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MAPLE SIRUP PRODUCERS MANUAL

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and
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MAPLE SIRUP PRODUCERS MANUAL

By C. O. WILLITS[1] and CLAUDE H. HILLS, *Eastern Regional Research Center, Northeastern Region, Agricultural Research Service*

No one knows who first discovered how to make sirup and sugar from the sap of the maple tree. Both were well-established items of barter among the Indians living in the area of the Great Lakes and the St. Lawrence River, even before the arrival of the white man (*36*, *101*).[2]

The maple crop, one of our oldest agricultural commodities, is one of the few crops that is solely American. Until only a few years ago, it was both produced and processed entirely on the farm.

The last 20 years have witnessed some vast changes in the maple sirup industry. For the first half of this century, maple sap was collected and converted to sirup in much the same way as it was in 1900, when atmospheric evaporation equipment was developed by Yankee ingenuity (*56*). Many of the more recent changes have been the result of scientific and engineering studies carried out by the Eastern Regional Research Center in Philadelphia, Pa., and by the experiment stations and agricultural colleges of Michigan, New Hampshire, New York, Ohio, and Vermont. Recently the Forest Service has established a facility for research on maple sirup production at the Northeastern Forest Experiment Station in Burlington, Vt.

Maple sirup is a woodland crop. Since the trees grow best at altitudes of 600 feet and higher, maple sirup is usually produced in hilly country. Its production is a vital part of the local economy in dozens of communities from Maine westward into Minnesota, and south to Indiana and West Virginia (chart 1). The same type and quality of maple products are produced throughout the area.

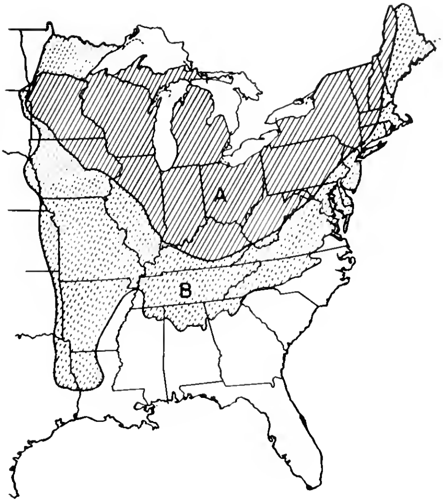

Chart 1.—A and *B*, range of hard maple trees; *A*, range of commercial production of maple sirup.

Maple sirup, like other crops, is subject to yearly fluctuations in production because of climatic and economic conditions. Production in the past has been affected by the cost or supply of white sugar and by the supply of farm labor. In 1860, a record crop of 4,132,000 gallons of maple sirup was produced. For the next decade the price of cane sugar declined. Production of maple sirup also declined to a low of 921,000 gallons in 1869. As cane sugar became scarce during World War I, production of maple sirup again rose, slightly exceeding the 1860 record. Production also increased during World War II. Since then, production has decreased (table 1) (*125*, *126*).

The decreased production since World War II is a reflection of the shortage of farm labor

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[1] Retired February 1969.

[2] Italic numbers in parentheses refer to References Cited, p. 128.

TABLE 1.—MAPLE SUGAR AND SIRUP: *Trees tapped, production, average price received by farmers, and imports, United States, selected years, 1918–70* [1]

Year	Trees tapped	Production					Price [3]		Imports for consumption	
		Sugar made	Sirup made	Total product in terms of sugar [2]	Average total product per tree		Per pound of sugar	Per gallon of sirup	Sugar	Sirup [4]
					As sugar [2]	As sirup [2]				
	1,000 trees	*1,000 pounds*	*1,000 gallons*	*1,000 pounds*	*Pounds*	*Gallons*	*Cents*	*Dollars*	*1,000 pounds*	*1,000 pounds*
1918	17,053	11,383	4,141	44,511	2.61	0.33	----------	----------	3,807	----------
1925	14,070	3,238	2,817	25,774	1.83	.23	26.9	2.08	3,911	113
1930	13,158	2,134	3,712	31,830	2.42	.30	30.2	2.03	9,735	1,575
1935	12,341	1,241	3,432	28,697	2.33	.29	26.7	1.42	1,920	2,469
1940	9,970	394	2,601	21,202	2.13	.27	29.4	1.65	4,087	4,660
1945	7,685	202	1,030	8,442	1.10	.14	54.6	3.21	4,131	1,232
1950	8,090	246	2,006	16,302	2.02	.25	77.2	4.12	6,549	5,282
1955	6,138	----------	[5] 1,578	12,624	----------	.26	----------	4.68	6,024	5,044
1960	----------	----------	[5] 1,124	8,992	----------	----------	----------	4.96	5,742	10,009
1965	----------	----------	1,266	10,128	----------	----------	----------	5.04	4,688	9,700
1970	----------	----------	1,110	8,880	----------	----------	----------	6.83	3,561	10,549

[1] For 1918–40, production estimates for Maine, Maryland, Massachusetts, Michigan, New Hampshire, New York, Ohio, Pennsylvania, and Vermont; in 1945 Minnesota was added.

[2] Assuming that 1 gallon of sirup is equivalent to 8 pounds of sugar.

[3] Obtained by weighting State prices by quantity sold from 1945 to date; prior to 1945 weighted by production.

[4] A gallon of sirup weighs about 11 pounds.

[5] Includes sirup later made into sugar.

SOURCES: Data for 1918–50 from *Agricultural Statistics, 1957*, table 133 (*125*). Data for 1955 and 1960 from Statistical Reporting Service and Economic Research Service, for 1965 and 1970 from *Agricultural Statistics, 1972*, table 137 (*128*).

during this period. Although the trend in the country as a whole is downward, production of maple sirup in Michigan, Minnesota, and Wisconsin has increased. In fact, based on the number of tappable trees, production in these States could exceed production in New York and the Northeastern States. For example, Michigan has one-fifth of the total stand of maple trees. Canada's total maple crop is about double that of the United States.

Table 2 shows the number of maple trees of tappable size and the percentage tapped in 1951.

Surveys in the eastern maple-producing areas (*126*) of the number of maple trees tapped as well as the total number of tappable size have shown that the industry is not suffering from too few trees. Although many sugar maples have been cut for lumber, vast stands remain, and these stands can supply our maple sirup needs.

Table 3 shows the production of maple sugar by the 11 principal States for selected years, 1926–71.

TABLE 2.—*Tappable maple trees, and trees tapped, Eastern States, 1951*

State	Tappable trees [1]	Trees tapped	
	Thousands	*Number*	*Percent*
Maine	53,553	136,000	0.25
Maryland	1,660	28,000	1.7
Massachusetts	11,913	166,000	1.4
New Hampshire	12,103	261,000	2.2
New York	73,128	1,960,000	2.7
Pennsylvania	33,553	422,000	1.3
Vermont	25,840	3,118,000	12.1
West Virginia	13,031	----------	----------

[1] Larger than 10 inches in diameter at breast height.

TABLE 3.—*Rank of States in production of maple sugar, selected years, 1926–71*

Rank	1926	1931	1936	1941	1946	1951	1956	1961	1966	1971
1	N.Y.	Vt.	Vt.	Vt.	Vt.	Vt.	Vt.	Vt.	N.Y.	N.Y.
2	Vt.	N.Y.	N.Y.	N.Y.	N.Y.	N.Y.	N.Y.	N.Y.	Vt.	Vt.
3	Ohio	Ohio	Ohio	Ohio	Ohio	Pa.	Ohio	Ohio	Wis.	Ohio
4	Pa.	Pa.	Pa.	Pa.	Mich.	Mich.	Pa.	Wis.	Pa.	Pa.
5	Mich.	Mich.	Mich.	Mich.	Pa.	Mass.	Wis.	Mich.	Mich.	Mich.
6	N.H.	Wis.	Wis.	Mass.	N.H.	N.H.	Mich.	Pa.	Ohio	Wis.
7	Mass.	N.H.	N.H.	N.H.	Mass.	Wis.	N.H.	N.H.	N.H.	N.H.
8	Wis.	Mass.	Mass.	Wis.	Wis.	Maine	Mass.	Mass.	Mass.	Mass.
9	Maine	Md.	Md.	Maine	Maine	Md.	Md.	Md.	Md.	Maine
10	Md.	Maine	Maine	Md.	Md.	Ohio	Maine	Maine	Minn.	------
11	----------	----------	----------	----------	----------	Minn.	Minn.	Minn.	Maine	------

ECONOMICS

Maple sirup, a noncultivated, nonfertilized crop derived from trees of the farm woodlot, provides supplemental cash incomes for many farmers, and it is the major cash crop for some farmers (*24, 26, 132, 140, 142*). The trees on 1 acre will provide 160 tapholes and an average yield of 1 quart of sirup per taphole, or 40 gallons of sirup per acre. At $10 per gallon, this sirup provides an annual per-acre gross income of $400.

With the advent of the central evaporator plant, maple sap became a marketable commodity. Annual gross income for sap ranges from 90¢ to $2.50 per taphole for sap delivered at the evaporator plant.

The maple season is short and comes in the early spring when most other farm activities are slowest. Thus, it does not compete with other farm activities. Because the season occurs when off-farm employment is at a seasonal low, it fits well into a part-time farming program.

Surveys in New York (*5, 8*), Ohio (*63*), Michigan (*92*), and Wisconsin (*113*) have shown that earnings from the production of maple sirup are among the highest on the farm. Wages average $3 per hour with a high of more than $5 for every hour spent in cleaning equipment, tapping trees, installing and taking down equipment, and collecting and boiling the sap.

With the high annual cash crop and high wages earned in producing sap and sirup, it is difficult to understand why only 1 of 20 tappable maple trees is being utilized. However, until recently maple sirup production methods were antiquated, at least when compared to modern methods of crop and livestock farming, and the unfavorable working conditions made sap collection and sirupmaking unattractive.

Both equipment and processing methods are being modernized. Modernization should do much toward making maple sap and sirup production more attractive (*71, 143*). This modernization includes plastic pipelines for collecting and transporting sap; taphole germicidal pellets; sanitary practices in tapping and sap handling; oil-fired evaporators; improved methods for evaporating sap, filtering sirup, and packaging the products; and the central evaporator plant. All these changes have reduced labor requirements and production costs, and have contributed to producing better grades of sirup that have a correspondingly greater value. Because of the relatively high fixed costs for producing sirup on the farm, net income may be too low when sap from fewer than 500 tapholes is available, and the sap could be more profitably sold to a central plant.

Sirup can be sold immediately to produce ready cash, or it can be held for a more favorable market or as a supply of raw material for producing more profitable maple products. If the sirup is held, it can be used as collateral for short-term loans.

Since 1940, the proportion of the maple sirup produced in the United States that has been sold directly to the consumer by the producer has increased. In many instances this has increased returns for the producer. To stabilize this expanded outlet, the producer has improved the appearance of the package and the quality of the sirup so that it meets State and Federal specifications. Many producers are obtaining larger returns by converting their sirup to confections such as maple cream and hard and soft sugar candies.

Maple sirup producers have formed associations so they can pool their stocks. The chief functions of these associations are to maintain adequate supplies, to promote sales, and to maintain the quality of the products. A number of communities hold annual festivals to stimulate interest in maple items.

The central evaporator plant has made it possible for the first time to separate sap production from the processing of sap to sirup. Thus, farmers can realize a substantial income from maple sap without having to make large capital investments in an evaporator house, an evaporator, sap storage tanks, and miscellaneous equipment.

The States, in cooperation with the Agricultural Research Service and the Extension Service of the U.S. Department of Agriculture, are conducting strong extension programs. These programs have brought the results of research directly to maple producers. In New York, a leader in this program, it is not uncommon for more than a thousand producers to attend the annual "maple sirup" schools held throughout the State in the premaple season.

SUGAR MAPLES

Only 2 of the 13 species of maple (*Acer*) native to the United States are important in sirup production (*6*, *55*, *124*, *157*).

Acer saccharum Marsh. (better known as sugar maple, hard maple, rock maple, or sugar tree) furnishes three-fourths of all sap used in the production of maple sirup. Although this tree grows throughout the maple-producing areas (chart 1), the largest numbers are in the Lake States and the Northeast. Trees grow singly and in groups in mixed stands of hardwoods. The trunk of a mature tree may be 30 to 40 inches in diameter. The tree is a prolific seeder and endures shade well but unfortunately does not grow rapidly. It is best distinguished by its leaf (chart 2).

Acer nigrum Michx. F. (black sugar maple, hard maple, or sugar maple) grows over a smaller range than does *A. saccharum*. It does not grow as far north or south but is more abundant in the western part of its range. This tree is similar to *A. saccharum* in both sap production and appearance. Its principal distinguishing feature is the large drooping leaf of midsummer (chart 2).

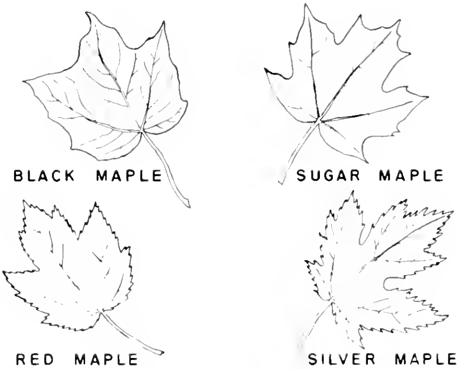

Chart 2.—Leaves of the sugar maple (*Acer saccharum* Marsh.), red maple (*A. rubrum* L.), silver maple (*A. saccharinum* L.), and black maple (*A. nigrum* Michx. F.).

Other species of maples commonly found in our hardwood forests are the red maple (*Acer rubrum* L.) and the silver maple (*A. saccharinum* L.). These trees, readily identified by their leaves (chart 2), are not good sources of maple sirup because their sap is less sweet than that of *A. saccharum* and *A. nigrum*, and it often contains excessive amounts of sugar sand. The red maple, the more common of the two, is easily identified in the spring by the red color of its buds.

The Sugar Grove

Most maple sugar groves, commonly called sugar bushes, are parts of stands of old hardwood forests. In the ideal sugar grove, most of the other trees have been cut out and the maples have been thinned sufficiently to allow the trees to develop a good crown growth (*63*). Thinning should be done according to a carefully planned program, with the assistance of the State extension forester and the State forester for the area. If the stand is made up entirely of maples, approximately the same volume of sap is produced per acre regardless of the size of the trees (*26*). As the number of trees per acre decreases below 160 trees 10 inches in diameter at breast height (d.b.h.) or 40 trees 25 inches d.b.h., the size of the crowns and the yield per tree may increase but the cost of collecting sap also increases because the distance between trees requires longer sap mains when tubing is used, and sap collected by hand must be carried farther.

Figures 1 and 2 show a maple grove with the large full crowns that are so important to the production of large amounts of sweet sap.

For maximum returns, the grove should contain at least 500 tapholes, that is, a minimum of 500 trees 10 inches d.b.h. Groves with fewer than 10 maple trees per acre are not profitable; groves with 30 to 40 trees 25 inches d.b.h. are ideal (*64*).

Maples grown in the open—for example, along the roadside (fig. 3)—are excellent sap producers (*64*, *65*, *67*) not only because they have large crowns but also because they have a large leaf area, which is necessary for both starch and sugar production. Because of their shorter boles, roadside trees do not make as good saw logs as do trees that grow under crowded conditions. Studies have been conducted on the effect of fertilization (*46*).

Trees in a crowded stand have smaller crowns and therefore are not good sap producers (figs. 4 and 5) because of their reduced leaf area.

The ideal sugar grove (figs. 6 and 7) requires not only a planned spacing of trees but also a good understory to protect the ground, keep it moist, and permit growth of seedling maples to replace mature trees that should be cut down (fig. 8). Often these mature trees can be sold for lumber. However, there is no such thing as a dual-purpose maple tree—one that serves

PN–4698

Figure 1.—Grove of maple trees with large crowns, which are needed for large yields of sweet sap.

PN–4699

Figure 2.—Same grove shown in figure 1 after defoliation, showing the branch structure of trees with large crowns.

PN-4700

Figure 3.—Large-crowned maples, typical of roadside trees.

PN-4701

Figure 4.—Trees in a crowded stand have small crowns and small boles. This grove requires thinning before it will be a profitable source of maple sap.

equally well as a sap producer and as a source of lumber—because the factors favoring the growth of trees for the two purposes are not compatible.

Consult your State extension forester, farm forester, and county agent and work with them to develop a management plan for your sugar grove. Aim for 160 tapholes per acre.

PN-4881

Figure 5.—Mixed stand of crowded trees. Some trees have long boles and small crowns. They make good saw logs but are poor sap producers.

PN-4702

Figure 6.—An ideal spacing of maple trees, favoring the growth of large crowns.

Sap Yields

The yield of sap in a sugar grove should be expressed in terms of the number of tapholes rather than the number of trees. The yield per hole is independent of the number of holes per

PN-4703

Figure 7.—This grove shows the effect of heavy grazing, a practice not recommended since it results in reduced sapwood production, stag-headedness, loss of reproduction, and root damage caused by soil compaction.

PN-4704

Figure 8.—Removing overmature trees that produce sap low in sugar content, to encourage growth of young stock. The high cut is made to avoid some of the sap stain and diseased wood associated with old tapholes.

tree. A mean range per taphole is from 5 to 15 gallons (*95*). However, a single taphole often produces from 40 to 80 gallons of sap in a single year—the equivalent of 3 or more quarts of sirup.

The sugar content of the sap produced by different trees in a grove varies considerably (*45, 110*). The sap produced by the average tree has a sugar content of 2° to 3° Brix.[3] Frequently trees produce sap with a sugar content of less than 1° Brix, and occasionally a tree produces sap with a sugar content of 9° or even 11° Brix. A conservative estimate is that the sap from four tapholes will yield 1 gallon of sirup. This sap most likely would have a density of 2.2° Brix. Thus, 10 gallons of sap from each taphole would be required to yield 1 gallon of sirup.

No device has been developed that will enable a maple sap producer to determine when sap will begin to run. However, sap will flow from the tapholes over a period of several weeks. The greatest yield of sap may be produced in a single run that occurs at the beginning of the period, at any time during the period, or at the end of the period. In 1960 almost all the sap crop was collected in a 24- to 48-hour period and the Brix value of the sap was much higher than 2.2°. Many producers reported sap of 5° Brix and higher. Because of the large volume of sap collected in this short period, many producers reported that their buckets overflowed. How much was lost will never be known. This loss would not have occurred had plastic tubing been used for collecting and transporting the sap.

Because of the large yield of sap in 1960 and its high sugar content, many producers who sold their sap to central evaporator plants received as much as $1.90 per taphole. A yield per taphole of 10 gallons of 5°-Brix sap having a value of 19.5 cents per gallon gives $1.95 per taphole. On this basis, a sugar grove with only 100 tapholes per acre would produce a gross of $195 per acre. This may answer the question that has often been raised as to whether the sugar orchard should be operated to produce sap or should be cut and sold as lumber.

The yield and sweetness of the sap produced by a tree vary from year to year, but trees that produce sap with a high sugar content and trees that produce sap with a low sugar content maintain their relative positions from year to year (*112*). It is important to know the exact sugar content of the sap produced by each tree. Measuring the sugar content of sap is not difficult. All that is needed is a sap hydrometer or refractometer and a thermometer.

To make the reading, float the hydrometer in the sap bucket or in a hydrometer can containing the sap (fig. 9). Also, obtain the temperature

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[3] The density of sap and sirup is due to a mixture of dissolved solids and not just to sugar. The physical instruments used to measure the density of sap and sirup do not distinguish between the density due to sugar and that due to other solids. The degrees Brix (° Brix) means that the solution has the same density as a solution containing a percentage of sugar numerically equal to the Brix value.

PN-4705

Figure 9.—Measuring the density of sap (° Brix) with a precision hydrometer calibrated in 0.1°. If the bucket contains too little sap to provide the necessary depth for the measurement, transfer the sap to a hydrometer can.

of the sap so the hydrometer reading can be corrected. (The sap should contain no ice.) Subtract 0.4° Brix for temperatures of 32° to 50° F., 0.3° Brix for temperatures of 51° to 59°, and 0.1° Brix for temperatures of 60° to 68°.

The sap hydrometer is usually calibrated from 0° to 10° Brix, with divisions of 0.5°. A more accurate measurement can be obtained by using a hydrometer with divisions of 0.1° (fig. 9).

The amount of sugar in sap is of great economic importance. A taphole that produces 15 gallons of sap with a sugar content of 2° Brix yields 2.5 pounds of sugar, or one-third gallon of sirup; whereas a taphole that produces 15 gallons of sap with a sugar content of only 1° Brix yields only 1.3 pounds of sugar, or less than one-fifth gallon of sirup. The cost of producing the sirup from both tapholes is approximately the same. Trees producing sap with a sugar content of 10° Brix are especially profitable, as 15 gallons of sap from 1 taphole yields nearly 1¾ gallons of sirup, or more than five times as much as the 2°-Brix sap. Trees that produce sap low in sugar (1° Brix or less) should be culled.

Research is being conducted at the Universities of Vermont and New Hampshire, at the Ohio Agricultural Experiment Station, and by the U.S. Forest Service on the propagation of maple trees from selected high-yielding trees (*20, 32, 33, 34, 45*). This research should eventually make it possible to set out maple orchards or roadside trees that will produce sap with a high sugar content.

Use of a germicidal pellet to prevent premature drying up of a taphole may increase sap yields as much as 50 percent. Since the results obtained by using the pellet are due to its germicidal action, it will not increase the sap crop in sugar groves where sanitary measures are already being practiced.

Summary

(1) Consult your State extension forester, farm forester, and county agricultural agent and work with them to develop a management plan for your sugar grove. Aim for 160 tapholes per acre (160 trees 10 inches d.b.h. or 40 trees 25 inches d.b.h.).

(2) Remove all defective, diseased, and weed trees.

(3) Check the yield and sugar content (° Brix) of the sap from each tree. Cull trees that yield sap low in sugar (1° Brix).

(4) For maximum sap yields use germicidal taphole pellets.

TAPPING THE TREE

The sap of the sugar maple, from which sirup and sugar are made, differs in composition from the circulatory sap of a growing tree. We know little concerning this sap, or sweet water as it is called in western Pennsylvania. Intensive study of maple sap at the University of Vermont (*34, 35, 57–59*) should lead to a better understanding of its nature, function, and source, and of the factors responsible for sap flows.

Sap will flow any time from late fall after the trees have lost their leaves until well into the spring, each time a period of below-freezing weather is followed by a period of warm weather. The sap will flow from a wound in the sapwood, whether the wound is from a cut, a hole bored in the tree, or a broken twig.

Date of Tapping

To establish a rule of thumb that can be used to set the date for tapping sugar maples is not a simple matter. The date should be early enough to assure collecting large early flows of sap (*66*). Michigan and New York provide sugarmakers with radio weather forecasts of the correct tapping dates (*22*). A similar service is being set up in other maple-producing States including Massachusetts, Vermont, and Wisconsin. Generally, trees should not be tapped according to a calendar date. In 1953 when this practice was followed, many producers failed to collect the large early flow that resulted from an unseasonable, early warm spell. The danger of tapping too early is now largely eliminated through use of germicidal taphole pellets (*17*). When pellets are used, trees can be tapped several weeks ahead of the normal season.

Selecting Trees

Selecting trees for tapping is of greatest importance and can be done at any time throughout the year.

Trees that produce sap with a density of only 1° Brix, as determined with a sap hydrometer or refractometer, should be culled. Culling must be done during the period of sap flow (*64*). If time does not permit testing all the trees during one sap season, test as many as possible the first year and test the remaining trees during succeeding years.

Trees selected for tapping should have a minimum diameter of 10 inches at $4^1/_2$ feet from the ground (d.b.h.) (fig. 10).

A good rule (*14, 64*) for determining the number of tapholes that can safely be made in a single tree is as follows:

Diameter of tree, inches	*Tapholes per tree,[1] number*
Less than 10	0
10 to 14	1
15 to 19	2
20 to 24	3
25 or more	4

[1] Number of buckets.

PN-4706

Figure 10.—Measuring the diameter of the tree to determine the number of tapholes the tree will support.

To undertap a tree reduces the potential size of the crop without any benefit to the tree. On the other hand, to overtap (fig. 11) may seriously damage the tree (*72, 94*).

Once the trees have been measured, they should be marked so they will not have to be remeasured each season. This can be done by painting a numeral or a series of dots on the tree or by using paints of different colors, such as white for 1 taphole, yellow for 2 tapholes, etc.

Boring Tapholes

Tapholes are made by boring with either a $^3/_8$-inch or a $^7/_{16}$-inch fast-cutting wood bit. Although tapholes can be bored by hand with a carpenter's brace (fig. 12), this method is used only for very small operations.

For large operations, a portable motor-driven drill not only speeds up the operation but also is far less fatiguing. These drills are made in two basic designs, one powered by a gasoline motor and the other by an electric motor. In one of the earlier models that is still popular (fig. 13), the gasoline motor is mounted on a packboard

PN–4707

Figure 11.—Overtapped tree (8 buckets on a 4-bucket tree). Note attempt to tap over large roots.

PN–4708

Figure 12.—Boring the taphole at convenient breast height. The hole is 6 inches from that bored the previous season.

and is connected to the drill by a flexible shaft. In other models, the drill is attached directly to the gasoline motor, which is held in the hand.

The electric battery-powered drill (figs. 14 and 15) is newer than the gasoline-powered drill. It is light and free from vibration and is fast becoming popular. With either a gasoline- or an electric-powered drill, one man can drill holes as rapidly as a crew of two or three can set the spouts and hang the buckets or bags, or install the tubing.

The hole is bored into the tree, preferably at a downward pitch of approximately 5 degrees. The downward pitch is especially desirable if germicidal pellets are used in the tapholes. The hole is bored 3 inches deep or until stained heartwood is reached. Studies at Michigan State University (*57*) have shown that a taphole 3 inches deep (fig. 16) produces up to 25 percent more sap than a taphole only 2 inches deep.

The position of the first taphole is selected arbitrarily. The hole should be 2 or 3 feet above the ground or, if there is snow on the ground, as close as possible to this height. This low position is particularly well suited to the use of plastic tubing. The compass location of the hole is not important. Data obtained in New York (*114*) and in Michigan (*16*, *93*, *94*, *96*) have shown that the total yield is essentially the same regardless of the compass location of the hole. However, the warm side of the tree is favored. Data also show that the height above ground level has little effect on yield. The best practice is to make the new taphole on successive years 6 to 8 inches from the previous year's taphole, working up the tree in a spiral pattern (fig. 17). With this procedure, the producer may tap his tree year after year in different quadrants and avoid striking an old taphole or dead tissue that has been hidden by new bark, either of which would result in a smaller flow and poorer quality sap.

When plastic tubing is used to collect sap, there is no minimal distance at which the taphole is located above the ground, and an even larger area of the tree becomes available for tapping. This permits a longer interval between periods when a repeat tap has to be made in the same area of the tree.

PN–4709

Figure 13.—A gasoline-powered portable tapping drill with flexible shaft.

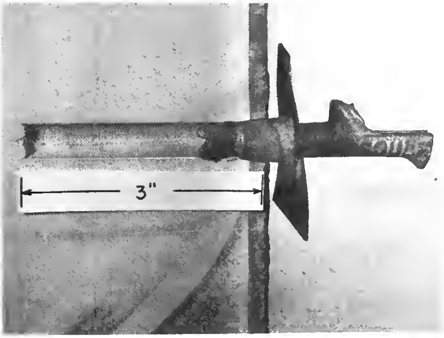
PN–4710

Figure 14.—An electric battery-powered tapping drill.

The time required for new bark to grow over a taphole depends on the health and vigor of the tree. It is not uncommon to find the hole nearly covered in a year (fig. 18). The hole itself remains open, but fungus growth (*109*) may occur in the new hole and stain the wood several inches above and below the hole and an inch or less to the side (figs. 19 and 20).

PN–4711

Figure 15.—The power tapping drill permits drilling the hole at different heights.



PN–4712

Figure 16.—The taphole is bored into the tree 3 inches deep.

Life of a Taphole

A taphole should be usable from the time it is bored until the buds begin to swell and the sirup acquires an unpalatable or buddy flavor. In the past, the taphole often dried up within 3 or 4 weeks after the hole was bored. Drying up is caused by growth of micro-organisms in the taphole rather than by air drying of the wood tissue (*13*, *102*, *103*). When the microbial growth has reached a count of 1 million per cubic centimeter, sap will no longer flow from the hole, and it is said to be dried up (*77*).

In the past, a dried-up taphole was reamed to make it flow again; it was assumed that this procedure would remove the air-dried wood tissue. However, reaming was never successful. Research has shown that the reaming bit did not sterilize the hole. Reaming removed only a layer of the microbial deposit; the remaining bacteria kept on growing. Soon, sufficient numbers were again produced to stop the flow of sap. The newly developed germicidal pellets have prevented premature drying of the taphole.

PN-4713

Figure 17:—Tapholes arranged in a spiral about the tree.

PN-4714

Figure 18.—In a healthy, vigorously growing tree, the taphole will be completely covered with new wood and bark in 1 year.

PN-4715

Figure 19.—A split section of a tapped maple log showing the longitudinal stain area above and below the taphole and the new growth of bark that has covered the outside end of the hole (left).

Sanitizing Tapholes

Germicidal Pellets

A germicidal taphole pellet (fig. 21) has been developed at Michigan State University (*17*). If put into the taphole as soon as it is bored, the

PN-4716

Figure 20.—Cross section of a maple log showing stained area caused by fungus growth in old tapholes. The stains show the exact contour of the holes including the area entered by the screw of the bit, but do not indicate whether the holes lie above or below the plane of the cut. Note that the stain is confined to the width of the taphole, which indicates that the lateral damage to the tree is restricted to within one-half inch on each side of the hole. But damage may extend several inches above and below the hole, as shown in figure 19.

pellet will keep the hole essentially sterile throughout the sap season (6 to 10 weeks) and therefore will permit flow of sap (*4*, *5*, *6*) each time the weather is favorable. If large early flows of sap occur, a second pellet may be needed after 4 weeks. The active ingredient of the pellet is paraformaldehyde which, because of its germicidal effect and low solubility, makes it ideally suited to this use. Each pellet must contain a minimum of 200 milligrams of available formaldehyde at the time it is placed in the taphole.

The function of the pellet is to contribute enough formaldehyde to the 1 to 5 milliliters of sap remaining in the taphole between flow periods to keep microbial growth to a minimum. When the sap is flowing, the short time it is in contact with the pellet permits only a trace of formaldehyde (less than 5 p.p.m.) to be dissolved. This small amount of formaldehyde is removed from the boiling sap while it is being concentrated to sirup in the evaporator pan. The very low concentration of formaldehyde in the sap in the storage tanks will not maintain the sap in a sterile condition (*133*, *134*). This is fortunate because it is sometimes desirable to culture the sap with specific micro-organisms or enzymes. Sap is cultured as one step in producing high-flavored maple sirup; it is also cultured to destroy substances that are responsible for the buddy flavor in "buddy" sap (*8*). Other germicides are under investigation (*40*, *41*).

Because of the very low residue of formaldehyde in sirup, the U.S. Food and Drug Administration issued in February 1962 a regulation governing its use (*130*).

However, under no circumstances should more than one paraformaldehyde pellet be placed in a taphole, nor should formaldehyde be added to the storage tanks. To do either might raise the concentration of formaldehyde in sap and contribute to a high concentration in the sirup. This would produce sirup containing more formaldehyde than specified in regulations of the U.S. Food and Drug Administration or of the State in which the sirup is made.

PN-4717

Figure 21.—A germicidal pellet is inserted in a taphole immediately after the taphole has been drilled or after it has been flushed with hypochlorite solution.

While pellets were being developed and during the first 2 years they were used commercially (1962–63), records show that when weather was favorable to microbial growth in the tapholes, pellets doubled or trebled the yield of sap. Pellets are less effective when good sanitary practices are followed or when the entire maple season remains cool, since microbial growth is retarded under these conditions.

Elimination of the cause of premature drying of the taphole permits tapping the tree before the sap season with the assurance that the first as well as the late run of sap will be obtained. Also, the cause of diminished flows throughout the season is eliminated. Both of these factors increase yields of high-quality sap and decrease the man-hours required to harvest sap (*156*). Germicidal pellets are especially desirable where plastic tubing is used to collect and transport sap in the woods. The pellets help to keep the pipeline (tubing) clean and sterile.

Chlorinated Solutions

In many sugar groves, chlorinated solutions are being used to control microbial growth in the taphole (*133*). The best procedure is to flush the taphole as soon as it is drilled with a solution consisting of 10 parts of a commercial hypochlorite solution (containing approximately 5.25 percent of sodium hypochlorite) and 90 parts of water (fig. 22).

Often where there is a week or more between sap runs and particularly if the nonrunning period is warm, the tapholes should be reflushed with a solution of the same strength. Where this chlorination procedure has been practiced, a change to germicidal pellets may not increase sap yields.

Summary

(1) Do not tap by the calendar. Follow your State's maple weather reports.
(2) Tap before the sap-flow season.
(3) Make 1 taphole in a tree 10 inches in diameter and 1 additional hole for each additional 5 inches of the tree's diameter.
(4) Make the taphole with a $^3/_8$-inch or $^7/_{16}$-inch fast-cutting (special) wood bit.
(5) Use a power tapper if the grove is large enough to justify the expense.
(6) Bore the hole into the tree to a depth of 3 inches at a slight downward pitch.
(7) The location of the taphole in respect to compass position and roots is not important.
(8) Space the holes at least 6 inches apart (circumference of tree) and in a spiral pattern.
(9) Sanitize the taphole. Use 1 germicidal pellet per taphole.


PN–4718

Figure 22.—Flushing the taphole with a 10-percent commercial hypochlorite solution.

SPOUTS AND BUCKETS

Sap Spouts

The spout or spile has three important functions: (1) It conveys the sap from the taphole to a container; (2) it either connects the plastic tubing to the taphole or serves as a support on which to hang the sap bucket or bag; and (3) it keeps adventitious (wild or stray) bacteria from gaining access to the moist taphole, which should reduce infection if plastic tubing is used.

Over the years a large number of sap spouts have been designed and used, with special features claimed for each. The earliest spouts were hollow reeds, often a foot or more in length. Two reeds inserted in adjacent tapholes carried the sap to the same container (fig. 23). There are only a few basic differences in the design of the various sap spouts. Some have a large opening at the delivery end. Others have a hook to support the bucket and a hole for attaching the bucket cover. On others the bucket is supported directly on the spout. All commercial spouts are satisfactory. A few spouts are shown in figure 24.

Plastic spouts are used with plastic tubing and they have tubulations to which the tubing is attached.

All spouts have a tapered shoulder so that when they are driven into position in the taphole, they form a watertight seal with the bark and outer sapwood but leave a free space between the sapwood and the spout. In setting the spout (fig. 25), care must be exercised not to split the tree at the top and bottom of the taphole. A split results in sap leakage and often all the sap from that hole is lost. To strike the bark a sharp blow damages the tree and often kills an area for several inches.

PN-4719

Figure 23.—Reed sap spouts, the forerunner of metal spouts.

PN-4720

Figure 24.—Wood and metal sap spouts.

Spouts should be cleaned at the end of each season. Metal spouts can be washed by tumbling in a small concrete mixer containing a solution of a good detergent. Just before the spouts are taken into the sugar grove at the beginning of a sap season, they must be sterilized by heating them in boiling water for 15 minutes or longer. The spouts are then put in a pail and covered with a chlorine solution containing 1 cup of a commercial bleach (5.25 percent of sodium hypochlorite) in 1 gallon of water. The pail of chlorine-wetted spouts is carried into the sugar grove. Rubber or rubber-

PN–4721

Figure 25.—Setting the sap spout.

coated canvas gloves must be worn to protect the hands from the strong bleach.

Rainguards

Heavy rains often occur during the sap season. Rainwater running down the tree picks up dirt and leaches tannins from the bark. Both the dirt and the tannins, if permitted to get into the sap bucket, lower the grade of the sirup produced. Most sap spouts are provided with "drip tips" to deflect runoff rainwater from the tree and prevent it from entering the bucket. In heavy downpours, drip tips are often inadequate. Use of a simple, homemade rubber rainguard (fig. 26) prevents the heaviest runoff rainwater from entering either a sap bucket or bag.

To make a rainguard, cut a 2-inch square from a thin sheet of rubber, such as an old inner tube. With a leather punch, cut a $^5/_{16}$-inch hole in the center of the square. Slip the rainguard over the end of the spout near the tree and set it far enough forward so that when the spout is seated in the taphole there will be a free space of $^1/_4$ to $^3/_8$ inch between the rubber guard and the bark of the tree.

PN–4722

Figure 26.—Rubber rainguard prevents water from reaching the sap bucket.

Sap Buckets and Bags

Three types of containers have been used to collect the sap from the spout: (1) The wooden bucket; (2) the metal bucket; and (3) the plastic bag.

The wooden bucket, because of its size and the care required to keep it watertight, has largely disappeared from use.

Zinc-coated 15-quart buckets are the most commonly used metal buckets. Large 20-gallon galvanized cans that eliminate daily collection of sap are used in some "cold" sugar groves (high altitude, northern exposure). In a cold grove, the buckets often contain ice sap which retards microbial growth. The minute amount of zinc that is dissolved from the galvanized coating by the sap tends to reduce microbial growth, but the germicidal effect is nullified if the zinc coating is overlayed with a deposit from the sap (*108*). It can be made effective again by carefully removing the protective film overlaying the galvanized surface. The 20-gallon containers tend to reduce microbial growth more than do the smaller buckets (*28*). Lead-coated metal (terneplate) or lead-soldered buckets and buckets painted with lead paint should not be used because the lead may be dissolved by the sap, especially sap that has been allowed to ferment and sour. Sirup made from this sap may contain illegal amounts of lead. Aluminum buckets, which are being subsidized in Canada, tend to eliminate most objections to metal buckets.

Every bucket should be provided with a cover to keep out rain and falling debris. Covers are of two general types: Those that are attached to the spout (fig. 27) and those that are clamped to the bucket (fig. 28).

The plastic sap bag (fig. 29), a comparatively recent development, met with much favor, especially before the development of plastic tubing. Some advantages of plastic bags are: (1) Because of their small bulk and weight, they require minimum storage space, and they are easily transported to the woods and hung. (2) They have a self-cover that encloses the spout when the bag is in place, and thus limits access of micro-organisms to the open end of the spout and to the taphole. (3) Emptying the sap is a one-handed operation (fig. 30). The bags need not be removed from the spout; they can be rotated on the spout. (4) Because they are transparent to sunlight radiation, which is lethal to micro-organisms, they tend to keep the sap sterile (*76*). Sterile sap contributes to the production of high-quality sirup.

Some disadvantages of plastic bags are: (1) They may open at seams, especially if the sap in a filled bag freezes. (2) They are difficult to empty when filled with ice. (3) The bag may be too small to hold a day's run. (4) The bags are subject to damage by rodents. (5) Washing and rinsing the bags may be difficult.

PN-4723

Figure 27.—Sap bucket cover attached to the spout by means of a pin. With this type of cover, the bucket must be lifted free of the spout for emptying.

PN-4724

Figure 28.—A clamp-on cover stays fixed to the bucket and is not easily blown off. With this type of cover, a bucket that is attached to the spout by means of a hook must be lifted free of the hook for emptying. However, a bucket that hangs on the spout by means of a large hole that will slip over the spout can be emptied by rotating the bucket and cover on the spout.

PN-4725

Figure 29.—Plastic sap bag: The amount of sap is easily seen and accumulations of sap, even from short runs over a long period of time, tend to remain sterile because ultraviolet rays of daylight are transmitted through the plastic. The bag has its own plastic cover. Since the spout is completely covered, it is free from contamination.

Summary

(1) Any commercially available spout is satisfactory.
(2) Use only clean, sterile spouts.
(3) Drive the spout into the taphole with a firm enough blow to seat it securely, but do not drive it so far as to split the bark and wood.

PN-4726

Figure 30.—Emptying the plastic bag by rotating it on the sap spout makes it a one-handed operation.

(4) Use a 2- x 2-inch rubber runoff rainguard on the spout.
(5) Carry clean, sterile spouts wetted with a dilute, hypochlorite solution into the sugar grove.
(6) Do not use buckets coated with lead paint or with terneplate.
(7) Use containers large enough to hold a normal day's run of sap.
(8) Use only clean sap buckets or bags.
(9) Use covers on all sap buckets or bags.

COLLECTING THE SAP

Collecting (gathering) sap by hand (fig. 31) is the most expensive and laborious of all maple sirupmaking operations and accounts for one-third or more of the cost of sirup production.

When buckets or sap bags are used, much time can be saved if the trees to be serviced on both sides of a roadway bear a mark to distinguish them from the trees to be serviced from an adjacent roadway. This prevents servicing the same tree from both roadways. Different colored paints can be used to mark the trees.

