top of the smoke stack (**Figures 13.7 and 12.12**). Wood fires can create large amounts of sparks, especially if resinous softwoods are used for fuel. A spark arrester will minimize the danger of sparks being emitted from the smoke stack. Spark arresters are particularly valuable during the latter part of the season when the snow cover is gone.

Figure 13.7. Spark arrester on top of smoke stack.

### Fuel Oil

Oil burners should be inspected and adjusted if necessary before the season begins. Likewise, during operation they should be serviced on a regular basis and maintained as required. Do not disable any safety devices that have been designed and built into the unit as they serve a vital

purpose, namely to protect the operator and the facility. Inspect all fuel lines, fittings and connections, and valves to be sure the system is ready for the maple season. Remember to uncap the stack prior to firing the burners as a buildup of stack pressure will not only affect performance of the burner, but could also contribute to a safety problem. If the burner does not ignite after one or two attempts, stop and wait at least five minutes before attempting again. If the unit still does not ignite, shut off the power to the burner and call for repair service. The fuel oil tanks should be located separately from the evaporator room and away from the parking area. A fuel containment system, equal to the size of the tank's capacity should be constructed to capture any spilling oil in the event of a tank rupture or leak. This may be a concrete structure surrounding the fuel tank.

### Propane/Natural Gas

Propane or natural gas is used to fuel evaporators in some parts of the maple region. The same safety precautions should be taken for these units as for fuel oil.

### High-Pressure Steam

While not commonly used by maple producers, high-pressure steam is a safe, efficient, clean heat source that can be used to produce a high quality maple product. For most maple producers, however, its use will require mastering new knowledge and methods somewhat different from those associated with more traditional heat sources. As with any "new" technology, it presents its own set of safety concerns. For example, unlike other systems there are no open flames and the fuel and stack are well away from the boiling pans. On the other hand, a thorough understanding of boiler management is crucial, and the potential for severe burns is greater due to the high temperature of the steam. It is essential that anyone using high-pressure steam thoroughly master the knowledge and practice of using this method, and know and adhere to the rules, regulations, and safety requirements appropriate for their locale. In most areas where maple syrup is produced, steam boilers must be inspected periodically by the proper authorities.

### Carbon Monoxide

All types of fires produce carbon monoxide, an invisible, odorless, deadly gas. Carbon monoxide poisoning is a danger any time there is fire or combustion, whether it is from wood, oil, gas, or anything else that will burn. To detect carbon monoxide levels in buildings, detectors are commonly installed about as frequently as are smoke detectors. The construction of new, tighter sugarhouses has increased the possibility of high carbon monoxide levels in the work area. Provision for a supplemental air source for combustion should be considered if very tight structures are built. In newer structures producers should consider installing carbon monoxide detectors, particularly in any building with sleeping quarters. Smoke detectors should also be installed.

### Fire Extinguishers

The sugarhouse and all vehicles used in sugaring operation should have fire extinguishers. A fire extinguisher is the first and often only line of defense in the event of a fire. There are many different types and sizes of portable fire extinguishers. Minimally, an ABC type dry chemical extinguisher of at least 10-pound (4 kg) size should be placed in service near the entrance to the sugarhouse.

Fires are categorized by type:

**Class A** fires include most common combustibles (e.g. trash, wood, paper, clothing)

**Class B** fires are flammable liquids, oils, and grease

**Class C** fires are all energized electrical fires.

Three commonly available portable fire extinguishers include the following:

- Dry chemical extinguishers are among the most commonly used portable fire extinguishers. Multi-purpose dry chemical agents themselves are nontoxic and are generally considered safe to use. However, when released the cloud of chemicals may reduce visibility and can create respiratory problems for some. Many dry chemical agents are corrosive to metals, although this is a secondary concern

in the event of a fire. It may be advisable to have an alternative type of extinguisher available (e.g. carbon dioxide) in the sugarhouse for use with fires of different origins. An ABC dry chemical extinguisher is acceptable for all types of fires. If only one type of fire extinguisher is installed it should be an ABC dry chemical extinguisher.

- Carbon dioxide is stored in extinguishers as a liquefied gas ready for release at any time. Small dry ice crystals or carbon dioxide "snow" usually accompany the gaseous discharge. When released the carbon dioxide ($CO_2$) gas displaces available oxygen and smothers the fire. The dry ice crystals also lower the temperature of the fuel. Carbon dioxide produces no vapor-suppressing film on the surface of the fuel, so re-ignition is always a possibility. Carbon dioxide extinguishers are acceptable for all types of fires.
- Stored-pressure water extinguishers, also called air-pressurized water (APW) extinguishers, are useful for small Class A fires. Water-type extinguishers should be protected from temperatures lower than 40°F (4°C). This may be a problem in unheated sugarhouses. Freeze protection may be provided by adding antifreeze to the water or by storing in a warm area. Pressurized water extinguishers should be used for Class A fires only. Never use a water extinguisher on Class B fires as rapid spreading of the fire could occur if the burning liquid is dispersed. Likewise these extinguishers should not be used on electrical fires as the danger of electrocution could result from water contacting an energized electrical system.

Extinguishers should be checked frequently to verify that they are fully charged and operable. They should be placed in strategic locations that are clearly visible throughout the facility. Installing bright red and white "Fire Extinguisher" signs will help identify the location of each extinguisher.

Everyone who works in the sugarhouse should be trained in the proper operation of the extinguisher. The following four-step procedure, known as the P.A.S.S. system, should be used.

- **P**ull the pin.
- **A**im at the base of the fire, stand about 8 feet (2 to 3 meters) back.
- **S**queeze the handle.
- **S**weep from side to side until the fire is completely out.

When in doubt, don't take chances. After the fire has been extinguished it is advisable to contact the local fire department to come and check out the situation. Too often following a fire producers have shut down the operation and left the facility only to return to a burned-down sugarhouse.

## Electrical Safety

The human body was not designed to tolerate contact with electrical current without significant harm. In fact, under certain conditions an electrical shock of less than 1/10 amp can be fatal. Proper grounding of all electrical services and equipment is absolutely necessary for personal safety and the safety of the investment. Grounding also eliminates the dangers of ground-fault hazards.

The electrical service should be installed and maintained by a qualified electrician. While many maple producers believe they can adequately wire a sugarhouse or pumping facility, it is always recommended that a competent electrician inspect the completed installation. It is also advisable to perform an "electrical service check" on a regular basis. Some of the questions that should be addressed when completing the inspection include:

- Has it been 10 or more years since the service was installed?
- Have significant changes been made in electrical usage or consumption that has increased the load on the system since the installation was completed?
- Do the lights dim when certain equipment is turned on?
- Do motors run "hot"?
- Are circuit breaker ground fault switches tripping regularly, or do fuses blow frequently?
- Was the original system installed or since modified by someone other than a qualified electrician?

If the answer to any of these questions is yes, it is recommended that a certified electrician inspect the service and make any needed modifications.

Ground fault circuit interrupters (GFCI) (**Figure 13.8**) should be used to protect all circuits in the sugarhouse. A ground fault occurs when electric current in an electrical circuit travels outside its intended path. If a person's body provides a path to ground for the stray current, serious injury or even death may occur. Ground faults often result from damaged electrical wiring or water getting into electrical equipment. These are both situations that could occur in a sugarhouse. A ground fault circuit interrupter is an inexpensive electrical device that constantly monitors electricity flowing in a circuit and trips or shuts off the current if the electricity to an electrical device differs even slightly from that returning. The primary purpose of the ground fault circuit interrupter is to protect individuals from electrical shock, burns, or even electrocution.

The advantage of using GFCIs is that they detect even those amounts of electricity too small to trip a fuse or circuit breaker. Three types of UL listed GFCIs are readily available:

- Wall Receptacle GFCI—replaces the standard wall outlet currently installed.
- Circuit Breaker GFCI—in buildings equipped with circuit breakers, this type of GFCI may be installed directly into the panel.
- Portable GFCI—this unit requires no special knowledge or equipment to install. It can be plugged into a regular grounded outlet, and the electrical appliances are plugged into the GFCI outlet. (**Figure 13.8**)

Because a GFCI detects ground faults, it can also prevent some electrical fires and reduce the severity of others by interrupting the flow of electrical current. GFCI's should be tested monthly; a "TEST" button is present on the unit to allow testing. The GFCI should disconnect the power to that outlet. Pressing the "RESET" button reconnects the power. If the GFCI does not disconnect the power it should be checked by a qualified electrician, and may need to be replaced.

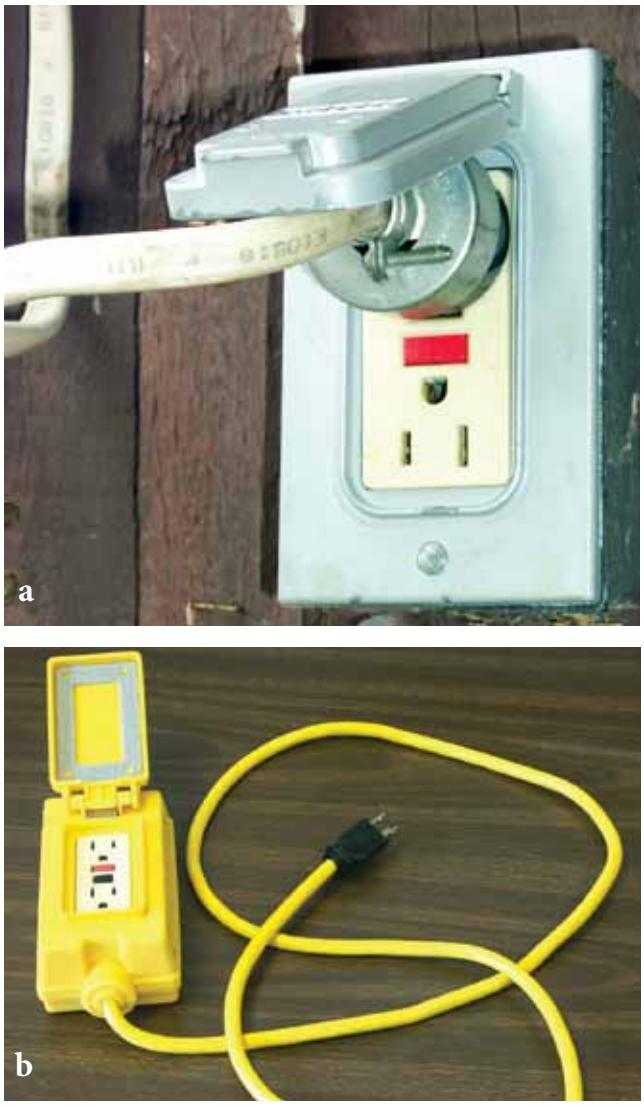



Figure 13.8. Permanently installed (a) or portable (b) ground fault circuit interrupters (GFCI) should be used to protect all circuits in the sugarhouse.

Ground Fault Circuit Interrupters should be installed and used anywhere moisture may be present, or where portable electric tools may be plugged into the circuit and used on damp ground or under damp conditions. This includes just about every location in the sugarhouse. Moisture-proof covers should be installed over receptacles that have the potential of becoming wet.

## Lighting

Good lighting is essential to safe and efficient operations. Lighting needs should be carefully determined before fixtures are purchased and installed. A well-illuminated sugarhouse will increase the efficiency of the many operations

that occur there. Important areas that need illumination include pathways to and around the sugarhouse, the pump room, the sap storage area, the room where the reverse osmosis unit is located, over the evaporator, and in the woodshed. Covered, shatter-proof bulbs/fixtures should be installed wherever there is possible contact with sap or syrup. A combination of fluorescent and incandescent bulbs may be necessary as some are more appropriate for different applications and locations. For example, fluorescent lighting is more efficient than incandescent bulbs and is a better substitute for natural lighting when grading syrup. However, cold temperatures may cause difficult, delayed start-up, or even failure of some fluorescent units. Spotlights can provide valuable additional point lighting when directed at the syrup draw-off, filtering, or canning area.

## Floors and Floor Drains

Sugarhouse floors should be finished to provide an easily cleanable, non-slippery surface. Provision should also be made for floor drains to handle water, sap, and other liquids that result from condensation, spillage, and cleaning. Several of the features and desirable characteristics of sugarhouse floors and drains are discussed in Chapter 12.

## Traffic Flow

Traffic pattern and flow in the sugarhouse can be a major concern, especially in sugarhouses that are open to visitors. When the sugarhouse is occupied with several individuals, the risk of injury to both workers and visitors is increased. Care must be taken to ensure that injuries resulting from falling or burns do not occur. Railings, walkways, or barriers may be a practical means of allowing visitors to observe boiling and other activities while maintaining a safe distance from equipment. This may be especially important if large groups including tourists, school children, or others can be expected to visit the operation. Most visitors to the sugarhouse will not be familiar with sap collection, evaporation, and other processing operations, or the risks associated with these activities (**Figure 13.9**).

Figure 13.9. Railings, walkways, or barriers may be a practical means of allowing visitors to observe boiling and other activities while maintaining a safe distance from equipment.

## Burns

Burns are one of the most frequent injuries occurring in the sugarhouse. Common burns include burning the hands when reaching over the front pan with a scoop or opening a stem hood door, or burning the face when opening the steam hood door and looking in. Producers should be aware that steam hoods are under a slight positive pressure when the damper is partially closed, resulting in steam rushing out when the hood doors are opened.

Time is critical for initiating appropriate first aid treatment for burns. Some suggestions include the following:

- Cool all burns quickly to minimize the severity of the damage to tissue that lies under the skin. One of the best steps is to immerse the burned part immediately in cold water. In the sugarhouse cold sap works just as well. Snow is also often readily available to cool a burn.
- Keep the affected areas cool for 10 to 15 minutes.
- After cooling, cover the skin with a dry, sterile dressing and bandage loosely.
- Whenever there is any question as to the severity of the burn, the victim should be seen by a physician.
- A physician should see individuals who suffer burns to the head, face, or chest as soon as possible. Severe burns in these areas increase the risk of serious injury to the respiratory system.

- At no time should ointments, salves, or butter be applied to the site of any burn; these do not aid in the healing process and may increase opportunity for infection of the wound.

A pair of welding or fireplace gloves used when refueling the arch will reduce the likelihood of burns to fingers and hands.

## Avoiding Spills

Remove the handles from unused valves to avoid an accidental opening that could cause spilling of both hot and valuable contents. By the same token, make operations easier and safer by putting handles onto pans, buckets, or other containers used for dumping sap or pouring hot syrup.

## Water Supply

Whenever possible sugarhouses should be constructed in locations where a dependable source of clean, running water is present. Processing equipment should be cleaned after use with non-contaminated clean water. A dependable source of clean water will help with personal hygiene, washing, processing, and packaging and in keeping the facility as clean as possible. An adequate pressurized source of running water can also be very helpful in the event of a fire.

Sugarhouses that do not have running water have successfully used large, plastic water tanks to store a day's supply of water, or larger tanks periodically filled from a truck to hold a longer supply[80]. When this is done, the tanks should be made from food-grade material, and should be cleaned and sanitized on a regular basis. In many sugarhouses water produced from equipment such as preheaters, STEAM-AWAY®s, Piggybacks, or reverse osmosis units are an excellent source of clean water, some of which may be hot depending on the source.

It is important that water in the sugarhouse be of high quality and potable (suitable for human consumption). Untreated water sources, such as a well or spring, can contain microbiological, chemical, and physical contaminants. Regular testing of untreated water for potential impurities can help prevent individuals from becoming sick, or tainting otherwise good quality syrup. Sugarmakers should check with local county health departments to obtain information about water testing.

## Cleaning Equipment Safely

Several of the commercial cleaners used to remove sugar sand (niter) and other materials from the surface of maple equipment are defined as Hazardous Materials (HazMat) in both the United States and Canada. To use these products in a safe and environmentally friendly manner, it is important that the user read, understand, and follow the information and directions provided on the labels (**Figure 13.10**). Do not use cleaners that do not have adequate instructions. Obtain, read, and understand the Materials Safety Data Sheet (MSDS) provided for each product. The MSDS contains essential safety and handling information including chemical composition, identification of degree or type of risk or danger, first aid information, and recommendations for safe use, transport, storage, and disposal. Labels should remain with the cleaner so they can be referenced as needed. One copy of the MSDS should remain in the storage cabinet or on file for reference, and one copy should be posted in a visible location in the sugarhouse. In the event of an emergency, the information contained in the MSDS could be critical to providing helpful information to emergency personnel, the physician, or poison center.

When using cleaners:

- Buy only the amount of cleaning materials that will be used in the current season. Avoid storing cleaners from one season to the next, as this may constitute an unnecessary hazard.
- Use the exact amount as directed on the label.
- Drain empty cleaner containers for 30 seconds before rinsing.
- Triple-rinse each empty container. A triple rinse requires the container be rinsed and thoroughly drained, and then rinsed and thoroughly drained two more times.
- Dispose of empty containers in accordance with the label and local recycling regulations.

[80] Some local, state, or provincial regulations permit this, others do not.

- Use recommended personal protective equipment (PPE) identified on the label such as goggles, a face shield, protective gloves, an apron, boots, etc.
- Store all chemicals and their MSDS in a secure (locked), dry storage facility according to manufacturer's recommendations. This location should be separate from the evaporation room and the parking area.

Do not contaminate local water supplies or the local environment when disposing of cleaning solutions or rinse water by dumping them into a stream, "over the bank," or out the back door. Always follow the printed disposal instructions found on the label and consult local environmental regulators if there are questions. Be aware that any pollution of local water supplies can affect water sources used for drinking and other uses.

## Heavy Metals—Lead and Mercury

Public concern about contamination of food materials with "heavy metals" such as copper, mercury, cadmium, and lead has increased in the lasts several years. Evidence is available that links the presence of these metals to serious health problems. The majority of maple syrup producers are aware of the potential health hazard posed by the small amounts of lead that may be present in finished syrup. Since the mid-1990s substantial efforts have been undertaken by all involved in the maple industry to reduce or eliminate the potential for lead contamination in the maple production process. Equipment and production practices appropriate to this effort have been discussed in several places in this manual. They are summarized here since they can have a direct and extremely important effect on the health and safety of producers as well as consumers.

To reduce or eliminate the potential for lead contamination in maple syrup production:

- Upgrade/replace older equipment made with lead solder by using only lead-free, stainless steel equipment or food grade plastic.
- Eliminate the use of galvanized equipment in the storage of sap and processing of maple syrup. Older galvanized metal tanks, especially those soldered with lead solder, can contain high levels of lead.
- Process all sap quickly; do not let sap set in storage tanks or syrup in the evaporator for long periods of time.
- Boil water in the evaporator pans and rinse before boiling sap.
- Do not clean lead soldered equipment with corrosive acid or alkaline cleaners.
- Clean evaporator pans with soft water, or water obtained from preheaters and reverse osmosis equipment.
- Test for lead in the solder with a lead testing kit. These kits are available at most hardware stores in the United States, or from Extension advisors and inspectors in Canada.
- If syrup is still produced using equipment that contains lead, periodically test syrup for the amount of lead that may be present. At the time of publication of this manual the guideline for permissible lead level in most states and internationally was 500 parts per billion (ppb); in Vermont the acceptable level was 250 ppb.

Although it hasn't received the publicity or notoriety that lead has, mercury is another heavy metal of concern to maple producers. Excess exposure to mercury can contribute to a variety of health problems. To eliminate the primary risk of mercury exposure in the sugarhouse, do not use mercury-containing thermometers that might break.

## Processing and Packaging Area

High temperatures can be a potential hazard in the sugarhouse, packaging room, and candy kitchen. Exercise particular care when working around finishing or reheating units, or when handling open containers of hot syrup. When bulk quantities are handled in this area, safe lifting practices need to be enforced so that the likelihood for back injuries, slips, or falls is minimized. In the warehouse area, stack barrels and other supplies carefully to reduce the likelihood of falling. Caution should be exercised any time motorized vehicles are used to transfer supplies throughout the storage facility. Motorized

vehicles should be equipped with backup alarms and operated only by workers who have received proper training in their use.

## Visitors

The use of barriers, marked travel ways, and other facility modifications to minimize the risk of injury to visitors is discussed elsewhere in this chapter and manual. In addition to what has been presented, before allowing groups to visit a maple producing facility, some practical awareness training should be provided. Information should be provided to potential visitors, including school administrators, teachers, and other group leaders, about preparing students, parents, and others for a fun, educational, and safe experience. The information and advice provided should include a discussion of expected behavior (particularly important with younger visitors and their chaperons), potential hazards, areas of restricted access, and recommended dress (warm clothing and boots if going into the sugarbush), as well as what not to wear (such as nylon jackets that may be affected by high temperatures). Lastly, each group visit should begin with a welcome that includes an orientation about what will be seen and what can be expected as they visit the facility.

Figure 13.10. To use cleaners and other chemicals safely and in an environmentally friendly manner, it is important to read, understand, and follow the information and directions provided on the labels.

# Appendix 1 · Maple Equipment Manufacturers and Sources of Information

This Appendix contains contact information for a variety of industries, agencies, and organizations of particular value to maple producers. Included in separate lists are

- Major Equipment Manufacturers
- Manufacturers of Accessory Equipment (e.g. refractometers, color meters, ROs, automatic draw-off systems)
- Container Manufacturers
- North American Maple Associations
- Media Resources (e.g. periodicals)
- United States Government Resources
- State Resources
- Canadian Government Resources
- Provincial Resources

Contact information for each entry in this Appendix includes the address, phone number, FAX number, and e-mail and web address if available. In many instances one or more contact persons are identified. All of this information is current as of the publication of this manual, but some will certainly change over time, particularly individual contact persons and their personal contact information. Companies, agencies, and organizations will be more stable. Web addresses, however, change frequently. If the contact information provided in this Appendix no longer works, new contact information for most of the entries will be found by running a Web search using one of the search engines (e.g. Google, Yahoo, others)

## Equipment Manufacturers

**D. G. U.S.A., Inc.**
164 Yankee Park Road, Fairfax, Vermont 05454, USA
Phone: (802) 524-9625 Fax: (802) 524-9643
E-mail: info@domgrimm.com
Web: www.domgrimm.com/

**Dominion & Grimm, Inc.**
8250 Marconi, Ville d'Anjou, Montreal, Quebec, H1J 1B2, Canada
Phone: (514) 351-3000 Fax: (514) 354-6136
E-mail: info@domgrimm.com
Web: www.domgrimm.com/

**Evaporateurs Dallaire, Inc.**
280 chemin St-Hilaire, St-Evariste, Quebec, G0M 1S0, Canada
Phone: (418) 459-6218 Fax: (418) 459-3210
E-mail: evapdal@globetrotter.net
Web: www.cdl-dallaire.com

**GBM LLC**
33186 County Highway W., Holcombe, Wisconsin 54745, USA
Phone: (715) 447-8440 Fax: (715) 447-5560
E-mail: gbmllc@yahoo.com
Web: www.gbmllc.com

**H2O Innovation / Darveau, Inc.**
201, 1ère Avenue, Ham-Nord, Quebec, G0P 1A0, Canada
Phone: (819) 344-2288 Fax: (819) 344-2706
E-mail: info@h2oinnovation.com
Web: www.h2oinnovation.com

**Lapierre USA, Inc. (Division of Lapierre, Waterloo Small, Inc.)**
102 Airport Access Road, Swanton, Vermont 05488, USA
Phone: (802) 868-2328 Fax: (802) 868-4113
E-mail: lapierreusa@yahoo.com

**Leader Evaporator Co., Inc.**
49 Joergin Drive, Swanton, Vermont 05488, USA
Phone: (802) 868-5444 Fax: (802) 868-5445
E-mail: sales@leaderevaporator.com
Web: www.leaderevaporator.com

**Les Equipements D'Erabliere CDL Inc.**
257 Route 279, St-Lazare Quebec, G0R 3J0, Canada
Phone: (418) 883-5158 Fax: (418) 883-4159
E-mail: equicdl@globetrotter.net
Web: www.cdl-dallaire.com

**Les 'Equipments Lapierre, Inc.**
99 Rue De L'Escale, St-Ludger, Beauce, Québec, G0M 1W0, Canada
Phone: (819) 548-5454 Fax: (819) 548-5460
E-mail: info@equipementslapierre.com
Web: www.equipementslapierre.com

**Lapierre Waterloo Small Inc.**
201 Rue Western C.P. 610, Waterloo, Quebec, J0E 2N0, Canada
Phone: (450) 539-3663 Fax: (450) 539-2660
E-mail: info@equipementslapierre.com
Web: www.equipementslapierre.com

**Maple Pro**
39 Rewes, St. Albans, Vermont 05478, USA
Phone: (800) 762-5587 or (802) 527-0000
Fax: (802) 524-3666
E-mail: info@maplepro.com
Web: www.maplepro.com or www.cdl-dallaire.com

## Equipment Accessories

**Airablo, Inc.**
1700 `rue Principale, St-Adrien de Ham, Québec, J0A 1C0, Canada
Phone: (819) 828-2828 Fax: (819) 828-3408
E-mail: airablo@airablo.com
Web: www.airablo.com

**Atago USA, Inc.**
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**Hanna Instrument USA Inc., Corporate Office**
584 Park East Drive, Woonsocket, Rhode Island 02895, USA
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Fax: (401) 765-7575
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Web: www.hannainst.com/

**Hanna Instruments Canada, Inc.**
3156 Industrial Boulevard, Laval, Quebec, H7L 4P7, Canada
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**Marcland Instruments USA, Inc.**
220 River Road, Schroon Lake, New York 12870, USA
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E-mail: marcland@bluemoo.net
Web: www.marcland-usa.com

**Misco Palm Abbe**
3401 Virginia Road, Cleveland, Ohio 44122, USA
Phone: (866) 831-1999 or (216) 831-1000
Fax: (216) 831-1195
E-mail: www.misco.com/email-form.php
Web: www.misco.com

**Wes Fab**
14420 12th Avenue, Merrill, Wisconsin 54452, USA
Phone: (715) 536-0501 Fax: (715) 536-6994

## Container Manufacturers

**The Bacon Jug Company**
**Division of Gamber Container, Inc.**
46 North Littleton Road, Littleton, New Hampshire 03561, USA
Phone: (603) 444-1050 Fax: (603) 444-6659
E-mail: info@baconjug.com
Web: www.baconjug.com

**Hillside Plastics Inc.**
**Sugarhill Containers**
262 Millers Falls Road, Box 490, Turners Falls, Massachusetts 01376, USA
Phone: (413) 863-2222 Fax: (413) 863-3774
E-mail: crusso@hillsideplastics.com
Web: www.hillsideplastics.com

**Les Cruchons J.U.G.S. Inc.**
1233 Cameron, Hawkesbury, Ontario, K6A 3S8, Canada
Phone: (613) 632-0622 or (877) 632-0622
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E-mail: gerard@cruchonsjugs.com
Web: www.cruchonsjugs.com

**New England Container Company**
60 Jonergin Drive, Swanton, Vermont 05488, USA
Phone: (802) 868-3171 Fax: (802) 868-3172

## North American Maple Associations

**American Maple Museum**
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Joe Polak, Secretary/Treasurer

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Larry Myott, Executive Secretary

## Media Resources

**Farming: The Journal of Northeast Agriculture**
374 Emerson Falls Road, P.O. Box 449, St. Johnsbury, Vermont, 05819, USA
Phone: (802) 748-8908 or (800) 422-7147
Fax: (802) 748-1866
E-mail: farmingpr@farmingmagazine.com
Web: www.farmingmagazine.com
Published Monthly
Robert Montgomery, Editor

**Maple Syrup Digest**
P.O. Box 240, Canterbury, New Hampshire, 03224, USA
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E-mail: mapledigest@tds.net
Published 4/year
Roy Hutchinson, Editor

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4318 State Route 22, Salem, New York, 12865, USA
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Published 8/year

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**United States Standards for Grades of Maple Syrup–United States Department of Agriculture**
U.S. Dept. Of Agriculture, AMS FV Processed Products Board, 1400 Independence Ave., SW Stop 0247, Washington, D.C. 20250, USA
Phone: (202) 720-5021 or (800) 333-4636
Fax: (202) 690-1527
E-mail: webmaster@usda.gov
Web: www.ams.usda.gov/standards/mplesirp.pdf or www.usda.gov

**United States Department of Agriculture–National Agricultural Statistics Service**
USDA-NASS, Room 5829 – South, Washington, DC 20250, USA
Phone: (800) 727-9540 or (202) 720-3878
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E-mail: nass@nass.usda.gov
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**United States Food and Drug Administration**
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E-mail: webmail@oc.fda.gov
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## State Resources

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**Maple Syrup Producers Association of Connecticut Inc.**
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Newsletter: Drop In The Bucket–Published 2/year
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Newsletter: The Tapline–Published: 4/year
Louise Jewell, Public Relations

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Newsletter: Massachusetts Sugarbush News–Published: 2/year
Tom McCrumm, Coordinator, Editor

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Newsletter: Michigan Maple Syrup Association Newsletter – Published: 3/year
Tom Cook

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Newsletter: The Gathering Tank–Published: 2/year
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**New York State Maple Producers Association Inc.**
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Newsletter: The Pipeline–Published: 3/year
Mary Jeanne Packer

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Newsletter: The Ohio Maple News–Published: 4/year
Roger Gortner, President

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Newsletter: The Drop Line–Published: 4/year published electronically
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## Rhode Island

Note: Most Maple Producers in Rhode Island belong to the Connecticut Maple Producers Association. Look at the Connecticut section to find contact information.