Another timesaver requires punching a second hole in the sap bucket opposite the original hole, and painting a stripe from that hole to the bottom of the bucket. The buckets are hung first from one hole (for example, with the stripe away from the tree and plainly visible); after they are emptied, they are hung from the opposite hole. This makes it easy for the sap collector to tell whether a bucket has been emptied and keeps him from skipping full buckets as well as wasting time revisiting empty

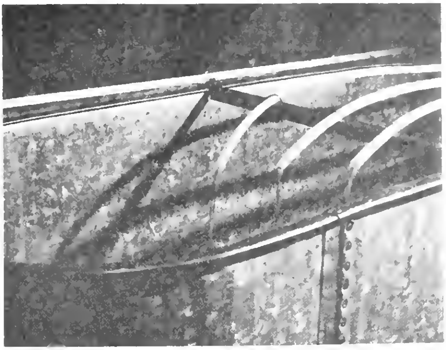
PN-4727

Figure 31.—Collecting sap by hand is expensive. Usually two pails are used to collect the sap from the sap bags or buckets, and the sap is carried by hand to the collecting tanks.

buckets. The only objection is that a bucket with holes on both sides holds less sap than a bucket with one hole because it hangs from the spout at an angle.

Some producers empty the buckets by rotating (spinning) them on the spout. This requires the use of a cover attached directly to the bucket and a spout on which the bucket is hung by means of a hole in the bucket. More sap may be spilled when buckets are emptied by spinning than when they are lifted free of the spout and tree. Spillage of sap when transferring it from bucket to gathering pail and from pail to collecting tank may account for an appreciable loss of the sap crop. Plastic tubing eliminates this loss (fig. 32).

Sap must not remain in the buckets more than a few hours before it is collected. During short runs that produce too little sap to warrant collecting, the buckets must be emptied, even though this is time consuming and expensive. The sap left standing in the bucket will ferment and spoil and will spoil other sap to which it is added in the collecting or storage tanks.



PN-4728

Figure 32.—No labor is required when tubing is used to collect sap.

Collecting Tanks

Collecting tanks vary in size according to the needs of the sugar grove. The tanks usually are provided with a strainer, baffled to prevent loss of sap by splashing, and a drainpipe.

The method of hauling the tank is governed by conditions in the sugar grove. The tank can be mounted on any of several types of carrier, including stoneboat or skids, 2-wheel trailer, high wheeled wagon gear, and underslung rubber-tired, 2-wheel trailer (fig. 33).

High-mounted tanks should be avoided because of the labor required to lift the sap (fig. 34). Usually an additional worker is needed.

A rig of excellent design has a low-mounted sump tank and a self-contained, power-driven pump to lift the sap up to the large tank (figs. 35–38).

A new type of collecting tank being widely adopted employs vacuum (suction) for filling. Tanks to be filled by suction must be airtight and structurally strong enough to withstand an external pressure of 15 pounds per square inch (1 atmosphere). Tanks larger than 300 gallons require internal bracing. The vacuum can be obtained by a separate pump or by connecting a line from the manifold of the truck or tractor engine (fig. 39). To prevent sap from entering the engine manifold, a float check valve is mounted on the tank and the vacuum line is attached to this (fig. 40). The check valve is

PN–4729

Figure 33.—Collecting tank mounted on a truck body. This type of assembly does not require special rigs, but an additional man is needed to empty the pails into the tank.

PN–4730

Figure 34.—Additional labor is required to lift sap to a tank mounted on a trailer.

similar to those used in milking machines that prevent milk from entering the pump. If sap reaches the motor, it causes serious damage.

A 1,000-gallon tank can be emptied and put back into operation in only a few minutes. The suction line is a 1-inch hose, which will pick up 30 gallons of sap per minute. Instead of a slow-acting valve in the suction line, a tapered plug is used in the pickup end of the hose. This plug is removed just before the hose is submerged in the sap in the tank or bucket to be emptied.

PN–4731

Figure 35.—For large operations or for collection from roadside trees extending along several miles of roads, the large tank trailer is desirable.

If a closed tank and an engine manifold vacuum system is not available, a pump-and-vacuum system can be used (*2*). In this novel system, an air-cooled gasoline motor operates a pump which, in turn, creates a vacuum in a small tank. The sap is discharged into a conventional collecting tank.

Regardless of how the vacuum in the suction (sap pickup) line is developed, this method of collecting sap is efficient and fast, causes a minimum of loss due to spillage, and can be used for collecting sap from the conventional metal bucket, from the large 20-gallon container, and from small and large storage tanks. Whether or not the collecting tank has a vacuum line pickup, the tank must be as large as roads and other conditions will permit. The smaller the tank, the greater the number of costly trips that must be made.

Pipelines

Metal pipelines have been used in the maple sugar grove for 50 years or more. The early metal pipe carried the sap over almost impassable terrain, from one sugar grove to another or to the evaporator house (figs. 41 and 42). Metal or wooden troughs have also been used as "pipelines."

All these pipelines, whether metal pipe or metal or wooden troughs, had one serious draw-

PN-4732

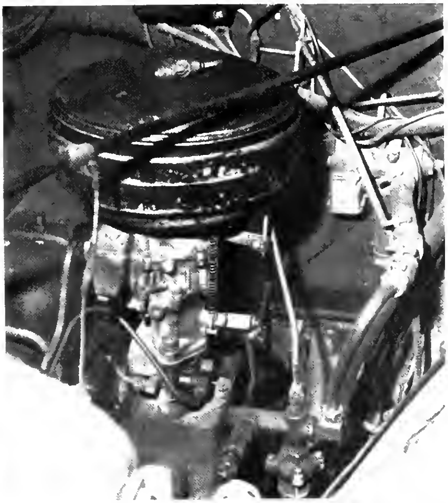
Figure 36.—Sap is easily poured from buckets into a low sump tank, from which it is pumped into the large tank.

PN-4733

Figure 37.—The sap is lifted from the sump by means of a pump. Power for the pump can be supplied by a takeoff from the tractor or truck engine or by a small gasoline motor.

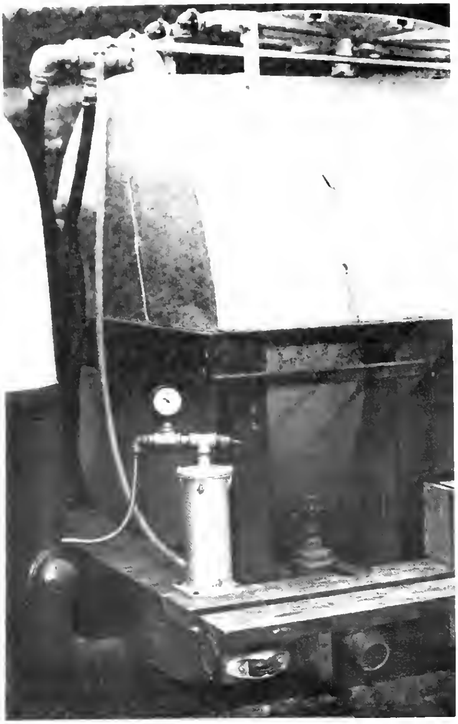
PN-4734

Figure 38.—Vacuum lines operated by a vacuum pump can be used to empty buckets and small containers in the woods or at the roadside.



PN-4735

Figure 39.—The vacuum is obtained from the manifold of the truck engine.



PN–4736

Figure 40.—Float valve assembly and vacuum (suction) line.

back; they had to be installed with great care so that there would be no sags in the line. Sags in pipes permitted the sap to lie there and, when a freeze occurred, the ice formed would often burst the pipe. Sags in troughs permitted the sap to overflow. In addition, metal pipe was hard to clean. Since metal pipes are opaque, there is no simple means to determine when they are clean. Nevertheless, the saving in time and labor made possible by these earlier pipeline systems justified their use.

Summary

(1) Collecting sap by hand and hauling it is the most expensive operation of sirupmaking. Examine all steps and introduce laborsaving methods where possible.

PN–4737

Figure 41.—Use of pipelines to carry sap over impassable areas saves time. With a lateral system of dumping stations, collecting tanks can be eliminated in some locations. The pipeline also makes accessible some sugar groves that would be impossible to reach by tractor or truck.

PN–4738

Figure 42.—When the sugar grove is at a higher elevation than the evaporator house, the pipeline carries sap from dumping stations at the edge of the sugar grove to the evaporator house. This eliminates long and costly hauls of sap.

(2) Wherever possible, use pipelines to transport the sap.

(3) Do not collect spoiled sap. Do not allow small runs of sap to remain in the buckets.

(4) Do not spill sap when pouring it into collecting pails and tanks. This can account for a 10-percent loss.

(5) Use as large a collecting tank as possible to avoid repeated hauls.

(6) Use a pump or vacuum to fill the tank.

(7) When vacuum is used, be sure the tank is internally braced to withstand the high external pressures.

(8) Keep all equipment sanitary at all times.

PLASTIC TUBING

With the advent of plastic tubing, most of the objections associated with metal pipes have been overcome. Not only can plastic tubing be used for collecting and transporting the sap, but also it is cheaper to install, it has greater flexibility and elasticity, and it is easy to keep clean. Wide acceptance of plastic tubing by maple producers (*38*) has been a major factor in modernizing the 300-year-old maple industry.

Use of plastic tubing has practically eliminated the hard, unattractive labor of collecting sap and has lowered the cost of sirupmaking as much as 40 percent. No longer is it necessary to construct expensive roadways through the woods to support heavy tanks of sap and to open these roads after heavy snows (fig. 43). Tapping need not be delayed until the sap season has arrived. Large crews do not have to be hurriedly assembled to tap the trees and hang the buckets. Instead, the lightweight plastic tubing can be carried by hand through the woods when convenient.

Some setbacks were encountered when plastic tubing was first introduced. Since it had been emphasized that sap issues from the tree under high pressure (*39*), systems for installing the pipelines were patterned after those used for high-pressure waterlines. It was anticipated that enough pressure was developed by the tree to force the sap through the pipelines, but this was not true. The sap leaks from the tissues of the tree under a wide range of pressures, from very low (almost immeasurable) to as much as 40 pounds per square inch. The pressure is affected by many factors, among which are the temperatures of the air, tree bark, and soil. In many runs, and often throughout most of a run, sap leaks from the tree under very low pressure. Thus, only a slight obstruction in a pipeline provides sufficient back pressure (resistance to flow) to equal or exceed the pressure at which the sap is being exuded from the tree. Hence, sap flow is prevented.

Causes for back pressures (obstructions) in the line are (1) gas (vapor) locks resulting from pockets of gas exuded from the tree along with the sap (*8*) or from air pockets that result from air that has leaked into the tubing around the different connections, especially at the spouts (through the vent tubes); (2) low places in the line where pockets of sap collect, and (3) ice plugs of frozen sap. Of these three causes, gaslocks are most frequent and may cause enough back pressure to support a 5-foot column of sap. However, gaslocks can be kept to a minimum by careful installation and by providing vents to free the trapped gases or air.

The effect of ice in the pipelines is a controversial subject. Many believe that by the time the air temperature has risen sufficiently to cause sap to flow from the tree, the tubing will have warmed sufficiently to partly melt the ice and allow passage of the sap. Others believe that the elasticity of the tubing will permit the sap to pass by the ice plug. This is unlikely. Still others believe that tubing laid directly on the ground, whether snow covered or not, will absorb enough latent heat from the earth to melt the ice in the tubing before any appreciable flow of sap occurs. Ice in tubing installed on the ground often melts before ice in tubing suspended in the air. (This can be observed when the two systems are installed in the same sugar grove.) There is almost complete agreement that ice in tubing layered between two falls of snow melts very slowly because of the insulating effect of the snow. The tubing must be pulled up out of the snow before the ice will

PN-4739

Figure 43.—Tubing can be used for a small group of trees in an inaccessible area or for roadside trees.

melt and unblock the lines; this is not easy to do when the lines are suspended.

Since maple sap is not exuded from trees at all times under high pressure, the best method for installing the tubing is one patterned after that used in gravity-flow waste-disposal systems. These systems are installed with a continuous, even though slight, pitch of both the feeder lines (laterals) and main lines toward the exit end. Main or trunk lines must be of sufficient diameter so that they are never overloaded. Vents must be installed at all high points to prevent gaslocks, and a vent must be installed at each spout.

One of the outstanding features of the plastic pipeline is the "closed" system—transparent to daylight which minimizes microbial infections and keeps the sap clean and free of foreign matter (*29, 31*). However, infection can and does occur; therefore, sanitary precautions must be observed in installing and maintaining the system.

The immediate effects of infection are deterioration and spoilage of the sap. Since infection can be translocated by the moving sap, two or more tapholes must not be connected in series. This might spread infection from one taphole to another (*31*) and prematurely stop sap flow. For the same reason, tubing that connects the taphole to either lateral or main lines must be installed with enough elevation between the lateral line and the taphole to drain the sap away from the taphole freely and completely during periods of flow and to provide sufficient hydrostatic pressure to insure flow in the main lines laid on level ground.

Installation of flexible plastic tubing (lateral or main lines) suspended in the air above the ground, free of sags between points of support and with a continuous pitch, would be an even greater problem than installation of iron pipe. A suspension cable would be required. It would be stretched from tree to tree above the tubing; the tubing would be suspended from it and held in a "straight" course by hangers of different lengths. In practice, however, sags cannot be prevented because fluctuating air temperatures expand and contract the tubing and cable and because the tubing between the hangers is not rigid. Also, locating these lateral and main lines so that all tapholes will be a short but fixed distance above the main lines (*48–50*) would increase the difficulty of installation because numerous main lines and short lengths of lateral lines would be required. This system is ideal for small installations involving one or only a few trees. Do not connect tapholes in series except on individual trees. To do so may spread microbial infection and stop flow of sap prematurely.

In expanding this system to a large operation, the costs of initial installation, takedown, and reassembly might be excessive. The system does, however, eliminate the need of taphole vents, since the short length of the dropline is attached to main lines that are not completely filled with sap and so will not air-lock. A properly installed pipeline system drains itself. If sags occur in either ground- or aerial-supported systems, pockets of sap will form. These pockets cause buildup of back pressures, reduce flows, are sites of microbial infection, and form ice plugs on freezing.

Installing Tubing

There are many methods for installing plastic tubing (*68, 70*). The following method (*152*) is economical of materials and labor, minimizes spread of microbial infection, and tends to eliminate gaslocks and other obstructions that build up back pressures in the lines. It provides a simple, inexpensive, and satisfactory means for installing, taking down, washing, sanitizing, and reinstalling plastic tubing.

Equipment

Droplines.—Complete assemblies of 5-foot lengths (for level land use 6- to 7-foot lengths) of $^5/_{16}$-inch inside diameter (I.D.) tubing with a tee at one end and a sap spout at the other. The spout has a vent tube attached. Vent tubes are U-shaped $^5/_{16}$-inch I.D. tubes formed with a short piece of wire; they are from 6 to 12 inches long and are attached to the vent tubulation of the spout (chart 3). The U-shape tends to keep micro-organisms out of the system.

Lateral Lines.—Lateral lines, made of $^5/_{16}$-inch I.D. tubing, connect the droplines to the main lines. They are laid on the ground.

Main Lines.—Main lines vary in size from $^1/_2$ to $1^1/_2$ inches I.D.

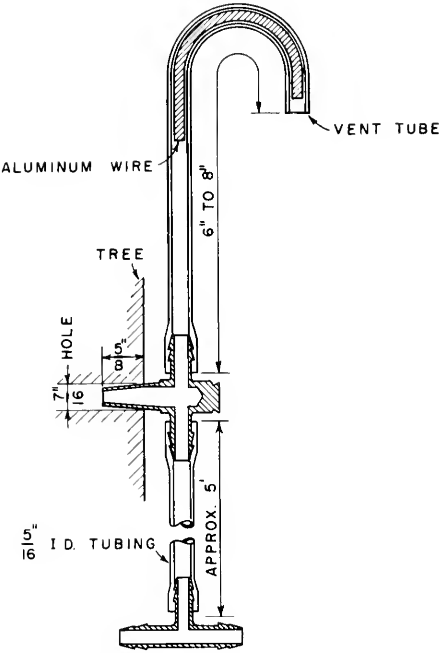


Chart 3.—Vent tube and drop line assembly.

Spouts.—Spouts have two tubulations, one for discharging the sap and the other for venting gases.

Tees and Connectors.—Plastic tees, connectors, and other fittings of appropriate size are required for connecting droplines, lateral lines, and main lines.

Hypochlorite Solution.—A commercial bleach containing 5 percent of sodium hypochlorite is diluted with water at the rate of 1 gallon of bleach to 19 gallons of water.

Germicidal Pellets.—One germicidal pellet is required for each taphole.

Some producers find it desirable to flush all new tubing with a stream of pure water for 10 to 15 minutes before putting it into use. This removes any soluble material in the tubing, including that which might produce an off-flavor.

Droplines can be completely assembled at odd hours before the sap-flow season. They are assembled before they are installed in the sugar grove and are not disassembled until they need to be replaced. A complete dropline is used for each taphole on each tree.

To install the lateral and main-line tubing so that it will have the desired pitch without sags, lay out the route it should follow before the sap season when the ground is bare and the trees along the route have been blazed. Painting the trees with vertical lines (blaze marks) will show the number of tapholes to be made per tree. The paint can be applied in a fine stream from a pressure paint can.

Where the slope of the ground is not too steep, it is recommended that a tractor with scraper blade be run over the route to level it. A short time before the sap season, the trees should be tapped and the tubing installed. Although this can be done by one man, a three-man team is more efficient. Not more than 25 droplines (tapholes) per lateral line should be installed.

Main Lines

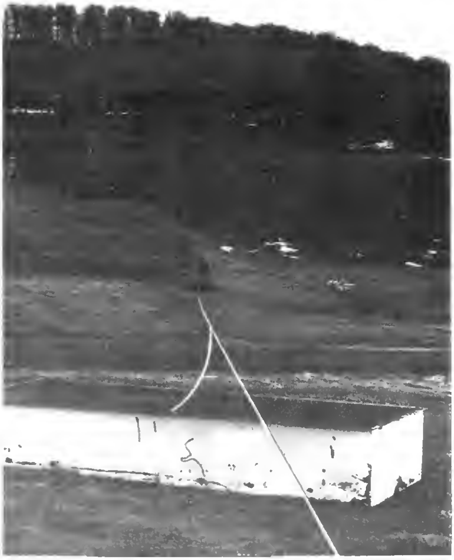
Beginning at a location farthest from the storage tank and where two lateral lines converge, main lines should be laid in the most direct route to the storage tank (figs. 44–49). Low places should be avoided if possible. The first length of the main line should be 1/2-inch I.D. The size should be increased as the quantity of sap entering it increases. On level ground, a 1/2-inch main line will carry the sap from 75 tapholes. Where two or more 1/2-inch I.D. main lines converge, they should be attached to 3/4-inch or 1-inch main lines. These, in turn, are connected to still larger main lines as the number of converging lines increases. In many sugar groves only 1/2-inch I.D. main lines are required.

There is no absolute rule regarding size and length of main lines except that they must be large enough in diameter to prevent buildup of back pressure. Pressure buildup can easily be seen by installing 6-foot lengths of 5/16-inch vent tubes in a vertical position at the junction points. If sap rises in the vent tubes, the main line is too small. The carrying capacity of a 1/2-inch main line equals three to four 5/16-inch lateral lines, and a $^3/_4$-inch main line equals two $^1/_2$-inch lateral lines.

When a graded course having a uniform downward pitch to the tank lines is impossible because of the contour of the land, the main lines should be suspended from overhead guy wires or cables. Suspended installation is especially suited for long runs of main lines over very rough, rocky land, gullies, ravines, and valleys. A properly installed main line will drain itself.

Tapping and Droplines

If trees are tapped and droplines are installed by a three-man team, the first man locates the position for the taphole and bores the hole. He sanitizes the bored hole either by syringing it with the hypochlorite solution or by inserting a germicidal pellet. The second man carries the dropline assembly and attaches it to each taphole by driving the spout firmly into the taphole. The third man furnishes droplines, hypochlorite solution, and other supplies to the first two men.



PN-4740

Figure 44.—Main line used to transport sap across inaccessible area.

PN-4741

Figure 45.—Junction of several main lines with surge tank and vent.

PN-4742

Figure 46.—Main lines transport sap to storage tank at the evaporator house.

PN-4743

Figure 47.—Main line to roadside tank for pickup.

Lateral Lines

Coils of $^5/_{16}$-inch I.D. tubing are taken to the starting point of installation in the sugar grove, usually the storage tank at the roadside or at the evaporator house. The laterals are laid out and connected by a second three-man team.

The leadman of the team carries the coil of tubing. One of the other men holds the end of the tubing. The leadman lays the tubing to the first tree tapped. The line should be kept free of loops and should lie flat on the ground. The tubing is gently pulled to straighten it out and the desired length is then cut from the coil. One of the other two men holds the cut end of the coiled tubing, and the leadman advances to the second tree, laying out the tubing as he goes. The second and third men alternate in the following tasks: Holding the tubing while it is being laid out; disinfecting the ends of the tubing, tees, and connectors; and connecting the laterals to the tees of the droplines. Where there are multiple drops (tapholes) on one tree, they are connected with 1-foot pieces of $^5/_{16}$-inch I.D. tubing.

Laying tubing in shaded areas should be avoided. All connections and droplines to later-

PN-4744

Figure 48.—Droplines are installed before ground lines are laid out.

PN-4745

Figure 49.—The leadman carries the coil of tubing.

als should be on the southern side of the tree to favor early thawing of any ice formed in the joints (figs. 50 and 51).

After the tubing has been installed, the entire system must be checked to insure that all connections have been properly made. Inspection tours should be repeated throughout the sap-flow season to check for leaks and separated joints. Inspections are necessary if the tubing was installed over deep snow that melts during the sap season or if new falls of snow cover the tubing.

Taking Down Tubing

Tubing must be taken down not later than 1 week after the last run, or after the trees begin to bud. To delay permits growth of micro-organisms and makes washing and sanitizing more difficult. During the sap-flow season, temperatures are usually cool enough so that the rate of germination of any micro-organisms in the tubing is slower than their death rate caused by the transmission of ultraviolet radiation of sunlight through the tubing. But, as the season progresses beyond the budding period, the warmer weather causes the growth rate to greatly exceed the death rate of the organisms, and abundant growth occurs. Therefore, taking the tubing down immediately after the end of the season makes the cleaning operation easier.

PN-4746

Figure 50.—Droplines are connected to laterals.

PN-4747

Figure 51.—Several laterals are joined to the main line with tees or the newly developed collector.

The process for taking the tubing down is merely a reversal of that described for its installation. Like the installation, this process can be a one-man operation; but it is more efficient when done by two 2-man teams.

The leadman of the first team at each tapped tree disconnects the droplines from the laterals and the foot-long connectors, which he collects. The second man pulls the spouts from the tree and collects the dropline assembly. Disconnecting lateral lines, short connectors, and droplines, and tying tubing bundles are shown in figures 52–56.

When 25 droplines have been collected, they are tied into bundles, with the tee ends flush. Since all droplines are alike, no labeling is needed.

PN-4748

Figure 52.—Taking down droplines.

PN-4749

Figure 53.—Taking up lateral lines.

PN-4750

Figure 54.—Tying and labeling bundles of lateral lines.

The second team collects, bundles, and tags the disconnected lateral lines. The leadman collects the tubing. Beginning at the first tapped tree, he picks up the end of the tubing that extends from the main line or storage tank and pulls the tube to the second tree. There he picks up the end of the tube extending between the first two trees and places the end flush with the end of the first tube. Then he pulls the two lengths of tubing to the third tree and repeats the process until a handful of tubing (20 to 25 pieces) has been collected. Smaller lots may be obtained from an isolated section of the sugar grove.

When a handful of tubing has been collected, it is left at the tree where the last piece was collected. Another member of the team ties the flush ends together into a bundle and attaches a label showing the general area of the sugar grove where it was installed. The bundle of tubing is then tied into a coil approximately 2 feet in diameter for easy handling.

This system of installing and dismantling the tubing not only is simple but makes washing and sanitizing of the tubing easy.

Washing and Sanitizing Tubing

At the end of the maple season most of the interior of the tubing is either wet or moist with sap. With the warmer weather at that time,

PN-4751

Figure 55.—Coiling lateral lines for ease of handling.

PN 4752

Figure 56.—Load of tubing to be taken to evaporator house for cleaning and storage.

temperatures are favorable to microbial growth (yeasts, molds, and bacteria). However, if the sap in the tubing were sterile, either because of excellent sanitary practices or because of the sterilizing effect of sunlight, no subsequent growth would occur. But this seldom, if ever, happens. Excessive microbial growth usually occurs, especially if higher temperatures follow takedown of the tubing. Once growth occurs, it becomes increasingly difficult to clean the tubing. Therefore, the tubing should be washed within a few hours after its takedown, and if that is not possible, within 1 or 2 days. Tubing in which microbial growth is excessive must be cleaned by more elaborate methods.

Equipment

The following equipment is required for washing the tubing:

(1) A *tank* to hold the hypochlorite solution. This can be a 55-gallon drum or a stock-watering tank of approximately 200-gallon capacity.

(2) A *gear-pump* that will deliver at least 50 gallons per hour at 10 to 15 pounds' pressure. A bypass arrangement on the pump provides flexibility of operation. The pump is attached to the drain valve of the tank and is equipped with a 15-foot length of hose provided with a tapered nozzle.

(3) *Wash or sanitizing solution* consisting of a 10-percent solution of a commercial liquid bleach (which contains approximately 5 percent of sodium hypochlorite); 20 gallons should be used with 180 gallons of water.

(4) *Rubber gloves* to protect the hands against the caustic action of the sanitizing solution.

Washing Laterals

Rubber gloves are worn. A coil of the tubing is submerged in the tank of hypochlorite solution (fig. 57). The drain valve connecting the tank and pump is opened, and the pump is started. The stream delivered from the hose nozzle is adjusted by means of the pump bypass valve. The bundle of tubing is picked up by the flush ends. The nozzle is inserted into one of the tubes until the tube is completely filled with the wash solution (fig. 58). Filling a tube completely usually requires less than a minute. When air bubbles no longer emerge from the discharge end, the tube is completely filled. As each tube is flushed and filled with hypochlorite solution, it is released so that only the unwashed tubes are held. When all tubes in a bundle have been flushed and filled with cleaning solution, the coil is allowed to sink to the bottom of the tank and another coil of tubing is placed in the tank. Then the process of flushing and filling each tube of the new coil is repeated. This is continued until the tank is filled with tubing.


PN-4753

Figure 57.—Coils of lateral lines are submerged in hypochlorite solution, and all the ties are cut except those at the end of the bundle.

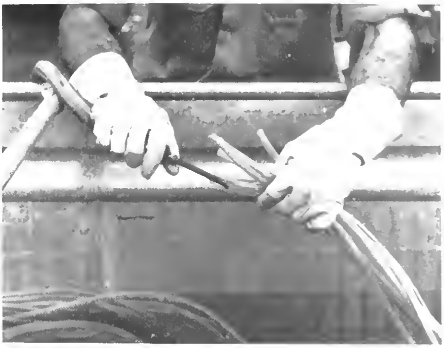

PN-4754

Figure 58.—After soaking, the tied end of the bundle is held and each tube is washed separately.

CAUTION

Because of the caustic action of the hypochlorite solution, rubber gloves must be worn during the washing operation.

The tubing is soaked for 2 hours; then each tube is flushed again, beginning with those in the first coil put in the tank. As soon as all the tubes in a bundle have been washed, the strings holding the bundle in the coil are cut but *not the string* holding the flush ends of the tubes. Then, the bundle, held by the flush ends, is pulled slowly from the tank (fig. 59). As the coil unwinds, the solution in the tube drains back into the tank.

The bundle of tubing is then pulled to a slope or laid over the roof of a building to drain (fig. 60). Thus, the hypochlorite solution is drained from the tubing but not washed out.

After 10 to 15 thousand feet of tubing has been washed, the tank should be drained and refilled with fresh hypochlorite solution.

After the bundles have drained for about 2 weeks, they are taken down and coiled (fig. 61).

PN-4755

Figure 59.—The wash solution drains back into the tank as the tubing is slowly withdrawn.

PN-4756

Figure 60.—The tubes are laid out on an incline or over a roof to drain. Here, 12 miles of tubing is being dried.

PN-4757

Figure 61.—The tubing is coiled on a homemade reel, tied into bundles for storage.

Extremely dirty tubing or tubing with an excessive amount of microbial growth should be thoroughly cleaned (*144*).

For storage, several bundles of tubing from the same area of the sugar grove may be wound and tied in the same bundle. The coils of tubing are stored in a clean, dark, cool place that is free of rodents. Large metal drums or tanks with 1/4-inch-mesh hardware cloth covers make ideal, rodent-free storage containers.

Washing Droplines

A bundle of droplines held by both ends is lowered *slowly* and perpendicularly, tee end first, into the tank of hypochlorite solution to displace the air and to completely fill the tubing and fittings (tees, spouts, and vent) with solution (fig. 62). Without releasing the bundle, it is lifted out of the solution and held in a vertical position for a few moments to drain. The ends are then reversed and the bundle is again lowered into the solution. After the second filling the bundle of droplines is left in the tank to soak for 2 hours. After the soaking period, it is lifted free of the solution and held in a vertical position for a few seconds to permit most of the hypochlorite solution to drain back into the tank. The bundle is then hung by the cord ties at the spout end for 2 weeks (fig. 63). After draining, the bundle of droplines is taken down and stored in the same manner as the lateral lines.

PN-4758

Figure 62.—A bundle of droplines is lowered slowly and perpendicularly into the wash solution.

Washing Main Lines

The coils of main lines are washed, drained, and stored in exactly the same manner as the lateral lines. A larger nozzle is used to fill and flush the tubing with the hypochlorite solution.

Reinstalling Tubing

The operation of reinstalling the tubing in the sugar grove proves the merit of this system. This operation is carried out in practically the same manner as that of the initial installation.

Main Lines

The cut, clean, large-diameter tubes are laid out in the sugar grove in the same manner as in the initial installation.

Droplines and Lateral Lines

Two 3-man teams are used to reinstall droplines and lateral lines. The first team drills and sanitizes the tapholes and inserts the germicidal pellets, and installs the dropline assemblies that have been kept intact in convenient bundles.

PN-4759

Figure 63.—The drained droplines are hung in a vertical position to dry.

The second team lays out and connects the lateral and main lines. The coiled bundles of lines are sorted and the one with the label for the sugar grove area where the work is to begin is selected. The coil is cut apart, and the leadman of the team, holding a bundle by the tied flush ends, pulls it to the first tapped tree, following the blaze marks of the preceding year. Since each bundle contains tubing of different lengths, the second man (who is at the starting point at that time) selects the tube that matches the distance from the starting point to the first tree and pulls it from the bundle. Both men now advance. The leadman proceeds to the second tree and the second man to the first tree, where he again selects a length of tubing that matches the distance between the two trees. He connects the lateral lines with the tees of the droplines. This procedure is repeated until the entire grove has been reassembled with the droplines and lateral lines.

Summary

General

Plastic tubing can be used for the full operation of sap collection and transportation or it can be used to perform parts of these operations.

(1) Install plastic tubing as a drainage system with proper vents and adequate size tubing so as not to restrict sap flow in tubes.
(2) Do not connect tapholes in series, except possibly those on individual trees.
(3) Lay the tubing on the ground or suspend it. Avoid any sags in the lines, and vent these whenever they occur.

Installing Tubing

(1) Tubing is ground-supported lateral and main lines.
(2) Each taphole is connected to the lateral line by a dropline consisting of a spout, vent, and 5-foot length of $^5/_{16}$-inch tubing, and a tee connector, preassembled.
(3) Lateral lines are $^5/_{16}$-inch tubing cut to fit between different trees.
(4) Make connections of lateral lines and droplines on warm side of trees.
(5) Lay the lateral lines along a route of constant pitch free of sags, previously laid out.
(6) A 3-man team lays out the lateral line most efficiently.
(7) The number of droplines connected to one $^5/_{16}$-inch lateral line will depend on (a) the flow of sap per taphole and (b) the pitch of the lateral line. Do not connect more than 25 tapholes per lateral line.
(8) A $^1/_2$-inch main line will carry sap from 75 tapholes (3 laterals).
(9) Increase the size of the main lines so that they are never overloaded. Failure to do so will cause back pressure and loss of sap.
(10) Periodic inspection of the tubing is required for leaks.

Taking Down Tubing

(1) Take the tubing down as soon as possible—never later than 1 week after last run.
(2) Remove all droplines intact, and tie in a bundle.
(3) Keep 1-foot connectors separate.
(4) Collect lateral lines, keeping the lead ends flush in the hand-held bundle.
(5) Coil and tie for ease of handling.
(6) Label the bundle at flush ends for the area of woods where installed.

Washing and Sanitizing

(1) Wash all tubing in a 5-percent hypochlorite (bleach) solution.
(2) Submerge and soak all tubing and fittings in hypochlorite solution for at least 2 hours.
(3) Flush out all tubing as per preceding instructions.
(4) Keep flush ends of tubing tied in bundle at all times.
(5) Open coiled tubing after washing.
(6) Lay tubing on incline to drain.
(7) Hang droplines in vertical position.
(8) Recoil droplines and mains for storage.
(9) Store in dark, dry, rodent-free area.

Reinstalling Tubing

(1) Follow the same procedure as initial installation:
    (a) Install droplines.
    (b) Connect droplines.
    (c) Lay out lateral lines and connect to droplines.
    (d) Connect lateral lines to main lines.
(2) Lateral lines are laid out according to the scheme outlined in text.

VACUUM SYSTEMS

The most recent development in collecting sap has been the use of vacuum to increase taphole flow and facilitate sap transportation in plastic tubing and pipeline systems (*7*, *47*, *105*). To utilize vacuum, an unvented or closed tubing system must be used. The vacuum may be created by the flow of the sap through the tubing due to gravity (natural vacuum) or by the use of a pump (pumped vacuum). The best vacuum system will depend on the individual characteristics of terrain and tree stand for each sugar bush. Where an adequate natural slope exists, natural vacuum can produce sizable increases in the yield of sap. The details of installing such a system are described by Morrow (*73*). Gains in sap production are generally directly proportional to the amount of vacuum in the system, whether produced by natural flow or by a pump. As there are many areas in the North American maple belt where the slope of the land is not sufficient for an effective natural vacuum, artificial vacuum systems have been developed. Several agencies have done research on pumping systems (*19*, *106*). A review of the different types of units that can be assembled was presented at the Eighth Conference on Maple Products (*44*).

It has been well substantiated that vacuum markedly increases sap yield. However, the reports on the use of vacuum emphasize the relative complexity of the equipment systems. Those wishing to incorporate vacuum, either natural or pumped, into their sap collection should obtain assistance from someone thoroughly experienced with these systems. County agricultural agents in the maple sirup-producing areas can recommend sources of expert advice on using vacuum and on installing the equipment needed in a sap-collection system.

STORAGE TANKS

Storage tanks serve the dual purpose of providing supplies of sap to the evaporator and of storing sap until it can be processed or hauled to an evaporator plant. Tanks supplying either a farm evaporator or a central evaporator plant must hold enough sap for at least 2 days' operation. Tanks used as pickup stations must be large enough to hold the maximum daily sap production of the sugar grove or of the area they serve. Pickup tanks used to haul sap from the sugar grove or to deliver sap to the evaporator house must be as large as possible to reduce the cost of haulage.

Wherever possible, locate the tanks so that they can be filled and emptied by gravity (figs. 64 and 65). When this is not possible, motorized pumps (electric or gas engine) can be used.

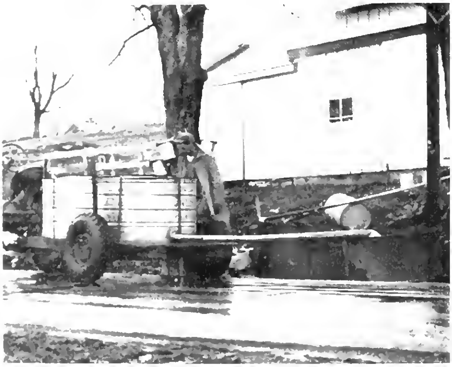
The tanks should be located in a cool place (fig. 66) and not inside the warm evaporator house, since warm sap favors microbial growth. The tanks should be covered to keep out foreign material, and the cover should be clear plastic or some other transparent material that will transmit the short ultraviolet rays of daylight (*100*). This type of installation is especially suited for roadside storage.

If aboveground tanks are not emptied frequently, they should be insulated to prevent the stored sap from freezing. Underground tanks with opaque covers, although less likely to freeze, are difficult to irradiate with ultraviolet light (fig. 67). When the covers of underground tanks are not transparent to the ultraviolet irradiation, germicidal lamps must be installed at the top of the tanks to illuminate the entire surface of the sap. Underground tanks will usually keep the sap at a more even (and perhaps at a slightly lower) temperature than will aboveground tanks. But since many of the bacteria that infect sap grow well at low temperatures, underground storage will not prevent microbial fermentation and spoilage of sap. Even lowering the temperature of the sap by adding ice will not prevent this.

Large storage tanks such as those at the evaporator house should also be provided with germicidal, ultraviolet lamps to prevent microbial growth. These lamps should be mounted at the top of the tanks above the liquid level and arranged so that they will illuminate as much of the surface of sap as possible. Directions for making an inexpensive ultraviolet-irradiation

PN-4760

Figure 64.—The plastic-covered roadside tank should be large enough to hold a maximum daily run and should be located so as to permit gravity filling of the collecting tank.



PN-4761

Figure 65.—This receiving tank is mounted at the roadside. Sap is pumped from it to the evaporator storage tank.

PN-4762

Figure 66.—This small evaporator storage tank, mounted in the shade, is exposed to daylight and covered with transparent plastic.

unit for pasteurizing flowing sap are available (*43*).

CAUTION

Care must be taken **never to expose the eyes to ultraviolet lamps. Lamps *must be turned off* when workers are in or around the tanks.**

Tanks must have easy access for cleaning and repair. Workers must be extremely careful when working in tanks that have only a manhole opening, so as to be sure they do not exhaust the oxygen (fresh air) supply and suffocate.

Metal or glass-lined tanks such as surplus milk tanks are ideal, since their walls are nonporous and easy to clean.

The walls and floor of masonry tanks should be smooth and treated with a water-insoluble coating to prevent places for microbes to lodge. This surface-treating material must be one that is approved by the U.S. Food and Drug Administration as safe for being in contact with food.

The tanks should be washed with a detergent after each run of sap and the detergent should be completely removed from the tanks by using at least three separate fresh-water rinses.

There must be some indicating device inside the evaporator house to show the level of sap in the tank. This device may be simple sight glass (a perpendicular glass tube connected to the feed line of the evaporator), or it can be a float-and-weight type, where a string attached to a float in the tank is carried into the house, and a weighted object is raised and lowered by means of guides and pulleys as the level of the sap varies.

PN-4763

Figure 67.—A large underground concrete storage tank of silo-type construction.

If the feed line from the tank to the house is aboveground, it too must be well insulated. Numerous cases have been reported when the sap line, even when in operation, has frozen and shut off the supply of sap, with the result that the pans were burned.

Summary

(1) Construct tanks with smooth, easy-to-clean walls.

(2) Locate tanks in a cool place—never inside a warm evaporator house.

(3) Cover tanks with clear plastic to utilize the sterilizing action of sunlight.

(4) Provide sterile lamps for large tanks with opaque covers.

(5) Provide an indicating device in the evaporator house to show level of liquid in tank.

(6) Keep tanks clean and sterile.

EVAPORATOR HOUSE ON THE SAP-PRODUCING FARM

Location

Originally, most evaporator houses were located near the center of the sugar grove to shorten the distance the sap had to be hauled (fig. 68). With the use of pipelines and large collecting tanks, many producers today find it more profitable to locate the evaporator house near the other farm buildings and close to a traveled road (fig. 69). This offers many advantages: (1) Water and electric power are available; (2) laborious and time-consuming travel to and from the evaporator house is eliminated; (3) full family participation is encouraged; and (4) the evaporator house is accessible to visitors and potential customers.

Function

The evaporator house, or sugar house as it is often called, like the evaporator, has developed without engineering design. In the early days of the iron kettle, little thought was given to any form of shelter. At first only a lean-to type of shed was used to protect both the sirupmaker and the boiling sap from inclement weather, which so often occurs during the sirup season. The shed introduced a new problem—how to get rid of the steam from the boiling sap. This problem was solved by completely enclosing the evaporator and installing ventilators at the top. These crude shelters were the forerunners of today's evaporator houses.

Since the evaporator house is used only from 4 to 6 weeks each year, its cost must be kept low; otherwise, the interest on the capital investment is out of proportion to its use. The site should permit use of ramps for filling the storage tank by gravity (figs. 70 and 71). The house should be constructed so that it not only permits sanitary handling of sap and sirup but also provides a place to process and package the sirup, to make confections, and to sell maple products.

Requirements

The evaporator house need not be elaborate. It should be large enough to allow plenty of free space (at least 4 feet) on all sides of the evaporator, and it should be set on a foundation that extends below the frostline. The house should be tightly constructed and should have provisions for venting the steam. If open hoods are used, there should be intakes to supply air for the fire and to replace air that is exhausted with the steam. Provision should also be made for easy access to the fuel supply and sap storage tanks.

PN-4764

Figure 68.—Evaporator house located in center of sugar grove. Without a covered evaporator, steam completely fills the evaporator house. This is unfavorable for sanitary conditions.

PN-4765

Figure 69.—The trend is to locate the evaporator house near the other farm buildings and on an improved road.

Design

Chart 4 shows a suggested plan for an evaporator house with a wing in which the sirup can be processed and maple products can be made. The house itself is designed to contain only the evaporator and a workbench along one wall. The width (16 feet) allows an aisle space of 5 feet on each side of an evaporator 6 feet wide to provide easy access to all parts of the evaporator.