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Tom Abbott, Principal Forester

## Vermont

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Web: www.vermontmaple.org/
Newsletter: Maple Mainline, Published: 2/year
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**Proctor Maple Research Center, University of Vermont**
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Bruce Martel, Ag Development Coordinator

### Wisconsin

**Wisconsin Maple Syrup Producers Association**
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Newsletter: Wisconsin Maple News–Published: 2/year
Gretchen Grape, Executive Director–Joe Polak, President

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## Canadian Government Resources

**Agricultural Canada Statistics on Maple**
Statistical Reference Centre (National Capital Region)
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Web: www.statcan.ca/english/freepub/23-221-XIB/free.htm

**Agriculture and Agri-Food Canada (AAFC)**
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## Ontario

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# Appendix 2 · Maple Chemistry and Quality

Maple sap is composed of a mixture of water, organic, and mineral constituents. During the process of collection and boiling, a number of physical and chemical changes occur which result in the transformation of maple sap into syrup. Since maple syrup is a food product, the large number of steps involved in the sugaring process requires care to maintain a high level of quality, and to insure there is no contamination with any potentially harmful substances. Finally, it is necessary for the industry and regulators to continue to develop and utilize a variety of methods to detect adulteration, which will ensure that maple remains a pure and wholesome food product.

## Chemical Composition of Sap

Several, but not all of the components of maple sap have been described in detail (**Table A2.1** through **Table 2.5**). The exact levels of these substances will vary from producer to producer, region to region, from season to season, and within a season (**Table A2.4**). It is important to identify and understand the roles and interactions of sap precursors of maple syrup colors and flavors in order to minimize syrup off-flavors and to maximize production of light syrup grades.

**Table A2.1** shows the range of values of the organic compounds in maple sap. Total sap solids, which are predominantly sugars, commonly range from 1.0 to 5.4 percent, with an average content of 2.0 to 2.5 percent, but can range up to 10 percent or above. The percent solids concentration in sap is typically measured in degrees Brix (°Brix), a measurement which is commonly used by the food industry for expression of sweetness of fruit juices, other sweetened beverages, and syrups. Since sugars comprise more than 98% of the solids in sap, the Brix measurement of sap is commonly referred to as the percent sugar concentration. The prevalent sugar in maple sap is sucrose, which typically comprises 98 to 99 percent of the dry matter in sap. In addition to sucrose, however, sap contains a small percentage (2 percent or less) of various other substances including: amino acids, organic acids, phenolic compounds, hormones, minerals and salts, and other components. These are used by the tree in a variety of physiological processes to help initiate and regulate growth.

The mixing and interaction of these compounds during boiling of sap is what accounts for the flavors (and some off-flavors) associated with maple syrup. Syrup colors are determined primarily by the types of sugars (**Table A2.2**) and the length and intensity of boiling. Amino acids (**Table A2.3**) and some organic acids (**Table A2.4 and A2.5**) are responsible for the characteristic "maple" flavor and for some of the off-flavors, such as "metabolism" or "buddy." The role of nitrogenous and phenolic compounds on syrup grade is not well known, however, they may be involved in flavor determination, and have been implicated in the occasional problem of syrup darkening and layering during storage.

## Chemical Composition of Sugar Sand

As sap is heated to concentrate sugars, other constituents of sap will also be concentrated, eventually forming a precipitate called "sugar sand," "niter/nitre," or "scale." Sugar sand ranges in appearance from a white, to brown, or even black, sand-like crystalline substance, or it can be oily, viscous and sticky. Maple niter is composed primarily of calcium and magnesium compounds of malic acid (**Table A2.6**), commonly calcium malate.

Sugar sand often precipitates onto the surfaces of the evaporator, where it can cause scorching or burning of the syrup and equipment and impart a bitter taste to the syrup. Sugar sand particles that are suspended in maple syrup must be filtered prior to sale, otherwise they will cause cloudiness, a gritty-texture, and digestive problems if consumed in moderate quantities. The amount

and type of sugar sand varies from sugarbush to sugarbush, from season to season, and within an individual season. Methods to remove sugar sand from maple syrup are described elsewhere in this manual. One important aspect of sugar sand is that it may contain very high levels of lead, therefore good filtration is imperative in maintaining low syrup lead levels.

## Sap Chemical Changes Due to Wood Metabolism

The biochemical composition of maple sap is dependant chiefly upon the genetic and physiological status of the tree. Environmental factors such as weather and tree health may also be important contributing factors. Maple trees respond to various conditions and stresses in their environment by triggering physiological activity. Warmer air temperature affects tree cell and tissue metabolism, which in turn influences sap biochemistry. For example, amino acid changes in the spring prior to maple bud break (**Table A2.3**) are related to warming trends. Phenolic compounds may also vary in accordance with tree health.

## Sap Chemical Changes Due to Microorganisms

Sap within a tree is generally sterile; however, sap is rapidly colonized by a variety of microorganisms upon exiting the tree. If clean practices are used during sugaring operations, a low microorganism count (< 1,000/ml sap) can be achieved, especially in the early season when the temperature is still cold and collecting systems are fairly clean. Towards the end of a season, heavy microbial loads exceeding one million to one trillion per milliliter of sap may be found. Such contamination might not be obvious to the producer until sap becomes quite turbid (cloudy) and milky looking.

Microorganisms grow rapidly in maple sap. Warm temperatures greatly enhance the growth and reproduction of microorganisms. Sap within maple tubing can reach temperatures considerably higher than the outside air. As the sun increases sap temperature within plastic tubing, microorganisms grow rapidly, doubling in number approximately every twenty minutes.

Microbes, which in large part cause "drying out" of sap flow from tapholes, also induce changes in sap biochemistry. In addition, these microorganisms adhere to the walls of maple tubing, impeding the flow of sap through the system.

Storage tanks can also rapidly become contaminated with microorganisms. Previous studies have shown that microorganisms increase more rapidly if sap temperatures are warm (60°/15°C). Cooler storage conditions for short time periods are best to maintain high sap quality. At higher temperatures during the season, short storage time is crucial to ensure high sap quality.

Activity of microorganisms on sap reduces sap quality by influencing the form of sugars in maple sap, and thus causing darkening of color, a higher degree of caramelization, and higher invert sugar levels. Maintaining good filtering procedures for sap reduces microbial loads. In addition, treating sap by in-line UV light has been demonstrated to kill or weaken microbes, resulting in the production of higher grade syrup. Attempts to sterilize sap using ozone are in experimentation, however, early results do not appear to be promising because the high sugar level in sap appears to inhibit the efficacy of ozone on microorganisms.

## Chemical Composition of Maple Syrup

Pure maple syrup consists predominantly of sugars, with sucrose being the major type, comprising 88 to 99 percent of the dry weight of syrup. The remaining sugars (0 to 12 percent) are primarily hexoses (also called "invert sugars", glucose and fructose) with only trace amounts of other sugars (**Table A2.2, Table A2.7**). Other chemical components of maple syrup include amino acids, proteins, organic acids, and vitamins.

Maple syrup ranges from slightly acidic to slightly alkaline. Caloric content at standard density is approximately 50 calories per tablespoon.

The results of several mineral analyses of maple syrup are shown in **Table A2.7**. In general, the values tend to agree across a wide geographic range. Maple syrup is particularly high in potassium and calcium, with a somewhat lower amount

of magnesium. Sodium (unless made from sap from roadside trees where road salt is prevalent in the soil) and phosphorus are found in still lesser amounts.

Maple syrup also contains various metals, including (in decreasing concentration) iron, zinc, tin, and copper. Lead, chromium, antimony, nickel and cadmium are, on rare occasion, found in minute amounts (**Table A2.7**).

Several organic acids have been identified in maple syrup. Malic acid is the most prevalent, with fumaric, citric, and succinic acids being present in varying amounts (**Table A2.7**). Additionally, maple syrup contains low levels of several vitamins, especially thiamin, niacin, and riboflavin, with trace amounts of folic acid, biotin, pyridoxine (vitamin B6), and vitamin A present.

## Colors, Flavors and Off-Flavors

Sap biochemistry is the main factor that influences the color and flavor, and thus grade of maple syrup produced. Sap that has not been affected, or only slightly affected by microorganisms, will produce light grades of syrup with a subtle maple flavor. When sap has been heavily acted upon by microorganisms, darker colored and stronger-flavored syrup will be the result.

Maple sugar made by freeze-drying sap is very light in color and has only a faint, sweet flavor. Color and flavor develop primarily during the early stages of boiling sap. Research indicates that the interactions among the level and forms of sugars, amino acids, and phenolic compounds give rise to the color and flavor of maple syrup upon heating. Carmelization and darkening of syrup during boiling is chiefly attributed to prior microbial activity on sap, although the exact development of these changes is not entirely understood.

Syrup color is generally determined by light transmittance at standard density and temperature using either spectrophotometric transmission measurements (**Figure A2.1**), a permanent optical color comparator (e.g Lovibond) or, more commonly, a temporary grading kit made of glycerin and caramel coloring. A newer device based upon a portable spectrophotometer has recently been introduced, but has not yet gained wide acceptance.

Several off-flavors may be found in maple syrup; not all can be attributed to specific causes, as many factors that occur before, during, and after processing can affect flavor. Some of the more common off-flavors and their causes are described in Appendix 4.

Ongoing studies at the University of Vermont Proctor Maple Research Center and at Centre Acer are focusing on the origins of "metabolism" or "woody" off-flavor. The compound most commonly associated with this off-flavor is 2, 5-dimethy pyrazine, sometimes with other

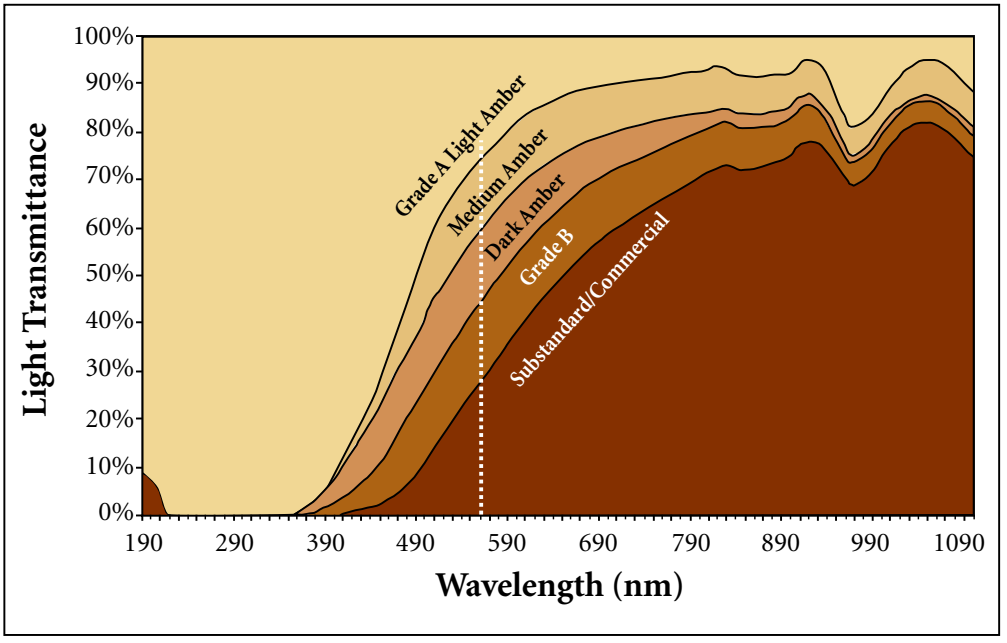



Figure A2.1. Light transmittance profiles of maple syrup measured with a spectrophotometer. Syrup grade is determined by the transmittance value at 560 nm.

associated pyrazine compounds. However, the precise environmental and management activities that lead to strong development of this off-flavor are not yet certain.

## Contamination and Adulteration of Maple Syrup

Food adulteration is regulated under the U.S. Food, Drug and Cosmetics Act and the Canadian Food and Drugs Act. Adulteration covers many different types of activities, including: the accidental or deliberate addition of substances; substitution of less expensive, but similarly tasting ingredients; the addition of non-declared substances; contamination by filth or pesticides; the presence of naturally occurring toxic materials; and contamination by microorganisms.

In general, adulterants are found in maple syrup either due to inadvertent contamination, or by deliberate addition of various substances in an attempt to alter the characteristics or value of syrup. Contaminants of maple syrup include substances which are accidentally introduced into maple sap during collection and processing, or materials which maple syrup comes in contact with that causes an undesirable addition of these materials to maple syrup. Contaminants include cleaning residues, diatomaceous earth (used in filter presses), excessive defoaming agents, microorganisms responsible for fermentation, paraformaldehyde, lead and other heavy metals, and almost anything else that can accidentally be introduced into sap and syrup.