Steam Ventilation

In concentrating sap to sirup, vast quantities of steam are produced. Without proper means

PN-4766

Figure 70.—When possible, select the evaporator house site so that the natural elevation will permit building a ramp, and sap can be delivered by gravity from the hauling tank to the storage tank and from the storage tank to the evaporator.

PN-4767

Figure 71.—When the site is level, the sap can be pumped to storage tanks mounted on elevated frames; it will then flow by gravity to the evaporator.

for removing it, the steam fills the evaporator house and, on cold days with high humidity, the inside of the house becomes dripping wet. In a steam-filled evaporator house, the sanitary dry conditions desired in a food-processing plant are impossible (fig. 72). Instead, the wet building favors microbial growth.

The earliest method of removing steam and the least effective was to cut a hole in the center of the roof directly above the evaporator. The hole was the same size as the evaporator. The cover for this hole was fastened to the roof with hinges on the side of the hole parallel to and opposite the ridge of the roof. These hinged roof sections or louvers were raised or lowered by a rope and pulley. The rope was wound on a windlass mounted on the wall of the house.

The Open Hood

The next method for removing steam from evaporators was the open hood (fig. 73). In this

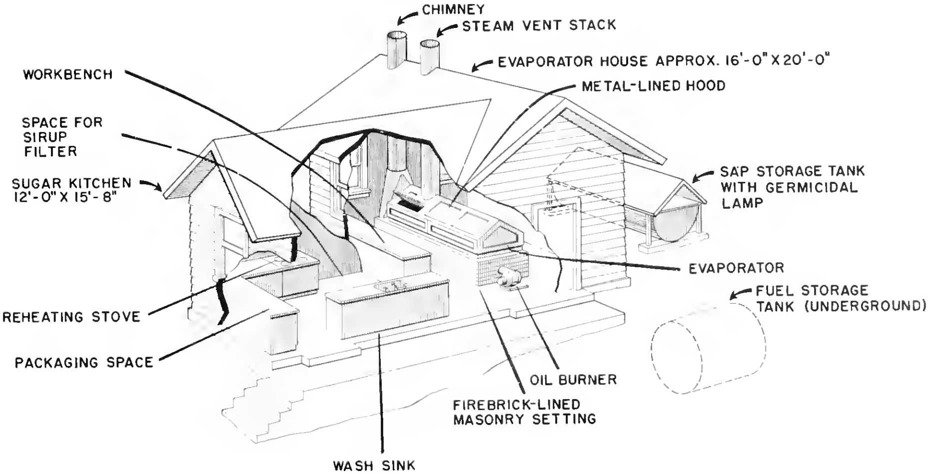


Chart 4.—Suggested plan of an evaporator house with "L" to provide space for filtering and packaging sirup and making maple confections.

PN–4768

Figure 72.—Evaporator house with opening in the roof for venting the steam results in a steam-filled building.

method, four walls extending from the rectangular roof opening to within 6 feet of the floor are constructed to serve as a chimney for the steam. The walls are sloped so that the lower edge projects 1 foot or more beyond the four sides of the evaporator. The efficiency of the hood is increased by attaching a strip of lightweight canvas 1 to 3 feet wide to the lower edge of the hood. A small gutter $^1/_2$-inch deep is attached to the lower inside edge of the hood to collect water that condenses in it. Since the hood has nothing to support, it can be made of lightweight, noncorroding material such as sheet aluminum. The supporting frame can be made of lightweight lumber, and covered with aluminum on the inside so that only the metal is exposed to the steam.

This type of hood will keep the evaporator house free of steam, but it has many drawbacks. Being open, it requires 10 volumes of air for each volume of steam removed. Thus, large volumes of air must be drawn into the evaporator house, which makes the house cold and drafty. Also, the efficiency of the hood is affected by wind and by barometric pressure. Although the open hood is found in many older evaporator houses, it is not recommended because it results in unfavorable sanitary conditions.

The Covered Evaporator

A simple, effective method for removing steam from evaporators is a close-fitting, but not airtight, cover from which the steam is conducted to the outside of the house through a duct or stack (fig. 74). The cover rests on the evaporator. This method uses the same principle as that used to vent the steam out the spout of a boiling teakettle (fig. 75). The method has none of the objectional features associated with earlier methods. It does not require an exhaust fan and it does not raise the boiling point of the sirup, since there is no measurable increase in pressure within the steam-venting system.

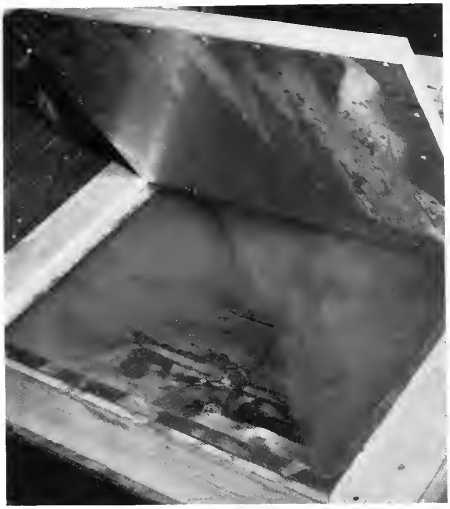
The cover is made of lightweight, noncorroding metal such as sheet aluminum and has a

PN–4769

Figure 73.—A canopy-type hood removes steam more efficiently than do louvers. However, large volumes of air are required to sweep the steam into and up through the hood and the result is a cold, drafty building.

PN–4770

Figure 74.—The tight-cover steam-venting system with steam stack provides a simple, highly efficient means for removing steam. This results in a steam- and draft-free evaporator house.



PN-4771

Figure 75.—The hot steam causes a natural draft and does not require air intake ports.

light wooden frame of gable design made from 1- x 4-inch pitch-free lumber (spruce or basswood). The aluminum sheets are cut to size and are attached by aluminum nails to the inside of the wooden frame, completely covering the wood so that it is not exposed to the steam. Galvanized iron should not be used, since the acidic gases in the steam will quickly corrode and dissolve the zinc coating.

A satisfactory pitch of the gabled cover is 6 inches to the foot, or 30°. The walls of the cover should be 6 to 8 inches high to provide adequate headspace for the free boiling sap. A trap door should be placed over the flue (back) pan to permit inspection and skimming. However, the tight cover has practically eliminated the need for skimming. This is no doubt due to the absence of air from the steam-filled area above the boiling sap.

The pipes for the stack or steam vent should be made of the same lightweight metal, and they can be fabricated in any sheet-metal shop. The stack should be placed over the flue or sap pan, because that is where most of the steam is generated. The stack should be fastened at its base to the evaporator cover. It should be long enough to extend up to and through a hole in the roof of the building to 1 foot above the ridge of the roof.

The opening in the roof should be 1 inch larger in diameter than the stack, so that the stack can be moved freely. The diameter of the stack is not critical; however, it must be large enough for the steam to escape readily. Stacks of different diameters are required for different size covers, as follows:

Size of covered evaporator		*Diameter of stack* [1]
Width (feet)	*Length (feet)*	*Inches*
3	3	6
4	4	8
4	5	
3	7	10
5	6	
3	10	
4	8	12
6	6	
5	8	14
4	12	
5	10	16
5	12	
6	10	
5	14	18
5	20	

[1] For covers over flue pans use next larger diameter; for covers over sirup pans use next smaller diameter.

For evaporators with two or three sections, it is easier to construct separate covers with individual steam stacks for each section.

To remove the cover, hoist it and the attached steam stack vertically—push the stack up through the roof opening—by means of a rope attached to eye bolts at each end of the ridge pole of the cover. Pass the rope through pulleys located overhead and then down to a windlass mounted at a convenient height on the sidewall of the evaporater house.

Location of Evaporator

The evaporator should be located directly under the ridge of the roof and centered under the hood (if an open hood is used). The foundation for the evaporator arch should be made of masonry or cast iron. The masonry arch or the base of the cast iron arch should extend below the frostline and sufficiently high above the floor level so that the height of the evaporator permits the sap to flow by gravity from the pans to the filter tank and then from the filter tank to the finishing pan. Setting the evaporator high also makes it easier to fire when the fuel is wood, and brings the thermometer (for checking the boiling point of the sirup) to eye level for ease of reading.

If the sirup is only partly finished in the evaporator and evaporation is completed in a finishing pan, the finishing pan should be mounted adjacent to the evaporator.

Air Supply

When the evaporator is in operation, great quantities of outside air are required for combustion of the fuel. For example, 150 cubic feet of air per minute is required to burn seasoned hard maple at the rate of one-fourth cord per hour. If the steam is removed through an open hood, an additional 10 cubic feet of air per minute per square foot of evaporator will be required. For example, an evaporator 4 feet wide and 12 feet long requires 480 cubic feet of air per minute to remove the steam through a ventilator.

If this air is supplied through an open door or window, the evaporator house will be very cold and drafty. A more desirable method is to deliver air where it is needed. Ducts along both sides of the evaporator will supply the hood ventilation and the combustion air. These ducts should be 8 inches wide and open at the top and at the ends toward the firebox. They should run the entire length of the evaporator. The air coming in through these ducts tends to keep the steam under the hood. If the evaporator is covered and has a steam vent pipe, the ducts will need to supply air only for combustion.

Sirup-Processing Room

If the evaporator house is a single room, it must have space for filtering the sirup and for canning it. It is better to process the sirup in a second room built as an "L" to the evaporator room (chart 4). This arrangement does not add appreciably to the cost of construction and the sirup can be processed under better working and sanitary conditions.

The processing room houses such operations as filtering, heating, and packaging the sirup, and making maple confections. The equipment consists of a filter rack, a stove for boiling the sirup (preferably heated with gas), a maple-cream beater, and sugar stirrers.

There should be a sink for dish washing, a hot water heater, and a trough with cold running water in which sirup that has been cooked for making maple cream can be cooled rapidly. Storage space should be provided for cooking utensils and containers.

If the evaporator house is to serve as a salesroom, space should be provided for displaying the products attractively and for storing the products.

Fuel Storage

When wood is used for fuel, sheltered storage must be provided in a convenient location. This storage space holds enough wood for a run of sap. The supply is replenished from a larger storage shed. In some large operations, the wood is stored in a separate building and is transported to the evaporator house in a truck mounted on rails (fig. 76). An overhead tramway can also be used. By installing the tracks with a slight downgrade toward the evaporator, the heavy loads of wood can be moved by gravity.

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Figure 76.—Wood for fuel is conveniently stored in a separate shed. The wood is moved in a flanged-wheel truck that runs on rails to a point adjacent to the evaporator. If the storage shed is at a slightly higher elevation, the loaded truck can be moved by gravity.

Fuel oil storage tanks must be large enough to hold enough oil for at least 1 day's operation. Larger tanks may lower delivery costs. The tanks must be installed to meet local building codes.

Summary

(1) If possible, locate the evaporator house on the main road close to the other farm buildings.
(2) Build it large enough to provide at least 4 feet of free space on all sides of the evaporator.
(3) Construct it so that it can be kept clean.
(4) Provide a workbench along one wall.
(5) Provide the evaporator with a cover and steam vent pipe.
(6) Elevate the evaporator arch on a foundation that extends into the ground below the frostline.
(7) Make the floor of concrete or other easily cleaned surface.
(8) Provide ducts in the house for intake of outside air.
(9) Set the evaporator high enough above ground to raise the pans a minimum of 4 feet above the floor.
(10) If possible, provide a separate but adjoining room for processing the sirup and making other maple products.
(11) If possible, equip the house with running water, electricity, and gas fuel supply.
(12) Provide adequate storage for dry wood or oil.
(13) If wood is used for fuel, provide means for transporting the wood to the evaporator.
(14) Locate the sap storage tanks outside the building.
(15) Cover the tank with material (plastic) transparent to the low ultraviolet radiation of daylight.
(16) If the tank is enclosed, illuminate the sap with germicidal lamps.

THE EVAPORATOR AND ITS FUNCTION

The maple sirup evaporator is an open pan for boiling water from the sap. Although the primary purpose of the evaporator is to remove water, it must do the job economically and in such a way as to improve but never to impair the quality of the sirup being made.

Maple sirup evaporators have gone through an evolution in design. The first evaporator, used by the Indians, was a hollowed log in which water was evaporated from the sap by adding hot stones. The next evaporators were metal kettles used by the white settlers. Both of these were batch-type evaporators, that is, the entire evaporation process, from the first addition of sap to the last, was done in one kettle. Sap both high and low in sugar content was added. It might be many hours before the sirup was finally drawn. As a result, a dark strong-flavored sirup was produced.

The next improvement in evaporators was the use of multiple kettles (fig. 77). This evaporator was the forerunner of today's continuous evaporators.

The sap was partly evaporated in the first kettle, transferred to the second kettle for further concentration, and then finally transferred to a third and sometimes a fourth kettle where evaporation was completed. The multiple-kettle method was a semicontinuous operation and resulted in an improved (lighter colored) sirup because the time of heating at near-sirup density was shortened.

The source of heat for all the early evaporators was an open fire, which is poor in fuel economy.

The first major change in design of evaporators was the introduction of the flat-bottom pan and the enclosed firebox (fig. 78). Both the increased heating surface of the pan and the confined fire increased the efficiency of the fuel. This design was quickly followed by partitioned pans, which were the forerunner of flue-type evaporators.

The modern flue-type evaporator, developed about 1900, was the next and last major change in design. Use of "flues" or deep channels in the pans, and altering the firebox so that it arched the hot gases between the flues, caused the hot gases and luminous flames to pass between the flues before escaping up the chimney. Fuel economy was increased. Also, the rate of evaporation was increased, which shortened the

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Figure 77.—Multiple-kettle method of making maple sirup. In this method, the sap was partly evaporated in the first kettle, then transferred to the second and third kettles, and finally to the fourth kettle, where evaporation was completed. (Courtesy of W. W. Simonds, Pennsylvania State University.)

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Figure 78.—The flat pan was the forerunner of the modern flue pan.

evaporation time, improved the quality of the sirup, and lowered the cost of production.

Design of Evaporator

The modern flue-type evaporator, which operates under atmospheric pressure, consists basically of two sections: (1) The sap pan, in which the flues are located, and (2) the sirup pan. The sections are separated to facilitate their removal from the arch for cleaning and repair. A semirigid pipe or tubing connects the pans. The connections tend to restrict the free movement of sap as it travels through the evaporator and minimize the intermixing of the dilute sap in one pan with the more concentrated sap in the adjacent pan.

So that the evaporators can be operated in a continuous or semicontinuous manner, baffles or partitions are built in the pans to form channels through which the sap flows as it is being concentrated. The location of these partitions and the size and shape of the channels differ with different manufacturers.

The sap pan can be made with narrow, deep channels because the sap, while in this pan, is never concentrated enough to become viscous; it flows readily. Use of narrow flues increases the heating surface and thereby increases transfer of heat. Fresh sap is admitted to the sap pan through a float valve that can be adjusted to maintain the desired depth of liquid in the evaporator (fig. 79).

The sirup pan, often called the front pan, is usually located over the firebox. Concentration of the sap to sirup is completed in this pan. It has a flat bottom to facilitate cleaning and to permit evaporation of shallow layers of sirup without danger of burning.

Changes in Sap During Its Evaporation to Sirup

Development of the desired maple flavor and color is the result of chemical reactions that occur while the sap is boiling in the evaporator. (See p. 67.) The extent of these reactions is determined in part by the length of time the sap is boiled (*141*).

Chart 5 shows the effect of length of boiling period on amount of color (*150*) produced in sap of different solids concentrations (° Brix). At low

PN-4775

Figure 79.—The float valve on the sap pan adjusts the depth of the liquid in the evaporator. Different devices are used to obtain precise valve settings.

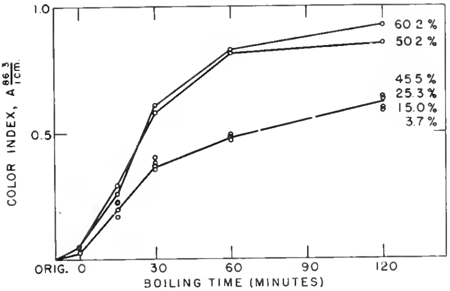

Chart 5.—Effect of length of boiling period on color formation (color index) in sap of different solids concentrations.

concentrations little color is produced in a given boiling time, whereas at higher concentrations more color is produced. The rate of color formation does not increase appreciably until the Brix value of the sap reaches 25° or more, and this occurs after the sap reaches the sirup pan.

To provide a basis for comparing color of maple saps of different concentrations, color is expressed as color index. Color index is measured with monochromatic light in a spectrophotometer:

$$\text{Color index} = A\,\frac{86.3\%}{1\text{ cm}} = A_{450}\,(86.3/bc)$$

where A_{450} is the observed absorbance at 450 millimicrons with distilled water used as the blank; b is the depth of the solution in centimeters; and c is the grams of solids as sucrose per 100 milliliters of solution as determined on an Abbé refractometer. The maximum color indices for table sirup of various grades are: 0.510 for U.S. Grade AA (Light Amber), 0.897 for U.S. Grade A (Medium Amber), and 1.45 for U.S. Grade B (Dark Amber).

Other changes that occur in the sap as it boils are shown in charts 5 and 6. The rate of color formation is greatest as the sap approaches the concentration of finished sirup (*150*). Thus, the length of time that sap is heated in the sap pan (when the Brix value is low) is relatively unimportant in the formation of color. In the sirup pan, however, color develops rapidly as concentration increases.

The rate at which water is removed from sap at different boiling times and the corresponding solids concentration are shown in charts 7 and 8.

The curves show that the average time that a lot of sap with an initial solids content of 2.5° Brix is in the evaporator is approximately 1½ hours—a little less than 30 minutes in the sap pan and slightly more than 60 minutes in the sirup pan. To make high-quality, light-colored sirup, the time required to evaporate the sap to sirup must be kept to a minimum. Conditions that affect the boiling time are: (1) The design of the evaporator; (2) the amount of heat applied to the evaporator; (3) the efficiency of the heat transfer; and (4) the depth of the boiling liquid. Once an evaporator is selected and purchased, the sirupmaker controls only the amount and steadiness of heat applied to the pans and the depth of boiling sap.

Evaporation Time

The evaporation time is measured from the time a unit of sap enters the sap (flue) pan until it is removed from the sirup pan as sirup. Evaporation time should not be measured until the evaporator is operating steadily, the heat

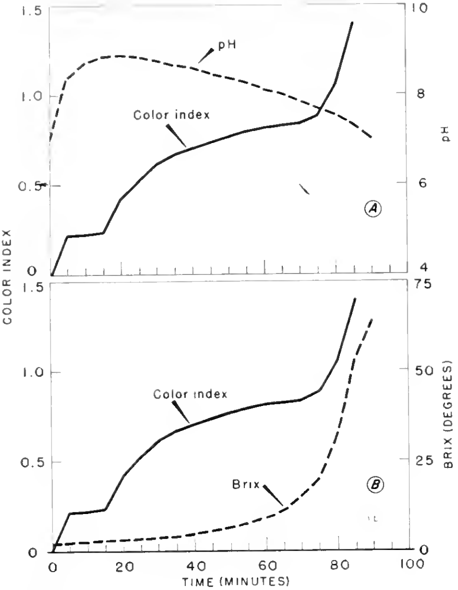

Chart 6.—Changes in Brix value, color, and pH in sap during the evaporation period. *A*, Soon after evaporation begins the sap becomes alkaline, reaching a pH of 8 to 9; it then decreases in alkalinity until at the end of the period it is about neutral. Little color is produced until after the sap reaches a pH of 8, at which point color increases at a rapid rate. It increases further as the concentration of the sap approaches that of finished sirup (30° Brix and above). *B*, Increase in Brix value is slow at the beginning and becomes more rapid as evaporation progresses.

source is constant, the liquid in both the flue and sirup pans is in a state of full boil, and the sirup is being drawn off at a constant rate or at regular intervals. The evaporation (holdup) time can be lengthened by increasing the level of liquid in the pans. The lowest depth of liquid in the evaporator (both pans) will give the shortest evaporation time. If the depth of liquid is too low, the pans will burn, so this control is limited.

Liquid Level in Evaporator

The depth of sap to maintain in the evaporator is determined by a number of factors. Most important is the minimum depth that must be maintained to keep the pans from burning. Many sirupmakers find that a liquid level of 1 inch in the sirup pan is ideal. When the evaporator is operating correctly with a steady source of heat, there will be a slight gradient or decline in the liquid level in the evaporator. The highest level will be at the point of sap intake and the lowest at the point of sirup drawoff. With uneven firing, this gradient is upset. During periods of low heat, when the sap is merely simmering, the gradient is lost. The depth of the sap tends to become level, and there is an intermixing of sap of different concentrations. Intermixing, together with an increase in the average depth of sap, results in a longer holdup time and the production of darker sirup. The lower the Brix value of the sap, the longer the holdup time, since there must be greater gradient in the sap levels. Since the minimum level at the point of sirup drawoff is fixed to prevent burning the pans, the level at the sap intake

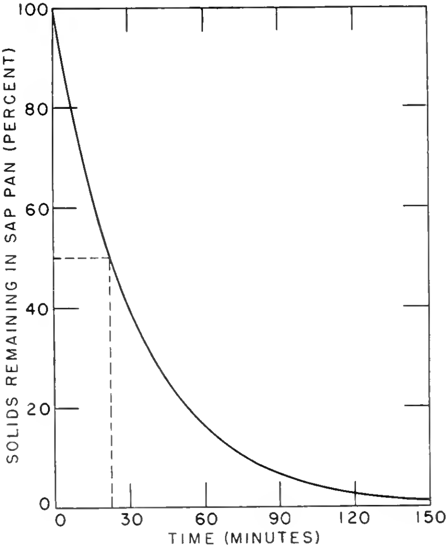

Chart 7.—The average time (time required to remove 50 percent of the water) that any lot of sap remains in the sap pan (see dotted lines) is slightly less than 30 minutes. The time can be shortened or lengthened by using sap of lower or higher solids concentration (° Brix), by varying the depth of sap in the evaporator, and by varying the intensity of the heat.

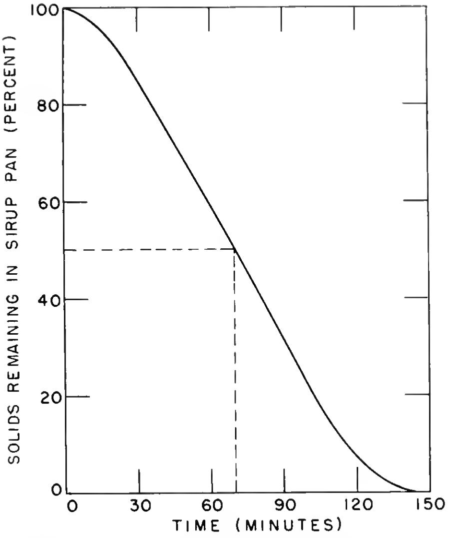

Chart 8.—The average time (time required to remove 50 percent of the water) that any lot of sap remains in the sirup or front pan (see dotted lines) is a little more than 60 minutes. The time in this pan can also be shortened or lengthened by changing the Brix value of the sap entering the sirup pan, by varying the depth of the sap, and by varying the intensity of the heat.

must be adjusted to keep the sap proportionately deeper. A change in the Brix value of the sap in the supply tank requires a readjustment of the float of the intake valve. Changing to sap with a higher Brix value without readjustment may result in a burned pan.

Rates of Evaporation

The solids concentration of the sap is about doubled before it leaves the sap pan, that is, nearly 50 percent of the water that is to be removed has been evaporated (*111*, *140*). By the time the sap reaches a concentration of only 19° Brix, 90 percent of this water has been evaporated.

The changes in the concentration of a typical sap (2.5° Brix) during evaporation are given in table 4.

A two-section evaporator with three channels in the sap (flue) pan and four in the sirup (front) pan and the points at which the concentration was measured (table 4) are shown in chart 9.

To make 1 gallon of standard-density sirup from this sap required $\frac{86}{2.5}$, or 34.4 gallons of sap; 33.4 gallons of water had to be evaporated. The solids concentration of the sap was doubled (from 2.5° to 5.0° Brix) in the sap pan. This removed 17.3 gallons of water, or more than 52

TABLE 4.—*Changes in the solids concentration of sap (° Brix) and water evaporated in a simulated evaporator, for each gallon of sirup produced*

Section of evaporator	Solids concentration of sap [1]	Water evaporated			
		Per section		Total	
	° Brix	*Gallons*	*Percent*	*Gallons*	*Percent*
Original sap	2.5	------	------	------	------
Sap pan:					
First section	3.0	5.77	17.35	5.77	17.35
Second section	3.7	5.40	16.24	11.17	33.59
Third section	5.0	6.16	18.53	17.33	52.12
Sirup pan:					
Fourth section	8.0	6.45	19.40	23.78	71.52
Fifth section	19.0	6.26	18.83	30.04	90.35
Sixth section	42.0	2.48	7.46	32.52	97.81
Seventh section	54.0	.45	1.35	32.97	99.16
Finished sirup [2]	65.5	.28	.84	33.25	100.00

[1] Percentage of sugar.

[2] When this experiment was conducted, the Brix of standard sirup was 65.5°.

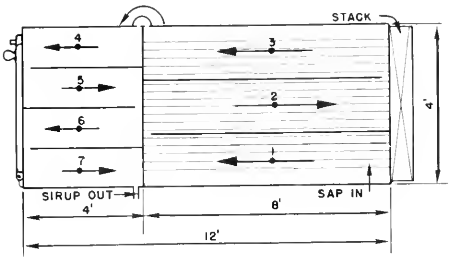

Chart 9.—Top view of a simulated maple sap evaporator having 3 channels in the sap pan and 4 channels in the sirup pan. Arrow shows direction of sap flow. The solid circles show the location of sap of different solids concentrations (° Brix), as indicated in table 4.

percent of the 33.4 gallons of water that had to be removed to make 1 gallon of sirup. By the time the solids had increased to only 19° Brix, 90 percent of the water had been removed, and the sap had progressed only halfway through the sirup pan. Thus, the remaining 10 percent of the water was removed in the last half of the sirup pan. This shows that most of the water is evaporated while the solids are at sufficiently low concentrations to have little effect on the color of the sirup. It also shows that sap must be kept moving forward through the pan as it approaches sirup concentration, so that it can be removed from the evaporator as quickly as possible.

This also explains why adding one or more sap (flue) pans in a series does not increase evaporation time but does increase evaporation rate and capacity. Lengthening the evaporator system by increasing the number of feet that the sap must travel through the different channels makes use of the engineering rule that evaporation (heat transfer) increases as the rate at which the liquid moves over a heated surface increases. Thus, lengthening the evaporator by using supplementary flue pans will not increase holdup time; it actually decreases it.

Rule of 86

The amount of water that must be removed to reduce the sap to sirup varies with the solids concentration of the sap.

The "Rule of 86" can be applied to determine the number of gallons of a particular sap required to produce 1 gallon of standard-density sirup. The number 86 is used in the calculation as representative of the percentage of solids (as sugar) on a weight-volume basis that is found in a gallon of standard-density sirup. (Until 1974 the standard density for maple sirup was 65.5° Brix, and sirup of this density contains 86.3 percent solids as sugar. Now that the standard density is 66.0° Brix, the percentage of sugar in a gallon of standard sirup is actually 87.2, but the traditional "Rule of 86" persists in the industry and is quite satisfactory for practical purposes.)

Since the solids concentration of sap is comparatively low, its Brix value and percentage of solids (weight-volume) are essentially the same. Therefore, the percentage of solids (weight-volume) of the sirup divided by the Brix value of the sap equals the number of gallons of sap required to produce 1 gallon of sirup. The equation is:

$$a = \frac{86}{X}$$

where a = the number of gallons of sap to produce 1 gallon of standard-density sirup.

X = the Brix value of the sap (to represent the solids concentration of the sap).

From this number, 1 is subtracted to obtain the number of gallons of water that must be evaporated from the sap to obtain 1 gallon of sirup. The following equation is used:

$$a = \frac{86}{X} - 1$$

Example: With sap having a density of 2.4° Brix,

$$a = \frac{86}{2.4} - 1, \text{ or } 36 - 1 = 35,$$

the number of gallons of water that must be evaporated to obtain 1 gallon of standard-density sirup.

Summary

(1) The modern evaporator is an open-pan, flue type and has a high evaporation efficiency.

(2) The major changes that affect sirup quality, color, and flavor occur after the sap has been concentrated to 45° Brix.

(3) The development of color and flavor depend on the length of time sap with a Brix value of 45° or higher is boiled.

(4) Evaporation rate is increased if the path the sap travels over the heated surfaces is lengthened.

(5) Use of multiple sap pans assembled in series increases the rate of evaporation.

(6) The time required for the last stage of evaporation is determined by the holdup time (depth of sap in evaporator, last section or in finishing pan) and the intensity of the heat.

(7) Production of light-colored sirup is favored by shallow depth of sap in the evaporator and by intense constant heat.

OPERATING THE EVAPORATOR

Starting the Evaporator

The sap is run into the evaporator until the bottom of the front pan is covered to a depth of 1 inch; then the fire is lit. As soon as the sap begins to boil, the sap inlet float valve is adjusted to maintain the desired depth of liquid (1/2 to 1 inch) in the sirup pan. As water evaporates, the float valve admits more sap (fig. 79).

If sirup has not been made previously, a series of adjustments of the float will be necessary to be sure the liquid in the sirup pan i always maintained at a depth of 1/2 to 1 inch at the point of drawoff.

The constant addition of sap keeps the sap in the pan dilute. It becomes progressively more concentrated at points farther from the sap inlet. The sirup drawoff is at the farthest point.

Saps of different solids concentrations (° Brix) require different adjustments of the inlet-valve regulator to maintain the same depth of sirup in the front pan. The depth of sap in the sap pan must be greater for sap with a Brix value of 1° than for sap with a Brix value of 2° and it must be lower for sap with a Brix value of 3°. By checking the Brix value of the sap in the storage tank, the float valve can be set to maintain the desired depth of sap in the evaporator. The Brix value should be checked with a hydrometer every half hour or whenever a new lot of sap is run into the storage tank. This will prevent burning the pan, which might happen with a change to sap with a lower Brix value unless the depth of liquid is increased.

The pipeline between the storage tank and the evaporator must be large enough to assure a constant and adequate supply of sap to the evaporator, so that a constant level of sap is maintained. If this pipe is connected to an outside storage tank, it must be insulated to prevent the sap from freezing in the line. Were this to occur, the supply of sap would be cut off and the pans would burn.

The sap feed line should be equipped with a fast-acting valve that can be used to adjust the flow of sap and to stop the flow when the evaporator is taken out of use. A secondary sap feed line should also be installed. This line should be equipped with a flexible hose long enough to reach any part of the evaporator or finishing pan. This is an emergency line for use whenever there is a stoppage in the main feed line or for quickly supplying sap to any part of the evaporator where sap is needed to prevent burning the evaporator.

Drawing Off the Sirup

The boiling point of standard-density sirup is 7° F. above the boiling point of water. This is discussed in detail in the section "Elevation of Boiling Point," page 72.

Any thermometer that has a range of 200° to 230° F. and a sufficiently open scale can be used to determine the boiling point of sirup. It should be calibrated in 1/2° and preferably in 1/4°.

With older procedures, it was customary to make finished sirup in the evaporator. It was seldom possible to continuously remove sirup of standard density from the sirup pan, except in very large evaporators. Instead, the sirup was removed discontinuously or in batches. The last channel of the sirup pan was in effect a finishing pan. This caused the following undesirable conditions: The sirup channel was seldom isolated, so that the turbulence of the boiling sirup caused a constant intermixing of the finished or nearly finished sirup with less concentrated sap. This lengthened the holdup time (time sap is heated) and occurred when heating is a critical factor in flavor and color development. Also, each time a lot of finished sirup was drawn off, some sirup had to be left in the last channel of the evaporator to keep the evaporator from burning. The sirup that was left was then mixed with the next lot of dilute sirup. The prolonged heating period darkened the color.

However, when this procedure is followed, the drawoff valve must be opened as soon as the boiling sirup reaches a temperature 7° F. above that of boiling water. The temperature of the boiling sirup should be watched closely to be sure it neither rises above nor falls below this temperature, and the sirup should be drawn off at a rate to maintain this temperature. If the boiling sirup falls below the proper temperature, the drawoff valve should be closed immediately.

Finishing Pan

Because of the difficulties of finishing the sirup in the evaporator, use of a separate finishing pan is recommended (figs. 80 and 81). A separate finishing pan permits (1) complete removal of the almost finished sirup (45° to 60° Brix) from the evaporator, so that there is no possibility of intermixing with less concentrated sirup; (2) complete control of finishing the sirup without extending the total time the sap is heated; and (3) complete removal of the finished sirup from the pan.

The size of the finishing pan is determined by the size of the evaporator. Partly finished sirup should be removed from the evaporator at least once each hour and finished in batches. Since sirup transferred to the finishing pan will have a solids concentration of not less than 45° Brix and since it requires 2 gallons of 45°-Brix sirup to yield 1 gallon of 66.0°-Brix (standard-density) sirup, an evaporator that has a rated capacity of 4 gallons of finished sirup per hour requires a finishing pan that holds 8 gallons of 45°-Brix sap and provides additional space to take care of foaming. A pan 18 inches square will hold approximately 1.5 gallons for each inch of depth. Therefore, to accommodate 8 gallons of 45°-Brix sap the pan should be 5 inches deep and should have an additional 10 inches for foaming. The pan will therefore be 18 inches square and 15 inches deep. It should have handles and a cover and should be equipped with a precision thermometer having a range of 200° to 230° F. in $^{1}/_{2}$° or preferably $^{1}/_{4}$° divisions and a sirup drawoff cock. Preferably, the pan should be heated by gas flame since gas heat can be easily adjusted and can be shut off when the sirup reaches the desired boiling temperature.

For convenience two finishing pans can be used alternately. When a finishing pan is used, the sap being drawn from the evaporator for transfer to the finishing pan need not be of constant density. It can be any density above 45° Brix (3° or more above the boiling point of water). The higher the density of the sirup that is withdrawn from the evaporator, the smaller the amount of liquid that has to be evaporated in the finishing pan.

Another and important advantage of using a finishing pan is that it permits filtering the sirup that is being transferred from the evaporator to the finishing pan. Sirup at this density (45° to 60° Brix) has essentially all of its sugar sand (see p. 78) precipitated. At this density, it has a viscosity (fluidity) only slightly higher than water and filters much more readily than does standard-density sirup.

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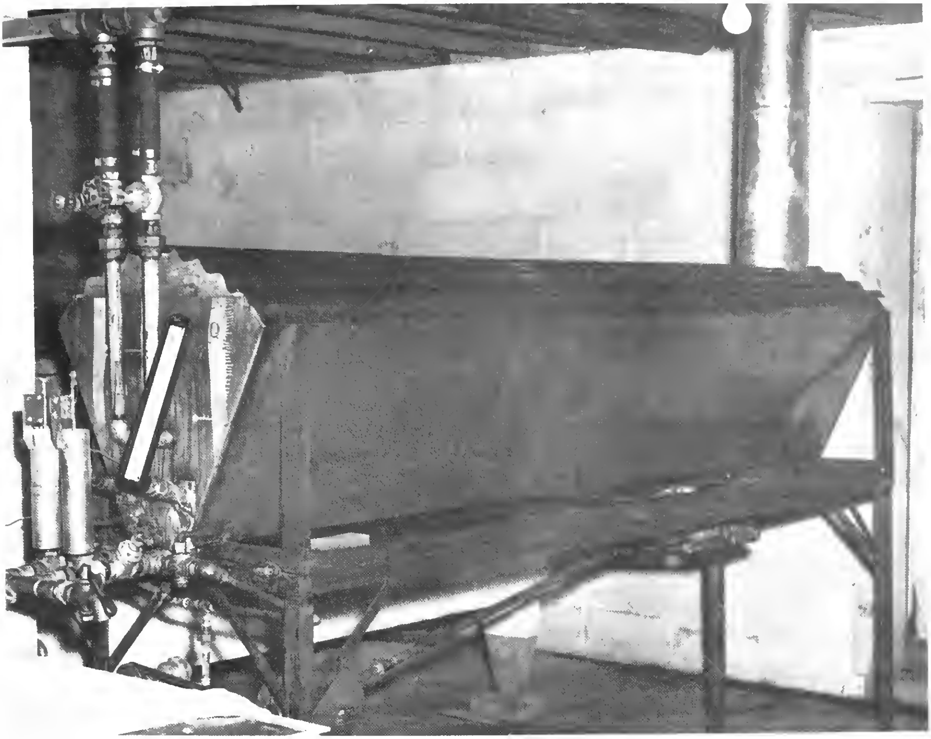
Figure 80.—The finishing pan allows complete control over the final stage of the evaporation of sap to sirup. Generally, the fuel is bottled gas.

In some installations, the sirup is pumped from the finishing pan to the holding or canning tank. A cartridge-type filter can be placed in this pipeline to serve as a polishing filter. It will remove any sugar sand that was not removed by the major filter or that may have been formed in the finishing pan.

Many producers using bottled gas to heat the finishing pan report that the cost of fuel is approximately 7 cents per gallon of finished sirup.

A finishing pan is always used in conjunction with a complete evaporator (flue pan plus flat pan). The flat or sirup pan of the evaporator serves as a semifinishing pan. The capacity of the evaporator is readily expanded by adding one or more flue (sap) pans, each with its own arch and separate heat source (preferably oil).



PN-4777

Figure 81.—A steam-heated finishing pan, like a gas-fired pan, provides positive control of the finished sirup and eliminates danger of scorching.

When a finishing pan is used, the following procedures should be observed:

(1) Do not finish more than 5 to 10 gallons of sirup in a batch.

(2) When the sirup is finished, that is, when it reaches the proper temperature (7° F. above the exact boiling point of water), heating must be stopped immediately.

(3) Drain all the finished sirup from the pan. If any sirup is left in the pan, it will darken the next batch.

(4) Use two finishing pans alternately.

Automatic Drawoff

An automatic drawoff is well suited for drawing the partly evaporated sap from the evaporator for later completion in the finishing pan (fig. 82). A high precision thermoregulator is not required, since a tolerance of ±0.5° F. is acceptable. Corrections need not be made for slight changes in the boiling point caused by changes in barometric pressures throughout the day.

Automatic valves can be purchased as complete packages, or they can be assembled as indicated in chart 10. These valves are operated by a solenoid, which in turn is operated by a thermoregulator. The thermoregulator is adjusted by hand to open or close the valve when the boiling sirup reaches the desired temperature, as measured by a precision thermometer.

A thermoregulator, if used to control the removal of finished sirup from the evaporator

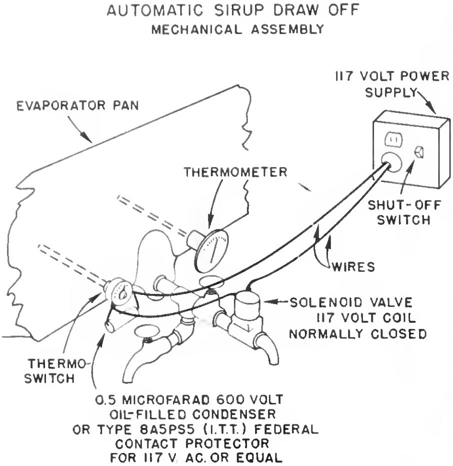


Chart 10.—Automatic sirup drawoff.

PN-4778

Figure 82.—The automatic drawoff is especially well suited for removing sirup from the evaporator. When a finishing pan is used, the evaporator functions as a semifinishing pan.

or finishing pan, must be sensitive to changes of ±0.1° F. The thermoregulator must be recalibrated three times a day.

When the thermoregulator is operated on 110 v. a.c., a condenser must be shunted across the line (see chart 10) to protect the contact points against the surge of heavy current that is set up each time the solenoid coil operates. To avoid this, it is better to operate the thermoswitch on low d.c. voltage and use a high-capacity mercury relay to operate the solenoid valve.

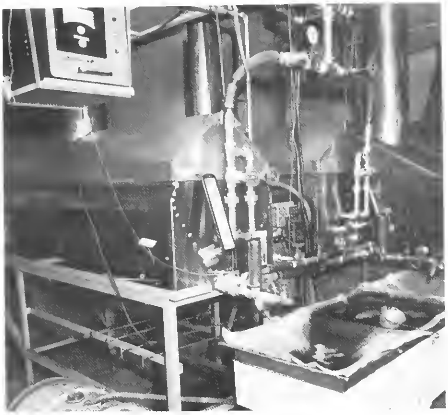
Another type of temperature regulator uses thermistor probes as the sensing element. A sensitive electrical relay must be used with this type of regulator, and it is recommended for use with the thermoregulator.

The thermistor probes in the boiling sirup must be kept free of sugar-sand deposits. Deposits of sugar sand on the probes will change their heat-transmitting properties and cause error in their response to the sirup boiling temperatures. The probes can be kept free of sugar sand by soaking them in 10-percent sulfamic acid between runs. This same precaution applies to the bulb of the thermometer.

A further advance in controlling automatic drawoff has been made at the Eastern Regional Research Center (*15*). A new thermoregulator containing a Wheatstone bridge, thermistor probes, and a meter relay automatically compensates for changes in boiling point caused by changes in barometric pressure (fig. 83). The instrument employs two thermistor probes. The water probe continually responds to changes in the temperature of boiling water. The sirup probe causes the valve to open whenever the temperature of the boiling sirup reaches a predetermined number of degrees above the temperature of the boiling water—7° F. for standard-density sirup and slightly more for heavier sirup.

End of an Evaporation

When the evaporation of a run of sap has been completed, care must be taken or the pans may be burned. If water is available, it can be run into the storage tank as the last of the sap is being withdrawn. Little sap will be lost, and the pans can be flooded with 3 to 5 inches of water before the fire is extinguished. This precaution is necessary when either wood or oil is used because enough heat will remain in the



PN-4779

Figure 83.—Automatic thermoregulator that compensates for changes in barometric pressure.

firebox and arch to melt the solder and the thin metal of the pans if the pans become dry before the firebox has cooled.

If water is not available, the fires must be extinguished and evaporation stopped while there is still enough sap in the storage tank to fill the evaporator to a depth of 3 to 5 inches.

Cleaning the Evaporator

When maple sap is concentrated to sirup in a flue-type open-pan evaporator, the organic salts become supersaturated; that is, they are concentrated to a point where they can no longer be held in solution. They are then deposited on the sides and bottom of the evaporator as a precipitate or scale. This scale forms an impervious layer that builds up with continued use of the evaporator. The scale reduces heat-transfer efficiency and thus wastes fuel and holds up sirup in the evaporator unduly.

The scale is of two types. One type is a protein-like material that forms in the flue or sap pans. The other, called sugar-sand scale, forms in the sirup or finishing pan. It is a calcium and magnesium salt deposit similar to milkstone and boiler scale.

Sugar-sand scale is the more troublesome of the two types. It is especially troublesome if it is allowed to build up to an appreciable thickness. Also, sugar sand contains entrapped caramelized sugar, which contributes to the production of dark-colored sirup.

Removing sugar-sand scale is not easy, and doing it by physical means (scraping, scrubbing with steel brushes, or chiseling) is almost impossible. Removal becomes more difficult as the layer of scale becomes thicker. Clean the evaporators often enough to prevent buildup of sugar sand. Teflon-coated pans are easier to clean. Also, keep the underside of the flues clean.

Methods Used in the Past

Some methods used in the past to prevent formation of scale and to remove thin layers include—

(1) Reversing the flow of sap through the evaporator, according to the manufacturer's directions; this retards the formation of scale.

(2) Running soft spring water through the evaporator for a long period; this tends to dissolve small amounts of scale.

(3) Pouring skim milk into the pan and letting it remain until it sours; the lactic acid of the sour milk has some solvent action on the scale.

Chemical Cleaners

Equipment manufacturers have used muriatic acid to remove heavy incrustations of sugar-sand scale from evaporators returned to them by maple-sirup producers. This acid is highly corrosive and must be used with great care to avoid damaging the pans by dissolving the thin tinplate coating. Also, unless a person is experienced in the use of muriatic acid, there is danger that he will get the acid on other materials or on his skin.

Laboratory and field tests have shown that sulfamic acid (*121*), one of the chemicals developed for cleaning milk-processing equipment and marine boilers, can be used to remove sugar sand from most maple sirup equipment. Sulfamic acid (the half amide of sulfuric acid) is an odorless, white, crystalline solid and is highly soluble in water. It must not be confused with sulfuric acid. Sulfamic acid crystals can be handled easily, with little risk of spilling and little danger from volatile fumes. As a solid, sulfamic acid is reasonably harmless to the skin and clothing. However, a solution of the acid can irritate the skin. If either the dry acid or its solution comes into contact with the skin, it should be washed off immediately with large quantities of water. Also, it should be removed from clothing and equipment by rinsing repeatedly with large quantities of water. Bulk supplies should be stored in a tight container in a dry place.

Despite its strong acid characteristics, sulfamic acid has only a slight corrosive action on most metals except zinc plating, especially if contact is for a short period. For example, on tin (the metal coating of most evaporators), hydrochloric acid is almost 25 times more corrosive than sulfamic acid and sulfuric acid is approximately 80 times more corrosive.

Gluconic acid, another chemical cleaner, is recommended for cleaning galvanized-iron equipment because it has much less corrosive action on the zinc coating. However, use of gluconic acid need not be limited to cleaning galvanized equipment; it is effective on most metals, even though it has a slower cleaning action than sulfamic acid. It is usually sold as a 50-percent water solution.

Both sulfamic acid and gluconic acid can be obtained from suppliers of maple sirup equipment.

Use these amounts of acid:

Sulfamic Acid.—For a thin scale, use $^1/_4$ pound ($^1/_2$ cup) per gallon of water. (This is a 3-percent solution.) For a heavy deposit, use $^1/_2$ pound (1 cup) per gallon of water. (This is a 6-percent solution.)

Gluconic Acid.—For all deposits, use 1 gallon of 50-percent stock solution (obtained from your supplier) for each 4 gallons of water. (This is a 10-percent solution.)

To avoid damaging the tinned surface of the evaporator, do not use a stronger solution than recommended; and do not leave the solution in the evaporator longer than is required to soften the scale.

Cleaning Procedure

Use the same methods to clean the flue (sap) pans and the sirup (finishing) pan.

You will need a good supply of piped water, so that you can use a hose to rinse the pans. If water is not available at the evaporator house, take the evaporator pans to a source of piped water.

You should wear rubberized gloves to protect your hands from the acid solution.

The best maintenance practice is to remove the sugar-sand scale between each run. The following procedure should keep the evaporator clean and bright: With a cloth, swab the pans with the acid-cleaning solution; allow it to remain a few minutes; then thoroughly rinse the pans with water, to be sure the acid is completely removed.

If a layer of scale has accumulated on the evaporator, use the following procedure:

(1) Remove all loose scale and dirt from the pan with a broom or brush. Then rinse the pan with a good stream of water from a hose.

(2) Plug the outlets of the pan. If the outlets have threaded fittings, use metal screw plugs; otherwise, use wood, cork, or rubber stoppers.

(3) Fill the pan with water to the level to be descaled. Measure the water as you put it in the pan, and make a record of the number of gallons for future use. Also, make a record of the estimated volume of the pan.

(4) Add the correct amount of acid to the water in the pan. Stir to help dissolve the acid.

(5) Warm the solution in the pan to a temperature of 140° to 160° F. This hastens the rate at which it softens or dissolves the scale. After the warm solution has been in the pan for a short time (usually 15 to 20 minutes is enough), brush the sides and bottom of the evaporator with a fiber brush to speed up removal of the deposited sand.

(6) When the evaporator is clean, drain the acid from the pan. Turn the pan on its side and flush it out with a stream of water. Repeat the water rinse five or six times, and allow the pan to drain between each flushing. Thorough rinsing is necessary to insure complete removal of the acid and its salts from the pan.

To remove a thin layer of scale with sulfamic acid requires from 30 to 35 minutes; to remove a thick layer requires from 60 to 90 minutes. With gluconic acid, about twice as much time is required. The acid solution can be stored and reused a number of times. Do not store it in iron or galvanized containers; glass or earthenware containers are best.

To economize on the amount of acid, use a smaller quantity of solution and tilt the pan first in one position and then in another until all the scale-covered surfaces have been soaked.

Sulfamic acid and its salts are toxic to growing plants. For this reason, it is an effective weedkiller. But care should be taken not to discard the used acid solution where desirable plants may be damaged or killed.

End-of-Season Cleaning

A much-used procedure for cleaning evaporator pans at the end of the season is to fill them with sap and let them stand several weeks. The sap will ferment and the acids formed will loosen the scale. If the sap becomes ropy and jellylike, it will be difficult to remove. However, if it is allowed to stand longer, it will again become liquid and can be removed easily. As with the other cleaners, the pans must be rinsed after the fermented sap treatment and dried before they are stored. Fermented sap will not remove heavy scale deposits.

Whether to clean the evaporator at the end of the sap season is debatable. Some producers store the evaporator pans with the deposit, assuming that this serves as a protective coating and keeps the evaporator surfaces from corroding. The preferable method is to clean the equipment so that it is ready for use the next spring. In either case, the evaporator pans should be dried and stored in an inverted position.

Summary

(1) Use a flue-type open-pan evaporator as the basic unit.

(2) Evaporate more than 90 percent of the water in the evaporator. The sap should have a Brix value of 45° to 60°.

(3) Complete the evaporation in a finishing pan.

(4) To expand the evaporation, add one or more flue pans and operate them in series.

(5) Operate the evaporator with a minimum depth of sap. Keep the depth of sirup at point of drawoff at 1/2 to 1 inch.

(6) Keep sap boiling vigorously at all times.

(7) For wood fires keep the fire uniform and keep the fire doors closed except when adding fuel.

(8) If a finishing pan is not used, draw off the sirup as soon as it reaches the proper boiling temperature (7° F. above the boiling point of water for that hour and place).

(9) If a finishing pan is used, draw off the sirup at 45° to 60° Brix (boiling temperature at drawoff 2.5° to 5.1° F. above the temperature of boiling water). Use an automatic valve controlled by a thermoswitch.

(10) Filter the sirup in transferring it from the evaporator to the finishing pan.

(11) As soon as the temperature of the boiling sirup in the finishing pan rises 7° F. above the boiling point of water (which yields standard-density sirup; 7.5° above the boiling point yields 67°-Brix sirup with better taste), immediately stop heating, cover the pan and withdraw the sirup.

(12) Clean the evaporators often enough to prevent buildup of sugar sand.

(13) Rinse the evaporator pans with large amounts of water (use three separate rinses, draining the pan between each rinse after each time a chemical cleaner is used in the evaporator or finishing pan).

(14) Keep the underside of the flues clean.

OTHER TYPES OF EVAPORATORS

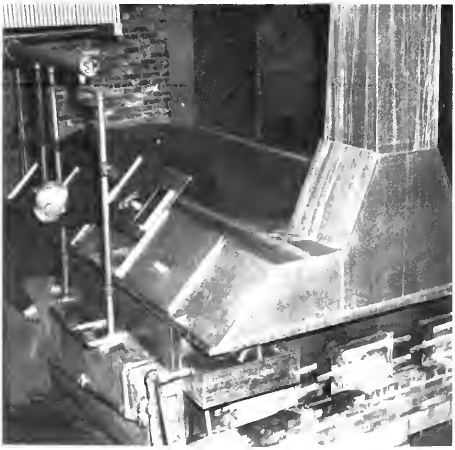
Other types of evaporators include the steam evaporator (or a combination of oil and steam) and the vacuum evaporator.

Steam Evaporator

The evaporation of maple sap with high-pressure steam (figs. 84–86 and chart 11) is practiced by a few producers (*97*). Its use, however, has never become widespread. Steam evaporators have several advantages, as follows: (1) The heat is steady; therefore, the sap can be evaporated at a continuous and even rate. (2) Heat can be supplied in steam coils, manifolds, or a jacketed kettle. (3) The evaporator can be constructed with smooth walls; flues are unnecessary. (4) Scorching of sirup is minimized. (5) The evaporator room can be separated from the boiler room, which makes it

PN-4780

Figure 84.—High-pressure steam boilers are economical when low-priced fuel is available. Approximately 20 gallons of finished sirup per hour can be made in the two 100-h.p. boilers shown.



PN-4781

Figure 85.—A converted evaporator that uses high-pressure steam coils with steam generated by two 100-h.p. boilers.

PN-4782

Figure 86.—This evaporator consists of several units connected in series with the partly evaporated sap moving successively to the next evaporator by means of a float control to prevent intermixing of concentrated sap with less concentrated sap.

easier to keep clean. (6) The high-pressure steam can be used as the source of heat in making a variety of maple products. (7) Where soft coal can be obtained cheaply, high-pressure steam is economical.

The disadvantages of steam evaporators are: (1) A license may be required to operate a steam boiler. (2) The boiler needs periodic inspection and overhauling. (3) In some areas the water is not suitable for use in a steam boiler. (4) The initial cost of the steam boiler may not be justified.

The approximate size of a steam boiler (boiler horsepower, b.h.p.) required to evaporate sap to sirup can be calculated, since 1 b.h.p. will evaporate approximately 3.25 gallons of water (sap) per hour. The value 3.25 varies slightly, depending on the temperature of the sap as it enters the evaporator and the operating pressure of the boiler. As indicated earlier, 33.25 gallons of water must be evaporated from sap with an initial Brix value of 2.5° to produce 1 gallon of sirup. Approximately 10 b.h.p. $\left(\frac{33.25}{3.25}\right)$ will be required to produce 1 gallon of sirup per hour.

A system that is proving successful is the combination of oil and steam. In this two-stage system, oil is used to concentrate the sap to about 30° or 40° Brix in flue pans, and steam is

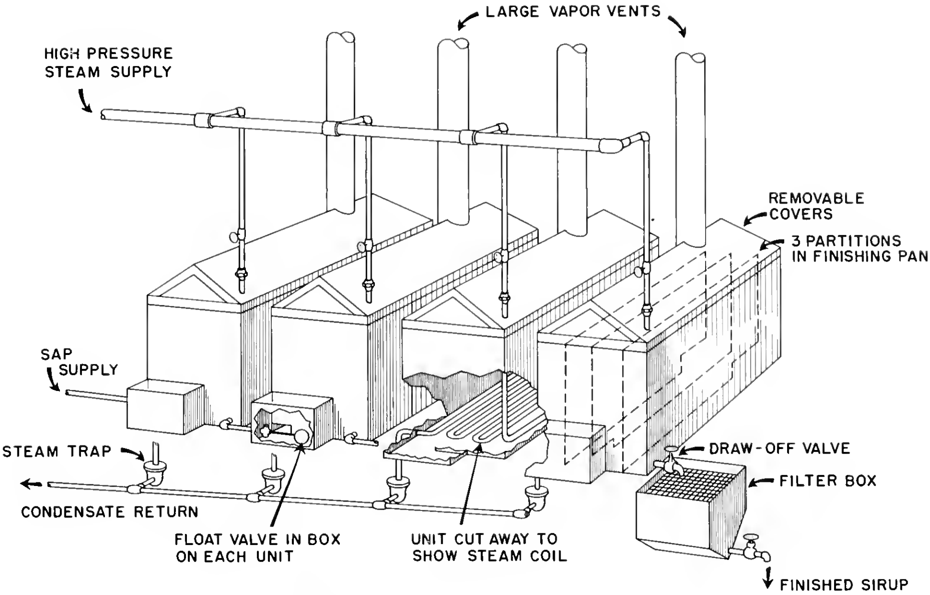


Chart 11.—Multiple-unit steam evaporator.

used to complete the evaporation. This combination has all the advantages of steam for finishing the sirup, but requires a smaller, and therefore less expensive, steam boiler.

Vacuum Evaporator

Milk-concentration or fruit-juice evaporation plants in maple-producing areas can be adapted for evaporating maple sap. This was done during the 1930's at Antigo, Wis., where a milk plant was used to make sirup during part of the day in the spring sirup season (*3*).

The procedure used at Antigo is as follows: The sap is concentrated to between 25° and 30° Brix in the conventional open-pan evaporator at the farm site. This is 90 percent of the required evaporation. Evaporation is completed in a vacuum evaporator at the central sirup-finishing plant. This two-stage method of evaporation results in a nearly colorless and flavorless maple sirup. Such sirup is not marketed for direct use, but it is ideal for the production of high-flavored sirup, as described on page 106.

A study at Cornell (*42*) showed that the use of milk-plant equipment during off-peak seasons for evaporating maple sap was practicable but that the sirup produced had to be treated by the high-flavoring process to obtain marketable maple sirup. The fixed costs for use of milk-plant equipment are negligible. However, the perishable, partly concentrated sap must be transported to the milk-concentrating plant, and use of a central sirup-finishing plant requires a new procedure for maple-sirup production.

Summary

(1) The steam evaporator provides a steady source of heat, and danger of scorching is minimized. The sirup produced is light colored and delicately flavored. However, the steam evaporator is expensive to install. A combination oil-and-steam system (two-stage method of evaporation) is proving successful; it has all the advantages of steam but is less expensive to install.

(2) The vacuum evaporator, which is limited to large-scale or central-plant operation, is used to complete the evaporation of sap that has been partly concentrated on the farm. The equipment used usually is idle milk-evaporation equipment. The sirup produced has essentially no maple flavor, but it is excellent for use in making high-flavored sirup.

FUEL

Wood

The modern flue-type evaporator was designed for burning wood. A wood fire carries a luminous flame throughout the entire length of the arch. The flue area of the evaporator and the part that lies over the firebox are heated both by radiant and by convection heat liberated by the burning gases. The wood may be sound cordwood, defective trees removed in improvement cuttings, or sawmill wastes—either culls or slab (*69*).

In the evaporation process, the object is to evaporate the water in the shortest possible time. Therefore, it is essential to use only dry, sound wood that will produce a hot fire. Wet or green wood will not produce as much heat as will the same volume of dry wood. Poor burning fuel results in a slower boiling rate. This, in turn, causes the sap to be held in the evaporator for a longer time and results in a darker sirup.

A steady fire shortens the boiling time. The best results are obtained by charging the firebox first on one side and then on the other, keeping the fuel in the firebox at almost constant volume (fig. 87). The fire doors should be closed immediately after each charging to reduce the intake of cold air which cools the underside of the pans. When this happens, the boiling rate of the sap decreases and holdup time in the evaporator increases. Likewise, ash-pit draft doors that are open too wide will admit more air than is required for combustion, and the excess air has a cooling effect. Introduction of cold air beneath the evaporator pan in either the firebox or the flue area not only reduces the boiling rate but also tends to set up counter currents in the flowing sirup in the different channels of the evaporator. This also contributes to the production of a darker sirup.

Based on $25 per cord of wood, the fuel to produce a gallon of sirup would cost about $1. This represents about 10 percent of the cost of sirup production (*5*, *113*). The heating values of different wood fuels expressed in British thermal units (B.t.u.'s) for a standard 4- by 4- by 8-foot cord are maple, 22,800,000; beech, 20,900,000; and hickory, 24,800,000.

Oil

The advantages offered by using oil as the heat source for evaporating maple sap to sirup are numerous (*104*). Chief among these are (1) it is automatic; therefore, it does not require the services of a fireman; (2) it provides a steady uniform heat, which is desirable for producing high-quality sirup; (3) it is clean and therefore aids in better housekeeping and sanitation in the evaporator house; and (4) in terms of British thermal units, the cost of oil at 35 cents per

PN-4783

Figure 87.—When both doors are opened for firing, the excess air admitted chills the pan. Boiling stops; sap and partly evaporated sirup intermix; and then, when the fuel is again burning briskly, the evaporator must equilibrate itself.

gallon is more than double the cost of wood at $25 per cord, but the operational costs may not differ greatly since oil does not require the services of a fireman.

The disadvantages of using oil as the fuel source, while few, are nevertheless important: (1) The initial cost (capital investment) of oil burners is high; (2) oil burners require a special arch (firebox) although in a new installation it is not necessarily more expensive than the conventional wood-burning arch; and (3) oil does not make use of the cull trees that must be removed each year from a well-managed sugar bush.

When oil is used as fuel, two pertinent facts must be observed. The first and most important is that wood and oil burn in different ways. Wood burns with a luminous flame (long fire path) throughout the length of the evaporator, including the area under the flue pans as well as under the sirup pan; oil, on the other hand, burns as a ball of flame in only a relatively small space. Secondly, of the two forms of heat transfers—radiant and convection—used in a sap evaporator, radiant heat accounts for approximately 80 percent of the heat transferred to the liquid, whereas convection heat (that which is derived from the hot flue gases passing over the surface of the pans and flues) supplies approximately 20 percent. Therefore, to make use of the radiant heat from the oil fire, the ball of burning oil must illuminate the entire undersurface of the pans. This necessitates properly positioning the ball of burning oil and eliminating any obstructions that will prevent illumination of the entire undersurface of the pans. This requirement will be met only through the proper design of arches made for the burning of oil as fuel.

A wood-burning arch cannot be successfully converted to an oil-burning arch without major changes. The principal fault of such a conversion is that the slope of the wood-burning arch behind the firebox does not permit illumination of the entire underside of the sap or flue pan by the ball of burning oil and, consequently, the sap will not boil.

Size of Burner

The size of burner to use is determined by two factors: (1) The length and width of the evaporator (the vertical area of the flues has a minor effect) and (2) the quantity of sap to be evaporated per hour. If the rated capacity of the evaporator in gallons of sap per hour is known, it can be divided by 13 (the approximate number of gallons of water evaporated per hour by 1 gallon of oil) to obtain the size of burner (g.p.h. = gallons of oil per hour) required for a specific evaporator.

The rated capacity of an evaporator burning wood cannot be accurately equated to that of an evaporator burning oil. Therefore, this method of calculation may indicate a burner that is too large. However, this is not serious since the amount of oil burned per hour can be changed, within limits, by changing the size of the nozzles.

To prevent damaging the pan by firing with an oversize burner, it is recommended that for the first trials a nozzle size 20 percent smaller than indicated by the above calculation be used. The burning rate (nozzle size) can then be increased as needed. An empirical method for determining nozzle size is to divide the surface area (length times width) by 5. Thus, a 5- by 12-foot evaporator would require an oil burner nozzle of 12 g.p.h.

Type of Burner

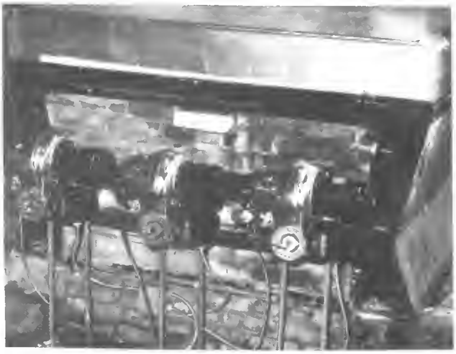
With few exceptions, high-pressure oil burners that use No. 2 oil are recommended. They are available with different nozzle sizes to fit evaporators of all sizes. Their lower initial cost offsets any advantage gained by using burners that require the heavier grades of oil.

Number of Burners per Arch

Only one burner is required for each evaporator (fig. 88). It must be correctly positioned under the evaporator and the combustion chamber must meet certain minimum standards. Use of a single burner reduces the capital investment and installation costs. For example, the capital investment and installation costs for an evaporator requiring 12 gallons of fuel per hour supplied by a single burner would be approximately half that for an evaporator supplied by two 6-gallon-per-hour burners. In addition, the two smaller burners will require more servicing and attention than will the larger one.

PN-4784

Figure 88.—A correctly positioned, single, high-pressure, domestic-type burner will give the required heat for the evaporation of the sap.



PN-4785

Figure 89.—When one large burner cannot be mounted sufficiently far below the pan, two or more smaller burners can be mounted horizontally to give the required amount of heat without danger of producing hot spots.

If one burner is used, it should be mounted far enough below the bottom of the pan so that the radiant heat will be effective across the full width of the pan. If construction of the arch does not permit mounting the burner this far below the pan (see table 5), then two or more smaller burners mounted horizontally should be used to insure heating the full width of the pan (fig. 89). If the slope of the arch is such that the undersurface of the flue pan cannot be illuminated by the ball of fire (see chart 12), boiling may not occur in the area not illuminated. This is especially true of wood fuel arches that have been converted for oil burners. To compensate for this, a supplementary firebox can be constructed under the flue pan, and another burner mounted; however, this is not always satisfactory.

Nozzle Tip

For evaporators in which the length is approximately twice the width, the nozzle tip should be at an 80° angle. For evaporators in which the length is greater than twice the width, the nozzle should be at a 60° angle. Irrespective of the type of nozzle tip or the angle, the burner must be adjusted so that the correct amount of air is fed along with the atomized oil to insure complete combustion. This can be checked with a flue gas analyzer.

Arch and Combustion Chamber

The arch for oil fuel also serves as a support for the evaporator pans and contains the combustion chamber and the flue for the hot gases. The arch should be located in the evaporator house to provide an adequate working space with room for installing supplemental arches as the operation is expanded. The arch need not be in the center of the evaporator house but may be at one side. The concrete footings for the arch should be on gravel and should extend below the frostline. An all-masonry arch, with external walls built of cinder block or brick, may be built on the site, or the arch may be prefabricated with exterior walls of sheet metal on a cast iron and steel frame. In either case, it must conform to certain minimum dimensions. The interior construction is similar for both.

Dimensions of Arch.—The size (length and width) of the arch is determined by the size of the evaporator. It must be wide enough to support the pans and long enough not only to support the pans but also to hold the base of the flue-gas stack. Chart 12 shows a masonry arch for a 5- by 12-foot evaporator (9-foot flue pan and 3-foot flat pan). The outside walls are

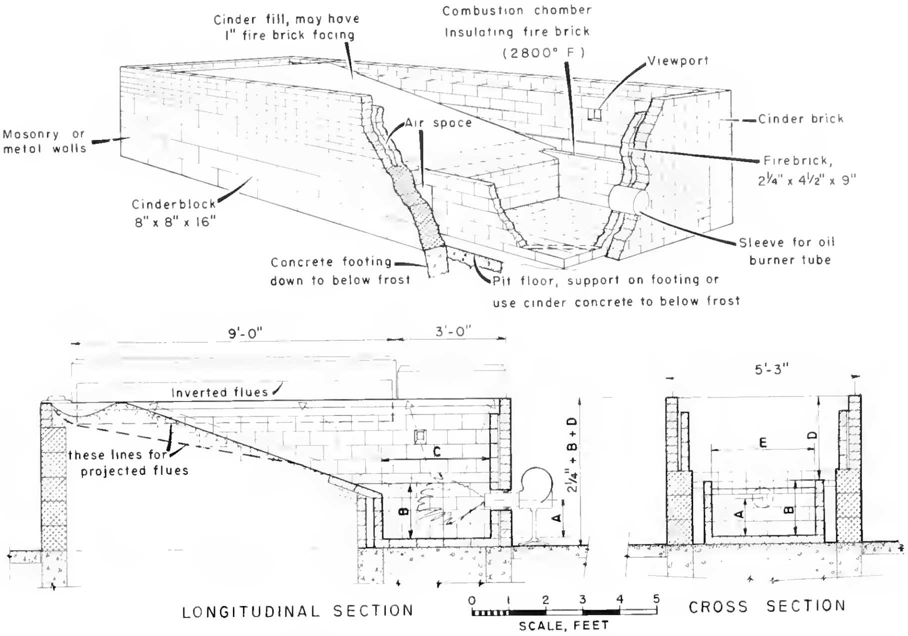


Chart 12.—Arch and firebox for oil-fired evaporator.

cinder block except for the top section, which is 3½-inch bricks to provide a 2-inch supporting surface for the pans and project 1½ inches beyond the pans. If the arch is made to the exact outside dimensions of the pans, the supporting wall of the arch would cover too much of the underpan surface (3½ inches on all sides). A large loss of heating surface would result.

The height of the arch is governed by the size of the combustion chamber, which in turn is governed by the size of the burner (see table 5) and the size of the evaporator. For a 5- by 12-foot evaporator, the height of the arch should be 46 inches (chart 12). The arch should elevate the pans 46 inches or more above the floor level to permit the use of gravity flow of the sirup in successive operations. If the arch raises the pans too high, especially when multiple evaporators are used, a catwalk can be installed; or the combustion chamber of the arch and the burner can be built in a pit.

Firebox and Combustion Chamber.—The entire open space enclosed by the arch under the pans is the firebox. Better results will be obtained if it contains a combustion chamber (see chart 12). The function of this chamber is (1) to provide a hot radiating surface and (2) to utilize the hot, incandescent surface to vaporize and insure complete combustion of the oil.

For maximum efficiency, the size of this combustion chamber must conform to minimum dimensions that are related to the nozzle size of the burner. These dimensions are given in table 5. A rule-of-thumb relation between combustion chamber and nozzle size is that there should be a floor area of 90 square inches for each gallon per hour of rated nozzle capacity.

The distance between the top of the combustion chamber and the bottom of the pans (dimension D of chart 12) is important for two reasons: (1) The ball of burning oil should be far enough below the "cold" pan surface to prevent

TABLE 5.—*Inside dimensions of combustion chamber and stack diameters*

Burning rate of oil (g.p.h.)	Distance from center burner draft tube to combustion chamber floor (A)	Minimum height (B)	(C) Length for nozzle angle of—		Distance between combustion chamber and top of arch (D)	(E) Width for nozzle angle of—		Approximate floor area	Minimum diameter of stack
			60°	80°		60°	80°		
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Square inches*	*Inches*
5	9	18	25	22	19	18	21	450	10
6	9	18	27	24	19	20	23	540	10
7	10	19	29	26	20	22	25	630	10
8	11	19	30	28	20	24	26	720	12
9	11.5	19	32	29	20	25	28	810	12
10	12	19	33	31	20	27	29	900	12
12	13	20	36	34	20	30	32	1,080	12
14	14	21	39	36	20	33	35	1,260	14
16	15	22	41	39	20	35	37	1,440	14
18	16	23	44	41	20	37	40	1,620	16
20	17	24	47	43	22	39	42	1,800	18
22	18	25	49	45	22	41	44	1,980	20
24	19	25	51	47	22	43	46	2,160	20

corrosive deposits on the underside of the pan; and (2) the ball of fire must be far enough below the pan so that the acute angle of radiation from the apex (ball of fire) to the extreme sides of the pan is kept to a minimum (table 5). If the ball of fire is too close to the pan, there is insufficient space between the pans and the top of the combustion chamber; and the angle of radiation becomes too great. This results in uneven heating across the width of the pan. Overheating occurs directly over the fire. This can be compensated for only by using more than one burner mounted horizontally.

Construction of Arch and Combustion Chamber

Arches may be made of sheet metal or masonry (chart 12). In arches made of either material, the combustion chamber is free standing within the arch and is constructed of insulating firebrick. In sheet-metal arches the remainder of the arch is lined with hard firebrick. The combustion chamber is separated from the exterior wall of the arch by an air space to allow for expansion of the heated bricks. For the same reason, there is an air space between the hard firebrick liner and the exterior walls of the arch. The fill between the combustion chamber and the rear of the arch must be of a nonpacking material such as cinders.

Size of Stack

Since the oil burner is operated under forced draft, the flue stack need not be as high or as wide as when wood is the fuel. The size of the stack is governed by the size of the oil burner (table 5).

With only one arch, it is recommended that a complete evaporator, flat pan, and flue pan be used. However, it is also recommended that the flue pan be at least two-thirds the total length of the evaporator. The flat pan serves as the semifinishing pan in which the sap is raised to a density of 55° or 60° Brix. The partly concentrated sap should be transferred from the evaporator to the finishing pan where the final stage of evaporation is completed. Although sap can be concentrated to sirup in the evaporator, this practice is not advised.

Installation of Multiple Arches

To increase the capacity of the evaporator, additional arches and pans can be added. Each additional arch should be equipped with a flue pan only and should be installed ahead of and in series with the complete evaporator (see chart 13). The supplemental flue pan arches are constructed in exactly the same manner as the one for the complete evaporator. To connect the supplemental flue pans in series with the evaporator requires only one point at which the raw sap is fed and one point at which the partly evaporated sap or sirup is removed for transfer to the finishing pan or bottling tank. In the multiple unit assembly, the flat pan of the evaporator continues to serve as the semifinishing or finishing pan (fig. 90).

Efficiency of Heat

A study of the use of oil as fuel for the evaporation of maple sap in an open evaporator was reported by Phillips and Homiller (*87*). They showed that commercial maple sap evaporators fired with oil haye an efficiency of 66 to 74 percent. Their data were obtained with a smaller-than-average evaporator; larger evaporators would be expected to be slightly more efficient. The efficiency of the open pan evaporator compares favorably with commercial steam generating plants, for which a combustion efficiency of 80 percent is considered good.

The efficiencies obtained by Strolle and others (*111*) in evaporating 45 to 55 gallons of 3°-Brix sap to standard-density sirup are given in table 6. These data indicate that efficiency decreases as the rate of sap feed (gallons of sap evaporated per hour) increases and that oil cost per hour also increases. However, from further

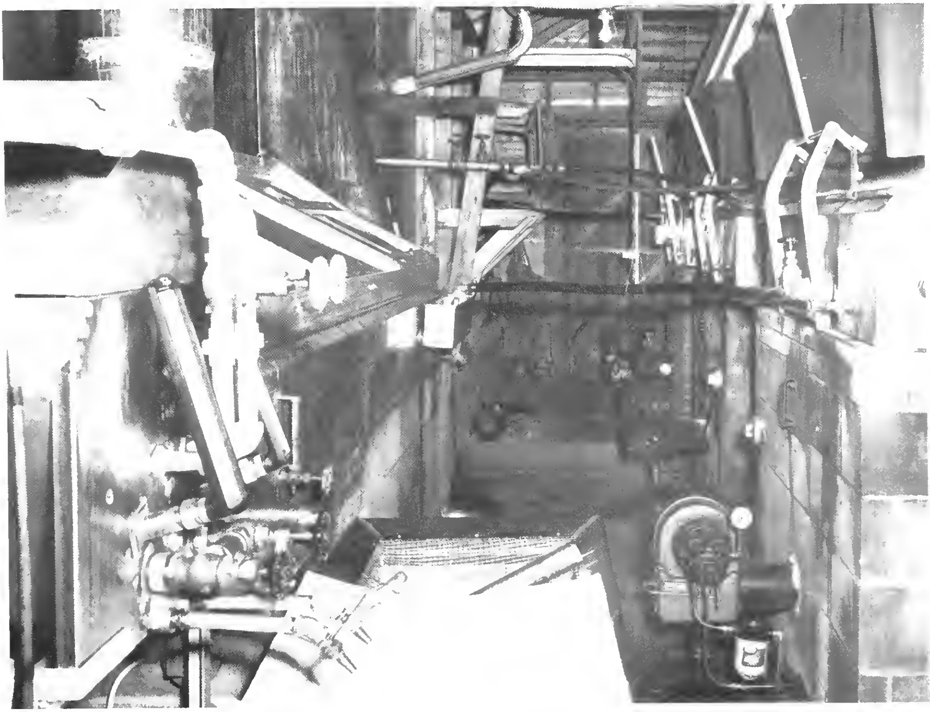


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Figure 90.—In one of the most economical and efficient types of evaporators, an oil fire and four flue pans are used for evaporation; high-pressure steam is used for the last stage of evaporation.

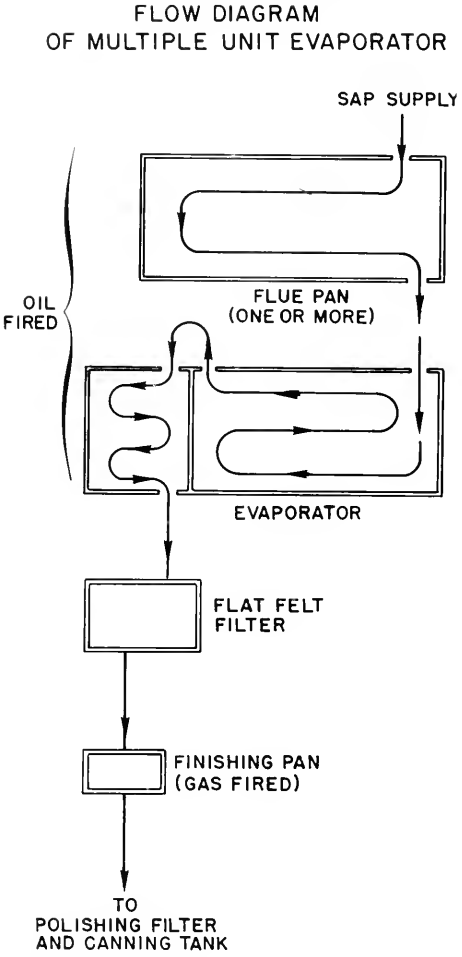

Chart 13.—Flow diagram of multiple-unit evaporator.

calculations and rough extrapolations the data in table 7 were obtained.

These data show that sirup production increases as the amount of fuel burned increases. The increase in cost of fuel per gallon of sirup is slight and is more than compensated for by the improvement in the grade of the sirup and the reduction in evaporation time and cost of labor.

TABLE 6.—*Efficiency of oil-fired experimental evaporator in evaporating sap of 3° Brix to standard-density sirup*

Sap evaporated per hour (gallons)	Oil burned per hour	Efficiency
	Gallons	*Percent*
45	3.9	74
50	4.7	69
55	5.3	66

TABLE 7.—*Extrapolated efficiency of oil-fired evaporator*

Sap evaporated per hour (gallons)	Oil burned per hour	Sirup made per hour	Cost of oil per gallon of sirup produced	Time required to evaporate 550 gallons of sap	Efficiency
	Gallons	*Gallons*	*Dollars*	*Hours*	*Percent*
65	6.7	2.36	1.00	8.5	59.6
60	6.0	2.18	.96	9.2	62.6
55	5.3	2.00	.93	10.0	66
50	4.7	1.82	.91	11.0	69
45	3.9	1.64	.84	12.2	74

The maximum efficiency that could theoretically be obtained from an oil-fired evaporator would utilize all the British thermal units (B.t.u.'s) of a gallon of oil. This heat would raise the temperature of the feed sap to its boiling point and then vaporize the water in the sap to steam. Assuming that the temperature of the sap is 35° F. and its boiling point is 210°, the heat (B.t.u.'s) required to evaporate 34.4 gallons of sap with a density of 2.5° Brix to yield 1 gallon of standard-density sirup can be calculated. Knowing the B.t.u.'s of No. 2 fuel oil (139,000), the number of gallons of oil required to produce this gallon of sirup at maximum efficiency is 2.2 gallons. Since no oil burner is 100-percent efficient, and oil-fired evaporators are only 60- to 75-percent efficient, the fuel required per gallon of sirup is 3+ gallons of oil.

To measure the efficiency of burners, arches, and evaporators, a number of factors must be carefully obtained. These are:

(1) *The Brix Value of the Raw Sap.*—For example, only half as much water is evaporated from 3°-Brix sap as from a $1^1/_2$°-Brix sap to make standard-density sirup. Therefore, other things being equal, it would require only half as much oil to make sirup from 3°-Brix sap as from $1^1/_2$°-Brix sap.

(2) *Temperature of Sap.*—The temperature of the sap as it enters the evaporator must be noted, since a great deal of heat is required just to heat the sap from its storage temperature to its boiling temperature. Therefore, the warmer the sap, the less oil required to heat it to boiling.

(3) *The Brix Value of the Finished Sirup.*—All too often the exact Brix value of the finished sirup is not considered in making efficiency studies. Yet a difference of only a few tenths of 1° in Brix value has a pronounced effect on the number of gallons of sap that must be evaporated to produce the sirup.

For cost accounting records, most producers will find that merely to divide the number of gallons of sirup made by the number of gallons of oil burned will give the fuel costs per gallon of sirup. These data should be considered an estimate of the efficiency of the oil-burner installation.

The cost of fuel oil can be kept low by contracting for it through competitive bidding. The heat (B.t.u.'s) produced by one cord of wood is approximately equivalent to that produced by 175 gallons of oil. The efficiency of wood depends on many variables, such as condition of the wood, size of the individual pieces, how it is fired, condition of the fire, and stack height.

Summary

(1) *Wood*
  (a) Use only well-seasoned dry wood, either cord or slab.
  (b) Keep a steady fire.
  (c) Fire first on one side of the firebox, then on the other.
  (d) Keep the fire doors open only long enough to charge the firebox.
  (e) Open the dampers and draft doors only enough to furnish the air for combustion.
(2) *Oil*
  (a) Oil is recommended if there is a shortage of labor.
  (b) The firebox and arch must be specially built.
  (c) The cost of fuel for making sirup is approximately the same for oil and wood.
(3) Increase the capacity of the evaporator through the addition of one or more sap or flue pans.
(4) Mount the supplemental pans on their individual arches.
(5) Hook up the supplemental arches in series with the evaporator.
(6) Use a finishing pan.

MAPLE SIRUP

The characteristics of maple sirup are discussed here so that the development of color and flavor will be better understood.

Composition of Sap and Sirup

Table 8 gives the composition of maple sap and sirup. The analyses in this and later tables are not average values; they are analyses of typical saps and sirups. Usually the sirup and sap have essentially the same composition, except that on an "as is" basis the constituents of the sirup show a thirtyfold to fiftyfold increase as a result of concentrating the sap to sirup. The amounts of some of the constituents, when expressed on a dry-weight basis, are less in sirup than in sap because of their removal from solution as insoluble sugar sand.

The different kinds of sugar in maple sap are not numerous (*91*). Sucrose, the same sugar as in cane sugar, comprises 96 percent of the dry matter of the sap and 99.95 percent of the total sugar (table 9). The other 0.05 percent is composed of raffinose together with three unidentified oligosaccharides. Unfermented sap does not contain any simple or hexose sugars.

The sap contains a relatively large number of nonvolatile organic acids (table 10), even though they account for only a small proportion of the solids (*89*). The concentration of malic acid is 10 times that of other organic acids. It

TABLE 8.—*Composition of maple sap and sirup* [1]

Item	Sap	Sap (dry weight)	Sirup (dry weight)
	Percent	*Percent*	*Percent*
Sugars	2.000	97.0	98.0
Organic acids	.030	1.5	.3
Ash	.014	.7	.8
Protein	.008	.4	.4
Unaccounted for	.009	.4	.5

[1] Typical values, not averages. Maple sap and sirup vary in composition between rather wide limits.