In general, sap and syrup are kept free of contaminants by careful attention to the materials and methods used in collecting and processing sap into maple syrup. Sugarhouses should be kept clean to the extent possible, and possible contaminants stored in areas away from the sap storage, syrup production, filtering, canning, and syrup storage areas. It is important that maple producers utilize food-grade materials and cleaning chemicals that are intended for use in the maple industry. There is growing public interest and scrutiny by consumers of how food products are grown and manufactured, as well as an increasing understanding on the part of maple producers that they are no longer just making maple syrup, but rather, they are making a food product.

Although the exact regulations may vary from place to place, it is incumbent upon maple producers to know the rules in their area. In general, producers must use only equipment that was produced for the maple industry, or, in the case of sap collecting equipment, is suitable for potable water use. All tubing, mainline, and sap storage tanks should be of either food-grade or water-potable construction. All materials should be kept clean and free from contamination and microbial growth. Plastic tanks constructed for stock animals and pipe intended for non-potable water use (e.g. septic pipe, most garden hoses) are not considered food grade as they are typically made using "re-grind" plastic, which may contain hazardous materials.

The majority of maple equipment made prior to 1990 contains some lead. Because sap is often slightly acidic, and may remain in buckets, tanks, and evaporators for many hours, it may accumulate lead from soldered equipment, terneplate (a lead alloy formerly used in buckets), and older galvanizing materials. Lead may then become concentrated during the boiling process. Although the majority of maple syrup produced contains nondetectable or very low levels of lead, in rare cases lead may be found in higher concentrations. Different states and provinces have set action-levels for lead in maple syrup, and frequently do random testing of producers and packers to ensure that lead levels remain low. Producers should consider testing their maple syrup on occasion, and, if necessary, replace equipment or follow recommended practices to reduce lead in their product.

Paraformaldehyde (PFA) can also be a contaminant of maple syrup. PFA tablets were once legally permitted as a means of inhibiting microbial growth in tapholes to extend the time during which sap would flow. Because PFA was later banned after it was shown that it caused extensive internal damage to trees (Houston et al. 1990), and

no legal use was permitted, the EPA revoked the former 2 mg/kg tolerance for added residual PFA, but did not set a limit for naturally-occurring PFA in maple syrup. Recent research has determined that formaldehyde typically occurs in very low amounts (usually < 0.5 mg/kg) in maple syrup, however, under certain conditions, natural aldehydes in maple syrup form formaldehyde when exposed to excessive heating (scorching). The illicit use of PFA has declined rapidly in recent years due to increased regulatory inspections and the testing of sap and syrup for formaldehyde residues.

The quality and character of maple products is also affected by collecting, storage, processing, and packaging equipment and materials. An industry group of maple equipment manufacturers (Les Manufacturiers d'Équipements Acéricoles—LMEA 2002) recently set minimum standard guidelines for their members to adhere to in the choice of materials and design of equipment and equipment parts in the maple industry. These standards were designed to reduce or eliminate contamination of maple sap and syrup by equipment in order to preserve the integrity of maple products. Similarly, regulators and the maple industry have developed guidelines for sanitizing, disinfecting, and cleaning products used in maple production.

The use of Hazard Analysis and Critical Control Points (HACCP) is also beginning to appear in the maple industry. HACCP is based upon using a systematic approach to the identification, evaluation, and control of hazards related to food safety. For each industry and setting, a HACCP plan is developed which is aimed at ameliorating chemical, biological, and physical hazards through the establishment of preventative procedures at a series of critical points in the process. At this point, HACCP procedures are primarily being used by maple syrup packers, however, some of the lessons gained will undoubtedly trickle down to the individual producer over time.

Distinct from accidental contamination, deliberate adulteration is generally recognized as the addition of sugars other than that derived from maple (such as cane, corn, or beet sugar), however, adulteration also includes the purposeful illegal addition of materials with the intent to alter the properties of syrup, or the misuse of products in common use in the maple industry. Several different types of materials may be used for different purposes.

Adulteration of maple syrup by adding other types of sugar violates state, provincial, and federal laws; defrauds consumers; and is damaging to the maple industry. Detection of sugar adulteration is possible within reasonable limits by the application of the carbon stable isotope ratio test (SIRA), natural isotope fractionation nuclear magnetic resonance spectroscopy (SNIF-NMR) methods, and other analytical methods.

Besides substitution of other, less expensive forms of sugar for maple, the next largest form of adulteration is artificial lightening of syrup to form a higher grade. Several different methods may be used to attempt this, including charcoal filtration, hydrogen peroxide, bleach, and other substances. Although some of these materials may be of some value in the maple industry when used correctly, it is the misuse of these chemicals that causes problems. Fortunately, these methods are readily detectable or cause undesirable side-effects in the syrup. Residues from many of these adulterants are detectable using simple test strips, which allow regulatory inspectors and volume purchasers a rapid means to screen suspect syrup.

A more recent concern is the possible illegal use of anion exchange resins developed by the cane sugar industry to remove color from liquid sugar. These resins do result in removal of color bodies from maple syrup with little change to the bulk chemistry of syrup. A method for screening maple syrup for detecting the possible use of anion exchange processing of maple syrup is in development and testing.

**Table A2.1. Organic Composition of Sugar Maple Sap[1].**

| Total Solids | 1.00–5.40% |
|---|---|
| Sucrose | 98.00–99.99% |
| Invert sugar (glucose) | 0.00–0.17% |
| Phenolic compounds | 0.00–4.55 ppm |
| Primary amines | 0.53–36.10 ppm |
| Peptides | 0.40–18.57 ppm |
| Amino acids (free) | 0.00–11.30 ppm |
| Proteins | 0.00–50.90 ppm |
| Organic acids | 2.03–45.00 ppm |
| pH | 3.9–7.9 |

[1]Morselli, 1980 (unpublished)

**Table A2.2. Sugars in Maple Sap and Syrup[1].**

| Sugars[a] | Sap Percent | Sap (dry weight) Percent | Syrup (dry weight) Percent |
|---|---|---|---|
| Hexoses | 0.0 | 0.0 | 0–12 |
| Sucrose | 1.44 | 96.00 | 88–99 |
| Raffinose and a glycosyl | .00021 | .014 | — |
| Oligosaccharides[b] | | | |
| I | .00018 | .013 | — |
| II | .00020 | .014 | — |
| III | .00042 | .028 | — |

[a]Typical values, not averages.

[b]The oligosaccharides have been isolated by chromatography but have not been identified.

[1]Willits and Hills, 1976, p. 66.

**Table A2.3. Free Amino Acids in Sterile Maple Sap[a].**

| | 1977 | | | 1979 | | | |
|---|---|---|---|---|---|---|---|
| | 3/9 | 3/15 | 3/27 | 3/27 | 4/11 | 4/13 | 4/20 |
| Taurine | tr | | | | | | |
| Urea | * | * | * | * | * | * | * |
| Aspartic Acid | * | * | tr | * | * | * | * |
| Theonine | | | | | | * | * |
| Serine | * | | | | | * | * |
| Asparagine/Glutamine | * | * | * | * | * | * | * |
| Glutamic Acid | tr | | tr | | * | * | * |
| Citrulline | | | | | | * | |
| Glycine | * | tr | tr | | tr | | |
| Alanine | | | tr | | | | * |
| Valine | | | | | | * | * |
| Methionine | | | | | | * | * |
| Isoleucine | | | | | * | * | * |
| Leucine | | | | | | * | * |
| Tyrosine | | | | | | | * |
| Phenylalanine | | | | | | | * |
| B-Aminoisobutyric Acid | | | | | | ? | ? |
| -Aminobutyric Acid | ? | ? | ? | * | ? | | |
| Ornithine | | tr | | | | | |
| Ammonia | * | * | * | * | * | * | * |
| Histidine | | | | | | | * |

[a]Free amino acids in sterile (0-1 CFU/m1) sap of two representative maple trees during the 1977 and 1979 season (Morselli and Whalen, unpublished).

KEY: * = quantifiable amount; tr = nonquantifiable amount; ? = uncertain, but most likely nonquantifiable amount.

**Table A2.4. Organic Acids in Sugar Maple Sap (per 100 mL) Throughout a Maple Season[1].**

| Flow date[a] 1980 | Sample size (mL) | Oxalic | Succinic | Fumaric | 1-Malic | Tartaric | cis/ Aconitic | Citric/ Aconitic | Total |
|---|---|---|---|---|---|---|---|---|---|
| **Parts per Billion (ppb)** | | | | | | | | | |
| 3/20 | 156 | 760 | 2300 | 200 | 4300 | 95 | 100 | 140 | 7895 |
| 3/23 | 151 | 250 | 600 | 55 | 1400 | 46 | ___b | 46 | 2407 |
| 3/27 | 101 | 130 | 740 | 1300 | 12000 | 110 | 160 | 150 | 14590 |
| 3/31 | 111 | __b | 340 | 30 | 45000 | 36 | __b | __b | 45406 |
| 4/07 | 148 | __b | 570 | 6800 | 12000 | 6 | 320 | 100 | 19867 |
| **Individual Acids as % of Total Acids** | | | | | | | | | |
| 3/20 | 9.6 | 29.0 | 2.8 | 54.0 | 1.2 | 1.3 | 1.3 | | |
| 3/23 | 11.0 | 25.0 | 2.3 | 58.0 | 1.9 | ___ | ___ | | |
| 3/27 | 0.9 | 5.2 | 8.8 | 82.0 | 0.8 | 1.1 | 1.1 | | |
| 3/31 | ___ | 0.7 | <0.1 | 99.0 | <0.1 | ___ | ___ | | |
| 4/07 | ___ | 2.9 | 35.0 | 59.0 | 0.3 | 1.6 | 1.6 | | |

[a]Five sap collecting dates, representing early-to-late sap flow season, from one sugar maple, one termination.

[b]Not detected using the above given sample size (detection limit = 15 ppb).

[1]Mollica and Morselli, 1984, p. 1127.

**Table A2.5. Organic Acids in Sugar Maple Sap (per 100 mL) in Three Individual Sugar Maples[1].**

| Tree[a] | Sample size (mL) | Oxalic | Succinic | Fumaric | 1-Malic | Tartaric | cis/ Arconitic | Citric/ Shikimic | Total |
|---|---|---|---|---|---|---|---|---|---|
| **Parts per Billion (ppb)** | | | | | | | | | |
| 1 | 151 | 260 | 600 | 55 | 1400 | 46 | __b | 46 | 2407 |
| 2 | 150 | 350 | 240 | 300 | 880 | 79 | __b | 190 | 2039 |
| 3 | 154 | __b | 710 | 1000 | 10000 | 45 | 120 | 91 | 12466 |
| **Individual acids as % of Total Acids** | | | | | | | | | |
| 1 | | 11.0 | 25.0 | 2.3 | 58.0 | 1.9 | ___ | 1.9 | |
| 2 | | 17.2 | 11.8 | 14.7 | 43.2 | 3.9 | ___ | 9.3 | |
| 2 | | ___ | 5.7 | 11.3 | 80.9 | -.4 | 1.0 | 0.7 | |

[a]One sap collection date (3/23/90), representing early sap flow, one determination per tree.

[b]Not detected using the above given sample size (detection limit = 15 ppb).

[1]Mollica and Morselli, 1984, p. 1128.

**Table A2.6. Composition of Sugar Sand[1].**

| | | |
|---|---|---|
| Sugar sand (in run) | % | 0.05–1.42 |
| pH | | 6.30–7.20 |
| Ca | % | 0.61–10.91 |
| K | % | 0.146–0.380 |
| Mg | % | 0.011–0.190 |
| Mn | % | 0.06–0.29 |
| P | % | 0.03–1.18 |
| Fe | ppm | 38–1,250 |
| Cu | ppm | 7–143 |
| B | ppm | 3.4–23 |
| Mo | ppm | 0.17–2.46 |
| Free Acid | % | 0.07–0.37 |
| Total malic acid | % | 0.76–38.87 |
| Acids other than malic | % | 0.08–2.62 |
| Undetermined material | % | 6.94–34.16 |
| Calcium malate | % | 1.30–49.41 |
| Sugars in dried samples | % | 33.90–85.74 |
| Sugar sand in dried samples | % | 14.26–66.09 |

[1]Willits and Hills, 1976, p. 66.

**Table A2.7. Organic and Inorganic Composition of Maple Syrup.**

| | Morselli[1] | Stuckel[2] | Dumont[3] | Perkins[4] | van den Berg[5] | Typical Mean |
|---|---|---|---|---|---|---|
| **General** | | | | | | |
| Total Solids (%) | 66.5 | 63.2–69.5 | — | — | 62.0–68.0 | 65 |
| Moisture (%) | 33.5 | 26.5–39.4 | — | — | — | — |
| pH | — | 5.6–7.9 | 5.7–8.5 | — | 5.5–7.3 | 6.4 |
| Conductivity (µS) | — | — | — | — | 96–318 | 189 |
| **Carbohydrates** | | | | | | |
| Sucrose (%) | 58.5–65.8 | 51.7–75.6 | 42.3–74.0 | — | 59.4–73.8 | 66 |
| Glucose (%) | 0–7.3 | 0.0–9.6 | 0.0–7.2 | — | 0.0–1.6 | 0.4 |
| Fructose (%) | Trace | 0.0–4.0 | 0.0–6.8 | — | 0.0–1.1 | 0.5 |
| **Minerals and Metals** | | | | | | |
| Nitrogen (%) | — | — | — | — | 0.001–0.077 | 0.03 |
| Potassium (ppm) | 1300–3900 | 1055–2990 | 541–4031 | 1600–2590 | 963–3319 | 2283 |
| Calcium (ppm) | 400–2800 | 266–1707 | 183–1943 | 600–1250 | 278–2494 | 911 |
| Magnesium (ppm) | 12–360 | 10–380 | 11–575 | 0–198 | 25–543 | 177 |
| Manganese (ppm) | 2–220 | — | < 1–252 | 0–117 | 0.01–223 | 39.8 |
| Sodium (ppm) | 0–6 | — | < 1–261 | 0–27 | 0.01–492 | 36 |
| Phosphorus (ppm) | 79–183 | — | < 2–235 | 20–113 | 0.01–91 | 37 |
| Iron (ppm) | 0–36 | — | 0–18 | 0–18 | 0.01–61 | 10 |
| Zinc (ppm) | 0–90 | — | 2–43 | 0–96 | 0–130 | 22 |
| Aluminum (ppm) | — | — | — | — | 0.01–18 | 2 |
| Boron (ppm) | — | — | — | — | 0.01–3 | 0.2 |
| Sulfur (ppm) | — | — | — | — | 0.01–100 | 18.2 |
| Copper (ppm) | 0–2 | — | 0–8 | 0–6 | — | 1.2 |
| Tin (ppm) | 0–33 | — | — | 0–24 | — | 8 |
| Lead (ppm) | 0–0.25 | — | 0–0.49 | 0–0.35 | — | 0.20 |
| Cadmium (ppm) | — | — | 0–0.09 | 0–0.07 | — | < 0.02 |
| **Organic Acids** | | | | | | |
| Fumaric Acid (%) | 0.006 | 0.001–0.012 | 0.0–0.13 | — | — | |
| Malic Acid (%) | 0.141 | 0.06–0.66 | 0.32–0.90 | — | — | |
| Citric Acid (%) | 0.015 | — | — | — | — | |
| Succinic Acid (%) | 0.012 | — | 0.0–0.26 | — | — | |
| | Morselli | CANDI6 | FAP7 | | | |
| **Vitamins** | | | | | | |
| Thiamin (ppm) | — | 1.3 | 1.3 | | | |
| Niacin (ppm) | 0.16 | 1 | 1 | | | |
| Riboflavin (ppm) | 0.046 | 0.6 | 0.6 | | | |
| Folic Acid | Trace | — | — | | | |
| Biotin | Trace | — | — | | | |
| Pyridoxine (B6) | Trace | — | — | | | |
| A | Trace | — | — | | | |

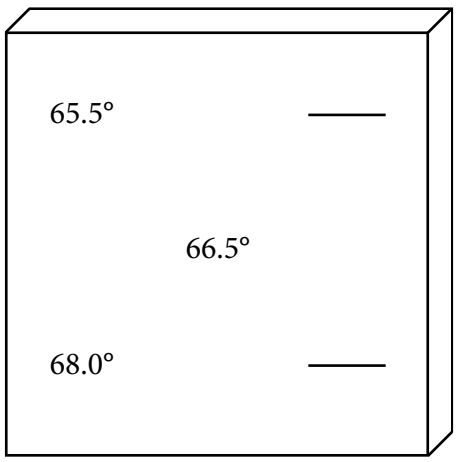
[1]Morselli, 1975, [2]Stuckel and Low, 1996, [3]Dumont, 1996, [4]Perkins (unpublished), [5]van den Berg, Perkins and Isselhardt (unpublished), [6]CANDI, [7]Food Analysis Plus

# Appendix 3 · Determining Proportions when Adjusting Off-Density Syrup by Blending with Syrup, Water, or Sap

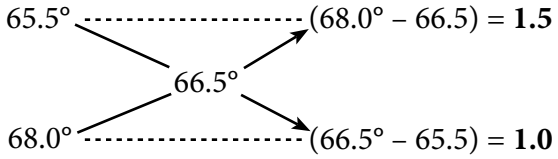
## Determining Proportions when Blending Syrup with Syrup

Determining the proportions of two different lots of syrup of known densities to mix to obtain a blend with the desired density can be done very simply, quickly, and directly using a Pearson's Square calculation, sometimes referred to as the method of allegation. This is the same method used by wine makers to determine the proportions of two wines to blend to obtain a desired alcohol level. The method is best explained by example using two syrups with densities of 65.5° Brix and 68.0° Brix to obtain a blend with a density of 66.5° Brix.

Visualize the method utilizing a diagram similar to the five side of a die. In the upper and lower left-hand corners write the densities of the two syrups to be blended; in the center of the diagram write the density of the desired blend. In our example:




Subtracting across the two diagonals provides the proportion (by weight) of each syrup required to produce the desired density. Always subtract the smaller number from the larger, irrespective of its location. The proportion (by weight) of each syrup to be blended is the number located directly across from it in the diagram. In our example:



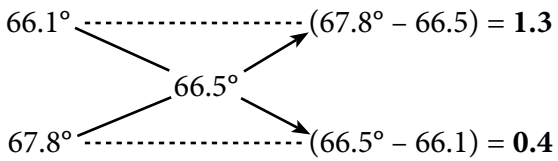

Blending 1.5 parts 65.5° Brix syrup with 1.0 part 68.0° Brix syrup results in a blend with a density of 66.5° Brix . If we had 150 pounds (68.3 kg) of 65.5° Brix syrup and wished to raise its density to 66.5° Brix by blending it with 68.0° Brix syrup, we would calculate the amount of 68.0° syrup required by solving for "x" in the simple ratio:

$$\frac{1.5}{1.0} = \frac{150\#}{x}$$

Accordingly, 100 pounds (45.5 kg) of the 68.0° Brix syrup should be blended with 150 (68.3 kg) pounds of 65.5° Brix syrup to produce 250 pounds (113.8 kg) of 66.5° Brix syrup.

As noted above, the Pearson's square calculation calculates the mixing proportions on a weight basis. However, since the difference in weight between syrups of different densities is relatively small, the proportions calculated using the method of allegation can be applied to volumes with relatively small error. In our example, applying the proportions to volume and mixing 1.5 gallons (5.7 liters) of 65.5° Brix syrup with one gallon (3.8 liters) of 68.0° Brix syrup would produce 2.5 gallons (9.5 liters) of 66.52° Brix syrup—two hundredths of a Brix too high. This accuracy is well beyond that which producers will ever measure.

Let's look at one more example of blending syrups with slightly messier results. Suppose we have 120 pounds of 66.1° Brix syrup we would like to blend up to 66.5° Brix using 67.8° Brix syrup. Using the Pearson's square to determine the proportions to blend:



Solving the ratio as in the previous example, the amount of 67.8° Brix syrup to be blended with the 120 pounds of 66.1° Brix syrup is determined as follows:

$$\frac{1.3}{0.4} = \frac{120\#}{x}$$

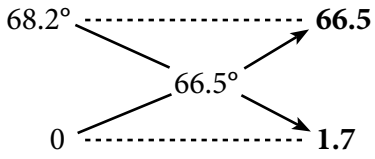
One hundred twenty pounds (54.5 kg) of 66.1° Brix syrup combines with 36.9 pounds (16.8 kg) of 67.8° Brix syrup to produce 156.9 pounds (71.3 kg) of 66.5° Brix syrup. Similarly, 3 gallons (11.36 liters) of 66.1° Brix syrup could be combined with 0.92 gallons (118 fluid ounces or 3.48 liters) of 67.8° Brix syrup to produce 3.92 gallons (14.8 liters) of 66.5° Brix syrup.

## Determining Proportions when Blending Syrup with Water or Sap

When blending syrup with water or sap on a weight basis, the proportions to mix can be determined using a Pearson's square calculation in the same way it was used when blending syrup with syrup. When blending on a volume basis, the proportions must be adjusted because of the substantial difference in the weight of syrup and water or sap.

### Blending on a Weight Basis

Blending on a weight basis will be considered first, with the question how much water to blend with 350 pounds of 68.2° Brix syrup to reduce its density to 66.5° Brix. First, determining the proportions to mix:

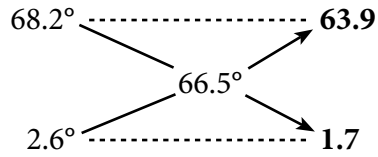



Then applying the ratio calculation to the proportions:

$$\frac{66.5}{1.7} = \frac{350\#}{x}$$

If we wish to lower the density of 350 pounds (159 kg) of 68.2° Brix syrup to 66.5° Brix by adding water, we need to add 8.95 pounds (4.1 kg) of water.

The process for determining the weight of sap to blend with given weight of syrup is identical. If 2.6° Brix sap is used instead of water in the above example, the proportions to mix would be as follows:




Then applying the ratio calculation to the proportions:

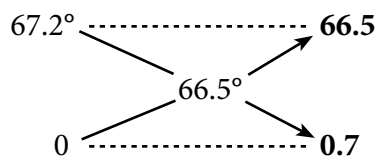
$$\frac{63.9}{1.7} = \frac{350\#}{x}$$

If it is desired to lower the density of 350 pounds (159 kg) of 68.2° Brix syrup to 66.5° Brix by adding 2.6° Brix sap, it is necessary to add 9.31 pounds (essentially 9 pounds 5 ounces or 4¼ kg) of sap.

### Blending on a Volume Basis

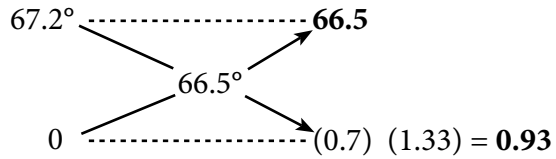
When blending syrup with syrup we observed that although the proportions determined by the method of allegation were, strictly speaking, weight proportions, they could be interpreted as volume proportions with relatively little error because the difference in weight between different lots of syrup of different densities was very small. This is not true when blending syrup with water or sap. Depending on its density, a gallon of syrup at room temperature generally weighs between 11 and 11¼ pounds, a gallon of water or sap between 8¼ and 8½ pounds. When combining syrup with water or sap, the weight proportions determined by the Pearson's square calculation must be adjusted for these differences in weight.

Again, this is best understood by example. If water is used, consider blending water with 15 gallons (56.8 liters) of 67.2° Brix syrup to reduce its density to 66.5° Brix. The weight proportions:




A gallon of 67.2° Brix syrup weighs approximately 11.10 pounds; a gallon of water weighs approximately 8.33 pounds. 1.33 gallons of water are

required to equal the weight of a gallon of 67.2° Brix syrup[81]. By multiplying the proportion of water (0.7) by 1.33 the weight ratio is converted to a volume ratio as follows:




Applying the ratio calculations to the proportions:

$$\frac{66.5}{.93} = \frac{15}{x}$$

To reduce the density of 15 gallons (56.8 liters) of 67.2° Brix syrup to 66.5° requires 0.21 gallons (0.8 liters) (almost 27 fluid ounces or 800 ml).

Fortunately, the determination of the correction factor can be greatly simplified. If the density of the syrup to be diluted is between 66.5° and 70.0° Brix and water or sap with a density of 4° Brix or less is used, 1.33 can always be used as the correction factor. If this is done, the maximum error in the desired density will be around 0.02° Brix. Again, this is far more accurately than most producers will ever measure.

[81] 11.10 divided by 8.33 = 1.33

# Appendix 4 · Identifying and Eliminating Undesirable Flavors in Maple Syrup*

Maple syrup has a unique, subtle flavor that can easily be damaged or destroyed by a variety of undesirable or off-flavors. Some off-flavors, such as metabolism and buddy, are the result of natural processes over which a producer has little control. Most off-flavors, however, are the result of mistakes in collection, processing, or storage that can be avoided. The following table contains a list of off-flavors commonly encountered in maple syrup, and identifies the characteristics of each off-flavor, as well as common causes and solutions to eliminate each off-flavor.

The descriptions listed in the second column, entitled "identifying characteristics," are, at best, word descriptions of what the mouth and nose sense. Each person will sense these off-flavors somewhat differently, and words are often inaccurate in expressing how an individual perceives and senses a particular flavor. Producers should take every opportunity to taste syrup with different and known off-flavors in order to develop a sensory recognition of each off-flavor. Similarly, producers should taste "good" syrup produced in different sugarbushes and geographic regions to develop an appreciation for the range in flavor that exists for pure, high quality maple syrup.

| Undesirable Flavor | Identifying Characteristics | Cause | Solution |
|---|---|---|---|
| Buddy | Taste ranging from chocolaty (almost tootsie roll-like), to butterscotch, to strong bitter. Odor of chocolate may be present, but not always. Odor, if present, better detected with normal rather than strong breathing. | Commonly occurs at the end of the season when sap is made from trees whose metabolism is changing and whose buds are beginning to swell. May be associated with increased amounts of amino acids in sap. Occasionally may occur earlier in season if extended warm period experienced. | Stop making syrup once buddiness is detected. A buddy odor may be detected in finished syrup, from sap being processed in an evaporator, and at some point in unprocessed sap. |
| Burnt Niter | Bitter, strong caramel flavor, often biting and bordering on burned flavor. Niter may produce a slight fizzy effect (like baking soda) on the tongue. | Accumulation and burning of niter on bottom of the front pan, particularly in the last compartment. | Avoid niter accumulation in evaporator as discussed in Chapter 7. |
| Chemical | Most often the flavor and smell of the chemical (e.g. soap, bleach). Most often affects the entire mouth, and may become more objectionable with breathing. Individual chemicals may have specific characteristics associated with them (e.g. bleach often produces a weeping sensation on the tongue). | Incomplete rinsing; improper chemical use. | Effective rinsing; avoidance of improper chemicals. |

*Adapted in part from Martel, B.A., H.J. Marckres, A. Dahlberg, M.L. Whalen, and M.F. Morselli. 1986. Maple quality control puts the accent on flavor. VT Dept. Agr., Montpelier, 2 pp.