TABLE 9.—*Sugars in maple sap and sirup* [1]

Sugars	Sap	Sap (dry weight)	Sirup (dry weight)
	Percent	*Percent*	*Percent*
Hexoses	0	0	0–12
Sucrose	1.44	96.00	88–99
Raffinose and a glycosyl sucrose	.00021	.014	------------
Oligosaccharides: [2]			
I	.00018	.013	------------
II	.00020	.014	------------
III	.00042	.028	------------

[1] Typical values, not averages.

[2] The oligosaccharides have been isolated by chromatography but have not been identified.

may prove to be useful in detecting adulteration (*151*). One or more of these acids may be important in forming "maple flavor." Sap contains soluble ligninlike substances that are involved in the formation of maple flavor (*117*).

The ash or mineral matter (table 11) accounts for only 0.66 percent of the whole sirup, or 1 percent of the dry solids. Although the minerals are only a minor part of the sirup, they have been useful in establishing the purity of maple sirup and they contribute an astringency to the sirup that many find desirable.

Calcium, a part of the ash, is responsible for the sugar-sand scale, calcium malate, which forms on the pans (*18*). The low sodium and high potassium content of the ash suggests the use of maple in dietary foods.

Composition of sugar sand ranges as follows (*18*):

		Range
Sugar sand in run	percent	0.05– 1.42
pH		6.30– 7.20
Ca	percent	0.61–10.91
K	do	0.146–0.380
Mg	do	0.011–0.190
Mn	do	0.06– 0.29
P	do	0.03– 1.18
Fe	p.p.m.	38–1,250
Cu	p.p.m.	7– 143
B	p.p.m.	3.4– 23
Mo	p.p.m.	0.17– 2.46
Free acid	percent	0.07– 0.37
Total malic acid	do	0.76–38.87
Acids other than malic	do	0.08– 2.62
Undetermined material	do	6.94–34.16
Calcium malate	do	1.30–49.41
Sugars in dried samples	do	33.90–85.74
Sugar sand in dried samples	do	14.26–66.09

TABLE 10.—*Nonvolatile organic acids in maple sap and sirup* [1]

Acid	Sap	Sap (dry weight)	Sirup (dry weight)
	Percent	*Percent*	*Percent*
Malic	0.021	1.40	0.141
Citric	.002	.13	.015
Succinic	.0003	.02	.012
Fumaric	.0003	.02	.006
Glycolic or dihydroxybutyric	.000	.00	.006
Unidentified acids:			
I, II, III, IV	Trace	Trace	Trace
V, VI, VII	0	0	Trace

[1] Typical values, not averages.

TABLE 11.—*Mineral composition of maple sirup* [1]

Item	Sirup	Dry weight
	Percent	*Percent*
Soluble ash	0.38	0.58
Insoluble ash	.28	.42
Total ash	.66	1.00
Potassium	.26	.40
Calcium	.07	.11
Silicon oxide	.02	.03
Manganese	.005	.008
Sodium	.003	.005
Magnesium	Trace	Trace

[1] Typical values, not averages.

The nitrogenous matter constitutes only a small part of the total solids (*88*).[4] Expressed as nitrogen, the sap contains only 0.0013 percent and the sirup 0.06 percent. The sap does not contain any free amino acids except late in the sap-flow season. Nitrogen occurs only in the form of peptides. Whether the nitrogenous matter enters into the formation of maple color or flavor is an open question. An increase in free amino acids is associated with the development of "buddy sap."

Color and Flavor

Maple sap as it comes from the tree is a sterile, crystal-clear liquid with a sweet taste. None of the brown color or flavor that we associate with maple sirup is in the sap. This is easily demonstrated by collecting sap aseptically, freezing it, and then freeze-drying it. The solid obtained is white or very light yellow and has only a sweet taste. The typical color and flavor of maple sirup are the result of chemical reactions, involving certain substances in the sap, brought about by heat as the sap boils (*148*). Since at least one of the products of the reaction is the brown color, it is known as a browning reaction. Neither the exact nature of this reaction nor the identity of the reacting substances is known. Indications are that one or more of the 6 sugars or their degradation products and one or more of the 12 organic acids in maple sap are involved in the browning reaction.

Experimental evidence indicates that the color and flavor of maple sirup are related to triose sugar (*52–54*, *118–120*, *122*, *155*). These sugars are not constituents of sap when it comes from the tree but are formed as a result of the two reactions shown in chart 14. Evidence also indicates that the phenolic ligninlike substances of maple sap are intermediate in the flavor reactions and may account for the specificity of maple flavor (*117*).

The amount of invert hexose sugars is directly proportional to the amount of fermentation that has occurred. The first reaction is the bacterial or enzymatic hydrolysis of the sucrose to form invert sugar, a mixture of fructose and dextrose (chart 14). The second reaction is the alkaline degradation of the fructose and dextrose to trioses (*98*). The second reaction occurs while the sap is boiling in the sap pan, where the alkalinity of the sap reaches a pH of 8 to 9. These trioses are highly active chemically. They can combine with themselves to form color compounds, and they can react with other substances in the sap (such as organic acids) to form the maple flavor substances (*79*).

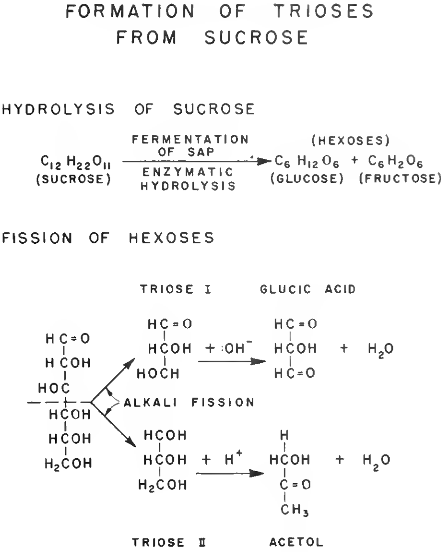

Chart 14.—Chemical reactions showing the formation of trioses from the sucrose of sap. In the first reaction, 1 molecule of sucrose is hydrolyzed by enzymes to yield 2 molecules of hexose sugars. In the second reaction, these hexoses are broken by alkaline fission into trioses.

Experiments have established that up to a point the amount of color formed is proportional to the amount of flavor formed. This makes it possible to evaluate flavor in terms of color, a measurable quantity. When the point is reached at which the background flavor "caramel" begins to be noticeable, this relation no longer holds.

The identity of the compounds responsible for the flavor of maple has proved to be elusive. Certainly all the components of maple sirup

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[4] Also unpublished data of Eastern Regional Research Center.

contribute to its flavor—the sugar, the organic acid salts, and even the oil, butter, or whatever was used as an antifoam agent during evaporation. An unknown number of trace materials in the sirup or sugar give it "maple flavor." These compounds have defied identification for many years because they exist in very small amounts (a few parts per million), and their chemical character in many cases is so similar to carbohydrates that separation from the sugars of the sirup has been extremely difficult (*123*). Now with the modern techniques of gas chromatography and mass spectrometry, progress is being made in solving the mystery of "maple flavor." The flavor compounds identified can be divided into two groups according to their probable source. One group, possibly formed from ligneous material in the sap, contains such compounds as vanillin, syringealdehyde, dihydroconiferyl alcohol, acetovanillone, ethylvanillin, and guaiacyl acetone. A second group, most likely formed by caramelization of the carbohydrates in the sap, includes acetol, methylcyclopentenolone (cyclotene), furfural, hydroxymethylfurfural, isomaltol, and alpha-furonone (*25, 116*). It has been impossible to make a synthetic maple flavor by combining these compounds. Perhaps one or more key compounds have not yet been identified. Even if all these compounds were available, a proper balance of the many parts of a mixture to give the desired combination flavor would be difficult to achieve since they have not been accurately measured.

Factors that control color and flavor are: (1) Amount of fermentation products in the sap (*75*); (2) pH of the boiling sap; (3) concentration of the solids (sugars); (4) time of heating (time necessary to evaporate sap to sirup); and (5) temperature of the boiling sap (*1a, 150*). The two most important factors are the time of heating and the amount of fermentation products in the sap (*150*). The temperature of the sap under atmospheric pressure (open pan) boiling is fixed, and nothing can be done about it. Neither can anything be done about changes in pH of the boiling sap. At the beginning of evaporation, the natural acidity of fresh sap is lost and the sap becomes alkaline. It is during this alkaline phase of the pH cycle that hexose sugars, if any are present, undergo alkaline degradations. The sap then remains alkaline until sufficient organic acids are formed by the decomposition of the sap sugars to make the sap acid again.

The longer the boiling time, the darker the sirup; and, conversely, the shorter the boiling time, the lighter the sirup. During evaporation, the effect of the boiling-point factor increases as the solids concentration of the sap increases. The relation between the amount of hexose sugars (invert sugar) produced during the fermentation of the sap and the length of time the sap is boiled is of the greatest importance. Thus, the color and flavor of sirup made in exactly the same boiling time from a series of saps of equal solids concentration (Brix value) but with increasing amounts of invert sugar will be progressively darker and stronger. The stronger maple flavor, however, is usually masked by the acrid caramel flavor. Although flavor and color are formed because of exothermic chemical reactions, the amount of flavor that can be produced is limited by the concentration of the sap-soluble lignaceouslike materials that are probable flavor precursors. Indications are that there are sufficient of these flavor percursors in sap to permit forming a product that is from 15 to 30 times richer in maple flavor than is commercial "pure maple sirup" (*154*). These precursors can be utilized to increase the flavor by subjecting the sirup to higher temperatures. This method is used in preparing high-flavored maple products, described later.

Buddy Sap and Sirup

As the maple tree comes out of dormancy, physiological changes in the tree form constituents in the sap which, when boiled, give off a noxious odor and impart a characteristic, unpleasant flavor to the sirup. This noxious odor is most noticeable in sap obtained from trees whose buds have swelled or burst during a period of warm weather; and sirup made from this sap is said to have buddy flavor. Due to the unseasonably warm weather in 1963, buddy sap was produced early in the sap season. Because of this, much of the crop was not harvested in some areas. Although the trees may not have come far enough out of dormancy to cause the buds to swell, they may have come out enough to produce the unwanted flavor. The formation of this buddy substance is accompanied by an increase in the free amino acids in the sap. Whether this parallel increase in free amino acids is involved in the formation of buddy flavor remains to be determined.

Often some trees in a sugar grove "bud" earlier than the rest. These trees should be identified and marked so that their sap will not be collected late in the season. To combine the sap from trees that have budded with that from the other trees would spoil the entire lot of late-season sap.

The practice of treating the taphole with germicidal pellets will cause the sap to flow late in the season and when the tree is far enough out of dormancy so that the sap is buddy.

Test for Buddy Flavor

It is essential that sap produced during or following a warm spell or from trees whose buds have swelled be tested for buddiness

The best and simplest test is easily performed by bringing 1/4 cup of the sap or sirup to be tested to a boil and sniffing the steam. If the buddy flavor substances are present, they can be detected in the steam. The sap or sirup can be heated with an electric immersion-type heater used for making instant coffee. This test is subjective, and the buddy odor may not be strong enough to be easily recognized by some people.

Another test that is applicable to sirup and not subjective has therefore been developed. This test involves the chemical test for amino acid groups whose presence in sap parallels buddy flavor formation (*115*).

To make the test the following equipment is needed:

A 1-ounce (30 ml.) screw-cap bottle to hold the standard amino nitrogen solution.

A box of wooden toothpicks.

Test papers—filter paper cut into 1/2- x 4-inch strips.

The following reagents should be used:

Standard amino nitrogen solution. This is made by dissolving 5 grams of leucine (an amino acid) in 30 milliliters of water. (Place 1 *level* teaspoon of leucine in the 1-ounce bottle and fill it to the neck with water.)

Ninhydrin spray. This is commercially available as an aerosol spray.

The test should be made as follows:

(1) To a small volume of the sirup to be tested, add an equal volume of water and mix thoroughly.

(2) With a pencil make three dots 1 inch apart down the center of the test strip, 1 inch from either end. Label X, S, and W.

(3) Holding a toothpick in a vertical position, dip the broad end into the diluted sirup and transfer a drop to the pencil dot at the top of the paper labeled X.

(4) Using fresh toothpicks, transfer a drop of the standard amino nitrogen solution to the dot at the center of the paper labeled S, and a drop of water to the dot at the bottom labeled W. The size of the wetted spots should be about the same.

(5) Lay the paper on a clean, dry surface (piece of filter paper) and allow the spots to dry at room temperature.

(6) Spray the entire paper strip with the ninhydrin reagent. Wet the paper thoroughly but not enough to cause the reagent to run.

(7) Dry the sprayed paper at room temperature.

(8) Heat the paper at a temperature of 175° to 195° F. for approximately 1 minute to hasten development of the color. The lid of a boiling kettle or other moderately hot surface will suffice. (From 1 to 2 hours will be required for the color to develop at room temperature.)

(9) Development of a violet color constitutes a *positive* test and indicates that the sap is buddy.

The standard amino nitrogen solution is used to indicate that the ninhydrin reagent is reacting properly to give violet color with amino compounds.

Ninhydrin reagent is a very sensitive stain. Care must be taken to keep the paper test strips clean. Handling the test strip with forceps, especially after staining, will prevent fingerprints which could produce false-colored spots. The papers are best sprayed by hanging them in an open cardboard box to prevent discoloration of other objects by the ninhydrin spray. The ninhydrin reagent is not stable and should be replaced at least every 6 months.

Always start with a fresh supply of the reagent at the beginning of each sirup season.

Reclaiming Buddy Sirup and Sap

Many sirupmakers make buddy sirup from the late runs of sap. Although this practice should not be encouraged because of the very low price commanded by buddy sirup, it is made—often unknowingly.

Buddy sap and buddy sirup can be treated by a fermentation procedure to remove their unpalatable flavor (*136, 137*). Because this process requires special equipment and a high degree of technical control, it has not been commercially successful. Recently a new procedure has been developed using ion-exchange resins to remove the buddy off-flavor (*36a*). This process removes the amino acids believed to be responsible for the buddy flavor of maple sirup. The cost of this treatment on a commercial scale is estimated to be less than $1 per gallon of sirup.

Rules of Sirupmaking

The following rules should be followed in sirupmaking:

(1) If possible, test all sap for buddiness; but especially test that produced late in the spring or following a warm spell. Do not use buddy sap.

(2) Do not use fermented sap. To keep the sap from fermenting, collect it often. Do not allow it to stand in the buckets or tanks, and keep it cold. If there is a small flow of sap that does not warrant collecting, dump it. At least once during the season, wash the sap-gathering equipment (buckets, pails, and tanks) and sanitize the equipment with a 10-percent hypochlorite solution.

(3) Handle the sap as quickly as possible. The sooner sap is evaporated after it has been obtained from the tree, the higher the grade and the lighter the sirup that will be produced. The faster sap is evaporated to sirup, especially during the last stages of evaporation when the solids concentration is highest, the lighter the color and the higher the grade of the sirup.

(4) Keep sap and equipment clean. Cleanliness is a must in maple sirupmaking for, aside from its esthetic aspects, cleanliness is the only way to control microbial contamination and subsequent growth in the sap. Sirup made from sap in which growth of micro-organisms has occurred tends to be dark colored and low in grade.

(5) By means of a hydrometer or other suitable instrument, measure and record the sugar content of the sap produced by each tree and also the sugar content of each batch of sap in the storage tanks.

(6) Store sap in a cool place.

(7) Store sap in tanks exposed to daylight (not necessarily direct sunlight).

(8) Cover the tanks with material transparent to ultraviolet radiation, such as clear plastic.

(9) Provide tanks having opaque covers with germicidal lamps.

Grades of Sirup

It is generally believed that the best sirup is made early in the season during the first and second runs of sap. However, this is not necessarily true, as was demonstrated in 1954 when sirup made early in the season was darker than some made later. The important factor is the atmospheric temperature. Warm weather favors microbial growth, and the byproduct of this growth—invert sugar—affects the color and grade of the sirup. It is only coincidental that the weather is usually cooler at the beginning of the season and microbial growth is low.

Sap that is essentially sterile contains very little invert sugar and will usually produce a light-colored, light-flavored, fancy sirup. Sometimes, as in 1954, the weather at the onset of the season is warm, and fermentation occurs. The result is that the first-run sirup is darker than expected. If conditions are reversed later in the season, fancy sirup will be produced, for with cold weather little or no fermentation of the sap occurs.

Making light-colored sirup with sterile sap that is very low in invert sugar does not test a sirupmaker's skill. However, skill is required to produce light-colored sirup from sap rich in invert sugar (with a high microbial count). This skill is actually a measure of how fast the sirupmaker can evaporate the sap to sirup.

Sirup can be darkened—changed from U.S. Fancy to U.S. Grade A, or from U.S. Grade A to U.S. Grade B, etc.—by prolonging the heating of the finished sirup. If a finishing pan is used, it should be covered immediately when the sirup reaches the correct density. The heat should be reduced to maintain a slow boil until the desired color is obtained. Adding 1/2 cupful of U.S. Grade C sirup for every 2 gallons of sap will hasten the darkening process.

Summary

(1) Maple sap and sirup contain only sugar, protein, organic acids, ash, and less than 2 percent of material not accounted for but which is of great importance because it includes the color and the flavor substances.

(2) Sterile maple sap has neither color nor flavor.

(3) Experimental evidence indicates that the color and flavor in maple sirup are related to triose sugars, organic acids, and soluble, ligninlike substances.

(4) Factors controlling the formation of color and flavor include fermentation, pH, solids concentration, length of boiling time, and the boiling temperature of the sap.

(5) The shorter the boiling time, irrespective of the quality of the sap, the lighter the color of sirup produced.

(6) For best sirup—
    (a) Use sap that has not fermented.
    (b) Use speed in collecting and in evaporating the sap.
    (c) Keep equipment clean.
    (d) Know the initial Brix value of the sap.

(7) Higher grades of sirup are usually produced earlier in the season than later on, because the early season temperatures are usually lower and there is less chance of fermentation.

(8) Sirup that is too light can be darkened by heating the finished sirup.

CONTROL OF FINISHED SIRUP

Finishing the sirup is one of the most exacting tasks in maple sirupmaking. The sirup must be drawn from the evaporator or finishing pan at just the right instant; otherwise, its solids content (density) will be either too high or too low. To conform with minimum Federal and State requirements, sirup must have a density of not less than 66.0° Brix at a temperature of 68° F. At this density, a little more or a little less evaporation has a relatively large effect on the concentration (table 12). Hence, when using large evaporators capable of evaporating several hundreds of gallons of water per hour, accurate control of the sirup being drawn off is both important and exacting.

Viscosity of Maple Sirup

Maple sirup having a density of only 0.5° to 1° Brix below standard-density sirup tastes thin. This is due to the big change in the viscosity of sugar solutions caused by only a slight change in concentration, especially in the range of standard-density sirup.

Table 13 shows that an increase in the sugar concentration of sucrose solutions up to 30° Brix has little effect on viscosity. For example, a solution with a density of 20° Brix at room temperature (68° F.) has a viscosity of 2.3 centipoises and at 30° Brix only 3.2 centipoises. However, as the concentration of the sugar increases, the viscosity increases at an extremely rapid rate. Thus, to treble the sugar concentration from 20° to 60° Brix increases the viscosity from 2.3 to 44 centipoises—more than a nineteenfold increase.

The change in viscosity is even more pronounced in sucrose solutions with densities in the range of standard sirup (66.0° Brix).

As shown in the table, the viscosity of sirup at room temperature (68° F.) is lowered 34.8 centipoises if its density is 1° Brix below standard density. It is lowered 61.9 centipoises if it is 2° Brix below standard density. The lowered viscosity has a marked adverse effect on the keeping quality of the sirup and on its acceptance by consumers. The tongue is extremely sensitive to these differences.

The tongue is also sensitive to slight increases in the density of sirup above 66.0° Brix at room temperature. An increase of only 1° Brix above standard density increases the viscosity of sirup 45.8 centipoises; and the sirup acquires a thick, pleasant feel to the tongue.

TABLE 12.—*Boiling temperature above that for water for solutions of different concentrations of sugar*

Temperature elevation, ° F.	Sugar solutions	Temperature elevation, ° F.	Sugar solutions
	Percent		*Percent*
0.0	0.0	5.0	59.7
0.2	7.5	5.2	60.4
0.4	13.8	5.5	61.5
0.6	19.0	5.6	62.0
0.8	23.4	5.8	62.5
1.0	27.1	5.9	62.9
1.2	30.3	6.1	63.4
1.4	33.4	6.4	64.4
1.6	36.0	6.6	64.9
1.8	38.4	6.9	65.6
2.0	40.5	7.1	66.0
2.2	42.5	7.3	66.5
2.4	44.3	7.5	67.0
2.6	46.0	8.0	68.0
2.8	47.7	8.2	68.5
3.0	49.0	8.5	69.0
3.2	50.4	8.8	69.5
3.4	51.6	9.1	70.0
3.6	52.8	9.5	70.5
3.8	53.9	9.9	71.0
4.0	54.9	10.4	71.6
4.2	55.9	10.7	72.1
4.4	56.9	11.1	72.5
4.6	57.8	11.5	73.0
4.8	58.8	12.0	73.5

Thus, the thicker the sirup, the better it tastes. However, sirup with a density of more than 67° Brix crystallizes on storage at room temperature; 67° Brix, therefore, becomes the upper permissible density.

Effect of Temperature on Viscosity

As the temperature of a sugar solution increases, its viscosity drops sharply. Standard-density sirup at its boiling point has a viscosity of about 6 centipoises, which is only one-thirtieth that of sirup at room temperature; that is why sirup filters so much better when it is at or near its boiling point. Likewise, the viscosity of boiling sirup with a density between 50° and 60° Brix is approximately one-half that of standard-density sirup; and that is why it is advantageous to filter sirup just before it is transferred to a finishing pan, when its density is approximately 60° Brix or less.

This lowering of the density by heating sirup explains why hot sirup, even though it is of standard density, tastes thin and watery.

Old Standards of Finished Sirup

In the past, the finishing point of sirup was determined by a number of methods. None of these methods was precise, and their skillful use was an art. For that reason, comparatively few men won the enviable title of "sugar-maker."

Typical of these methods was the "blow" test. In this test, a small loop of wire was dipped into the boiling sap. When the film that formed across the loop required a certain puff of breath to blow it off, the sirup was considered finished. Another method more commonly used was the "apron" test. In this test, a scoop was dipped into the boiling sap and then held in an upright position to drain. Formation of a large, thin sheet or apron with the right shape and other characteristics indicated that the sirup was finished.

Use of Precision Instruments

Precision instruments are now available by which the finishing point of sirup can be determined easily and with a high degree of accuracy. As concentration progresses, there is a progressive increase in the boiling point, in density, and in refractive index. These can be measured accurately and precisely with a thermometer, a hydrometer, and a refractometer, respectively. However, only the elevation of the boiling point is applicable to a sugar-water solution, such as sap, while it is actively boiling.

Elevation of Boiling Point

Chart 15 and table 12 show the changes in boiling-point temperature for sugar solutions at different concentrations. When a sugar solution has been evaporated to the concentration of standard-density sirup (66.0° percent of sugar, or 66.0° Brix), its boiling point has been elevated 7.1° F. above the boiling point of water. Between 0° and 27° Brix, there is only a slight

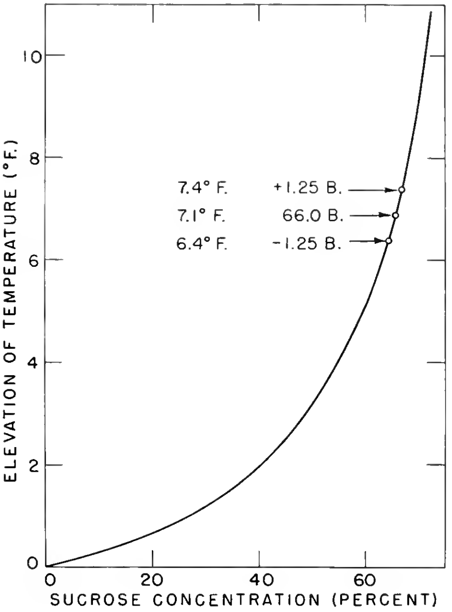

Chart 15.—Curve showing the relation between the concentration of a sugar solution (sap) and the elevation of its boiling point above the boiling point of water.

elevation in boiling point. However, as the solution nears the concentration of standard-density sirup, a change of only 2.5 percent in sugar concentration (from 64.5° to 67° Brix) raises the boiling point 1°. Hence, the boiling point method of measuring sugar concentrations is ideally suited to sirupmaking.

Any Fahrenheit thermometer calibrated in degree or half-degree intervals and with a range that includes 225° F. can be used. For greatest usefulness and accuracy, the distances between degree lines should be as open as possible and should be calibrated in one-fourth degrees.

Elevation of the boiling point as used here means the increase in temperature (° F.) of the boiling point of the sugar solution above the temperature of boiling pure water. It has nothing to do with the specific temperature 212° F. except when the barometric pressure is 760 millimeters of mercury. Under actual conditions of sirupmaking, the barometric pressure is seldom at 760 millimeters; therefore, it is best not to associate the fixed value of 212° F. with the boiling point of water.

The recommended procedure is to establish the temperature of boiling water on the day and at the place sirup is being made. To do this, merely heat water to boiling, insert the bulb of a liquid stem thermometer or the stem of a dial thermometer, and note the temperature while the water is actually boiling. This is the *true* temperature of boiling water for the barometric pressure at that time and place. In practice, the boiling sap in the sap pan can be used to establish the temperature of boiling water since, as was shown in chart 15, at low-solids concentrations (up to 10° Brix) there is little elevation of the boiling point. The boiling temperature of standard-density sirup is then found by adding 7° to the temperature of the boiling sap.

It is of the greatest importance to redetermine the temperature of boiling water (sap) at least once and preferably several times each day, especially if the barometer is changing. A change in the weather usually indicates a change in barometric pressure. The result of failure to making frequent checks on the boiling point of water is illustrated in the following examples:

On March 1, at Gouverneur, N.Y., the boiling point of water was determined to be 210° F., which established the boiling point of standard-density sirup as 217°. On March 2, the producer neglected to redetermine the boiling point of water, assuming it to be unchanged, and continued to use 217° as the boiling point of sirup. Actually, the barometric pressure had fallen, which lowered the boiling point of water to 208° and of standard-density sirup to 215°. The sirupmaker, by using the temperature of 217°, was boiling his sirup 2° too high, and the sirup contained 69.8 percent of solids instead of 65.8 percent (table 12). This high-density sirup resulted in the production of fewer gallons of sirup; and, in addition, the sirup crystallized in storage, since it was above 67° Brix.

If, on the other hand, the reverse had occurred, the sirupmaker would have made sirup with a boiling point 2° F. too low. This sirup would contain only 59.7 percent of solids as

TABLE 13.—*Viscosity of sucrose solutions of various densities (° Brix) at temperatures of 20° C. (68° F.) to 105° C. (221° F.)*[1]

Density of solution (° Brix)	Viscosity (centipoises) at—										
	20° C. (68° F.)	30° C. (86° F.)	40° C. (104° F.)	50° C. (122° F.)	60° C. (140° F.)	70° C. (158° F.)	80° C. (176° F.)	90° C.[2] (194° F.)	100° C.[2] (212° F.)	103.5° C.[2] (218.3° F.)	105° C.[2] (221° F.)
20	2.3	1.5	1.2	1.0	0.8	0.7	0.6				
30	3.2	2.4	1.8	1.5	1.2	1.0	.9				
50	15.3	10.1	7.0	5.0	3.8	2.9	2.3	1.8	1.6	1.5	1.5
60	44.0	33.8	21.0	14.0	9.7	7.0	5.2	4.4	3.6	3.4	3.4
61	69.2	39.3	24.1	15.8	10.9	7.6	5.7	4.7	3.8	3.6	3.5
62	82.4	46.0	27.8	17.9	12.2	8.6	6.4	5.0	4.1	3.9	3.8
63	99.1	54.3	32.3	20.5	13.8	9.7	7.1	5.6	4.6	4.3	4.2
64	120.1	64.5	37.7	23.7	15.7	10.9	7.9	6.3	5.1	4.8	4.7
65	147.2	77.3	44.4	27.5	17.9	12.4	8.8	7.0	5.8	5.4	5.3
66	**182.0**	**93.5**	**52.6**	**32.1**	**20.6**	**14.1**	**9.9**	**7.8**	**6.6**	**6.2**	**6.1**
67	227.8	114.1	62.9	37.7	19.4	16.1	11.3				
68	288.5	140.7	76.0	44.7	22.6	18.4	12.8				
69	370.1	175.6	92.6	53.3	26.3	21.4	14.7				
70	481.6	221.6	114.0	64.4	31.0	25.0	16.8				

[1] Based on data from Circular C440 issued by the National Bureau of Standards, U.S. Department of Commerce, July 31, 1958.

[2] Values obtained by extrapolation.

sugar. It would not meet specifications for standard-density sirup, would tend to spoil easily, and would have a low viscosity and therefore would taste watery.

Therefore, with a good indicator to detect the end point of evaporation (thermometer calibrated in 1/4° F.), together with the slowdown in rate of evaporation, as shown in chart 16, the sirupmaker is able to stop evaporation precisely at the desired concentration. He can do this either by drawing off the sirup from the evaporator or, if he uses a finishing pan, by turning off the heat.

Finishing Pan

When a finishing pan is used, it is necessary to know when the sap has been concentrated enough to be transferred from the evaporator to the finishing pan. This can be determined by measuring the elevation of the boiling point of the partly concentrated sap. Table 12 shows the elevation of the boiling temperature of sugar solutions (above that for water) for concentrations from 0° to 73.5° Brix.

To use the table, determine the boiling temperature of pure water and then observe the boiling temperature of the partly evaporated sap. The difference between the two boiling points represents the elevation in boiling temperature.

Two examples of how to select a boiling point elevation to give sirup of a desired density (° Brix) follow:

Example 1. A producer wants to draw off sirup from the evaporator at about 40° Brix. At what boiling temperature should the sirup be removed if water boils at 210° F.?

Table 12 shows that the boiling temperature is elevated 2.0° F. for solutions having a density of 40.5° Brix. Thus, when the boiling temperature rises to 212° F. (210° + 2°), the sap will be concentrated to approximately 40° Brix.

Example 2. A producer wants to concentrate the sap to 50° Brix in the evaporator before transferring it to the finishing pan. At what boiling temperature should the sirup be drawn off if water boils at 211.5° F.?

Table 12 shows that for solutions having a density of 50.4° Brix, the boiling temperature is 3.2° F. above the boiling point of water. Thus, 211.5° + 3.2°, or 214.7°, is the boiling temperature of 50° Brix sirup.

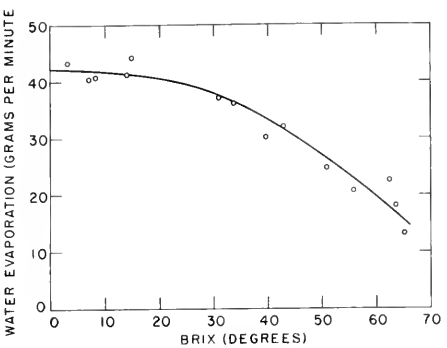

Chart 16.—Change in the rate of loss of water by evaporation, with constant heat, as the concentration of sap increases. Boiling sap with an initial density of 22° Brix loses 42 grams of water per minute, whereas sirup with a density of 65° loses only 15 grams of water per minute, a threefold decrease in rate.

Special Thermometers

In sirupmaking, a knowledge of the boiling point of standard-density sirup in ° F. is important provided a temperature reference point (the boiling point of water) is established and the correct boiling point of sirup is located 7° above it. On this basis, special thermometers have been developed for use in making sirup: The liquid-stem thermometer with movable target, the liquid-stem industrial thermometer, and the dial thermometer with movable dial.

Target Thermometer

The target thermometer does not have any markings on the stem. The degree lines on a movable target refer to the boiling point of water rather than to ° F., as on the conventional Fahrenheit thermometer.

The target thermometer is calibrated by placing the bulb in either boiling water or boiling sap. The target is moved by means of an adjusting screw until the line "water boils" coincides with the top of the mercury column. The line "sirup" is exactly 7° above the line "water boils." This is the boiling point of standard-density sirup for that hour and place. After adjustment, the thermometer is placed in the sirup pan adjacent to the place where the sirup is drawn off.

Unfortunately, any thermometer set in the evaporator will be surrounded by steam, which makes it difficult to read (fig. 91).

Use of a flashlight to illuminate the thermometer and a large funnel to divert the steam makes viewing easier. The funnel is held with the tip toward the thermometer, and the thermometer is viewed through the funnel with the aid of the flashlight.

Liquid-Stem Industrial Thermometer

The liquid-stem industrial thermometer does not have special markings or a movable target. But it does have an open scale—a lineal distance of approximately 3 inches for 10° F., which is almost three times that of other thermometers (fig. 92). It is calibrated in 1/4° and has a magnifying device. These features make it ideal for use in sirupmaking. These thermome-

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Figure 91.—The target thermometer is placed in the boiling sirup. The fine mercury column is difficult to see because of the steam. The boiling sirup being tested must be deep enough to cover the bulb of the thermometer. The thermometer must be in boiling sirup and as close to the point of sirup drawoff as possible.

PN-4788

Figure 92.—The liquid-stem industrial thermometer has an open scale that permits calibration marks for each ¼° F. and the temperature of the boiling sirup can be measured precisely. The thermometer is mounted outside the pan so it is not obscured by steam. It is especially suited when the pan is covered with a tight steam hood.

ters can be obtained with the stem bent at right angles and protected with metal armor.

The right-angle thermometer is mounted through the wall of the sirup or finishing pan using a special fitting. This arrangement permits the thermometer to be mounted high enough on the sidewall of the evaporator or finishing pan to be above the level of the sirup so that the thermometer can be removed for cleaning without loss of sirup. It also locates the scale of the thermometer at an obtuse angle for easy reading.

The thermometer is calibrated each day in terms of the boiling point of water. The bulb is immersed in water, the water is brought to a boil, and the temperature is noted. To this observed temperature is added 7°, the temperature elevation required to give the boiling point of standard-density sirup (see table 12).

Dial Thermometer

The degree lines of the dial thermometer (*23*), like the target thermometer, refer to the boiling point of water (fig. 93). This thermometer has a bimetallic element in the first 3 or 4 inches of the stem. As the indicator is a needle, the openness of scale is governed by the length of the needle and the accuracy required. The scale is twice as open in a dial thermometer 5 inches in diameter as in the target thermometer.

The dial thermometer is calibrated by immersing the part of its stem that contains the bimetallic element in boiling water or sap the same distance that it is immersed in the sirup; when the indicating needle comes to rest, the dial is rotated by means of an adjusting screw until the zero or water boils line coincides with the pointer. Then the sirup line is located 7° F. above the zero or water boils line to indicate the boiling temperature of standard-density sirup for that day and place.

The long straight stem of this thermometer is inserted through the wall of the sirup pan and sirup drawoff box so it will be parallel to the bottom of the pan and entirely immersed in the boiling sirup. The dial of the thermometer is on the outside of the evaporator where it is out of the steam and is easy to read (fig. 93).

Hydrometers

A hydrometer is not the ideal instrument for judging the finishing point of sirup. It is not calibrated for use at the temperature of boiling sirup, and it cannot be used to follow the concentration of the sap continuously. For accuracy, the exact temperature of the sirup being tested with the hydrometer must be known so that the necessary corrections can be made. However, the hydrometer and refractometer are the only instruments that can be used to measure the density of sirup that is not in an actively boiling state.

"Hot Test"

The "hot test" is often used to determine whether the process of evaporating sap to sirup is completed. It is made as follows:

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Figure 93.—The dial thermometer, like the target thermometer, has markings to indicate O, water boils, sirup, soft tub, and cake sugar. The dial thermometer, like the industrial thermometer, is mounted on the outside of the evaporator.

PN–4790

Figure 94.—Sirup at approximately 210° F. is used in making the hot test. The hydrometer cup is raised to eye level and the reading is made as soon as the hydrometer comes to rest.

Fill the hydrometer cup with boiling sirup from the evaporator or finishing pan (fig. 94). Immediately place the hydrometer in the sirup and, as soon as the hydrometer comes to rest, make the observed density reading. Perform all operations as quickly as possible. If the observed hydrometer reading is between 59.3° and 59.6° Brix, the evaporation of the sap to standard-density sirup is completed.

For best results with the hot test, the temperature of the hot sirup must be between 210° and 218° F. at the moment the hydrometer reading is made. To be sure that the sirup is in this temperature range, first determine the temperature of the hot sirup as follows:

Fill the hydrometer cup with boiling sirup. Place the hydrometer and the thermometer in the sirup. Then, instead of reading the hydrometer, measure the temperature as soon as the hydrometer comes to rest. Repeat this procedure and, if the two consecutive temperature readings are not obtained in the range of 210° to 218° F., speed up the operation until these temperatures are obtained at the time hydrometer readings are made.

The hot test is not a precise measurement. It is extremely difficult to make accurate hydrometer and temperature readings at the same time in sirup that is hotter than 180° F. because the sirup is cooling rapidly.

From the time the hydrometer cup is filled with boiling sirup until the observed hydrometer reading is made, the sirup will have cooled several degrees. The amount of cooling depends on the time involved and the temperature of the air surrounding the hydrometer cup.

Hydrotherm

The hydrotherm, a special hydrometer (chart 17), has a liquid thermometer built into it that automatically locates the point on the hydrometer (top of thermometer liquid column) for measuring standard-density sirup. The accuracy of this instrument depends on the relation of lineal expansion of the thermometer liquid to lineal displacement of the hydrometer stem by standard-density sirup at different temperatures. When used, sufficient time must be allowed for the thermometer of the hydrotherm to warm or cool to the temperature of the sirup, usually about 30 to 40 seconds.

Since the hydrotherm is not calibrated, the scale does not indicate how much too dense or too thin the sirup is.

Summary

(1) Finished sirup must contain not less than 66.0 percent of solids (66.0° Brix) at a temperature of 68° F.

(2) Table sirup that is between 66° and 67° Brix has the best taste. Table sirup that is below standard density tastes thin.

(3) Use precision instruments to measure standard-density sirup.

(4) The boiling temperature of standard-density sirup is 7° F. above the temperature of boiling water.

(5) Use a thermometer calibrated in 1/4° F. to measure the temperature of boiling sirup.

(6) Calibrate the thermometer frequently with reference to the boiling point of water.

(7) Completely immerse in the boiling water or sap the bulb of the stem of a liquid thermometer or that part of the stem of a dial thermometer containing the bimetallic element.

(8) To test hot sirup with a hydrometer, the temperature of the sirup must be noted and necessary temperature corrections applied to the observed hydrometer readings. Hot sirup (210° to 218° F.) of standard density is 59.3° to 59.6° Brix.

(9) To test hot sirup with a hydrotherm, sufficient time must be allowed for the hydrotherm to come to the same temperature as the sirup in which it is floated.

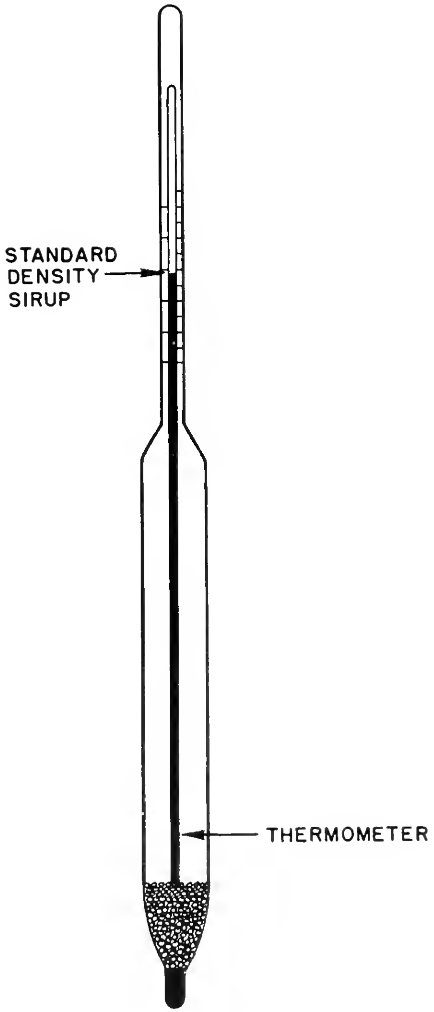

Chart 17.—Hydrotherm for measuring density of sirup. It automatically compensates for temperature correction.

CLARIFICATION OF SIRUP

Sugar Sand

Sirup as it is drawn from the evaporator contains suspended solids, commonly known as sugar sand. They are primarily the calcium and magnesium salts of malic acid. These salts are precipitated because they become less soluble as the temperature of the sirup solution increases and as its concentration increases. Sugar sand occurs in various forms, ranging from an amorphous black, oily substance to a fine, white, crystalline material. Dark sugar sand will usually cause the sirup to appear a grade or two darker than normal, whereas white sugar sand will often cause it to appear lighter.

The amount of this precipitate in the sirup is not always the same. Sap from the same sugar grove varies from year to year and even within the same season.

Studies at the Ohio (Wooster) Agricultural Experiment Station[5] indicate that trees at high elevations tend to produce more sugar sand than do those at lower elevations. The Ohio workers were not able to show any relation between climatological data or soil types and amounts of sugar sand formed.