| Undesirable Flavor | Identifying Characteristics | Cause | Solution |
|---|---|---|---|
| Chlorine | Medicinal or bathroom cleaner smell, may by salty, may cause weeping feeling on tongue. Degree of effect depends on chlorine concentration. | Usually caused by insufficient rinsing after using bleach sanitizer. | Effective rinsing. |
| Defoamer | May taste like whatever defoamer is used. Waxy or oily, depending on type of defoamer used. May actually feel greasy. If improper defoamer used (e.g. milk based or animal fat), may have rancid taste. | Use of excessive or improper defoamer. | Use as little defoamer as possible. Use commercial defoamers designed for maple; or if other substances are used, avoid those that will spoil or that have a flavor that will be detected in the syrup. |
| Detergent/ Soap | Maple flavor usually completely destroyed. Syrup may taste soapy, possible perfume odor and flavor depending on the type and amount of detergent/soap used. May cause nausea after tasting. Syrup may be sudsy if agitated. | Use of detergent/soap as a cleaning agent with incomplete rinsing (e.g. residual soap left in syrup bottles cleaned in a dishwasher). | Avoid use of detergents and soap whenever possible. When necessary, rinse appropriately. |
| Earthy | An earthy or rotten wood flavor. | Tapping into dark colored, stained, or decayed wood. | Avoid tapping wood as described under characteristics. Follow tapping guidelines discussed in Chapter 6. |
| Fermented | Sweet, often fruity and/or alcoholic flavor and odor. Syrup usually has foamy appearance, lots of bubbles if agitated. If in flexible container, container walls usually swell. | Conversion of sugars in syrup to alcohol by microorganisms, primarily yeasts. | Proper bottling/canning techniques, including cleaning and proper temperature. |
| Filters, New "Felt" | Slight chemical odor and/or flavor. | Improper or no cleaning of "felt" filters before use. | Before "felt" filters are used, they should be boiled in pure water and thoroughly dried. |
| Filters, Previously Used "Felt" | Depending on the cause, may be greasy or fatty from adsorbing excessive defoamer, detergent-like from improper cleaning, moldy from improper handling or storage. | See Characteristics. | Avoid excessive defoamer. Clean "felt" filters only with pure water and dry thoroughly before storing in a dry location free from potential contaminating odors. Never store "felt" filters with moth balls. |

| Undesirable Flavor | Identifying Characteristics | Cause | Solution |
|---|---|---|---|
| Food | Syrup tastes like specific food. | Bottling in a container that contains remnants of food on container or cap; use of unclean sap-collecting container (viz. gallon plastic milk or fruit juice bottles); storage of syrup in porous container near food material, particularly foods with strong odor (e.g. garlic) | Use of new bottles and caps, adequate cleaning of recycled bottles, use of new caps; adequate cleaning of food-grade, nonmaple plastic sap collection or storage containers; proper storage of syrup. |
| Metabolism | Sap and/or syrup may have disagreeable odor; syrup has an off-flavor ranging from slight (still palatable) to unacceptable. Metabolism odor/flavor is complex, and has variously been described as being woody or popcornish, sometimes with the flavor of peanut butter, or even cardboard being detectable. Some may have a chocolate smell, but a chocolate taste is not characteristic. | A naturally occurring off-flavor that results from changes in the chemical composition of the sap. It is currently believed to be most commonly associated with periods of warm weather during the maple season. See discussion in Appendix 2. | There is currently no management or processing recommendation for dealing with a strong metabolism flavor other than to cease processing. Research is underway to develop a method to eliminate or lessen this off-flavor. |
| Metallic | Tinny flavor, sharp, tingly, often can feel on teeth. Flavor not detectable by everyone. | May occur after prolonged storage in metal containers, though there are many instances of syrup being stored for more than ten years with no perceived metallic taste. Can also result from storage in poor quality (rusty, cracked epoxy) containers. | Use high quality storage containers. |
| Musty | Musty, light moldy, "dirty sock" odor and/or flavor. | Use of moldy filters. | Clean, store, and handle filters correctly—see discussion in Chapter 7. |
| Moldy | Stronger moldy odor and flavor. | Presence of substantial mold in syrup resulting from bottling at too low temperature, not inverting capped containers after bottling, or improper storage after opening. | Follow proper bottling recommendations as discussed in Chapter 8. Provide storage recommendations with each retail container sold. |

| Undesirable Flavor | Identifying Characteristics | Cause | Solution |
|---|---|---|---|
| Paint | Syrup has an oily, fatty flavor and feel on the tongue, often similar to cod liver oil. | Use of paint on surface that sap comes into contact with, such as inside of sap buckets or holding tanks, to prolong their usable life. | Avoid using paint on surfaces of maple equipment that will come in contact with sap or syrup. While there are paints approved for use with food, they are difficult to use correctly and should normally be applied only by a professional experienced in their use. |
| Plastic | Bittersweet flavor, or flavor resembling the odor of plastic. | Use of nonfood grade plastic to collect, store, or transport sap or syrup; or use of a plastic not meant for exposure to hot syrup for handling or storing syrup. | Use only food grade plastic appropriate for specific application. |
| Ropy Syrup | Syrup appears very viscous, pours with a stringy, wavy motion. At extreme, tends to behave like jelly or taffy, and may stretch out in a sticky filament when pouring is stopped. At extreme, feels rubbery in mouth. | Results from sour sap being made into syrup. Sour sap results from microbial action (particularly bacteria) acting on sap. May be due to bacterial action converting sugar to polysaccharides. | Follow recommendations in Chapters 6 and 7 for quickly collecting and processing sap in a sanitary manner. |
| Sour | Sour flavor to syrup. | Results from acids in syrup formed by bacterial acting on sugars in syrup. | Bottle syrup quickly and follow proper bottling methods as discussed in Chapter 8, particularly as they relate to achieving high enough temperatures to kill microorganisms. |
| Soap | See Detergent/Soap. | See Detergent/Soap. | See Detergent/Soap. |
| Scorch | Burned flavor, strong bite. | Burning of syrup. | Don't burn syrup. Common cause is operating the evaporator with too low a level of sap in the front pan, resulting in a burning of the syrup. |

# Appendix 5 · Sugarbush Lease Agreement

The following represents an example of a Sugarbush Lease Agreement that can be used as a guide in developing an agreement appropriate for a specific sugarbush. It identifies important areas to be covered, and provides examples of the kinds of subjects and considerations that should be addressed under each Section. Some of the examples should be included in all Sugarbush Lease Agreements, such as Points 1 and 2 in Section II, which address permitted tapping practices. Other examples, such as Points 4 and 5 in Section II, which address permitted thinning and the harvest of fuel (sugar) wood, may or may not be appropriate in a specific agreement. As with any agreement or contract, the agreement should be developed based on thorough discussions between the parties involved, so that it represents an agreement thoroughly understood by both parties.

## Section I. Contracting Parties, Description of Property, and Term of Lease

1. This lease is made between _____, hereinafter called the Landowner(s),

   and _____, hereinafter called the Renter(s).
2. The Landowner(s), in consideration of the agreements with the Renter(s) hereinafter set forth, hereby lease to the Renter(s) maple trees to use for tapping and the production of maple sap, and the right to transport such sap to a processing location herein described as:

   _____ (address or other specific property identification)

   _____ (town or city)

   _____ (county)

   _____ (state or province)
3. Description of lands included in this lease. (Include acreage and boundaries, perhaps as described on current Farm Services Agency map.)

   _____

   _____

   _____

4. This lease shall become effective on the first day of _____, 20____, and shall

   continue in force until the last day of the month _____, 20____. The Renter(s)

   shall have the option to renew for a period of ____ year (s) after the first lease period, provided that the Landowner(s) has not given notice of cancellation for cause, at least six months prior to the end of the current lease. The Renter(s) shall advise the Landowner(s) of intent to renew this lease not less than six months prior to the end of said lease.

## Section II. Land Use

Maple trees and the leased premises shall be maintained by the Renter(s) in their present condition, or improved, and the yield of sap maintained or increased by current methods of tapping, installation of tubing, or tree thinning as recommended by an Extension, State, or Provincial Forester, or mutually approved consulting forester. Any costs incurred shall be paid by the renter(s).

The following practices are mutually agreed upon:

1. Guidelines for tapping maple trees, as developed by the State or Provincial Department of Forests are attached and shall be the standard for tapping on this property. Both the Landowner(s) and Renter(s) agree to this guideline with their signed acceptance of this document.
2. Tapholes for buckets shall be made with a tapping bit not greater than 7/16 inches in diameter and shall not be more than 2.5 inches deep. For new tubing installations or replacement tubing installations, tapping shall use the so-called "health spouts," or small diameter spouts, and shall not be drilled to a depth greater than 2 inches, including bark thickness.
3. Chemical sanitizers shall not be used, but proper practices to maintain tree health and reduce bacterial growth are encouraged.
4. Thinning of maple trees for sugarbush improvement may be carried out by the Renter(s), with the concurrence of the Landowner(s), providing that the sugarbush has been marked for thinning by a professional forester, as described above, or by mutual agreement with the landowner. If by professional forester, such professional shall be mutually agreed upon by both the Landowner(s) and Renter(s) and shall be paid for by the Renter(s).
5. Wood harvesting for the evaporator shall be allowed, provided that such trees are marked by a professional forester, or have been identified by mutual agreement with the landowner(s). Firewood cutting or logging for personal use or sale shall not be allowed, except by mutual written agreement between the Landowner(s) and Renter(s).
6. Vehicles for use in tubing or bucket installation or sap gathering such as tractors, sleds, or trailers shall be operated with care so to prevent damage and scarring to the bases and roots of all trees.

## Section III. Time and Amount of Payment

The Renter shall pay to the Landowner the sum of _____ per tap in year one; _____ per tap in year two; _____ per tap in year three; _____ per tap in year four; and _____ per tap in year five.

Tap count is agreed to be _____, therefore the total amount due before adjustment is $_____.

If the tap count is to be adjusted, payment for such adjustment shall be made with the second payment. The first half of such payment shall be made prior to the end of the calendar year (December 31), before the referenced sugaring season. The remaining half shall be paid upon the completion of the sugaring season, but not later than May 15 of said year. Deviations from this agreement, in reference to payment, shall be only with the mutual written agreement of both parties.

## Section IV. Liability

The Renter(s) shall assume all responsibility and liability for all personal accidents, including those to him/herself or employees, family members, or visitors while engaged in the tapping of trees, gathering of sap, thinning, cutting and splitting of firewood, and crossing of the Landowner's land to get to or from the leased sugarbush. The Renter(s) shall obtain a premises liability policy covering the rented premises and shall provide a certificate of insurance, naming the Landowner(s) as an additional insured, in an amount not less that $500,000, not later than January 1 each year of the lease. Failure to provide said certificate of insurance shall be just cause for lease cancellation at the sole option of the Landowner(s).

The Renter(s) shall be responsible for suppressing forest fires that may start while he is working on this property, and shall maintain all roads or fences in the same or better condition than as of the initial lease.

The Renter(s) shall watch for any evidence of insect, disease, rodent, environmental, or other damage that might occur on the area and shall advise the Landowner(s) of such damage.

## Section V. The Landowner(s) Agrees to

1. Furnish the area described above and access to such area as described above, including the use of existing roads for the purposes of managing the leased area. The Landowner(s) shall be responsible for maintaining easily identifiable boundaries.
2. Pay all taxes and assessments against the said property.
3. Keep cattle and sheep out of the area described above during the period of sap collection.
4. Include the provisions of this lease in any deed for sale of this land to another party so that it will be binding upon the new owner.
5. In the event that the Landowner(s) should decide to sell the property, he shall offer the Renter(s) an option to purchase at the appraised or asking price and give the Renter(s) a period of 45 days to provide the Landowner(s) notice of his/her intent.

## Section VI. The Renter(s) Agrees to

1. Follow approved management practices for the development of existing young maple trees into trees of the size from which to harvest sap and to protect those trees from damage.
2. Furnish all labor, equipment, supplies, and all operational expenses unless use of the Landowner owned equipment is specified elsewhere in this agreement.
3. Replace any firewood already cut and ready for use in the sugaring process with firewood of equal value and in the same amount not later than June 1 of the contract year, unless other arrangements have been made with the Landowner(s).
4. Neither assign nor sublet any of the land or property covered in this lease to any other person or persons without the express written permission of the Landowner(s).
5. Maintain liability insurance as set forth in the provisions of Section IV.
6. Remove all spouts from the trees in a timely manner, but not later that May 15 of each year.

## Section VII. Rights and Privileges

The Landowner(s) or his designee shall have the right of entry at any time to inspect the property covered in this lease with respect to tapping, road maintenance, wood cutting, or any other use of the property covered in this lease.

## Section VIII. Enforcement of Agreements and Arbitration

1. Failure of either party to comply with the agreements sent forth in this lease shall make him/her liable for damages caused by such noncompliance. Any claim by either party for such damages shall be presented in writing to the other party at least 60 days before the termination of said lease.
2. If either or both parties of this lease die during the term of the lease, the provisions of this lease shall be binding upon the heirs, executors, and administrators.
3. Any disagreements between the Landowner and the Renter(s) shall be referred to an arbitration panel of three disinterested persons—one of whom shall be appointed by the Landowner, one by the Renter(s), and a third appointed by the two thus appointed. The decision of the arbitration panel shall be considered binding on the parties of this lease and enforceable by a court of law of competent jurisdiction. Any costs for such arbitration shall be shared equally by the Landowner and Renter(s).

## Section IX. Other Agreements

Any Federal or USDA Farm Service Agency agreements or tax stabilization agreements with the town or state shall be respected and honored by both the parties of this lease.

Cost share payments received during the term of this lease from any Federal or State/Provincial agency shall go to the party carrying out and paying for the work being done on the said leased property.

## Section X. Signatures

This lease is binding on all parties signing, before this witness, on this day:

_____ Date _____

Landowner

_____ Date _____

Landowner

_____ Date _____

Public Notary Witness

_____ Date _____

Renter

_____ Date _____

Renter

_____ Date _____

Public Notary Witness

# Glossary

***Acer:*** The genus name of maple trees, which belong to the botanical family *Aceraceae,* and which are characterized by having leaves and branches in opposite arrangement along the stem and a double samara fruit. See Chapter 3.

**additive solution:** Solution with a high invert sugar level added to amend syrup when the amount of invert sugars in the syrup is too low to make the desired confection.

**adulteration:** The accidental or deliberate addition of substances; substitution of less expensive, but similarly tasting ingredients; the addition of non-declared substances; contamination by filth or pesticides; the presence of naturally occurring toxic materials; and contamination by microorganisms.

**advertising:** The paid presentation of information in a public medium to attract favorable attention to a product or business.

**air injection devices:** Evaporator accessory that forces filtered air through a series of small holes in stainless-steel tubes lowered into the pans (either the flue pan or syrup pan).

**angle gauge:** Tool used to estimate basal area per acre or hectare.

**apron test:** Traditional method for determining whether the desired density of syrup had been achieved. A square-ended dipper was inserted into the syrup and held up to allow the syrup to "apron-off" in a sheet. Syrup was "finished" when the apron formed had the right shape and other characteristics.

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

**automatic draw-off:** Electrically operated, temperature sensing valve assembly that automatically opens to allow finished or near-finished syrup to be removed from the evaporator. The temperatures at which the valve opens and closes can be set by the evaporator operator.

**back pan (flue pan or sap pan):** Pan located towards the rear of the evaporator where sap enters and is concentrated prior to moving into the front (syrup) pan. Back pans typically have a number of deep channels that increase the heat transfer surface area. See also **raised-flue** and **drop-flue**.

**bare-rooted seedlings:** Relatively small seedlings, commonly less than three or four years old, that are lifted from a nursery bed and shipped without soil around the roots.

**basal area:** Cross-sectional area of a tree's trunk determined 4½ feet (1.37 m) above ground. Usually expressed on a tree, stand, or area (acre or hectare) basis (See Chapter 5).

**batch processing:** Evaporation method in which syrup is made by periodically adding sap to the kettle or other evaporating container. Usually done on a smaller scale. See **continuous flow evaporator**.

**Baume scale:** Scale used to determine the density of maple syrup; this scale relates the density of syrup to a salt concentration of the same density.

**bedrock:** Solid rock underlying a soil or loose overlying material.

**blow test:** Traditional method for determining whether the desired density of syrup had been achieved. A loop of wire was inserted into hot syrup and a gentle breath was blown against the syrup. Syrup was "finished" when a "certain puff" of breath blew the syrup off the loop.

**branch collar:** Swollen area (usually) around the base of a tree branch which anatomically is part of the trunk rather than the branch.

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

**browning:** Color (and flavor) development in a sugar solution caused by carmelization and Maillard reactions.

**BTU (British Thermal Unit):** Amount of heat required to raise 1 pound of water 1° Fahrenheit.

**buddy:** Off-flavor (and odor) in maple syrup ranging from chocolaty to butterscotch to strongly bitter. (See Appendix 4)

**buffer pH:** A measure of a soil's resistance to pH change, as when lime is added. Also referred to as lime test index.

**callus tissue:** Woody tissue produced by the cambium that develops around and over the outer edge of a taphole to eventually cover the opening.

**canister pressure filter (canister filter press):** Filtration device that utilizes a pump to push maple syrup (or occasionally sap) through a tubular device consisting of an inner perforated container, filter cloth, and diatomaceous earth to remove suspended particulate material.

**canker, disease:** Dead area on a branch or main trunk. Over time, some cankers become visible as swellings or deformations when callus tissue has begun to grow over the canker.

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

**carbon monoxide:** Colorless, odorless, poisonous gas (CO) formed by burning wood, petroleum products, or any organic fuel with an insufficient supply of oxygen. Its presence can cause asphyxiation and death by interfering with the body's ability to absorb oxygen.

**carmelization:** Browning of sugars that occur during heating which affect color and flavor development. See **Maillard reactions**.

**cation exchange capacity (CEC):** Measure of the ability of the soil to retain positively charged ions (termed cations) such as hydrogen, calcium, magnesium, potassium, and aluminum. An important soil characteristic since many plant nutrients occur in the soil in cation form.

**CCOHS:** Canadian Centre for Occupational Health and Safety.

**ceramic insulation:** Insulation made from ceramic fibers, commonly used between the sap and syrup pans, and between pans and the arch wall.

**chaps:** Personal protective equipment worn when operating a chainsaw that reduce the risk or severity of injury to the legs.

**chasing the sweet:** Use of water, preferably mineral free (permeate or condensate) to force the last of the partially concentrated sap (or "sweet) out of the evaporator.

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

**clearcutting:** Removal of all of the trees in a stand above a small minimum diameter (e.g. 2 inches or 5 cm) at one time (Figure 5.22).

**clinitest® tablets:** Tablets, obtainable at some pharmacies, that are used to test sugar level in human urine. Can be used to estimate amount of invert sugars in syrup.

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

**condensate:** Relatively pure water that has condensed into a colleting vessel, such as the water that collects in the drip pan below a preheater or hood.

**conifers:** Cone-bearing woody trees such as pines, spruces, and firs.

**continuous flow evaporator:** Evaporator designed so maple sap enters at one end of the evaporator and syrup is removed at the opposite end in a reasonably continuous semi-automatic fashion. Flow is normally controlled by a series of floats or valves**.**

**cord:** A stack of wood occupying 128 cubic feet (3.62 cubic meters) of volume, often represented as a pile of wood 4 feet high, 8 feet long, and 4 feet deep (1.22 meters high, 2.44 meters long, and 1.22 meters deep).

**crop trees:** Trees identified in a forest stand that are to be retained and favored to be vigorous because they contribute to ownership objectives.

**crop tree management:** Activities conducted to encourage the growth and vigor of individual crop trees to allow maximum production. Differs from other types of forest management in that the focus is on the individual tree rather than a stand.

**cross flow pans:** Syrup pans, 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 nitre build-up.

**crown class:** Classification of a trees based on the vertical position of its crown relative to surrounding trees.

**crown, tree:** Part of a tree bearing live branches and leaves.

**crowning:** Preparation of a road surface so that it is higher in the middle (as viewed in cross-section) than on either outside edge.

**crystal coating:** Coating molded candy with a moisture-resistant shell made from crystalline sucrose to prevent drying out.

**culvert:** Structure to move water from one side of a road to the other without the water flowing on the road surface. May be open (Figure 5.37). or closed (Figure 5.36).

**cupola:** Opening located on top of the sugarhouse, usually directly above the evaporator, through which water vapor from boiling sap is exhausted from the sugarhouse.

**dbh:** See **diameter breast height**.

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

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

**diameter breast height (dbh):** Diameter of a tree measured 4½ feet (1.37 m) from the ground.

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

**dolomite (dolomitic limestone):** Calcium magnesium carbonate, often used to increase soil pH where additional magnesium is desired.

**double samara:** See **samara**.

**draw-off partition:** Partition or channel in the front (syrup) pan from which finished or nearly finished syrup is removed.

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

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

**dual conductor:** Mainline installation system in which two separate lines are installed to maximize the transfer of vacuum (dry line) to lateral lines and the movement of sap (wet line) to the collection unit. See (or also known as) **wet-dry conductors**.

**dump unit:** See **releaser**.

**evaporator:** A device designed to efficiently process maple sap into maple syrup by evaporation though boiling. Consists of an assemblage of several individual components, principally including a sap or flue pan, syrup or front pan, arch, firebox, floats and other devices such as draw-off units.

**even-aged stand:** Stand in which the trees are predominantly within the same age class, and approximately the same size (Chapter 5 and Figure 5.3).

**exotic, species:** Plant (or animal) introduced into an area from another country or geographic region. Not native to the region.

**extractor:** See **releaser**.

**FDA:** United States Food and Drug Administration.

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

**feed tank:** Sap storage tank from which sap flows to the evaporator.

**feed rate:** The rate at which sap enters the evaporator through a float box, valve or other flow regulator device.

**felt-hat filter:** Cone-shaped syrup filter made of wool or synthetic material.

**filter aid (filter aide):** See **diatomaceous earth**.

**filter press:** See **canister pressure filter** and **plate pressure filter**.

**filtration system:** Process, using either a gravity or pressure filtration system to remove suspended sediments from finished maple syrup.

**finished syrup:** Maple sap that has been processed (boiled) until a sugar concentration of at least 66.0° Brix has been obtained (66.9° Brix in Vermont and New Hampshire).

**finishing pan:** Separate pan into which syrup slightly light in density (typically between 45° and 60° Brix) is further evaporated to reach finished density. Used principally to achieve better density control and to facilitate grading and filtering.

**firebrick:** Brick capable of tolerating high temperatures that is used to line the inside of a wood-burning arch.

**firing:** Starting and maintaining a fire in the arch of an evaporator.

**fixed costs:** Those costs that do not change as a function of the amount of sap and/or syrup produced.

**flat filter:** Wool or synthetic fabric filter placed over a metal screen through which hot finished syrup is passed to remove suspended sediments.

**flat-bottom pan:** Evaporator pan without flues or other similar features on the bottom of the pan. See: **syrup pan**.

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

**flooding the rig:** Filling an empty evaporator with sap to the proper depth. Typically done in preparing evaporator for start-up.

**flue:** Metal channel in the bottom of the sap pan designed to increase the surface of the pan, thereby increasing the heat input and shortening the processing time.

**flue pan:** See **back pan**.

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

**forced draft unit:** Blower assembly unit that forces additional air into the firebox of a wood fired evaporator to increase the rate of burning and thus the amount of heat produced.

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

**fructose:** See **invert sugar**.

**gathering pail:** Bucket or similar container used to carry sap from individual buckets or bags to a gathering tank.

**gathering tank:** Container used to transport sap collected from individual buckets to a larger sap storage tank, usually located near the sugarhouse.

**Geographic Information System (GIS):** Computer application used to store, view, and analyze geographic (spatial) information, especially mapped information.

**GFCI (Ground Fault Circuit Interrupter):** Device providing protection against electric shock and electrocution in situations where ground is compromised or electrical leakage occurs.

**girdling:** Removal of bark and outer sapwood in a complete circle around the trunk of a tree with the intention of killing the tree (Figure 5.16).

**GIS:** See **Geographic Information System**.

**Global Positioning System (GPS):** A geographic positioning system that utilizes signals from a system of satellites to identify a specific location on the ground.

**glucose:** See **invert sugar**.

**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.

**grading kit:** Collection of colored glass or colored solutions used as a visual guideline in determining the grade of finished maple syrup.

**grading standard:** Set of guidelines used to evaluate and determine the grade of finished syrup. Specific grading terminology is variable throughout the maple producing region.

**gravity filter:** Method of syrup filtration that relies on gravity to move syrup through a filtering medium.

**Ground Fault Circuit Interrupter:** See **GFCI**.

**group selection:** Cutting of trees in small groups throughout the stand. Not uncommonly the width of the openings produced by such harvesting average about twice the height of the dominant trees.

**hardwood:** Broad-leaf deciduous trees such as maples, oaks, hickories, and others.

**HazMat:** Hazardous materials.

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

**hood:** Structure, usually made of metal, placed over the evaporator to facilitate the movement of water vapor out of the sugarhouse.

**hot pack:** Process of filling and otherwise packaging maple syrup in containers when the temperature of the syrup is maintained at 180° F or higher.

**hot test:** Determining the density of a sample of hot syrup from the evaporator. Hot testing is commonly done with a hydrometer.

**hydrometer:** Glass measuring device containing a weighted bottom and a calibrated scale (Brix or Baume) which when floated in syrup indicates the density of the syrup (Figure 8.7).

**hypothermia:** Dangerous condition resulting when a person's core body temperature drops below 95°F (35°C) after prolonged exposure to freeing or near freezing temperatures.

**hydrotherm:** Specially designed hydrometer that has a liquid thermometer built into it that automatically locates the point on the hydrometer (the top of the thermometer liquid column) for measuring standard density syrup.

**increment borer:** Instrument used to obtain a small-diameter core of the cross-section of a tree to determine age and growth rate (Figure 5.7).

**indicator plants:** Plants whose presence in an area indicate a particular environmental condition (e.g. soil pH, soil moisture, elevation).

**individual tree selection:** Cutting of individual trees throughout the forest stand.

**in-sloping, road:** Preparing a road surface along a hill so that it slopes inward toward the uphill side, most commonly to a ditch.

**intermediate cut:** A cut done in a forest stand to improve the growth and quality of trees that remain after the cut (referred to as the residual trees or the residual stand).

**invert sugar:** Six carbon sugars, glucose (dextrose) and fructose (levulose), which are structurally different, but which both have the chemical formula $C_6H_{12}O_6$. Invert sugars are produced by the breakdown (hydrolysis) of sucrose, commonly by the action of microorganisms. The name invert comes from the fact that a solution of invert sugars rotates (inverts) the plane of polarized light passed through the solution.

**kickback:** Dangerous situation resulting from incorrect chainsaw use that occurs when the upper portion of the bar nose contacts a solid object or is pinched, resulting in the saw being forced rapidly and sometimes uncontrollably up and back toward the operator.

**lateral buds:** Buds located along the sides of a branch.

**lateral line:** Smaller tubing lines, usually 5/16-inch in diameter used to collect and transport sap from individual tapholes (droplines) to mainlines.

**lenticel:** An area of cells on the surface of a twig through which gases pass. Lenticels on twigs are often seen as small rounded or near-rounded areas, somewhat different in color from the surrounding bark.

**lime:** Calcium carbonate or other calcium containing material used to increase soil pH.

**lobe:** Distinct projection or division related to the shape of a leaf, as in the five lobes that define the characteristic shape of a sugar maple leaf.

**macronutrients:** Nutrients required by maples (and other plants) in large quantities, including hydrogen, carbon, oxygen, nitrogen, potassium, calcium, magnesium, phosphorus, and sulfur.

**Maillard reactions:** Chemical reactions between amino acids and sugars that affect color and flavor development in many food products including maple syrup. See also **carmelization**.

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

**mainline installation tool:** Tool used to attach fittings such as manifold units, connectors, etc. to mainline tubing.

**management plan:** Planned set of activities designed to improve the maple resource for the purpose of producing sap. Management activities may include planting, thinning, selected individual tree harvest, and other activities.

**Manitoba maple:** Boxelder

**maple butter:** See **maple cream**.

**maple candy:** Molded maple candy made by evaporating additional water from maple syrup until the temperature of the liquid is 32° to 34°F (18° to 19°C) above the boiling temperature of water, followed by processing and molding as described in Chapter 9. Unlike maple fondant (nougat), the sugar crystals in maple candy can be felt or sensed on the tongue.

**maple confection:** A sweet, maple flavored food product made from maple syrup, such as maple candy, maple sugar, and maple cream.

**maple cream (maple crème** or **maple butter** or **maple spread):** Semi-solid spread made by evaporating additional water from maple syrup until the temperature of the liquid is 22° to 24°F (12° to 13°C) above the boiling temperature of water and processing as described in Chapter 9.

**maple fondant:** A nougat or fudge-like confection made by evaporating water from maple syrup until the temperature of the liquid is 27° to 29°F (15° to 16°C) above the boiling temperature of water and processing as described in Chapter 9. Maple fondant is smoother in texture than molded maple candy; sugar crystals should be so small as to not be detectable when fondant is eaten.