Sirup to be sold for table use must be clear (free of suspended matter) to meet Federal and some State specifications. Sirup can be clarified by sedimention, filtration, or centrifugation. On the farm, sedimentation and filtration are the methods generally used.

Sedimentation

Sedimentation or settling is the simplest method of clarifying maple sirup, but it has several disadvantages. It cannot be used to clarify all sirup. Some sirup contains suspended particles so fine that they resist settling. Clarification by sedimentation requires a long time—days and sometimes weeks. After settling at room temperature, the sirup must be reheated to 180° F. before packaging to insure a sterile pack. This reheating may darken the sirup enough to lower its grade.

To clarify by sedimentation, the hot sirup is first put through a coarse filter, such as several layers of flannel or cheesecloth, to screen out large particles of foreign matter. It is then transferred to the settling tank. The tank should be of noncorrosive metal, and its height should be at least twice its diameter. It should have a dustproof cover and a spigot or other means of drawing off the sirup about 2 inches above the bottom of the tank. The sirup should be left in the tank until samples that are withdrawn show it to be sparkling clear. It is then drawn from the tank, standardized for density, heated to 180° F., and packaged. Sirup that has failed to clarify after several weeks of standing must be filtered. Because of the uncertainty of the sedimentation method, it is rapidly losing favor.

In large operations, the sirup can be kept sterile if it is added to the settling tank while it is hot (above 180° F.) and if the entire surface of the sirup is continuously irradiated by germicidal lamps.

Filtration

Filtration of maple sirup is not a simple procedure. As with sedimentation, the success and ease of clarifying sirup by filtration depend on the nature of the suspended particles that are to be removed. It is best to use two filters—a prefilter to remove the coarse material and a thicker filter to remove the fine. In the past, the most commonly used prefilter was several layers of cheesecloth, outing flannel, or similar cloth. Today, a nonwoven rayon material called miracle cloth or maple prefilter paper is used with considerable success. After prefiltering, the sirup is run through a thicker filter. Formerly these filters were made of wool, but now they usually are a layer of synthetic felt (Orlon).

Synthetic felt filters have many advantages over wool felt filters. They do not impart a foreign flavor to the sirup, shrink very little or not at all, do not pill, resist abrasion, stain only slightly, and have a long life. Synthetic filters that have been in use more than 5 years show little evidence of wear.

The disadvantage of the two-filter system is that the large particles are removed on the coarse prefilter. The fine particles are collected on the finishing filter, and they may form a compact bed that resists flow of the thick sirup.

The most common filtration assembly in the past was a large milk can in which was inserted a cone-shaped, felt bag supported at the top of the can. However, this is little used today.

Flat Filters

A flat filter consists of a felt sheet for a filtering surface (fig. 95) instead of a cone. It

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[5] Unpublished data.

PN–4791

Figure 95.—A simple type of flat filter. A basket of hardware cloth is supported above the two tanks for holding the felt and above this is the support for the prefilter. The prefilter is moved across the tray as new filtering surface is needed.

was first used in New York and is gaining in popularity everywhere. The flat filter provides a larger filtering area than does the cone-shaped filter. Distribution of the filter cake over this larger area results in a thiner layer, so the filters can be used for longer periods before cleaning is necessary.

The felt sheet is supported in a shallow basket of hardware cloth with 2-inch walls (*147*). The felt is cut at least 4 inches larger than the bottom of the basket, and the edges are turned up 2 inches to form a shallow tray (chart 18). Usually the felt can be used two or three times longer between cleanings if the sirup is first put through a prefilter. However, because of the physical form of the particles of sugar sand, filtering may be more rapid if the prefilter is not used. This can be determined only by experiment. The prefilter is mounted above the felt and is supported on a wire screen basket the same size as that used for the felt (chart 18). The prefilter is cut to fit across the basket, but a length of filter paper is left hanging over the edge of the basket. As the prefilter becomes clogged, a new filtering surface is provided by pulling the prefilter across the basket (fig. 95).

The filters can be built in multiples over a common tank (fig. 96). As one becomes clogged with sugar sand, the assembly can be moved to place a clean filter under the spigot.

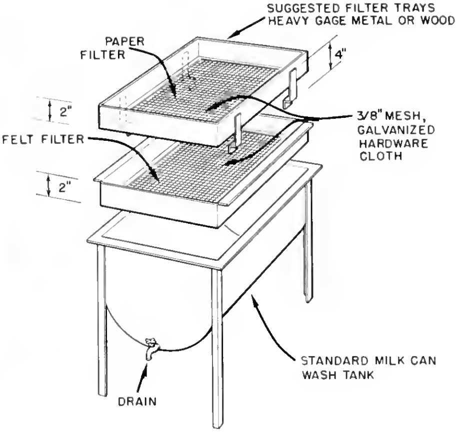

Chart 18.—Sirup filter. A flat felt filter assembly, constructed on a milk-can washer that serves as a temporary storage tank from which the hot sirup can be drawn for packaging. Shortening the legs and attaching casters or wheels permits the assembly to be moved easily into place under the sirup drawoff spigot.

To maintain filtration at a rapid rate the flat prefilters and felts must be cleaned often, especially if the sirup contains a large amount of sugar sand. To clean the filters, the filter cake is first scraped off with a wooden scraper to prevent damage to the filters. The entrapped sirup is dissolved by dipping the filter into a pan of hot water. The filters are folded with the sugar sand on the inside so that it will not be

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Figure 96.—A more elaborate type of installation in which three felt filter units are installed over a common tank. The units are mounted on rollers so that they can be replaced by a fresh unit when necessary. The tank is provided with a drawoff valve.

washed into the recovered sirup. The felt is rinsed repeatedly in hot water. The recovered sirup is returned to the evaporator.

A homemade washer for flat filters is shown in figure 97. By means of an eccentric, the felt is lifted from the hot water and then dunked repeatedly for 15 to 30 minutes until it is clean. No detergent can be used since it would impart an undesirable flavor to the filter. The felts are then hung on racks to dry or drain. Two or three extra felts are required for replacements while the others are being washed. With an efficient washing machine, the felts can be reconditioned for use so easily that some producers have discontinued using prefilters.

Filtering Semiconcentrated Sirup

When a finishing pan is used, another filtering procedure has proved very successful. This procedure takes advantage of these facts: (1) Most of the sugar sand is precipitated (formed) and in suspension when the sap is concentrated to 55° to 60° Brix, and (2) hot sap at 55° to 60° Brix has a viscosity of only 1.5° centipoises as compared to 5.4° for standard-density sirup. Therefore, when sap has been concentrated to 55° to 60° Brix, it is filtered as it is being removed from the evaporator and before it is transferred to the finishing pan. In bringing the sirup to standard density in the finishing pan, a small amount of additional sugar sand (precipitate) may be formed. This is easily removed by using another felt filter assembly.

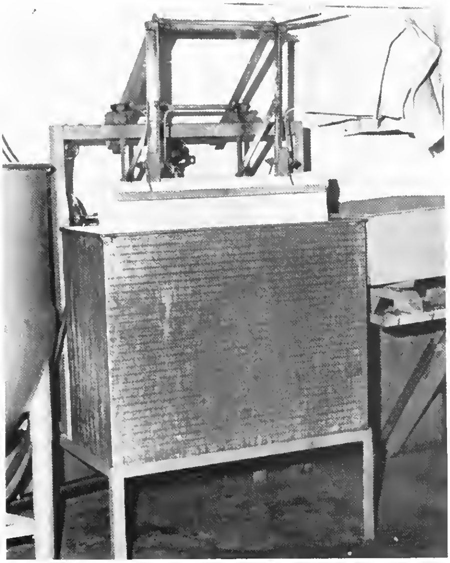

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Figure 97.—A simple type of machine washes flat filters by repeatedly dipping the felts into hot water.

This final filtration, like all other open filters, permits loss of water as steam that escapes from the hot sirup. This may increase the density of the finished, filtered sirup by as much as 1° Brix. To avoid this, a number of producers pump the sirup from the finishing pan through a pipeline to the closed bottling or canning tank. Since this is a closed system, there is no change in the density of the sirup as a result of evaporation. To provide for the final or polishing filtration, an inline, cartridge-type filter is mounted in the pipeline from the finishing pan to the holding tank. Two cartridge filters are used, mounted in parallel with separate control valves so that they can be used alternately. This permits replacing a clogged filter without interrupting the sirup finishing and filtering operation.

Summary

Sedimentation

(1) Strain the sirup through a paper prefilter or cheesecloth.
(2) Place the sirup in settling tanks.
(3) Allow it to stand until all suspended matter has settled out. (Test by periodically drawing a small sample from the tank spigot.)
(4) Sedimentation is complete when the sirup is crystal clear as it is drawn off.
(5) If the sirup is still cloudy at the end of several weeks, it can be clarified only by filtration.

Filtration (Preferred Method)

(1) Run the hot, standard-density sirup from the evaporator or finishing tank directly on the filters.
(2) Use flat (preferably) filters consisting of a prefilter (paper or flannel) above the felt filter.

(3) Change the prefilter and the felt filter as often as necessary to maintain a rapid rate of filtration.

(4) When using a finishing pan, filter the partly evaporated sirup before transferring it to the pan.

(5) If a precipitate forms while the sirup is heating in the finishing pan, the sirup must be given a final or polishing filter.

(6) Use a closed system in transferring the finished sirup to the holding tank and use an inline, cartridge-type filter for polishing the sirup.

CHECKING AND ADJUSTING DENSITY OF SIRUP

The one specification that all grades of table sirup must meet, irrespective of color or other considerations, is density. The minimum allowable density of maple sirup is 66 percent by weight of soluble solids (66.0° Brix or 35.6° Baumé)[6] (*130a*). This corresponds to 11.025 pounds per gallon of 231 cubic inches at 68° F.

The density of sirup can be measured in three ways: (1) By weight; (2) by refractometry; and (3) by hydrometry.

Weight Method

Determining the density of sirup by the weight per unit of volume is not recommended as a testing procedure for farm use. This test can be made only under the most exacting conditions and with precision instruments. The gallon measure must have a capacity of *exactly* 231 cubic inches, the temperature of the sirup must be *exactly* 68° F., and the weight of the sirup must be determined *accurately* to within 0.01 pound. If any one of these conditions is in error, the measurement is valueless. For example, an exact gallon of 231 cubic inches of sirup at 68° F. with a Brix value of 63.5° weighs 10.90 pounds (*107*), whereas the same volume of sirup at the same temperature but with a Brix value of 67.5° weighs 11.10 pounds. Thus, two sirups could differ 4 percent in their solids content and yet differ only 0.2 pound in weight (an amount not detected by ordinary scales) so they would both appear to weigh 11 pounds per gallon. Or an error in weighing of 0.02 pound would cause an error in the solids content of approximately 1/2 percent (0.5° Brix). For these reasons, the fact that a gallon of minimum density sirup weighs 11 pounds does not mean that this is a recommended criterion for measuring the density of sirup. However, it is of great value when used properly and should be used to measure the amount of sirup sold as 1 gallon.

Since sirup is packed hot in cans that are large enough to allow for the expanded volume of the hot sirup, and since all sirup is not packaged at exactly the same hot temperature, the volume of a gallon of hot, standard-density sirup varies slightly. However, a gallon of standard-density sirup weighs 11 pounds whether it is hot or cold. It is therefore recommended that all packaged sirup be weighed before it is sold to determine if the required amount of sirup is in the package—11 pounds for 1 gallon; 2 pounds, 12 ounces for 1 quart; and 1 pound, 6 ounces for 1 pint. These are net weights and do not include the weight of the can or package.

Refractometry Method

Determining the density of sirup by measuring its refractive index, which changes in a regular manner with changes in the amount of dissolved solids, is the simplest of the three methods. This method is not generally used because it requires a refractometer, an expensive optical instrument (fig. 98). However, the precision with which density can be measured with the refractometer makes it well suited for use by Federal and State inspection services, by judges of sirups in competition, and by central evaporator plants. This instrument is not satisfactory for measuring the density of hot sirup (180° F. and above).

Hydrometry Method

Hydrometry is the most generally used method for measuring the density of cold sirup,

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[6] Bureau of Standards Baumé scale for sugar solutions, modulus 145.

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Figure 98.—Checking the density of sirup with a refractometer. Only one drop of sirup is required for this measurement.

and it is best suited for use by the sirupmaker. All that is required to make precise density measurements is a relatively inexpensive but accurate hydrometer, a thermometer, and a hydrometer tube or jar (fig. 99). Hydrometry is based on the Archimedes principle that the density of a liquid can be measured by the displacement of a floating body. The hydrometer, a partly immersed body, displaces a volume of liquid having a mass equal to the weight of the hydrometer. A hydrometric measurement is made by noting the point on the hydrometer stem that is in contact with the surface of the liquid. The hydrometer must be at rest and floating freely in the liquid, as shown in chart 19. The density value is read from a scale sealed in the stem.

The accuracy of a hydrometer measurement depends on the spacing of the markings on the scale in the hydrometer stem, which in turn depends on the diameter of the stem. Thus, the thinner the stem, the farther apart the markings, and the greater the accuracy with which the density measurements can be made. The scale of hydrometers for measuring density of sirup may be marked and calibrated in or on the stem of the hydrometer (chart 20). These scales can be marked by one of three systems or a combination of the systems: (1) Specific gravity; (2) Brix scale; or (3) Baumé scale.

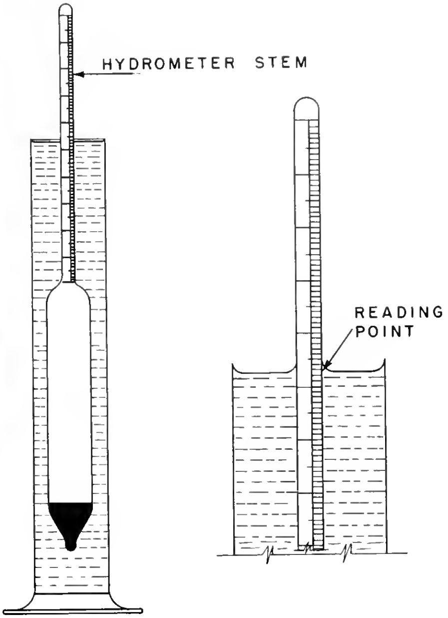

Chart 19.—Hydrometer used for measuring density. The hydrometer can should be filled to the top. It should be held at eye level for reading.

Both specific gravity and the Baumé scale relate the weight of a unit volume of maple sirup (the solution being tested) to some other liquid used as a standard; they give no direct information regarding the solids content of the sirup being tested.

Brix Scale

The Brix scale relates the density of sirup to sugar solutions of the same density and known percentages of sugar. The Brix value does not express the true percentage of sugar in a solution containing sugar plus other dissolved solids; rather, it indicates what the percentage of sugar would be if the density of the solution were due only to dissolved sugar. The Brix scale is particularly well suited for measuring the density of maple sirup because 98 percent of the dissolved solids is sugar. For practical purposes, the Brix value equals the percentage of sugar in the sirup.

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Figure 99.—A hydrometer is a simple, inexpensive instrument for precisely measuring the density (° Brix) of the sirup. The hydrometer should be read at eye level. The temperature of the sirup must be measured and a temperature correction made.

A good approximation of the weight of sugar in any lot of maple sirup, whether or not it is standard-density sirup, can be found by multiplying the weight of the sirup by its density (° Brix) and dividing by 100. This information is important to the producer who sells his sirup wholesale, since the price is based on its solids (sugar) content. Thus, 100 pounds of sirup at 65° Brix contains 65 pounds of sugar, whereas 100 pounds of standard-density sirup (66.0° Brix) contains 66.0 pounds of sugar. Therefore, 100 pounds of the low-density sirup has a lesser value than 100 pounds of standard-density sirup. Likewise, 100 pounds of sirup 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 sirup, and it has a greater value. If sirup has an original density of more than 67° Brix, the excess sugar will precipitate out, and the hydrometer will not measure it.

To obtain the weight of sugar in sirup when density is measured by a hydrometer whose

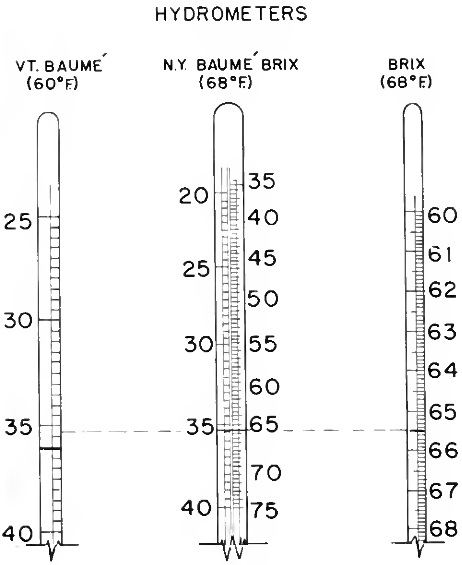

Chart 20.—The three hydrometer scales used in testing sirup. *Left*, Vermont Baumé scale, marked for testing sirup at 60° F.; standard-density sirup at this temperature is indicated by the heavy line at 36°. *Center*, hydrometer with double scale, marked for testing sirup at 68°; standard-density sirup on the Baumé scale of this hydrometer is indicated by the heavy line at 35.27°. The double scale requires a spindle so large in diameter that accurate readings are difficult to make, since the scale must be compressed. *Right*, Brix scale, marked for testing sirup at 68°; standard-density sirup at this temperature is indicated by the heavy line at 65.46°.

scale is in specific gravity or ° Baumé requires more involved calculation because neither scale has a direct relation to the amount of sugar present.

Baumé Scale

Even though the Baumé scale does not express directly the solids content of maple sirup and its continued use cannot be recommended, its long past use by the maple industry justifies the following explanation and the tabulation on page 85 for the conversion of Baumé values (points) to ° Brix.

The Baumé scale relates the density of a liquid to that of a salt solution, but it is more convenient to calculate the Baumé value from specific-gravity tables. Thus, ° Baumé = sp. g. $\frac{(\text{sp. g.})}{(M)}$, where M = the modulus.

In the past, unfortunately, neither the temperature for which the Baumé scale was calibrated nor M was standardized. Today, M is standardized at 145. The temperature for calibration is standardized at 68° F. (except in Vermont). In Vermont, the scale is marked at 36° (for use at 60° F.), and standard-density sirup has a Baumé reading of 36° when measured at 60° F. In other States and for Federal specifications, the scale is marked at 35.6° (for use at 68° F.). When this scale is used, standard-density sirup has a Baumé reading of 35.6° at 68°. When a Baumé hydrometer is used, caution must be exercised in observing the temperature at which the scale is to be used.

Measuring Density

Measuring the density of sirup by hydrometry is relatively simple. Many people, however, incorrectly assume that the observed hydrometer reading is the true density of the sirup. This error occurs because they neglect to consider that sirup and sap are water solutions and therefore behave as water does, expanding and contracting with changes in temperature.

Most hydrometers and refractometers made for use in this country are calibrated for use at 68° F. When used to measure sirup at this temperature, the observed hydrometer or refractometer value of the sirup is the true value. If sirup is heated above 68° F., it will expand to a greater volume and its apparent (observed) density will be less than its true density. Likewise, if sirup is chilled below 68°, it will contract to a smaller volume and its apparent (observed) density will be greater than its true density and corrections must be made.

To make exact density measurements, sensitive hydrometers that can be read with high precision must be used. The diameter of the hydrometer stem, therefore, must be small enough so that a change in the density of the sap or sirup equivalent to 0.1° Brix will cause an observable change in the depth at which the hydrometer stem floats, as measured at the intersection of the liquid surface and the hydrometer stem. The hydrometer will have a scale with 0.1° Brix graduations and will usually cover a range of 10° to 12° Brix. The stem will be approximately 6½ inches long, and the overall length of the hydrometer will be about 13 inches. This type of hydrometer will require a hydrometer cup at least 13 inches deep.

Since the Brix scale gives the density of sap or sirup directly in terms of dissolved solids as percentage of sugar, it is ideally suited for use by the maple industry. However, as stated earlier, many sirup hydrometers in use today have Baumé scales. Baumé values (commonly called points) can be converted to Brix values, as follows:

° Brix	° Baumé	° Brix	° Baumé	° Brix	° Baumé
0.0	0.0	3.8	2.1	13.5	7.5
0.1	.1	3.9	2.2	14.0	7.8
0.2	.1			14.5	8.1
0.3	.2	4.0	2.2	15.0	8.3
0.4	.2	4.1	2.3	15.5	8.6
0.5	.3	4.2	2.4		
0.6	.3	4.3	2.4	16.0	8.9
0.7	.4	4.4	2.5	16.5	9.2
0.8	.5	4.5	2.5	17.0	9.5
0.9	.5	4.6	2.6	17.5	9.7
		4.7	2.6	18.0	10.0
1.0	.6	4.8	2.7	18.5	10.3
1.1	.6	4.9	2.7	19.0	10.6
1.2	.7			19.5	10.8
1.3	.7	5.0	2.8	20.0	11.1
1.4	.8	5.1	2.9	20.5	11.4
1.5	.8	5.2	2.9		
1.6	.9	5.3	3.0	21.0	11.7
1.7	1.0	5.4	3.0	21.5	11.9
1.8	1.0	5.5	3.1	22.0	12.2
1.9	1.1	5.6	3.1	22.5	12.5
		5.7	3.2	23.0	12.7
2.0	1.1	5.8	3.2	23.5	13.0
2.1	1.2	5.9	3.3	24.0	13.3
2.2	1.2			24.5	13.6
2.3	1.3	6.0	3.4	25.0	13.8
2.4	1.3	6.5	3.6	25.5	14.1
2.5	1.4	7.0	3.9		
2.6	1.5	7.5	4.2	26.0	14.4
2.7	1.5	8.0	4.5	26.5	14.7
2.8	1.6	8.5	4.7	27.0	14.9
2.9	1.6	9.0	5.0	27.5	15.2
		9.5	5.3	28.0	15.5
3.0	1.7	10.0	5.6	28.5	15.8
3.1	1.7	10.5	5.9	29.0	16.0
3.2	1.8			29.5	16.3
3.3	1.9	11.0	6.1	30.0	16.6
3.4	1.9	11.5	6.4	30.5	16.8
3.5	2.0	12.0	6.7		
3.6	2.0	12.5	7.0	31.0	17.1
3.7	2.1	13.0	7.2	31.5	17.4

° Brix	° Baumé
32.0	17.7
32.5	17.9
33.0	18.2
33.5	18.5
34.0	18.7
34.5	19.0
35.0	19.3
35.5	19.6
36.0	19.8
36.5	20.1
37.0	20.4
37.5	20.6
38.0	20.9
38.5	21.2
39.0	21.4
39.5	21.7
40.0	22.0
40.5	22.2
41.0	22.5
41.5	22.8
42.0	23.0
42.5	23.3
43.0	23.6
43.5	23.8
44.0	24.1
44.5	24.4
45.0	24.6
45.5	24.9
46.0	25.2
46.5	25.4
47.0	25.7
47.5	26.0
48.0	26.2
48.5	26.5
49.0	26.8
49.5	27.0
50.0	27.3
50.5	27.5
51.0	27.8
51.5	28.1
52.0	28.3
52.5	28.6
53.0	28.9
53.5	29.1
54.0	29.4
54.5	29.6
55.0	29.9
55.5	30.2
56.0	30.4
56.5	30.7
57.0	30.9
57.5	31.2
58.0	31.5
58.5	31.7
59.0	32.0
59.5	32.2
60.0	32.5
60.1	32.5
60.2	32.6
60.3	32.6
60.4	32.7
60.5	32.7
60.6	32.8
60.7	32.9
60.8	32.9
60.9	33.0
61.0	33.0
61.1	33.1
61.2	33.1
61.3	33.2
61.4	33.2
61.5	33.3
61.6	33.3
61.7	33.4
61.8	33.4
61.9	33.5
62.0	33.5
62.1	33.6
62.2	33.6
62.3	33.7
62.4	33.7
62.5	33.8
62.6	33.8
62.7	33.9
62.8	33.9
62.9	34.0
63.0	34.0
63.1	34.1
63.2	34.1
63.3	34.2
63.4	34.2
63.5	34.3
63.6	34.3
63.7	34.4
63.8	34.4
63.9	34.5
64.0	34.5
64.1	34.6
64.2	34.6
64.3	34.7
64.4	34.7
64.5	34.8
64.6	34.8
64.7	34.9
64.8	34.9
64.9	35.0
65.0	35.0
65.1	35.1
65.2	35.1
65.3	35.2
65.4	35.2
65.5	35.3
65.6	35.3
65.7	35.4
65.8	35.5
65.9	35.5
66.0	35.6
66.1	35.6
66.2	35.7
66.3	35.7
66.4	35.8
66.5	35.8
66.6	35.9
66.7	35.9
66.8	36.0
66.9	36.0
67.0	36.1
67.1	36.1
67.2	36.2
67.3	36.2
67.4	36.3
67.5	36.3
67.6	36.4
67.7	36.4
67.8	36.5
67.9	36.5
68.0	36.6
68.1	36.6
68.2	36.7
68.3	36.7
68.4	36.8
68.5	36.8
68.6	36.9
68.7	36.9
68.8	37.0
68.9	37.0
69.0	37.1
69.1	37.1
69.2	37.2
69.3	37.2
69.4	37.3
69.5	37.3
69.6	37.4
69.7	37.4
69.8	37.5
69.9	37.5
70.0	37.6

Measuring Solids Content

The effect of temperature on density is more pronounced in sirup than in sap (*146*). Since sirup is more viscous than sap, the following precautions should be observed:

No sirup must be allowed on the part of the hydrometer stem that is exposed above the surface of the sirup being tested. The hydrometer must be clean and dry, and it must be inserted with clean fingers. Also, it must *not* be submerged below its floating position and permitted to rise. The sirup on the exposed stem of the hydrometer would add weight, the hydrometer would float too deep in the sirup, and the observed reading would be too low.

Sirup at room temperature is viscous, and therefore 30 seconds or more will be required for the hydrometer to settle to its point of rest. If the observed hydrometer readings are made too soon, they will be too high. Also, if the diameter of the hydrometer cup is too small, or if the hydrometer is floated too close to the wall of the cup, or if the cup is tilted, the movement of the hydrometer will be restricted and the observed reading will be incorrect.

To determine accurately the sugar content of maple sirup, use a hydrometer calibrated in 0.1° Brix (*146*). Place the sirup in a hydrometer cup whose depth is equal to, or slightly greater than, the overall length of the hydrometer and whose diameter is at least 1½ times larger than the diameter of the hydrometer bulb. Fill the hydrometer cup to the top with sirup, gently set the hydrometer into the sirup, and allow it to settle unaided until it comes to rest. When the hydrometer comes to rest, at least 30 seconds after it is placed in the cup, carefully lift the cup so that the liquid surface is at eye level and read the mark on the hydrometer scale at the point of intersection of the hydrometer stem and the liquid surface (fig. 99). This value is the observed hydrometer reading (° Brix) of the sirup.

Although most hydrometers are calibrated for use at 68° F., this does not mean that sirup must be heated or cooled to 68° before its density can be measured. Actually, the observed density can be measured at any temperature and the true density, or Brix value, calculated, if the exact temperature of the sirup at the time the reading was made is known. The temperature of the sirup should be measured with a precision Fahrenheit thermometer calibrated in intervals of 1.0°, or preferably 0.5°. Table 14 shows the amount to be added to or subtracted from the observed Brix reading to obtain the true density of sirup measured at a temperature other than 68° F.

The following examples show how to obtain the true density of sirup in ° Brix:

Example 1. What is the true density, in ° Brix, of sirup having an observed density of 65.9° Brix at 165° F.?

Since the observed reading is below 69.9° Brix, the correction to use is in column 2 of table 14. Locate the temperature 165° F. in column 1. Opposite this in column 2 is 5.0° Brix, the correction to add to the observed reading. Therefore, the true density of this sirup is 65.9° + 5.0°, or 70.9° Brix.

Example 2. What is the true density of sirup having an observed density of 61.0° Brix at 57° F.?

Since the observed reading is below 69.9° Brix, the correction to use is in column 2 of table 14. Locate the temperature closest to 57° F. (55° F.) in column 1. Opposite this in column 2 is 0.5° Brix, the correction to subtract from the observed reading. Therefore, the true density of this sirup is 61.0° − 0.5°, or 60.5° Brix.

Adjusting Density

Heavy sirup decreases the potential number of gallons of sirup that can be made from a quantity of sap. Sirup should, therefore, be adjusted to the proper density. Further, sirup with a density of more than 67° Brix (more than 36° Baumé at 68° F. or 36.27° Baumé at 60° F.) must be diluted or it will crystallize on storage. The sirup can be diluted either by adding water or sap or low-density sirup.

The amount of water needed to adjust 100 pounds of heavy sirup, or any part thereof, to the standard density of 66.0° Brix is shown in table 15. If sap or low-density sirup is used, the amount required can be calculated from the densities of the two liquids by Pearson's square. The calculation is explained on page 126.

The calculation for adjusting heavy sirup can be done accurately only after its true density (Brix value) has been determined.

If the true density of sirup is known, the amount of water to add to yield 66°-Brix sirup can be obtained directly from table 15. After adding the water, stir the sirup well to insure

TABLE 14.—*Corrections to be applied to observed Brix readings of maple sirup to compensate for effects of temperature* [1]

Temperature of sirup in hydrometer cup, ° F.	Correction to subtract from (−) or added to (+) observed Brix reading of—	
	60.0°–69.9°	69.9° and higher
(1)	(2)	(3)
	° Brix	*° Brix*
32	−1.4	−1.5
35	−1.3	−1.4
40	−1.2	−1.2
45	−1.0	−1.0
50	−.8	−.8
55	−.5	−.6
60	−.3	−.4
65	−.1	−.1
68[2]	**.0**	**.0**
70	+.1	+.1
75	+.3	+.3
80	+.5	+.5
85	+.8	+.8
90	+1.0	+1.0
95	+1.2	+1.2
100	+1.5	+1.5
105	+1.7	+1.7
110	+1.9	+1.9
115	+2.2	+2.2
120	+2.4	+2.4
125	+2.7	+2.7
130	+3.0	+2.9
135	+3.2	+3.2
140	+3.5	+3.4
145	+3.8	+3.7
150	+4.1	+4.0
155	+4.4	+4.2
160	+4.7	+4.5
165	+5.0	+4.9
170	+5.5	+5.2
176	+5.9	+5.7

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[1] If observed reading is in ° Baumé, first convert to ° Brix (p. 85), then apply the temperature correction.

[2] Most hydrometers are calibrated at exactly this temperature.

TABLE 15.—*Water to add to heavy sirup (66.1° to 70.0° Brix) to obtain 66°-Brix sirup*

True Brix value of undiluted sirup [1] (1)	Amount of water to add to heavy sirup [2]		
	Per 100 pounds (2)	Per 100 pounds (3)	Per pound (4)
	Pints	*Ounces*	*Fluid ounces*
66.1	0	2	0.02
66.2	0	5	.05
66.3	0	7	.07
66.4	0	10	.10
66.5	0	12	.12
66.6	0	15	.15
66.7	1	1	.17
66.8	1	3	.19
66.9	1	6	.22
67.0	1	8	.24
67.1	1	11	.27
67.2	1	13	.29
67.3	2	0	.32
67.4	2	2	.34
67.5	2	4	.36
67.6	2	7	.39
67.7	2	9	.41
67.8	2	12	.44
67.9	2	14	.46
68.0	3	1	.49
68.1	3	3	.51
68.2	3	5	.53
68.3	3	8	.56
68.4	3	10	.58
68.5	3	13	.61
68.6	3	15	.63
68.7	4	1	.65
68.8	4	4	.68
68.9	4	6	.70
69.0	4	9	.73
69.1	4	11	.75
69.2	4	14	.78
69.3	5	0	.80
69.4	5	2	.82
69.5	5	5	.85
69.6	5	7	.87
69.7	5	10	.90
69.8	5	12	.92
69.9	5	15	.95
70.0	6	1	.97

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[1] ° Brix of sirup after correction for temperature.

[2] For practical approximations, pints = pounds avoirdupois, and fluid ounces = ounces avoirdupois.

that the added water has been uniformly mixed with all the sirup. Then check the Brix value of the adjusted sirup to be sure that it is the correct density (66° Brix). Each additional heating causes an additional darkening of the sirup; therefore, try to make sirup of the correct density when the sap is first evaporated.

The following examples show how to use table 15 in calculating the amount of water to add to heavy sirup to yield a 66°-Brix sirup.

Example 1. A 100-pound sample of heavy sirup has a true density of 69.7° Brix. How much water should be added to adjust this sirup to 66° Brix?

In table 15 locate 69.7° Brix. Opposite this in columns 2 and 3 is 5 pints and 10 ounces, the amount of water to add to the 100 pounds of heavy sirup to adjust it to 66° Brix.

Example 2. If only 12 pounds of the sirup in example 1 is being adjusted, how much water should be added?

Table 15 column 4 shows that 0.9 fluid ounce of water must be added to adjust 1 pound of 69.7°-Brix sirup to 66° Brix. For 12 pounds, 12 × 0.9 or 10.8 fluid ounces of water is required to adjust 12 pounds of 69.7°-Brix sirup to 66° Brix.

Example 3. How much water should be added to 26 pounds of 68.2°-Brix sirup to change its density to 66° Brix?

In table 15 locate 68.2° Brix. Opposite this in column 4 find the value of 0.53 fluid ounce, the amount of water to add to 1 pound of 68.2°-Brix sirup. Then, 26 × 0.53, or 13.8 fluid ounces of water is required to adjust 26 pounds of 68.2°-Brix sirup to 66° Brix.

Summary

(1) Do not check the density of sirup by weight, unless precision instruments are available.
(2) The minimum allowable density is 66.0° Brix (at 68° F.) or 35.6° Baumé (at 68° F.). Sirup that has a density of 66.5° to 67° Brix (at 68° F.) has a higher viscosity and tastes better.
(3) To test the density of sirup with a hydrometer, fill the can or jar to the top with sirup.
(4) Use only a clean, dry hydrometer.
(5) Lower the hydrometer into the sirup carefully until it comes to rest.

(6) Hold the can so the top is at eye level and read the value on the hydrometer scale at the surface of the sirup. The value is the observed or apparent density of the sirup.
(7) To determine the true density of the sirup from the observed hydrometer reading, measure the precise temperature of the sirup and add to, or subtract from, the observed hydrometer reading, depending on how much warmer or cooler than 68° F. the sirup is, using table 14.

GRADING SIRUP BY COLOR

Color Standards

Sirup should be graded before it is packaged. Vermont producers are required to state on the label the grade of sirup they are offering for sale to consumers (*131*). Color is the principal grade-determining factor of table sirup that meets other requirements, such as density, flavor, and cloudiness.

The U.S. Department of Agriculture color standards are designated "Light Amber," "Medium Amber," and "Dark Amber." These correspond to Bryan Color Nos. 6, 8, and 10.

The original U.S. color standards were solutions of caramel in glycerin made according to Balch's (*4*) revised spectrophotometric specifications for Bryan color Nos. 6, 8, and 10. Master sets of these three solutions were supplied each year for Federal and State inspection of maple sirup. Unfortunately, these caramel solutions tend to fade. They should not be kept for use as standards for more than 1 year.

U.S. Color Comparator

The U.S. Department of Agriculture has developed a simple type of color comparator with permanent standards of colored glass (*9*, *10*). These standards became the official U.S. Department of Agriculture color standards for maple sirup in 1950 and were adopted by the Association of Official Agricultural Chemists (*153*). The colors of the different grades of sirup are given in table 16. A thick layer of the sirup to be tested is placed in the comparator (fig. 100). This aids in precise grading because the standards are widely spaced on a color scale when viewed in this thickness. The square container provides a field of view of uniform thickness and color, a feature that was not possible with the cylindrical bottles formerly used.

PN-4796

Figure 100.—Color-grading kit. The kit consists of the official USDA permanent glass color standard mounted in a comparator. The three clear blanks are in position in the comparator. For viewing, the sirup sample in the bottle to the right of the comparator is mounted in one of the two openings in the comparator.

TABLE 16.—*Grade designations of maple sirup, as determined by color*

Grade designation	Color	Color index range [1]
U.S. Grade AA (New York Fancy or Vermont Fancy).	As light as or lighter than Light Amber.	0–0.510.
U.S. Grade A (New York No. 1 or Vermont A).	Darker than Light Amber but as light as or lighter than Medium Amber.	0.510–0.897.
U.S. Grade B (New York No. 2 or Vermont B).	Darker than Medium Amber but as light as or lighter than Dark Amber.	0.897–1.455.
Unclassified (New York No. 3 or Vermont C).	Darker than Dark Amber.	Over 1.45.

[1] For description of color index, see p. 45.

The three clear blanks supplied with the color-grading kit are placed in the compartments in back of the three standard glasses: Light; Medium; and Dark Amber.

The sirup to be graded is poured into one of the clean square glass bottles and placed in one of the two open compartments. The comparator is held at a convenient distance from the eye and is viewed toward the sky but away from the sun (fig. 101). The color grade (classification) of the sirup is determined by comparing the samples with the standards. If the sample of sirup is cloudy, its true color classification may be difficult to determine because its brightness will be lowered.

PN-4797

Figure 101.—The sirup and color standards are viewed toward the sky (away from the sun), preferably toward the north sky.

Information concerning the color-grading kit, including the comparator block with glass standards, may be obtained by writing to the Processed Products Standardization and Inspection Branch, Agricultural Marketing Service, USDA, Washington, D.C. 20250.

Summary

(1) Color is the grade-determining factor for table sirups that meet all other requirements such as density, flavor, and cloudiness.
(2) Grade the color of the sirup by visually comparing it with color standards.
(3) Use as standards either the U.S. Department of Agriculture permanent glass standards (preferred) or suitable caramel-glycerin solutions.
(4) Do not use caramel-glycerin standards that are more than 1 year old.
(5) Designate the color of the sirup as either Light Amber, Medium Amber, Dark Amber, or Darker Than Dark Amber.

PACKAGING

The graded and clarified sirup with a density between 66° and 67° Brix at a temperature of 68° F. is ready for packaging (fig. 102). If the temperature of the sirup when tested after filtering is still above 180°, the sirup can be packaged immediately. If the sirup has cooled below 180°, it must be reheated. However, the sirup may become darkened if the temperature goes above 200° when it is reheated.

As stated previously, maple sirup is a water solution. Like water, sirup expands and contracts with changes in temperature. For this reason it is difficult to package hot sirup accurately by volume. Accurate packaging can be done only if the sirup is adjusted to that temperature for which the volume of the can will hold an exact gallon. Since standard-density sirup weighs the same regardless of its temperature, it is best to package maple sirup by weight. The sirup can be weighed on ordinary household scales. However, it is advisable to test the scales before they are used. This can be done by taking the scale to a grocery store and comparing it with the grocer's certified scales. To do this, weigh an object that weighs exactly 1, 2, or 10 pounds (such as a bag of sugar or a can of water) on the grocer's scale. Then weigh it on the scale being tested. If possible, adjust the household scale to make it read correctly. If it cannot be adjusted, make a calibration chart by recording in one column the household scale reading and in the other the corresponding true weight.

When packaging sirup by weight, allowance must be made for the weight of the container.

After the container has been filled with the correct weight of sirup, it is sealed and laid on its side so that the hot sirup contacts the closure and pasteurizes it. After the containers have been on their sides 10 to 15 minutes, they are ready for cooling.

PN-4798

Figure 102.—Sirup being packaged in lithographed cans.

Stack Burn

If packaged sirup is stacked while it is still hot, the same browning reaction that occurred in the evaporator will continue and darken the sirup by as much as one or two grades. This seldom occurs with fancy grades of sirup. Development of color in hot packaged sirup is called stack burn. To prevent stack burn, the containers should be temporarily stacked with an air space to allow air to circulate, and a fan should be used to speed up cooling. After the cans have cooled to room temperature, they can be close packed.

Control of Micro-Organisms

Standard-density sirup will not support active growth of micro-organisms with the exception of a few types of yeast and one or two types of bacteria. Because of the possible contamination of sirup with these organisms, sirup that is offered for sale to the consumer should be packaged hot. The sirup must be heated to at least 180° F. and then packaged immediately (*27*).

Everyone has seen mold growing on sirup. However, mold will not grow in standard-density sirup. These apparently contradictory statements are explained as follows: Cold-packed maple sirup may contain mold spores. The mold spores, like the spores of most yeast and bacteria, will remain in a resting state and will not germinate as long as all the sirup is of standard density.

Sirup stored under ordinary conditions usually undergoes some temperature change. When the storage temperature increases, some of the water of the sirup is distilled up into the head space of the container. When the storage temperature decreases, this vapor condenses into small drops of water that run down onto the surface of the sirup and produce a layer of low-density sirup in which mold and other types of spores can vegetate and grow.

Even though the sirup contains spores, their growth can be prevented by momentarily inverting the packaged sirup once or twice weekly (*74*). This destroys the layer of dilute sirup and thus inhibits germination of the mold spores.

Although sirup is packaged under clean, sanitary conditions, this does not guarantee that the sirup will not become inoculated with micro-organisms if it is packaged cold. Once mold or yeast has grown in the area where cold packaging is done, it is almost impossible to package sirup by the cold method without its becoming infected.