**maple nougat:** See **maple fondant**.

**maple sap:** Sugar (primarily sucrose) containing liquid collected from maple trees during the dormant season from which pure maple syrup is produced.

**maple spread:** See **maple cream**.

**maple sugar:** Specifically, a solid (sugar cakes or blocks) or granular sugar made by further evaporating water from maple syrup and processing as described in Chapter 9. More generally, used to refer to all or most of the confections made from maple syrup which have a definite crystalline structure including soft sugar, hard sugar, block sugar, molded sugar, and granulated sugar.

**maple syrup:** A sweet, viscous liquid made by boiling maple sap until the boiling temperature of the liquid is at least 7.1°F (3.9°C) above the boiling temperature of pure water, and which contains at least 66 percent solids (primarily sucrose) by weight.

**maple taffy:** Non-crystallized, taffy-like form of maple sugar made by evaporating additional water from maple syrup until the temperature of the liquid is 23° to 26°F (13° to 14°C) above the boiling temperature of water and processing as described in Chapter 9.

**margin, leaf:** Peripheral border or edge of a leaf, as in "red maple leaves commonly have small teeth along their margin."

**market research:** Efforts undertaken to determine the needs and wants of customers and how these needs can be satisfied most effectively.

**market segment:** Group of consumers with common characteristics that separate them from other groups.

**marketing:** Activities carried out by a business to promote and sell products and or services.

**micronutrients:** Nutrients required by maples (and other plants) in very small quantities, including iron, boron, managanese, copper, zinc, molybdenum, and chlorine.

**MSDS (Material Safety Data Sheets):** Detailed information on chemicals including such topics as chemical composition; safe handling, storage, and disposal; human and environmental risks; and emergency first aid care.

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

**niche market:** Market in which a particular segment is targeted; also a market in which marketing activities focus on a specific role or function of a product.

**niter** or **nitre:** See **sugar sand** and **scale**.

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

**open taphole:** A taphole made the previous year that has not yet closed.

**orthophotograph:** Photograph (viz. an aerial photograph) in which displacements or distortions caused by tilt, relief, or perspective (e.g. camera location) have been removed.

**OSHA:** United States Occupational Safety and Health Administration.

**out-sloping, road:** Preparing a road surface along a hill so that it slopes outward toward the downhill side.

**paraformaldehyde pellet (PFA):** Aspirin-sized tablet containing a small amount of paraformaldehyde that was formerly used in tapholes to prevent microbial growth.

**permanent glass comparator:** Grading kit that contains colored glass standards representing the minimum color associated with various grades of maple syrup; the glass color in each standard will not fade, hence the name permanent. Used as a guide when grading maple syrup.

**permeate:** Water removed from sap by a reverse osmosis machine, often stored and used for cleaning. See also **concentrate**.

**petiole:** The stalk or stem of a leaf.

**pH:** A measure of the relative acidity or alkalinity of a soil, with 7.0 being neutral, lower than 7.0 being acidic, and higher than 7.0 being alkaline.

**pig:** Metal pan portion of a maple candy making machine that holds hot syrup.

**Piggyback:** Evaporator accessory that sits over the flue pan and uses heat energy in the water vapor from the evaporator to heat and remove water from sap before it enters the flue pan.

**pinnately compound:** Describes the structure of a leaf composed of several leaflets (individual leaf blades), with the leaflets arranged along the sides of the petiole and often at the terminal. Ash, black walnut, hickory, and boxelder are among the species having pinnately compound leaves.

**plate pressure filter (plate filter press):** Filtration device utilizing a pump to force maple syrup through a series of plates and filter papers or pads along with diatomaceous earth to remove suspended particulate material.

**pole:** Commonly, a standing tree between 3 and 9 inches dbh.

**PPE (Personal Protective Equipment):** Safety equipment or appearal worn to reduce the risk of injury.

**prefilter:** Thin paper or synthetic filter placed on top of a flat or cone filter and through which maple syrup is passed to remove suspended particulate material.

**preheater:** Heat transfer piping unit that captures some of the heat produced by boiling sap to increase the temperature of sap before it enters the evaporator flue pan.

**pressure filter:** See **plate pressure filter** and **canister pressure filter**.

**prism:** Tool used to optically estimate basal area.

**promotion:** Efforts undertaken to communicate information about a product and to persuade consumers to purchase.

**pruning:** Removal of some competing branch leaders and all or a portion of a tree's side branches.

**PTO (Power Take Off):** Rotating shaft at the rear of most tractors designed to transmit power to an attached piece of equipment.

**pubescence:** Refers to hairs on the surface of a leaf.

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

**publicity:** The non-purchased presentation of favorable information about a business or product.

**reaming:** Occasionally used, but not recommended mid-late season practice of redrilling an existing taphole with a slightly larger diameter bit to remove dry wood and accumulated microbial growth.

**refractometer:** Instrument (Figure 8.6) used to measure the density of sap or syrup by determining the refractive index (the bending of light passing through the solution).

**regulator box:** Small compartment on the side of one or more evaporator pans containing a float or electronically operated valve to control the depth and flow of sap within the evaporator system.

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

**reproduction harvest (cut):** Cutting done in a sugarbush or other woodland to encourage the establishment and growth of new maple trees or other species.

**residual trees or residual stand:** Trees remaining after an intermediate cut.

**retapping:** Practice of making a new taphole in mid- or late-season in an attempt to obtain additional sap because of taphole drying or contamination of the original taphole. See also **reaming**.

**reverse flow pans:** Syrup pans, commonly with three or more partitions running front to back, that are designed to allow syrup to be drawn-off from either side so that the flow can be periodically reversed as a means of controlling the build-up niter.

**reverse osmosis (RO):** Process in which the sugar concentration of maple sap is increased prior to boiling by forcing the sap, under pressure, through a semipermeable membrane. The pores in the membrane are large enough to permit water molecules to pass through, but too small to allow the passage of sugar and other large molecules. See also **permeate** and **concentrate**.

**RO:** See **reverse osmosis**.

**roadside trees:** Maple trees growing alongside a road. Usually the sap sugar content of such trees is greater than for trees growing in a sugarbush due to the presence of larger crowns and thus more leaf area.

**rock candy:** Large sucrose crystals made by heating maple syrup to 8°F (4.4°C) above the boiling point of water and allowing it to sit unagitated for a considerable length of time at room temperature.

**root collar:** Location along the stem of a tree where the anatomy changes from that of the aerial stem to that of the root, commonly identified externally by a change in the color and texture of the bark.

**ROPS (Roll Over Protective Structures):** Devices installed on tractors and other open vehicles to protect the operator in the event the vehicle rolls over.

**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. See discussion in Chapter 7.

**saddle 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. See Chapter 3.

**sap:** Watery liquid obtained from tapholes in maple trees that is composed mainly of water, with a small percentage of sucrose and other lesser compounds.

**sap bag:** Plastic bag and frame used with a spout to collect maple sap.

**sap bucket:** Container usually made of galvanized metal, aluminum, or plastic that is placed on the spout and used to collect sap from individual tapholes.

**sap flow mechanism:** Physical-biological process by which maple 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.

**sap pan:** See **back pan**.

**sap preheater:** Piping device usually suspended under a hood over the flue pan designed to raise the temperature of sap entering the evaporator.

**sap run:** Term describing the period of time, usually measured in terms of a day or fraction thereof, when sap flows as a result of favorable temperature conditions.

**sap season:** Period of time in late-winter to early-spring when sap flow can be expected following favorable temperature changes.

**sap storage tank:** Tank or container used to store sap following collection but before it is processed.

**sapling:** Commonly, a tree larger than 4½ feet tall and less than 3 inches in diameter.

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

**sawtimber trees:** Trees, commonly with diameters greater than 10 inches and of appropriate quality, from which lumber can be produced.

**scale:** Niter material adhering to evaporator surfaces. See also **sugar sand**.

**scoop:** A uniquely shaped ladle used by some maple producers to skim foam from the top of sap in the evaporator, and by some sugarmakers to perform the apron test.

**secondary products:** Any of the several products that are produced by using maple syrup as the starting product for the manufacture of maple sugar, maple candies, maple crème, and other maple confections.

**seeding:** Addition of a small quantity of the finished product to a new batch of maple cream or other confection to induce the formation of crystals.

**seedling:** Commonly, a tree less than 4½ feet tall, that develops from seed rather than a stump sprout.

**selection harvest:** Trees removed from a woodland singly or in small groups to create gaps for young maples or other species to grow (Figure 5.21).

**settling:** Gravity filtration method for removing suspended particles from finished maple syrup by simply allowing the suspended materials to settle to the bottom of the storage container followed by decanting.

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

**shelterwood harvest:** Cutting of trees in a stand in a series of two or three cuts that gradually open the forest, creating an environment that encourages the establishment of more shade tolerant species like maple (Figure 5.23).

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

**single tree selection:** See **individual tree selection**.

**small pore filter:** Mechanical filter unit that forces maple sap through a series of filters to remove microbial organisms.

**soil type:** Classification given to soil that defines its characteristics, including profile (e.g. texture, structure, color, drainage), and the climate and type of vegetation under which it developed.

**spile:** See **spout**.

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

**stack burn:** Condition that may develop when freshly packaged containers of hot maple syrup are stored close together so the containers do not cool rapidly; usually results in syrup darkening.

**stain:** See **zone of discoloration**.

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

**stand, forest:** Contiguous group of trees similar enough in age/size, species composition, soil type, topography, use history, and tree health to be treated as a uniform area for purposes of management prescriptions.

**star ladder:** Arrangement of 5/16-inch tubing and fittings designed to lift sap from one level to another. See **sap ladder**.

**steam hood:** Enclosed structure over the evaporator to direct water vapor from the evaporator out of the sugarhouse.

**STEAM-AWAY®:** Evaporator accessory unit that sits tightly over the flue pan and uses the heat in water vapor to heat and remove water from sap before it enters the flue pan.

**stipules:** Leafy structure attached to the twig at the base of the leaf petiole. Stipules commonly occur in pairs.

**stocking, stand:** Expression of the amount of tree growth present on an area as compared to what is considered optimum, as in "the sugarbush is 70 percent stocked."

**sucrose:** The principal dissolved sugar in maple sap, $C_{12}H_{22}O_{11}$, and the primary sugar in maple syrup.

**sugar camp:** Traditionally, the site, often literally a camp in the woods, where sap was collected and processed into syrup.

**sugar sand (niter, nitre):** Substance that precipitates during the evaporation process. See also **scale**.

**sugarbush:** Woodland or other group of maple trees tapped for maple sap.

**sugarhouse:** Building used to house the evaporator and other equipment necessary for the production and processing of maple syrup including filtering and packaging.

**sugaring (syruping):** Process of collecting maple sap and converting it into maple syrup; sometimes used to as a reference for the business and/or season of producing maple syrup.

**sugaring season:** Period of time in the spring when sap is collected and maple syrup and other maple products are produced.

**sugarmaker (syrup maker):** Individual who makes maple syrup.

**sugar-on-snow:** Confection made by pouring maple syrup heated to 22° to 27°F (12° to 15°C) above the boiling point of water directly onto snow or crushed ice.

**sunscald:** Localized injury or death, of a portion of a tree's trunk due to sudden exposure of the area to intense sunlight and increased temperatures, most commonly during the winter.

**syrup density:** Component of grading referring to the concentration of solids, mostly sugars, in maple syrup. Finished syrup has a standard density (minimum) of 66.0° Brix except in Vermont and New Hampshire where it is 66.9° Brix.

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

**syrup grading:** Process and/or act of assigning one of the recognized standard grades to finished syrup.

**syrup pan:** See **front pan**.

**taphole:** Hole (typically 5/16 inch or 7/16 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.

**taphole drying:** The late-season failure of a taphole to produce sap. Usually tapholes become nonproductive due to the presence of microbial growth.

**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.

**target market:** A group of similar consumers (a market segment) to which marketing activities are directed.

**temporary grading kit:** Tool used as a guide to grade finished maple syrup which utilizes differently colored glycerine solutions as the base color for individual grades of syrup. Temporary refers to the fact that the colors in the various solutions will change over time, thus necessitating periodic replacement of old kits with a new kit.

**terminal bud:** Bud at the end or tip of a branch.

**terneplate:** Sheets of iron or steel coated with an alloy commonly containing three parts lead to one part tin.

**topographic map:** Map showing elevations and landforms, usually by means of contour lines and colors.

**tubing:** Flexible, plastic (usually 5/16 inch) tubes used as drop lines and lateral lines to channel sap from a taphole to a common collection container or mainline.

**tubing fittings:** Any of several different types of adapters used to connect both small and larger plastic tubing lines to accommodate sap collection and movement. Examples include spouts, tees, connectors, manifolds, etc.

**tubing manifold:** Mainline fitting to which individual lateral sap collection lines are attached.

**tubing system:** Network of mainlines, lateral lines, appropriate fittings, vacuum pumps, collection tanks, releaser units, and other equipment as appropriate established for the purposes of collecting sap from maple trees.

**tubing tool:** Tool used to cut and connect fittings to 5/16 inch tubing.

**ultraviolet light (UV light):** A device producing high intensity, short wavelength (antigermicidal) light used to kill microorganisms in maple sap, thereby maintaining high sap quality.

**uneven-aged stand:** Stand containing trees of many ages and sizes occupying the same area (Chapter 5 and Figures 5.1 and 5.2), 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.

**vacuum system:** A tubing system equipped with a vacuum pump used to collect sap from maple trees.

**vacuum transfer:** Effective movement of vacuum to the taphole.

**value added product:** Secondary products produced from pure maple syrup such as maple sugar, maple crème, maple candies, etc.

**vapor compression:** Method of evaporating water from sap which captures the energy in the water vapor produced during evaporation and repeatedly reuses this energy. See discussion in Chapter 7.

**variable costs:** Costs associated with production of a particular product that are subject to change, depending on quantity produced.

**vessel elements:** Cells in the vascular tissue of hardwood trees through which sap is conducted.

**viscosity:** Characteristic of syrup that expresses its resistance to flow.

**wet-dry conductors:** 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).

**woods trees:** Maple trees growing in a woodlot or sugarbush; distinguished from open-grown or roadside trees.

**zone of discoloration (stain):** Narrow band of discolored, nonconductive wood that develops above and below a taphole.

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