Chemical inhibitors have long been used for preserving foods. Studies (*30*) have shown that one of these, the sodium salt of propyl parahydroxybenzoate (PHBA), is effective in controlling growth of yeast and mold in maple sirup. A concentration of only 0.02 percent is required. Sodium propyl PHBA is available commercially under different trade names.

CAUTION

Before using this or any other chemical preservative, determine whether it has been approved by your State for use in intrastate sales and by the Federal Food and Drug Administration for use in interstate sales.

Bulk-stored sirup can be kept free from surface infection with spoilage micro-organisms by irradiating the surface of the sirup with germicidal lamps that emit low ultraviolet radiation, particularly in the region of 260 millimicrons (*133*). The lamps must be mounted to illuminate the entire surface of the sirup (chart 21).

> **CAUTION**
>
> **Never expose the eyes to radiation from germicidal lamps since permanent damage can result. Always turn the lights off before working in the area illuminated by these lamps.**

Size and Type of Package

The size and type of package are important when sirup is made for retail sale. Housewives dislike to repackage sirup from a gallon container to smaller ones for use as occasion demands. This has been demonstrated by the growing tendency on the part of the public to buy maple sirup in quart or even smaller packages.

The net weights for standard-density sirup are: 1 gallon weighs 11 pounds; 1 quart weighs 2 pounds and 12 ounces; 1 pint weighs 1 pound and 6 ounces. Since sirup must be packed hot (180° F. or above), the capacity of the container must be at least large enough to allow for the volume of the heat-expanded sirup. The volume of 11 pounds of standard-density sirup is 231 cubic inches at 68° F. (20° C.); its volume at 212° F. is 239.9 cubic inches. Thus, a gallon container should have a minimum capacity of 241±1 cubic inches; quart containers, 60.2±0.5 cubic inches; and pints, 30.1±0.5 cubic inches.

Consumers expect sirup to be as attractively packaged as other foods (fig. 103). When sold at roadside stands, sirup packaged in tin containers is attractive to tourists regardless of the size of the container, because they do not have to take special care in storing tin containers in the car as they must with glass containers. All metal containers should be carefully inspected before they are filled to be sure they are free of all foreign matter and contain no insects or rodents or their debris.

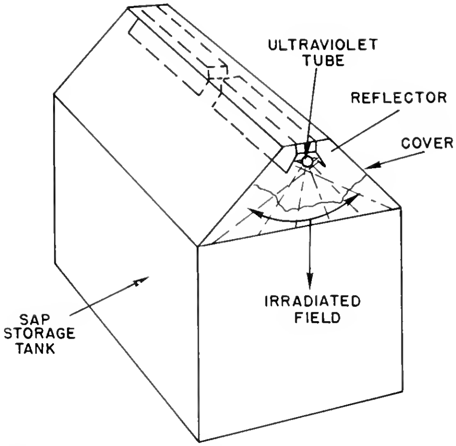

Chart 21.—Ultraviolet (germicidal) lamp must be positioned to illuminate the entire surface of the sirup. More than one lamp may be required.

Both glass and tin packages should be attractively labeled. The printed label must be put on squarely, and the outside must be clean. Many producers are finding that cans with the labels lithographed on the tin make an ideal package.

Summary

(1) Package sirup hot (180° F. or above).
(2) Do not reheat sirup above 200°.
(3) Fill sirup package by weight rather than by volume.
(4) In packaging by weight, allow for the weight (tare) of the container.
(5) Use scales that have been tested and calibrated against certified weights.
(6) Avoid stack burn by cooling the packaged sirup before close stacking it.
(7) Control mold growth in cold-packed sirup or in sterile sirup that has been opened and exposed to infection by inverting the container once a week.
(8) Yeast spoilage can be prevented only by hot packing.
(9) The chemical inhibitor sodium propyl PHBA in 0.02-percent concentration is effective in controlling mold and yeast growth in sirup. *CAUTION*—Obtain State and Federal approval before use.

PN-4799

Figure 103.—Maple sirup can be packaged in a variety of containers.

(10) Use germicidal lamps to irradiate surface of sirup in bulk storage to prevent spoilage.

(11) Package sirup neatly in attractive containers.

(12) Package sirup in small containers such as quarts, pints, and one-half pints, as well as gallons and one-half gallons.

STANDARDS FOR MAPLE SIRUP FOR RETAIL SALE

Maple sirup producers often find it profitable to sell their sirup directly to consumers. In doing so, farmers not only are producers; they also are food processors. As food processors, they are expected to offer for sale a product that meets Federal and State requirements, and they must package their sirup so that it will compare favorably in appearance and quality with other luxury food items.

Vermont has taken the lead in the United States in enacting regulations governing the sale and labeling of maple products (*131*). New York (*83*) and Wisconsin (*138*), among other States, are establishing similar regulations. To obtain information regarding your State regulations governing the sale of maple products, write to the Division of Markets, Department of Agriculture, at your State capital. These regulations protect the buyer and assure him that the product he has purchased meets certain minimum standards. They also protect the producer against unfair competition.

The United States standards for table maple sirup (*129*) are as follows:

UNITED STATES STANDARDS FOR GRADES OF TABLE MAPLE SIRUP

Effective May 24, 1967

PRODUCT DESCRIPTION

(a) "Maple sirup" means sirup made by the evaporation of maple sap or by the solution of maple concrete (maple sugar) and contains not more than 35 percent of water, and weighs not less than 11 pounds to the gallon (231 cubic inches).

(b) The standards in this subpart are issued for the purpose of classifying maple sirup packed in containers for table use. It is not intended that they shall apply to sirup which is packed in drums or other large containers for later reprocessing. Another set of standards entitled "U.S. Standards for Maple Sirup for Reprocessing" has been issued for this purpose (§ § 52.5921–52.5926).

GRADES

U.S. Grade AA (Fancy)

U.S. Grade AA (Fancy) Table Maple Sirup shall consist of maple sirup which meets the following requirements:

(a) The color shall not be darker than light amber as represented by the color standards of the U.S. Department of Agriculture.

(b) The sirup shall not be cloudier than light amber cloudy standard as represented by the standards of the U.S. Department of Agriculture for cloudiness.

(c) The weight shall be not less than 11 pounds per gallon of 231 cubic inches at 68 degrees F. corresponding to 65.4[7] degrees Brix or 35.27 degrees Baumé (Bureau of Standards Baumé scale for sugar solutions, modulus 145).

(d) The sirup shall possess a characteristic maple flavor, shall be clean, free from fermentation, and free from damage caused by scorching, buddiness, any objectionable flavor or odor or other means.

U.S. Grade A

(a) U.S. Grade A Table Maple Sirup shall consist of maple sirup which meets the requirements for U.S. Grade AA (Fancy) Table Maple Sirup except for color and cloudiness.

(b) The color shall not be darker than medium amber as represented by the color standards of the U.S. Department of Agriculture.

(c) The sirup shall not be cloudier than medium amber cloudy standard as represented by the standards of the U.S. Department of Agriculture for cloudiness.

U.S. Grade B

(a) U.S. Grade B Table Maple Sirup shall consist of maple sirup which meets the requirements for U.S. Grade AA (Fancy) Table Maple Sirup except for color and cloudiness.

(b) The color shall not be darker than dark amber as represented by the color standards of the U.S. Department of Agriculture.

(c) The sirup shall not be cloudier than dark amber cloudy standard as represented by the standards of the U.S. Department of Agriculture for cloudiness.

Unclassified

Unclassified Table Maple Sirup shall consist of maple sirup which has not been classified in accordance with the foregoing grades. The term "Unclassified" is not a grade within the meaning of the standards in this subpart but is provided as a designation to show that no definite grade has been applied to the lot.

TOLERANCE, PACKING

Tolerances for preceding grades

In order to allow for variations incident to proper grading and handling, not more than 5 percent, by count, of the containers in any lot may have sirup below the requirements for the grade: *Provided,* That no part of this tolerance shall be allowed for defects causing "serious damage": *And provided further,* That no tolerance is permitted for sirup that is darker in color than that which is required for the next lower grade.

Packing

(a) Containers shall be clean and new in appearance. Tin containers shall not be rusty.

(b) In order to allow for variations incident to proper packing, not more than 5 percent, by count, of the containers in any lot may fail to meet these requirements.

EXPLANATION OF TERMS

(a) "Cloudiness" means presence in suspension of fine particles of mineral matter, such as malate of lime, "niter," "sugar sand," or other substances that detract from the clearness of the sirup.

(b) "Clean" means that the sirup shall be practically free from foreign material such as pieces of bark, soot, dust, and dirt.

(c) "Damage" means any defect that materially affects the appearance or the edibility or shipping quality of the sirup.

(d) "Serious damage" means any defect that seriously affects the edibility or market value of the sirup. Badly scorched sirup, buddy sirup, fermented sirup or sirup that has any distasteful foreign flavor or disagreeable odor shall be considered as seriously damaged.

Summary

(1) Sirup sold directly to the consumer must meet State and Federal specifications.

(2) The package and label must meet State and Federal specifications.

(3) Know your State law and Federal specifications governing the retail sale of maple products.

MAPLE PRODUCTS

Many producers have found that the gross returns of their maple crop can be increased from 20 to 160 percent by converting their sirup to sugar or to confections such as maple cream, soft sugar candies, and maple spreads. The 8 pounds of sugar in a gallon of sirup is worth $1

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[7] The density requirement was changed in 1974 to 66.0° Brix (*130a*).

a pound, based on sirup selling at $8 per gallon. This same weight of sugar, if converted to sugar products, can be sold at prices ranging from $1.50 to $2.50 per pound or a gross of $12 to $20 per gallon of sirup. This increase in gross returns is usually more than commensurate with the additional labor involved in converting sirup to sugar products.

Equipment

Making the different maple sugar products is not difficult, nor does it require expensive or unusual equipment. It does require the same type of care and sanitation that is expected of any candy company. Maple confections should be made in a special room, either in the home (fig. 104) or in a part of the evaporator house (fig. 105). In some States the law specifies that confections for sale cannot be made in the home kitchen.

High-pressure steam is the ideal source of heat for evaporating sirup in making confections. High-pressure steam heat can be easily and instantaneously controlled; and, unlike other types of heat, there is no danger of scorching the sugars. When steam is not available, gas is preferred. Gas heat is also easily controlled (fig. 106). Bottled gas is available almost everywhere.

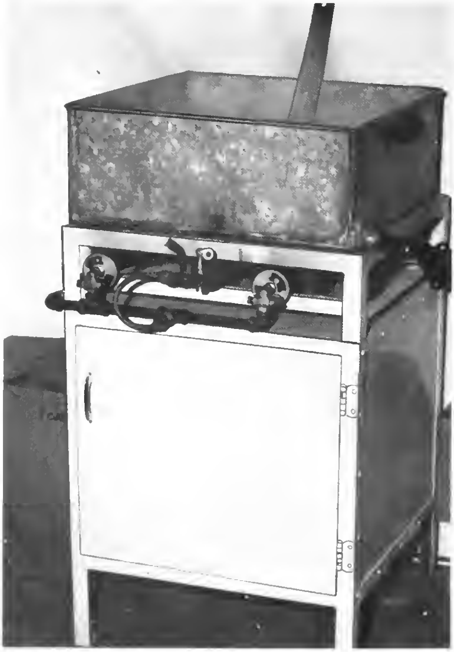
The size of the equipment (kettles, mixers, and pans) depends on the amount of sirup to be processed. A thermometer with a range of 200° to 300° F. in 1° units is a necessity; it can be either a dial thermometer or a candy thermometer. Other equipment includes measuring cups, wooden ladles, wooden paddles, and a house-

PN-4800

Figure 104.—A porch converted to a candy kitchen and salesroom.

PN-4801

Figure 105.—A separate room built in the evaporator house makes an ideal candy kitchen.



PN-4802

Figure 106.—Gas, whether supplied from tanks or mains, is a good source of heat for cooking maple products. The heat is easily controlled and can be stopped the instant cooking is completed. Here, sirup is being cooked for maple cream.

hold scale. Provision should be made for cooling the sugar products. This is especially desirable when making maple cream, fondant, or crystal-coating sirup. The cooler for cream can be a trough with circulating cold water into which the pans of cooked sirup are placed. A pan of chipped ice or ice water may also be used. For crystal-coating sirup, an insulated box, such as a used refrigerator from which the cooling unit has been removed, may be used.

Maple Sugar

Chemistry of Maple Sugar

Maple sirup is essentially a solution of sucrose in water. The amount of sugar that can be in true solution in a given volume of water varies with the temperature of the solution (*11*, *12*, *51*, *82*). Hot solutions can contain more sugar and cool solutions less sugar.

Maple sirup solutions containing 67 percent of sugar (67° Brix) are saturated at room temperature (68° F.). That is, no more sugar can be dissolved in the solution at that temperature. Sirup that has been heated to raise the boiling point of the sirup to 7.5° F. or more above the boiling point of water will be supersaturated when it cools to room temperature; it will contain more than 67 percent of sugar. This supersaturated sirup, with its excessive sugar content, is in an unnatural or abnormal condition, and it tends to return to normal by ridding itself of the excess sugar so that the sirup will again contain only 67 percent of sugar. The excess sugar is forced out of solution (precipitated), and sugar crystals are formed. The slower this occurs, the larger the sugar crystals.

To make any of the maple sugar products, it is necessary first to make supersaturated sirup. The degree of supersaturation is increased as the boiling temperature of the sirup is increased and more water is evaporated from the sirup. When the amount of supersaturation is small and cooling is slow and is accompanied by little or no agitation, the state of supersaturation may persist for a long time; and little sugar will be precipitated. When the amount of supersaturation is appreciable, as when sirup is boiled to 18° F. or more above the boiling point of water (11° or more above that of standard-density sirup), the sirup will appear to solidify on cooling. This solid cake is mostly sugar, but some liquid sirup (mother liquor) is mixed with the sugar.

Formation of Crystal Sugar

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 type of confection (*84*). These factors include the degree of supersaturation, seeding, the rate of cooling, and the amount and time of stirring.

Large crystals called rock candy, which represent one extreme, are formed when slightly supersaturated sirup (67° to 70° Brix) is cooled slowly and stored for a long time without agitation. A glasslike noncrystalline sirup represents the other extreme. This is formed when highly supersaturated sirup (the boiling point is elevated 18° F. or more above the boiling point of water) is cooled rapidly to well below room temperature without stirring. The sirup becomes so viscous that it solidifies before crystals can form and grow. If the hot supersaturated sugar solution is stirred while it is cooling, the tendency to form crystals increases. The mechanical shock produced by the stirring causes microscopic crystal nuclei to form. Continued stirring mixes the crystals throughout the thickened sirup, and they grow in numbers and in 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 grainy sugar tends to become more grainy the longer it is stirred.

To produce maple sugar with crystals that are imperceptible to the tongue (impalpable), the crystals must be kept very small, even microscopic in size. This is accomplished by first suddenly cooling a hot, highly supersaturated sirup so that a viscid, noncrystalline, glasslike mass is obtained. Then while it is still in the supersaturated state, fine crystals, called seed, are added to serve as nuclei, and stirring is begun. Since the mass is so highly supersaturated, billions of tiny crystals are formed at the same time, and the result is a very fine grained product.

Invert Sugar

Although sucrose is the only sugar in sap as it comes from the tree, some of the sucrose is changed into invert sugar as a result of microbial fermentation during handling and processing. Both sucrose and invert sugar are made up of two simple sugars, dextrose and levulose. In sucrose, these sugars are united chemically as a single molecule; in invert sugar, they occur as separate molecules.

A small amount of invert sugar is desirable in maple sirup that is to be made into maple sugar and maple confections. Invert sugar tends to reduce supersaturation, that is, more sugar can be held in solution before crystallization occurs. This helps keep the product moist (*62*). Also, it encourages the formation of exceedingly small sugar crystals. But too little invert sugar in the sirup will cause the product to be grainy; too much may prevent formation of crystals (creaming) as required for making maple cream. In general, all grades of maple sirup contain some invert sugar, the amount varying with the different grades. Fancy has the least; and U.S. Grade B or unclassified, the most. Thus, the grade of sirup should be a determining factor in selecting sirup for making a specific confection.

A simple chemical test to determine the amount of invert sugar in maple sirup is described on page 113. If the amount of invert sugar in the sirup is so small that a fine crystalline product cannot be made, a "doctor" solution is required (*60*).

"Doctor" Solutions

The simplest "doctor" solution and the one most commonly used is U.S. grade B pure maple sirup, which is naturally rich in invert sugar (more than 6 percent, as determined by the chemical test described on p. 113). As a rule, dark sirup made from sap produced during a warm spell contains a high percentage of invert sugar. The addition of 1 pint of this doctor sirup to 6 gallons of maple sirup low in invert sugar (less than 1 percent) usually will correct invert deficiency.

When sirup with a high content of invert sugar is not available, the doctor solution can be prepared as follows: To 1 gallon of standard-density maple sirup add 2½ liquid ounces of invertase (an enzyme that causes the inversion of sucrose to invert sugar). Stir the mixture thoroughly and allow it to stand at room temperature (65° F. or above) for several days. During this time sufficient invert sugar will form so that 1 pint of this solution can be used to doctor 6 gallons of maple sirup low in invert sugar. Invertase may be purchased from any of the confection manufacturers.

Another convenient type of doctor is an acid salt such as cream of tartar (potassium acid tartrate). Addition of ½ teaspoon of cream of tartar to 1 gallon of low-invert sirup just before it is boiled for candymaking will cause sufficient acid hydrolysis or inversion of the sucrose to form the desired amount of invert sugar.

Maple Cream or Butter

The amount of the maple sirup crop that is being converted into maple cream or butter has been increasing rapidly. Some producers have built up so large a demand for this confection that they convert their entire sirup crop to cream. Some producers make from 2 to 3 tons of this confection annually.

Maple cream (*84*, *85*), a fondant-type confection, is a spread of butterlike consistency. It is made up of millions of microscopic sugar crystals interspaced with a thin coating of saturated sirup (mother liquor). The crystals are impalpable to the tongue and give the cream a smooth, nongritty texture. The first step in making maple cream is to make a supersaturated sugar solution. This solution is cooled to room temperature so quickly that crystals have no chance to form. The cooled, glasslike mass is then stirred, which produces the mechanical shock necessary to start crystallization.

Sirup for Creaming

For best results, U.S. Grade AA (Fancy) or U.S. Grade A (No. 1) maple sirup should be used. However, any sirup may be used provided it contains less than 4 percent of invert sugar.

Invert Sugar Content

The amount of invert sugar in the sirup selected for creaming should be determined by the simple chemical test described on page 113. Sirup that contains from 0.5 to 2 percent of invert sugar should make a fine-textured cream that feels smooth to the tongue. Sirup with from 2 to 4 percent of invert sugar can be made into cream by heating it to 25° F. above the boiling point of water (instead of the usual 22° to 24°). Sirup with more than 4 percent of invert sugar is not suitable for creaming. It will not crystallize, or it will crystallize only if heated to a much higher-than-normal temperature. However, the cream will be too fluid and probably will separate a few days after it is made.

The belief throughout the maple-producing area that maple cream should be made only from first-run sirup and that all first-run sirup will yield a good cream is false. It is the amount of invert sugar in the sirup that determines its suitability for creaming, not the run of sap from which the sirup is made. The amount of invert sugar formed is directly proportional to the amount of microbial fermentation of the sap. This, in turn, is related to the temperature. Unseasonably warm weather is not uncommon during the first period of sap flow. Warm weather favors fermentation of the sap, and sufficient invert sugar is produced to make the early-run sirup unsuitable for making into cream.

Since most Fancy and Grade A sirup normally contains an adequate amount of invert sugar, the use of a doctor solution is not recommended. The addition or formation of too much invert sugar will ruin the sirup. Sirup for creaming should be selected on the basis of the quick test for invert sugar.

Cooking and Cooling

The sirup is heated to a temperature 22° to 24° F. above the boiling point of water (*37*). (The temperature of boiling water must be established at the time the sirup is boiled for creaming.) The boiling temperature indirectly adjusts the amount of sirup (mother liquor) left surrounding the crystals; this, in turn, governs the stiffness of the final product. As soon as the boiling sirup reaches the desired temperature, it should be removed from the heat and cooled quickly. If the cooked sirup is left on the hot stove (even with the heat turned off), enough additional water will be evaporated to produce a more concentrated sirup than desired.

Rapid cooling is necessary to prevent crystallization. To provide a large cooling surface, the sirup is poured into large, flat-bottom pans. The layer of sirup should be not more than 1 to 3 inches deep. The pans are set in a trough through which cold water (35° to 45° F.) is flowing (fig. 107).

The sirup is cooled to at least 70° F., and preferably to 50° or below. It is sufficiently cool when the surface is firm to the touch. If crystals appear during the cooling process, cooling is too slow, the pan was agitated, or the invert sugar content of the sirup is too low for the cooling conditions. This situation can be corrected either by more rapid cooling (using thinner layers of sirup or more rapid flow of cold water) or by increasing the invert sugar content of the sirup by use of a doctor.

Creaming

The chilled, thickened sirup should be creamed either by hand or mechanically in a room having a temperature of 70° F. or above. Many producers have developed their own mechanical cream beaters (fig. 108); also, there are a number of inexpensive ones on the market.

PN-4803

Figure 107.—Sirup that has been concentrated for creaming is poured immediately into large, flat-bottom pans, which are set in flowing cold water to cool to well below room temperature. The sirup is sufficiently cool when the surface is firm to the touch.

PN-4804

Figure 108.—Homemade cream beaters in which the stirrers are held stationary and the pan is rotated at approximately 50 r.p.m.

The homemade maple cream beater (fig. 109) consists of a pan approximately 13 inches in diameter that holds about 1.5 gallons of cooked sirup. In this beater, the scrapers are held stationary and the pan revolves at 40 to 50 revolutions per minute. In other beaters, this procedure is reversed. Both types worked equally well.

A hardwood paddle having a sharp edge 2 or 3 inches wide is used for hand beating (stirring). The cooked sirup is poured onto a large flat pan such as a cookie tin. The pan is held firmly, and the thick sirup is scraped first to one side and then to the other. Mixing should be continuous.

PN-4805

Figure 109.—At the beginning of the creaming operation, the butterlike mass has a shiny surface. When the surface becomes dull, creaming is complete.

If stirring is stopped, some of the crystals will grow and make the product gritty.

While being stirred, the chilled sirup first tends to become fluid and then begins to stiffen and show a distinct tendency to set. At this time the batch loses its shiny surface (fig. 109). If creaming is stopped too soon, that is, while the batch is too fluid, large crystals will form.

To hasten the creaming process, a small amount of "seed" (previously made cream) can be added to the glasslike chilled sirup just before beating. The addition of 1 teaspoonful of seed for each gallon of cooked sirup will provide crystals to serve as nuclei for the more rapid formation of crystals. The entire creaming process may require from 1 to 2 hours, depending on the size of the batch, but the use of seed will often shorten the time by half.

Holding Cream for Delayed Packaging

Often it is not convenient to package the cream at the time it is made. In this case, it can be stored or aged for periods from 1 day to several weeks in tightly covered glass or earthen vessels, preferably under refrigeration. Many candymakers believe that aging a fondant is desirable because it permits the crystals to equalize in the saturated sirup. Some producers age the cream 1 day by holding it in an open pan covered with a damp cloth; they package the second day without rewetting. Other producers remelt the aged cream for ease of pouring and packaging by carefully heating it in a double boiler (*99*). The temperature of the cream during this reheating must not go above 150° F. (The temperature can be controlled by not permitting the water in the double boiler to go above 150°.) If the temperature of the cream exceeds 150°, too much sugar will be dissolved, and large crystals may form when the remelted cream is cooled and stored.

Packaging and Storing

Maple cream can be packaged in tin, glass, plastic, or wax-paper cups. Containers with wide mouths are best for easy filling. Care must be taken to keep air bubbles from forming, especially when the cream is packaged in glass because the air bubbles are unpleasing in appearance and create the impression the package is short in weight. Furthermore, air pockets provide a place where the separated mother liquor can collect, and this also produces an unpleasant appearance.

Freshly made cream should be packaged immediately, before it "sets up" (fig. 110), or within a day if it has been covered and set aside to age. Remelted cream should be packaged while it is still warm and fluid. Since maple cream is a mixture of sugar crystals and saturated maple sirup, storing packaged cream at 70° F. or above will cause more sugar to be dissolved. The sirup tends to separate as an unattractive, dark, liquid layer on the surface of the cream. This sirup layer also forms if the cream is stored at fluctuating temperatures.

The cream is best stored at low temperature, preferably under refrigeration and at constant humidity. If the cream is packaged in glass or other moistureproof containers, it can be stored in refrigerators for long periods, with little danger of the saturated sirup in the cream separating.

Fondant

Fondant, a nougat-type candy, is known in Ohio as maple cream because of its very fine crystalline character. Fondant is made in exactly the same manner as maple cream except that the sirup is heated to a higher boiling point (27° F. above the boiling point of water). The thickened sirup is cooled to 50° and stirred as for creaming. Since there is less sirup left in the fondant, it will set up to a soft solid at room temperatures. Small amounts can be dropped on marble slab, waxed paper, or a metal sheet; or it can be packed into molds.

Soft Sugar Candies

Next to maple cream the making of soft sugar candies is gaining in popularity. Like maple cream, 8 pounds of soft sugar candies can be made from 1 gallon of sirup.

Soft sugar candies contain little or no free sirup, so they are stiffer than maple cream. The crystals in soft sugar candies are larger than in maple cream and are palpable to the tongue, but they should not be large enough to produce an unpleasant sandy effect. The candies can be made from any of the top three grades of sirup: U.S. Grade AA (Fancy), U.S. Grade A (No. 1),

PN–4806

Figure 110.—The finished or remelted cream is sufficiently fluid to be poured into containers. Use of wide-mouthed jars makes filling and emptying easy.

and U.S. Grade B (No. 2). Unlike maple cream, a small amount of invert sugar is desirable because it reduces the tendency to produce large crystals that give the candies a grainy texture. The invert sugar content can be increased by adding (1) a doctor solution consisting of 1 pint of dark sirup to 6 gallons of table grade maple sirup, or (2) a doctor consisting of $^1/_2$ teaspoon of cream of tartar to 1 gallon of low invert sirup. Use the quick test for invert sugar to check the sirup to be used for candymaking.

Cooking, Cooling, and Stirring

The sirup is cooked to 32° F. above the boiling point of water established for that time and place (fig. 111). The pans of cooked sirup should be cooled slowly on a wooden-top table to 155° F. (as tested with a thermometer). The thick sirup should then be stirred, either by hand with a large spoon (fig. 112) or with a mechanical mixer.

While the sugar is still soft and plastic, it is poured or packed into rubber molds of different shapes. Packing the molds is best done with a wide-blade putty knife or spatula (fig. 113). Rubber molds for making candies of different sizes and shapes can be purchased from any maple equipment supplier. Before use, the molds should be washed with a strong alkali soap, well rinsed, and dried. They should then be coated with glycerin applied with a brush. Excess glycerin is removed by blotting with a soft cloth. If the rubber mold contains too much carbon, it will make a mark on the molded sugar. To test for too much carbon, rub the mold on white paper.

The Bob.—Another method of preparing the sugar so that it can be run into the molds is that used by commercial confectioners. After stirring, the soft sugar is set aside for a day to firm and age. The following day it is mixed with an equal amount of "bob," and the mixture is run into the rubber molds while it is still fluid.

The bob (*84*) is sirup that is boiled to exactly the same boiling point as used in making the

PN–4807

Figure 111.—Many types of kettles may be used for cooking the sirup for making soft sugar candies. Where high-pressure steam is available, a steam-jacketed kettle is ideal since it permits cooking the sirup without danger of scorching.

soft sugar (32° F. above the boiling point of water). As soon as the bob is made and while it is still hot, the sugar made the previous day is added to it, and the mixture is stirred enough to get uniformity but not enough to cause it to set up. The hot bob partly melts the sugar, and the resulting semiliquid sugar can be poured easily.

PN-4808

Figure 112.—The thick supersaturated sirup is stirred until sugar crystals form and grow large enough to be palpable but not large enough to be gritty.

PN-4809

Figure 113.—The partly crystallized sirup is packed into molds while it is still plastic. In a few hours crystallization is complete, and the candies are firm and can be removed from the molds.

Semicontinuous Process.—Ingenuity can be used in candymaking. For example, one producer has developed the following semicontinuous process: The sirup is cooked in a special vessel (fig. 114) from which the cooled sirup is dispensed to a small mechanical agitator (fig 115).

Here the sirup is partly crystallized, and while it is still fluid it is run into the rubber molds where crystallization is completed. It sets up in 30 minutes to 1 hour. Candies formed by pouring rather than packing have an attractive glazed surface.

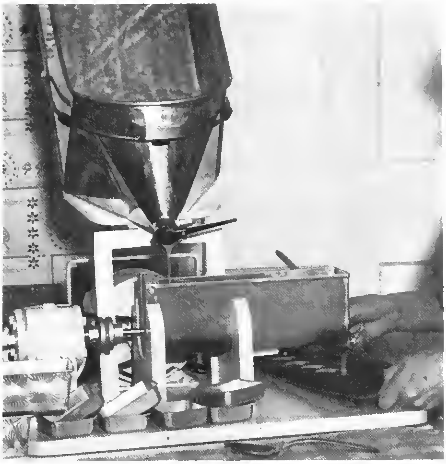
Crystal Coating

Candies can be prevented from drying by coating them with a moisture-impervious shell made from crystalline sucrose (*99*). The effect of crystal coating soft sugar candies is shown in figure 116. The crystallizing sirup is made as follows: Fancy maple sirup low in invert sugar is heated to 9.5° to 11° F. above the boiling point of water. This supersaturated sirup should have a Brix value of 70° to 73° at a temperature of 68° and 63.5° Brix at 210° (hot). One gallon of standard-density sirup (66° Brix) will make 7 pints of crystallizing sirup (70° to 73° Brix).

The hot, heavy sirup can be set aside to cool where it will not be disturbed by jarring or shaking, or it can be transferred immediately to

PN-4810

Figure 114.—A special candy-cooking kettle has one end shaped like a funnel and is provided with a spout and shutoff. After the cooked sirup has cooled but while it is still fluid, the kettle is mounted in an upended position and the sirup is run out through the shutoff. (Cooker designed by Lloyd H. Sipple, Bainbridge, N.Y.)



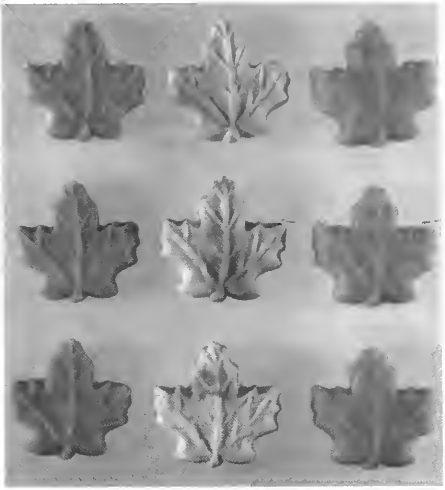
PN–4811

Figure 115.—A continuous candy beater of simple design. The cooked sirup is run in a small stream from the cooking kettle to the beater, which consists of a rotating worm in a metal trough. The worm beats the sirup, crystallizes it, and then drives the semiliquid sirup to the drawoff cock that controls the flow of the sirup into the molds. (Beater designed by Lloyd H. Sipple, Bainbridge, N.Y.)

large crystallizing pans. To retard surface crystallization (caused by rapid cooling of the surface), the sirup should be covered with a piece of damp cheesecloth or paper (preferably the same kind used as a sirup prefilter, since it has a high wet strength). The cloth or paper must be in contact with the entire surface of the sirup. If crystals form, they will attach themselves to this cover and can be removed along with the covering. The sugar crystals can be recovered by rinsing the cover in hot water.

The candies to be coated should be dry (24 hours old). They can be coated by either of two methods. In one method, the candies are loosely packed two or three layers deep in a tin pan, such as a bread tin, which has a piece of ½-inch-mesh hardware cloth in the bottom. The covering is removed from the cool (70° to 80° F.) crystallizing sirup, and any crystals not removed with the cover are skimmed off.

In the other method, the candies are loosely placed in wire mesh baskets of such size as to permit submerging both the baskets and the dried candies below the surface of the crystallizing sirup (figs. 117 and 118). A fresh cover is placed directly on and in contact with the entire surface of the sirup and left at a temperature of 65° to 80° F. for 6 to 12 hours, or overnight. This is the crystallizing period. The major part of the crystal coat forms on the candies during the first few hours. Therefore, the time the candies are left in the crystallizing sirup beyond a 6-hour period is not too critical. Actually, the most important factor is the Brix value of the crystallizing sirup; if too high, coarse crystals result. Sugar comes out of the thick sirup and is deposited and grows on the millions of tiny crystals on the surface of the candies. The best density of the sirup should be determined by trial runs. When sufficient sugar has been deposited on the candies, the paper or cloth cover is removed, and the wire baskets of coated candies are lifted out of the sirup and supported above the trays of sirup until the candies have drained.

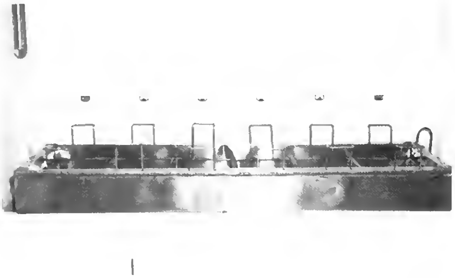


PN–4812

Figure 116.—Crystal-coated candies: *Left,* Freshly made, uncoated candies; *center,* uncoated candies that have been stored 3 months at room temperature—the unattractive appearance is caused by drying; *right,* these candies, made at the same time as those in the center, were coated with sugar crystals, which prevented loss of moisture. They have kept the appearance and characteristics of fresh candies.

PN-4813

Figure 117.—A french-fryer blanching assembly provides a practical means for crystal coating maple candies on a small scale. The candies are placed in the basket for crystallizing in the thick sirup and are left in the basket to drain. The drained sirup is caught in the sirup pan and is used for making other lots of candies.



PN-4814

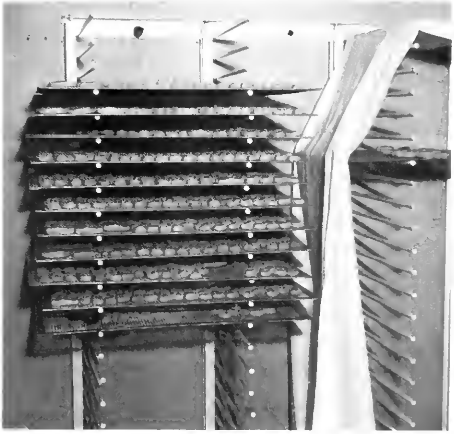
Figure 118.—A large crystallizing pan for use in a constant-temperature cabinet. Hangers are attached for suspending baskets for draining candies after crystal coating.

After the sirup has drained from the candies (one-half hour), the candies are dried by removing all remaining drops of sirup. Failure to do this results in areas having a glazed (noncrystalline) surface that is not a water barrier and that permits the candies to desiccate (dry out) during storage. Desiccated spots appear as white areas.

The drained candies can be freed of any remaining drops of crystallizing sirup by two methods. In one method the candies are spread out (one layer thick) on a sheet of paper and each piece is turned over at intervals of 1 to 2 hours. In the other method each piece of candy is wiped with a damp sponge to remove any moist areas. The dry candies are placed on trays (fig. 119); the bottoms of the trays are made of $^{1}/_{4}$-inch hardware cloth. The trays of candies are set in racks to complete the air-drying process at room temperature. This usually requires from 4 to 7 days. After drying, the candies are ready for packaging. Candies should not be crystal coated on humid or rainy days because they will not dry properly. If candies are not thoroughly dried, their coating will dissolve when they are packaged.

The packages have two functions: (1) To make the candies as attractive as possible and (2) to keep them in good condition (fig. 120). Boxes, individual wrappings, and candy cups can be obtained from a confectioner's supply house. The net weight of the candies must be stated on the outside of the package. This requires that the weight of the box (tare) and the net weight of the candies be determined for each box.

Candies that have been crystal coated have relatively good shelf life; they do not tend to take up moisture or to dry out. Candies that are not crystal coated may do either, depending on



PN-4815

Figure 119.—After the candies have been removed from the crystallizing sirup and wiped, they are put on wire screen trays and placed in racks for air drying before packaging.

PN-4816

Figure 120.—Packaging sugar candies, a popular confection often used as one of the items in a gift package.

the humidity of the room in which they are stored. In a room of low humidity, they will lose moisture. The dried-out areas will appear as white spots and will become stonelike in hardness. If the humidity is high, the candies will take up 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 can be controlled by a dehumidifier and air-conditioner. Never package on rainy days (*62*).

The best type of wrapper for the outside of the candy package is one that is moistureproof, such as metal foil or wax-coated paper. A moistureproof wrapper helps to prevent changes in the candies during storage. Unfortunately, most wrappers are not completely moistureproof. They reduce the gain or loss of moisture but do not prevent it, especially if the candies are stored under excessively high or low moisture conditions or for long periods. Some packers of maple confections obtain longer storage by puncturing the moistureproof wrapper with many small holes to permit the package to breathe.

Maple Spread

Maple cream, described on page 98, is not stable when stored at room temperature because saturated sirup (mother liquor) tends to separate from the cream and cover it with a sirup layer.

A new semisolid dextrose-maple spread has been developed that prevents this separation of sirup. Also, it requires no heating or stirring.

The process for making the spread consists of three simple steps: (1) The sirup is concentrated by heating it to a density of 70° to 78° Brix; (2) part of the sucrose is converted to invert sugar by enzymatic hydrolysis; and (3) the dextrose (part of the invert sugar) is crystallized to form a semisolid spread.

Standard-density maple sirup (66° Brix) is heated to about 10° F. above the boiling point of water (approximately 76° Brix), and then cooled to 150° or below (as tested with a thermometer). While the sirup is still fluid, invertase is added at the rate of 1½ ounces per gallon of sirup and thoroughly mixed with the sirup by stirring. The enzyme will be inactivated and hence ineffective if it is added while the sirup is too hot (above 160° F.). The enzyme-treated sirup is stored at room temperature for 1 or 2 weeks. At first, crystals (sucrose) appear, but they do not form a solid cake, and as the hydrolyzing action of the enzyme progresses, the crystals dissolve. The result is a crystal-free, stable, high-density sirup (70° to 78° Brix) containing a large amount of invert sugar. This sirup will remain clear at ordinary temperatures. Because of its high density, it makes an excellent topping for ice cream and sirup for waffles or pancakes.

Maple spread is made by seeding this high-density sirup with dextrose crystals. A crystalline honey spread, a stock grocery item, is a convenient source of dextrose crystals for seeding the first batch. For additional batches, crystals from previously made lots of the maple spread may be used as seed. The dextrose crystals are added at the rate of 1 teaspoon per gallon of high-density sirup and thoroughly mixed with the sirup. After mixing, the sirup is poured into packages and set aside at a temperature of 55° to 60° F. Within a few days a semisolid spread forms. It is stable at temperatures up to 80° F. If refrigerated, it will keep indefinitely without any sirup separating.

Maple spread eliminates the laborious hand beating or the expensive machine beaters required for making maple cream. Furthermore, the yield of maple spread per gallon of sirup is higher, because it is made from sirup concentrated to between 70° and 78° Brix, whereas sirup for maple cream is concentrated to 80° Brix.

Fluffed Maple Product

In making the maple products described in the preceding pages, only sirup low in invert sugar should be used, except for that used as a doctor. These products, therefore, are primary uses for the top grades of table sirup, U.S. Grade AA, U.S. Grade A, and U.S. Grade B.

A new maple product called fluff has been developed at the Eastern Regional Research Center (*135*). It can be made from the lower grades of sirup (sirup high in invert sugar). In addition, it has a number of other advantages. Some of these advantages are: (1) There is a large overrun because the volume of the cooked sirup is increased by incorporating air during the beating process; (2) the new product contains a higher percentage of water than does maple cream so that a larger volume can be made from 1 gallon of standard-density sirup; (3) the monoglyceride used in the formula tends to reduce its apparent sweetness and make it more palatable, but without loss of the maple flavor; and (4) the time required to whip it is only a fraction of that required for making maple cream. The fluffed product has excellent spreading properties and has an impalpable crystal structure. While there is less tendency for the fluff to bleed, it does tend to become somewhat grainy, especially if stirred too long. This tendency to grain is retarded by storing the fluff under refrigeration.

Making the Fluff From Maple Sirup

Heat the sirup until its temperature has been elevated 17° F. above that of boiling water. Allow it to cool, with occasional stirring, to between 175° and 185° F. (as tested with a thermometer). Add highly purified monoglyceride (Myverol 18–00)[8] equal to 1 percent of the weight of the maple sirup used, that is, 0.11 pound ($^1/_3$ cup) per gallon or 2 level teaspoonfuls per pint. Dissolve the monoglyceride by adding it slowly and stirring. If the sirup cools below 145°, the monoglyceride will not dissolve. Cool to between 150° and 160° and whip the mixture with a high-speed (household) beater. Fluffing should occur within 2 minutes.

Making the Fluff From Maple Sirup and Maple Sugar

To 1 cup of pure maple sirup (any grade) add $^1/_2$ cup of maple sugar and heat the mixture until the sugar is completely dissolved. Do not boil. Cool to between 175° and 185° F. with occasional stirring. Add slowly and stir until dissolved 1 teaspoonful of Myverol 18–00 for each cup of sirup. Cool to between 150° and 160°, and whip the mixture with a high-speed (household) beater. Fluffing should occur within 2 minutes.

The sugar must be completely in solution at the time it is whipped to prevent a grainy texture. If sugar crystals do form, they may be redissolved by heating the suspension; but loss of water must be avoided, and no more Myverol need be added.

Excessive heating of the Myverol tends to cause it to lose its properties.

The texture and consistency of the fluffed products can be varied as follows:

(1) *Whipping Time.*—As time of beating lengthens, the stiffness of the product increases. The initial, thin whip can be used as a topping for ice cream or other desserts. The stiffer product is an excellent spread or icing for baked goods. (The beating time will be affected by the temperature of the mixture at the start of the beating. The higher the temperature, the longer it will take to reach a given consistency.)

(2) *Ratio of Sugar to Water.*—The higher the sugar content of the mixture in relation to the water content at the time the sugar-water-stabilizer mixture is whipped, the greater the consistency of the fluffed product.

High-Flavored Maple Sirup

As stated earlier, the color and flavor of maple sirup result from a type of browning reaction that occurs between constituents of the maple sap during evaporation. Experiments have shown that all the potential flavor is not developed during the usual evaporation process. (*148*). To develop maximum flavor, the browning reaction must be carried further; that is, the sirup must be heated to a higher temperature and for a longer time.

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[8] Produced by Distillation Products Industry, Rochester, N.Y.

Unfortunately, high temperatures favor the formation of an acrid "caramel" flavor. The presence of large amounts of water favor caramel formation and the presence of some caramel in the initial sirup accelerates it (*90*). Therefore, only the two top grades of sirup—U.S. Grade AA (Fancy) or U.S. Grade A (No. 1)—should be used in making high-flavored maple sirup. It may be made by the atmospheric process (*149*), by the constant-volume pressure-cooking process (*139*),[9] or by the new continuous process.

High-flavored maple sirup made from U.S. Grade AA or U.S. Grade A sirup by either process will have a strong full-bodied flavor four to five times that of the sirup from which it was made, and it will be essentially free from caramel.

The high-flavored process does not concentrate the flavor; instead, it develops more maple flavor than present in the original sirup.

Atmospheric Process

In the atmospheric process the sirup is concentrated at atmospheric pressure by heating to a boiling temperature of 250° to 255° F. This reduces the water content of the sirup to approximately 10 percent. The sirup is held at this temperature for 1½ to 2 hours. It is then cooled, and water is added to replace that lost in evaporation so that the sirup is again of standard density.

Because of the low moisture content of the sirup during the cooking period, there is danger of scorching if it is heated in a kettle on a stove or other hot surface. It is recommended, therefore, that the high-flavoring process be conducted with high-pressure steam in a steam-jacketed kettle or in a kettle provided with a steam coil (chart 22).

The first step of the process—removing the water from the sirup—should be done as rapidly as possible. Steam pressure of from 30 to 100 pounds should be used. As soon as the sirup reaches a temperature of 252° F., the steam pressure is reduced until only enough heat is applied to maintain the sirup between 250° and 255°. Usually a steam pressure of 20 to 28 pounds is sufficient. A cover is placed over the kettle to prevent further loss of water through evaporation. The cover need not be airtight. Because of the high viscosity of the sirup, little water will be vaporized.

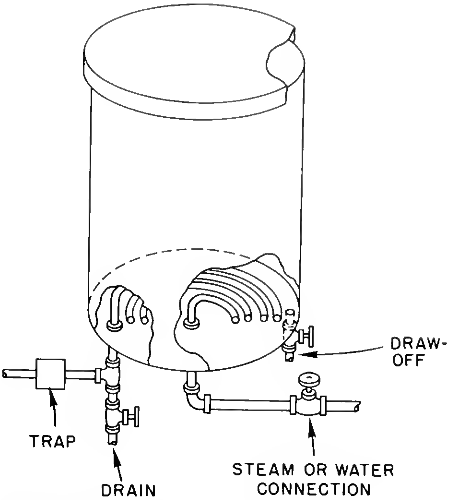

Chart 22.—Kettle with steam coil can be built in any tin shop. It is not as convenient to use as a tilting-jacketed kettle, but very satisfactory results can be had with it. Like the steam-jacketed kettle it must be operated with high-pressure steam and the condensed water must not be allowed to collect in the coils. Provision should be made for running cold water through the coils for cooling the sirup.

A thermometer calibrated in 1° intervals, with a range that includes 250° to 300° F., is kept in the sirup during the high-flavoring process. If the temperature of the sirup rises above 255° during the holding period, the steam pressure should be decreased. To prevent formation of crystals, the sirup should not be stirred or agitated during the high-flavoring process.

The end of the heating (cooking) period is best determined by odor. The cover is lifted, and a handful of steam is scooped up and brought toward the nose; heating is stopped as soon as an acrid caramel odor is detected in the steam. Care must be taken not to get a steam burn.

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[9] Described in U.S. Patent 2,054,873 issued to George S. Whitby on September 22, 1936. This patent has expired, and the process is now available for free use by the public.

Always bring the hand to the nose; do not bend over the kettle.

At the end of the cooking period, the thick, supersaturated sirup is cooled to 180° F. Approximately 3 pints of water is added for each gallon of sirup originally used to replace the water lost in evaporation and restore the sirup to standard density. Extreme caution must be exercised in adding the water because the water will be converted to steam with explosive violence if the sirup has not cooled to a temperature below the boiling point of water.

After addition of the water, the sirup is again brought to a boil and heating is continued until the temperature reaches that of standard-density sirup (7° F. above the boiling point of water).

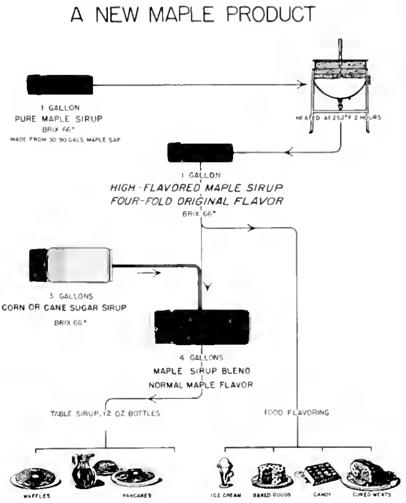
As flavor and color in sirup develop initially to the same degree, flavor development in the treated sirup may be measured indirectly by measuring the increase in its color. A sample of the high-flavored, standard-density sirup is weighed and then diluted with a colorless cane sugar sirup having a density of 66° Brix as measured with a hydrometer or refractometer. The colorless sirup is added slowly to the high-flavored sirup, with thorough stirring, until the mixture matches the color of the original maple sirup. Then the mixture is weighed. The increase in color and flavor is determined by the ratio,

$$\frac{\text{Weight of mixed sirup}}{\text{Weight of high-flavored sirup}} = \text{Increase in flavor}$$

This procedure can be used to follow the progress of the high-flavoring process, since different lots of sirup of the same grade develop flavor at slightly different rates. A sample is removed periodically from the cooking sirup and weighed. Enough water is added to restore the sample to standard density (66° Brix), and its increase in color and flavor is determined. The tests are easy to make; the 2-ounce French square bottle supplied with the U.S. color comparator (described on p. 89) is used. The high-flavor process and its end uses are shown in figure 121.

Pressure-Cooking Process

Many maple producers do not have high-pressure steam equipment. They may make high-flavored sirup by the pressure-cooking process (*139*). In this process, standard-density sirup is heated in a closed vessel, such as an autoclave or ordinary pressure cooker, at 15 pounds' pressure. Best results are obtained when the sirup is heated to a temperature of 250° to 253° F. as in the atmospheric process.



PN-4817

Figure 121.—A schematic drawing showing the high-flavoring process and its use in making blended sirup and as a food flavoring.

In the pressure-cooking process, the water content of the sirup is 34 percent during heating rather than 10 percent, as in the atmospheric process. The higher water content favors formation of caramel. However, the rate at which caramel forms depends on the original caramel content of the sirup. The higher the caramel content in the original sirup, the greater the amount formed in the product. Since the amount of caramel in sirup is related to the amount of color, only U.S. Grade AA (Fancy) or U.S. Grade A (No. 1) sirup should be used to make high-flavored sirup by the pressure-cooking process. Darker grades usually result in an unpalatable product.

The sirup is heated almost to boiling and immediately is transferred to jars, which are filled to within ½ inch of the top. The lids are set loosely in place, and the jars are placed in an autoclave or pressure cooker, which contains the amount of water specified by the manufacturer. The cover of the cooker is assembled, and steam is generated according to the manufacturer's directions. The sirup is heated at 15 pounds' pressure for approximately 1½ hours. Then the pressure is decreased slowly to zero without venting or quenching. The containers must not be jarred or the sirup may boil over.

Uses of High-Flavored Sirup

High-flavored sirup has a number of uses. Because it is richer in maple flavor, it is ideal for making maple products. It is especially desirable for use in making cream and candies. From 1 to 2 percent of invert sugar is formed in the high-flavoring process. This is the optimum amount to make perfect cream or soft sugar candies without the need of a "doctor." High-flavored, high-density maple sirup makes a superior topping for ice cream.

Only high-flavored sirup should be blended with other foods such as maple-flavored honey and crystalline honey spreads. Regular maple sirup usually does not have enough flavor to compete with or to break through the flavor of the food to which it is added. An inexpensive table sirup that has the full flavor of pure maple can be made by blending 1 part of high-flavored, standard-density sirup with 3 parts of cane sugar sirup that has a Brix value of 66°. Blended sirup must be properly labeled when offered for sale. The percentage of each ingredient must appear on the label, with the one in greater amount appearing first.

Crystalline Honey-Maple Spread

The development of a maple-flavored crystalline honey spread has produced a new farm outlet for both maple sirup and honey. This spread is made by mixing honey with high-flavored maple sirup (*81*). The maple flavor must be strong enough to break through the honey flavor and the sirup must contain a large amount of invert sugar. These requirements are met by converting U.S. Grade B (Vermont B or New York No. 2) sirup to high-flavored sirup as described earlier except that the sirup is heated to a temperature 19° or 20° F. above the boiling point of water. It is then cooled to 150° or lower, and 1½ to 2 ounces of the enzyme is added per gallon of sirup. The mixture is set aside at room temperature until the action has been completed, usually about 2 weeks. The sirup may have the appearance of soft sugar (*145*).

The high-flavored, high-density maple sirup is added to mild strained honey at the rate of 33 parts of maple sirup to 67 parts of honey by weight. The mixture is crystallized by the Dyce process (*21*) as follows: The honey-maple mixture is seeded with crystalline honey (available in most grocery stores) or with some honey-maple spread from a previous batch, at the rate of 1 ounce of seed to 1 quart of honey-maple mixture. After thorough stirring, the seeded mixture is held at 57° to 60° F. until crystallization is complete, usually 3 to 7 days. The resulting product is smooth, it has a barely perceptible grainy character, spreads well, and has a very pleasing flavor. This spread becomes liquid at temperatures above 85°. Therefore, it should be stored under refrigeration.

Maple sirup blends well with honey in making other honey-maple confections. Recipes for these can be obtained from Pennsylvania State University, University Park, Pa. 16802.

Other Maple Products

Rock Candy

Production of rock candy usually is unintentional. Although it should not be considered a product of maple sirup, this form of "maple sugar" is easy to make, as follows: When maple sirup is evaporated to a density between 67.5° and 70° Brix (heated to 8° F. above the boiling point of water), and the sirup 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 grow in size if the sirup is left undisturbed for a long time.

Hard Sugar

Because it is not easy to eat, hard sugar is not classified as a confection. Producers find there is a small demand for hard sugar since it offers a convenient form for the safe and stable storage of maple sirup. The hard sugar cake can be broken up and melted in water, and the solution can be boiled to bring it to sirup density. This sirup is called maple-sugar sirup to distinguish it from sirup made directly from sap.

Hard sugar is made by heating maple sirup to approximately 40° to 45° F. above the boiling point of water. As soon as the sirup reaches the desired temperature, it is removed from the heat and stirred. Stirring is continued until the sirup begins to crystallize and stiffen; then the semisolid sirup is poured into molds. If stirring is continued too long or if transfer of the sugar to the molds is delayed, the sugar will solidify in the cooking vessel.

In the past, hard sugar, often called maple "concrete," was the preferred form for holding commercial maple sirup in storage.

Granulated (Stirred) Sugar

Granulated (stirred) sugar is made by heating maple sirup to between 40° and 45° F. above the boiling point of water, as in making hard sugar. The hot, partly crystallized, thickened sirup is transferred from the kettle to a stirring trough, and it is stirred continuously until granulation is achieved. In the past, this form of maple sugar was made by stirring it in a hollowed log usually made from basswood (fig. 122).

Maple on Snow

Maple on snow is a favorite of guests at a maple-sirup camp. As in making stirred sugar, the sirup is heated to 22° to 40° F. above the boiling temperature of water. The final temperature within this range depends on individual preference. As soon as the sirup reaches the desired temperature, it is poured immediately, without stirring, on snow or ice. Because it cools so quickly, the supersaturated solution does not have a chance to crystallize; it forms a thin, glassy, taffylike sheet.

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Figure 122.—Stirred sugar, another popular item, while more easily made by stirring the sirup in a steam kettle, has often been made by stirring it in a hollowed-out basswood log with a wooden hoe.

Recipes for other maple confections can be obtained by writing to your State Department of Agriculture or your Extension Service.

Summary

Maple Sugar

(1) Converting maple sirup to maple sugar is not difficult. The only special equipment required for small-scale operations is a thermometer having an upper range of 250° to 300° F. calibrated in 1° units.

(2) Sirup that is saturated with sugar at one temperature will be supersaturated when cooled to another temperature.

(3) Supersaturated sugar solutions tend to regain their normal or saturated state by throwing the excess sugar out of solution. This precipitated sugar usually is in the form of crystals, and the amount formed depends on the degree of supersaturation.

(4) The size and number of crystals in the precipitated sugar depend on the degree of supersaturation, the rate of cooling the sirup, and the amount and time of stirring.

(5) Invert sugar, a product of sucrose, tends to retard the crystallization. Its presence in maple sirup is usually the result of fermentation of the sap. It influences the crystallization of maple sugar. Too much invert sugar may prevent crystallization of sugar from a supersaturated sirup. Too little will cause the maple sugar to be coarse and gritty.

Maple Cream or Butter

(1) Use a sirup low in invert sugar (0.5 to 2 percent). U.S. Grade AA (Fancy) or U.S. Grade A (No.1) usually meets these specifications.

(2) Test all sirup for invert sugar by the quick test. Do not use sirup that contains more than 4 percent of invert sugar.

(3) Heat the sirup to 22° or 24° F. above the boiling point of water.
(4) Cool the sirup rapidly to 50° F.
(5) Stir the thickened sirup continuously until creaming is completed.
(6) Freshly made cream can be packed immediately or it can be aged before packaging.
(7) Aged cream can be softened for pouring by heating to a temperature not exceeding 150° F.
(8) Store the cream under refrigeration.
(9) Causes of failure to cream:
    (a) If the sirup contains too little invert sugar or if it is not chilled sufficiently before stirring, the cream will have gritty texture.
    (b) If the sirup contains too much invert sugar, it will not cream (crystallize).

Fondant

(1) Prepare as for maple cream, except increase the boiling point of the sirup to 27° above that for water.
(2) Stir or beat the sirup as for maple cream.
(3) Place drops of the semisolid sugar on marble slab, waxed paper, or metal sheet—OR—
(4) Pour the semisolid sugar into rubber molds.

Soft Sugar Candies

(1) Use any of the top three grades of sirup.
(2) Heat the sirup to 32° F. above the boiling point of water.
(3) Cool the sirup slowly to 155° F.
(4) Stir the thickened sirup until enough crystals have formed to make a soft, plastic mass.
(5) Immediately pour or pack the soft sugar into molds—OR—
(6) Set it aside in a crock at room temperature for 24 to 48 hours.
(7) Concentrate an equal amount of sirup as before.
(8) As soon as the same elevation of boiling point (32° F.) is reached, add the hot concentrated sirup (bob) to the aged soft sugar.
(9) Stir only enough to mix and pour the semisolid sugar into the molds.

Crystal Coating

(1) Make crystallizing sirup from top grades of maple sirup.
(2) Concentrate the sirup to a density of 70° to 73° Brix by heating it to 9.5° or 11° F. above the boiling point of water (63.5° Brix hot test).
(3) Cool to room temperature.
(4) Keep the surface of the sirup covered with heavy paper, except when adding or removing the candies.
(5) Place the freshly made candies in the heavy sirup and leave them in the sirup 6 to 12 hours.
(6) Remove the candies and completely drain the sirup from them.
(7) Place the candies on paper-covered trays and turn each piece every hour until dry, or wipe with a damp sponge.
(8) Do not attempt to crystal coat candies during humid or rainy weather.
(9) Air dry at room temperature 4 to 7 days.

Maple Spread

(1) Use any of the three top grades of sirup.
(2) Heat the sirup to 10° or 11° F. above the boiling point of water (70° to 78° Brix).
(3) Cool the thick sirup to 150° or below and add 1½ ounces of invertase per gallon of sirup.
(4) Store at room temperature for 2 weeks. The resulting product is high-density sirup.
(5) "Seed" the high-density sirup with dextrose crystals from previous batches of spread or from crystallized honey. Use 1 teaspoonful per quart of sirup.
(6) Mix the seed thoroughly through the sirup and pour the mixture into the final package.
(7) Store at 55° to 60° F. Within a few days the dextrose crystals will grow to yield a plastic spread.

Fluffed Maple Product

(1) Can use lower grades of sirup.
(2) Heat the sirup to 17° F. above the boiling point of water.
(3) Cool with occasional stirring to 175° to 185° F.
(4) Add 1 percent (⅓ cup per gallon or 2 level teaspoonfuls per pint) of a purified monoglyceride (Myverol 18–00) slowly with stirring.
(5) Cool to 150° to 160° F., whip 2 minutes with a high-speed cake mixer.

High-Flavored Maple Sirup

Use either of the two top grades of sirup to make high-flavored maple sirup, and make it by either the atmospheric or the pressure-cooking process.

Atmospheric Process

(1) Concentrate the sirup by heating to 40° F. above the boiling point of water (250° to 255° F.). Process only in a steam kettle, jacketed or with coils.
(2) Hold the thickened sirup at the final temperature of concentration for 1½ to 2 hours.
(3) Cover the kettle and reduce the steam pressure to approximately 24 or 26 pounds per square inch—to keep the sirup at 252° to 255° F.
(4) Turn off the steam at the end of the processing period and cool the thick sirup to 180° F.
(5) Add water with caution and in small amounts until the sirup is restored to about standard density and reboil to 7° F. above the boiling point of water.

Pressure-Cooking Process

(1) Heat the sirup almost to boiling temperature (210° to 215° F.).
(2) Transfer to containers to fit the cooker (usually 1- or 2-quart jars).
(3) Place the lids on the containers loosely, and put them in the cooker.
(4) Add water to the cooker according to the manufacturer's directions and secure the cooker lid.
(5) Bring the steam pressure in the cooker to 15 pounds per square inch. Hold at this pressure for 1½ hours.
(6) Allow the pressure to fall slowly; do not vent or quench.
(7) When the pressure has fallen to zero, open the cooker and remove the high-flavored sirup.

Crystalline Honey-Maple Spread

(1) Use U.S. Grade B, Vermont B, or New York No. 2. sirup.
(2) Heat the sirup to 19° or 20° F. above the boiling point of water (80° Brix).
(3) Cool the thick sirup to below 150° F. and add 1½ to 2 ounces of invertase per gallon of sirup.
(4) Store at room temperature for 2 weeks to produce a high-density sirup.
(5) Mix thoroughly one part of the high-density sirup to two parts of mild flavored honey.
(6) Add seed (dextrose crystals) at the rate of 1 teaspoonful per gallon of mixture. Use a previous batch of honey-maple spread or crystalline honey as seed.
(7) Hold the seeded mix at 60° F. until the dextrose crystals grow to produce a semifluid plastic (from 3 to 7 days).
(8) Store under refrigeration.

Rock Candy

(1) Use one of the top grades of maple sirup.
(2) Heat the sirup to 8° F. above the boiling point of water (67.5° to 70° Brix).
(3) Store several months at or below room temperature.

Hard Sugar

(1) Use any grade of sirup.
(2) Heat the sirup to between 40° and 45° F. above the boiling point of water.
(3) Remove from the heat and begin stirring the hot, thick sirup immediately.
(4) Continue stirring until crystals form (sirup begins to stiffen).
(5) Pour the partly crystallized sirup into molds to harden.

Granulated (Stirred) Sugar

(1) Use a top grade of sirup.
(2) Heat the sirup to between 40° to 45° F. above the boiling point of water.
(3) Pour the hot sirup immediately into a tray or trough for stirring.
(4) Begin stirring immediately and continue stirring until granulation is completed.

Maple on Snow

(1) Use the top grades of sirup.
(2) Heat the sirup to between 22° and 40° F. above the boiling point of water.
(3) Without stirring, pour the sirup immediately onto the snow or ice; it will form a glassy, taffylike sheet of candy.

TESTING MAPLE SIRUP FOR INVERT SUGAR

The relation between the invert sugar content of maple sirup and its suitability for making maple cream is as follows:

Invert sugar content of sirup (percent)	*Suitability for cream*
0.5 to 2	The right amount of invert sugar for making a fine-textured cream—one that feels smooth to the tongue.
2 to 4	Can be made into cream if sirup is cooked until it is 2° to 4° F. hotter than temperature called for in standard recipes for cream.
4 or more	Not suitable for cream. If used, sucrose will not crystallize, or it will crystallize only if sirup is heated to a much higher-than-standard temperature. Such cream will be too fluid and probably will separate a few days after it is made.

Two tests are available for determining the invert sugar content of maple sirup. The simple, or short-cut, test merely shows whether the sirup contains less than 2 percent of invert sugar and is therefore suitable for creaming. The other is a quantitative test. It measures invert sugar in amounts up to 7 percent, the upper limit normally found in maple sirup.

Simple Test

The simple test for determining the invert sugar content of maple sirup has been adapted from a standard test for determining the sugar in urine (*78*, *80*). The test is made by first preparing a sirup-water mixture (1 part of sirup to 20 parts of water) and then color testing the diluted sirup. It can be made in 3 or 4 minutes.

Equipment

The few pieces of equipment required to make the tests can be obtained from the local pharmacy. The following items are required:

(1) Clinitest tablets[10] obtainable at 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 sirup to be tested (1 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) One "Clinitest" color scale.

(11) Water (20 fluid ounces).

Making the Test

(1) Carefully pour enough of the test sirup into a medicine glass to bring the level of the sirup exactly to the 1-ounce (2 tablespoons) mark. If too much (more than 1 ounce) is added, empty the sirup 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 solution by pouring the fluid ounce of sirup into the jar containing the 2½ cups (20 fluid ounces) of water.

(4) Pour some of the water-sirup mixture into the medicine glass and return it to the jar. Repeat this three or four times to be sure that all the sirup 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 ¾ inch deep.)

(6) Fill a clean, dry medicine dropper with the diluted (1:20) sirup in the fruit jar. Hold the dropper upright above the test tube and let 5 drops of the diluted sirup 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.

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[10] Trademark. This product is one of several that may be used by diabetics in testing for sugar in urine.

(9) Fifteen seconds after the boiling stops, add water to the test tube until it is two-thirds filled.

(10) Observe the color of the solution and compare it with the two colors marked + and − of the color scale furnished with the Clinitest tablets. Disregard everything else on the scale card. The other colors and the labels on the scale card have no relation to this test. Make the color comparison in a room illuminated with an incandescent bulb. The colors are not easily judged by fluorescent or direct sunlight.

Interpreting the Results

Color of Solution in Test Tube.—Blue indicates a negative test; the sirup contains less than 2 percent of invert sugar and can be used to make cream. Yellow or yellow green indicates a positive test; the sirup contains more than 3 percent of invert sugar and is not suitable for making cream.

Quantitative Test

The quantitative test is much longer than the simple test; it requires about 15 minutes.

Preparing the Sirup-Water Mixtures

For this step, you will need sirup, 15 quarts of water, measuring cup, quart measure, pail or other large container, long-handled spoon, small spoon, and five 4-ounce drinking glasses. The glasses should be thoroughly dry. You will also need a pencil and labels.

Stir thoroughly the sirup to be tested. Then fill the measuring cup exactly to the 1-cup mark with sirup.

Dilute this sirup with five successive additions of water, as follows:

1-and-12 Dilution (1 cup of sirup and 12 cups of water).—Pour 2 measured quarts (8 cups) of water into the pail. Pour the cupful of sirup into the pail; let the cup drain until most of the sirup is out of the cup.

Measure a third quart (4 cups) of water and use this to rinse the remaining sirup from the cup; fill the cup with water, stir with a small spoon, and pour into the pail until the quart of water is used.

Stir the sirup and water in the pail until it is thoroughly mixed.

Dip one 4-ounce glass into the dilute sirup and withdraw half a glassful.

Label the glass "12" and set it aside.

1-and-20 Dilution.—To the dilute sirup in the pail, add 2 measured quarts (8 cups) of water.

Stir the contents of the pail until well mixed. Remove half a glassful and label it "20."

1-and-32 Dilution.—Add 3 measured quarts (12 cups) of water to the mixing pail. Stir contents until well mixed. Remove half a glassful and label it "32."

1-and-40 Dilution.—Add 2 measured quarts (8 cups) of water to the pail. Stir contents until well mixed. Remove half a glassful and label it "40."

1-and-60 Dilution.—Add 5 measured quarts (20 cups) of water to the pail. Stir contents until well mixed. Remove half a glassful and label it "60."

Color Testing the Dilutions

For this step you will need the labeled samples of the five dilutions, test tube holder for five tubes, five test tubes, six medicine droppers, Clinitest tablets and color scale, a small amount of water, and pencil and paper.

Make the color test as follows:

(1) Place five of the test tubes in the test tube holder.

(2) Fill a clean, dry medicine dropper with the diluted sirup from the glass labeled "60." Hold this dropper upright above the test tube in the hole marked "60" and let *exactly* five drops of the diluted sirup fall into the test tube.

Similarly, place exactly five drops of the "40" dilution, five drops of the "32" dilution, five drops of the "20" dilution, and five drops of the "12" dilution in the tubes numbered for these dilutions (see fig. 123). Use a separate, clean, dry medicine dropper for each dilution.

(3) Fill another clean medicine dropper with water and add 10 drops of water to each of the five test tubes, refilling the medicine dropper as necessary.

(4) Remove five Clinitest tablets from the bottle or wrapper. Place them on a clean piece of paper.

(5) Place one tablet in each test tube, in order, starting with the tube marked "60."

The tablets, as they dissolve, cause the contents of the tubes to boil. Do not move the test tubes while the solutions are boiling.

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Figure 123.—Testing sirup for invert sugar.

(6) Fifteen seconds after the boiling stops, add water to the test tube marked "60" until the tube is two-thirds full. Add the same amount of water to the other four test tubes, in order, from right to left.

(7) Compare the colors in the test tubes with the two colors of the color scale marked "trace" and "+". Disregard everything else on the scale; the other colors and the labels on all the colors have no relation to this test.

Make this comparison in a room lighted with an incandescent bulb. You cannot judge the colors of the solutions for this test with fluorescent light or with sunlight only.

Assign to the mixture in each tube one of three values—positive (+) for invert sugar, negative (−) for invert sugar, or doubtful (±) according to the following standard:

Color of solution	*Value*
Same as or more blue than color on scale labeled "trace"	Negative (−)
Same as or more yellow than color on scale labeled "+"	Positive (+)
Between "trace" and "+" colors on scale	Doubtful (±)

Write down in order the values you have given the five dilutions, starting with the 1-and-12 dilution at the left.

Special Note.—If the first sirup you test proves positive in some dilutions and negative in others, you will quickly see the difference between a positive and a negative color reaction.

It is possible, however, that the sirup you test will give a positive or a negative test in all dilutions. If this happens and you are doubtful about your interpretation of the results, it will be helpful to have a solution that you know will give a positive test.

To prepare such a solution, add three drops of corn sirup to the 4-ounce glass containing the sample of the 1-and-60 dilution. Stir the corn sirup into the dilute sirup.

In a clean test tube place five drops of this solution. Add 10 drops of water, then one Clinitest tablet. After boiling has stopped add water until the test tube is two-thirds full.

The color that develops will indicate a positive reaction.

Determining Invert Sugar Content of Sirup

To find the invert sugar content of the sirup you are testing, find the line in table 17 that contains the same combination of values for the five dilutions that you obtained in the color test.

As the table shows, the sirups that are most suitable for making into cream are those that are negative in all dilutions or positive in the first (1-and-12) dilution and negative in all the others.

Summary

(1) Test the sirup for its invert sugar content before attempting to make maple cream.

(2) Use the simple or shortcut test, page 113.

(3) To check the color, positive or negative, use a test solution consisting of the 1- and 60-solution to which is added corn sirup, page 115. This will give a positive test.

(4) Sirup containing more than 3 percent of invert sugar is unsuitable for creaming.

TABLE 17.—*Key for interpreting results of color test for invert sugar content of five dilutions of maple sirup*

[− indicates negative reaction; + indicates positive reaction; ± indicates doubtful reaction]

Reactions for 5 test dilutions					Invert-sugar content of sirup	Suitability of sirup for making into cream
12	20	32	40	60		
					Percent	
−	−	−	−	−	Less than 2	Suitable.
+	−	−	−	−	More than 2, less than 3	Suitable.
+	±	−	−	−	More than 2, less than 4	Suitable if sirup is heated 2 to 4 degrees higher than usual in creammaking.
+	+	−	−	−	More than 3, less than 4	Not suitable.
+	+	±	−	−	More than 3, less than 5	Not suitable.
+	+	+	−	−	More than 4, less than 5	Not suitable.
+	+	+	±	−	More than 4, less than 6	Not suitable.
+	+	+	+	−	More than 5, less than 6	Not suitable.
+	+	+	+	±	More than 5, less than 7	Not suitable.
+	+	+	+	+	Above 6, may be 7 or more	Not suitable.

THE CENTRAL EVAPORATOR PLANT

Before 1955 no market existed for maple sap. The sap crop had to be converted to sirup or some other product on the farm where it was produced before it became marketable. Maple sap, therefore, occupied a unique position in American agriculture because all other farm crops are marketable as produced.

This practice contributed little toward developing the maple industry or toward modernizing sap production to make it competitive with dairying, stock raising, or grain farming.

The current trend toward central evaporator plants (figs. 124 and 125) has marked a new era in the maple industry. No longer do all sap producers have to be skilled sirupmakers; instead, the central plants are operated by and staffed with specialists not only in sirupmaking but also in marketing. Other advantages offered by the central evaporator plants are:

(1) The central plant eliminates the former duplication on each farm of invested capital for evaporator and related equipment and for an evaporator house.

(2) The farm plant often was too small to be operated economically and was wasteful of labor. A small evaporator having an output capacity of 1 to 5 gallons of sirup per hour requires as many man-hours for its operation as does the central evaporator plant that produces 15 or more gallons of sirup per hour.

(3) Thousands of farmers with stands of maple trees that they had not previously used for sap-sirup production now find it practical and economical to produce and sell a sap crop.

(4) A more uniform and better quality product can be produced in a central plant. This tends to stabilize the market.

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Figure 124.—This central evaporator plant at Ogema, Wis., has one evaporator.

PN–4821

Figure 125.—A large central evaporator plant located at Anawa, Wis. Some plants are large enough to make 20 or more gallons of sirup per hour.

Location

The site for a central plant should be carefully chosen. Some of the factors to be considered are:

(1) It should be centrally located in relation to the sap-producing farms.

(2) It should be on an improved road, preferably at an intersection. The road should bear considerable nonlocal traffic.

(3) It should have adequate space for driveways for delivery of sap.

(4) It should have an access roadway from the main road and off-road parking areas for visitors (customers).

Size

Like other industries, the size of the central evaporator plant will be governed by a number of factors that can readily be determined. Unlike other industries, the central plant can easily be expanded to accommodate increased demands because of the relative simplicity of equipment and plant design.

The initial plant must be large enough so that the volume of sirup produced will yield reasonable returns on the invested capital and so that labor will be used economically. These two factors will be determined by the cost of the sap, the number of hours per day the plant is operated and the length of the season, the number of man-hours required to operate the plant, the output, and the price of the finished product. These factors, in turn, depend on the size of the evaporators, the density (° Brix) of the sap, and the efficiency of the plant.

Since the plant handles liquids (sap and sirup), it can be completely automated. The extent of automation will be governed by the size of the plant and the budget. The cost of producing a gallon of sirup decreases as plant size increases.

Design

An evaporator plant building of shed roof design permits easy expansion. The shed roof building can be doubled in size by adding three walls to convert it to a gabled roof building. The building must be large enough to permit easy access to the evaporators and other equipment. The materials should be easy to clean, such as concrete floors, smooth walls, and built-in cupboards and restrooms. Provision should be made for a candy kitchen and a salesroom.

The most common type of central evaporator plant uses oil heat to evaporate the sap in flue pans, each of which is independently installed on its own arch with its own oil burner (see p. 59). A coil or tube of high-pressure steam is used to heat the finishing pan, which is also mounted on its own support (fig. 126 and chart 23).

PN–4822

Figure 126.—Interior of a modern central evaporator plant at Bainbridge, N.Y. Oil heat is used to evaporate the sap in the four flue pans and high-pressure steam is used at the finishing stage.

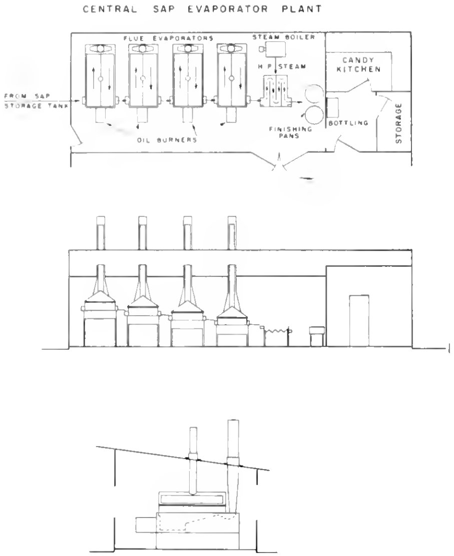

Chart 23.—Flow diagram: Oil-and-steam plant.

Coal is used in some areas, particularly where it is cheap. It is best used to generate high-pressure steam which, in turn, is used to evaporate the sap (fig. 127).

As with oil-fired evaporators, a series of pans is used. These pans, like the oil-fired pans, are mounted stepwise, as shown in figure 128. The pans are heated with 80 to 110 p.s.i.g. steam in coils or manifolds of 3/4-inch brass tubing mounted at the bottom of the flat pans.

The specifications for a small plant (about 8,800 gal. per season) described by Pasto and Taylor (*86*) are as follows:

Item	Density of sap at—	
	1.6° Brix	2.4° Brix
Sap .... gallons per hour	807	815
Water evaporated .... do	792	792
Sirup produced .... do	14.7	22.2
Tapholes .... number	32,000	32,000
Fuel consumption .... gallons	23,800	23,800
Capital investment .... dollars	25,291	25,291
Floorspace .... square feet	1,226	1,226
Sap storage .... gallons	20,000	20,000

Capital investment and cost for depreciation and repairs for a small plant, as reported by Pasto and Taylor (*86*), are given in table 18.

Smaller plants are in operation and are proving highly successful. Usually these plants are small initially, but they are built so that they can be enlarged after 2 or 3 years' operation. Typical of these is the central evaporator plant established in 1962 at Ogema, Wis. (fig. 124). This plant has one 6- x 20-foot evaporator and a separate finishing pan. Sap is supplied from 9,500 tapholes on 16 farms.

Operation

The sap supplied to the evaporator from the storage tanks is fed to the first flue pan. Since the flue pans are connected in series, the sap flows successively through each pan to the next. The sap is conducted between pans through large-diameter, heat-resistant tubes or pipe at least 1½ inches in diameter. The pans can be installed in a stepwise manner to insure no backward flow of sap from pans of higher concentration to pans of lower concentration and to better control the depth of the liquid level in each pan. Since the elevation between pans is only 6 to 8 inches, there is only a small hydrostatic pressure in each interconnecting feed line. Feed lines and valves must be large enough to supply sap to the pans rapidly enough under this low pressure to replace the vast quantities of water being removed by evaporation.

The liquid level in the evaporator pans is maintained at a fixed depth by means of a mechanical float valve or by an electrically operated liquid level sensing element and solenoid valve. Whichever mechanism is used, it must be sensitive to minute changes in liquid level and must operate instantaneously. In principle, when the finishing pan requires more liquid to maintain its depth of sap, the sap is obtained from the third pan of a 3-flue pan installation, which in turn obtains more sap from the second pan, and so on back to the storage tank. The sirup is removed from the finishing pan when it reaches standard density (66.0° Brix) or slightly higher.

The operation can be automated by use of a thermoswitch and solenoid valve. The thermoswitch is adjusted to open the valve when the boiling sirup reaches the desired temperature above that for boiling water at that location. The operation is not completely automatic, since the thermoswitch must be handset as many as three or four times a day to compensate for fluctuations in barometric pressure. The U.S. Department of Agriculture has developed a new controller that will automatically compensate for changes in the boiling point of water due to changes in barometric pressure (*15*).

PN-4823

Figure 127.—Where coal is inexpensive, high-pressure steam boilers may be used to evaporate sap to sirup.

PN-4824

Figure 128.—Interior of a multiple-pan, all-steam central evaporator plant at Stoystown, Pa.

In some installations, the partly concentrated sirup is not supplied to the finishing pan by gravity feed. Instead, an electric pump, activated by an electrically operated liquid level sensing device in the finishing pan, removes the sap from the last flue pan or semifinishing pan when it reaches the desired concentration—any point between 20° and 60° Brix.

If the Brix value of the sirup supplied to the finishing pan is above 50°, essentially all of the sugar sand will have been formed and will be in suspension. Its viscosity will be very low (see table 13). It is advantageously filtered at this point. The filtered sirup is then pumped into the finishing pan. When it reaches the desired density, it is automatically drawn by means of solenoid valves and thermoswitch, and piped to the holding or canning supply tank. With this procedure, little or no sugar sand is formed in the finishing pan. A cartridge-type filter can be installed in this line to polish the sirup (that is, remove the cloudlike precipitated sugar sand). If the sirup is not prefiltered, it can be piped from the finishing pan to a pressure filter such as a plate-and-frame type and then to the holding tank. Either method is desirable, since once the sirup reaches standard density, it is kept in a closed system so that it cannot evaporate further.

To reduce holdup time, it is good practice to keep the liquid level as low as possible in each evaporator. There is, of course, always a danger that because of some failure, insufficient liquid will be fed to each pan and the pan will be ruined by burning. This can be prevented by connecting a hose to the raw-sap feed line by which sap can be added quickly to any location in any one of the pans.

Although a gas-fired finishing pan is satisfactory for smaller plants, it is advisable to use high-pressure steam for the finishing pan in plants that make as much as 15 gallons of sirup per hour. The steam permits finishing the sirup without danger of burning it. The steam is best supplied from an automatically operated, high-pressure boiler (80 to 110 p.s.i. and a rated horsepower of 20 or more).

If no prefiltration or inline cartridge filters are used, the finished sirup can be efficiently and economically filtered immediately after it is drawn from the evaporator. A battery of three or more open, flat, felt filters should be used. Allowance must be made for loss of water as steam while the sirup is being filtered. This loss tends to raise the Brix value of the sirup approximately 1°.

Sap Suppliers

Sap can be obtained in any one of three ways: (1) It can be obtained from rented trees; (2) it

TABLE 18.—*Capital investment in plant and equipment and cost of depreciation and repairs for small oil-and-steam type plant* [1]

Item	Cost	Life length	Yearly depreciation	Yearly repairs
	Dollars	*Years*	*Dollars*	*Dollars*
Land (1 acre at $200)	200.00			
Roadway, ramps, grading	500.00	20	22.50	15.00
Building (1,226 sq. ft. at $4 per sq. ft.)	4,904.00	30	147.12	147.12
Equipment and other items:				
Sap-receiving tanks (19,495 gal. at $0.083 per gal.)	1,618.08	20	72.81	48.54
Germicidal lamps for sap receiving tanks (12 at $25)	300.00	10	27.00	9.00
Pump for sap	150.00	10	13.50	4.50
Sap filter	50.00	10	4.50	1.50
Flue-type sap evaporators (4 at $650)	2,600.00	10	189.00	63.00
Arches for sap evaporators (4 at $287)	1,148.00	10	103.32	34.44
Covers and stacks for sap evaporators (4 at $160)	640.00	10	57.60	19.20
Steam semifinishing evaporator, size 5 x 6 ft	138.00	10	12.42	4.14
Cover and stack for semifinishing evaporator	108.00	10	9.72	3.24
Steam finishing evaporators and coils (2 at $100)	200.00	10	18.00	6.00
Hoods and stacks for finishing evaporators	100.00	10	9.00	3.00
Float valves (5 at $5)	25.00	10	2.25	.75
Oil burners (4 at $332)	1,328.00	10	119.52	39.84
Smokestacks (4 base stacks at $31; 4 top stacks at $57)	352.00	10	31.68	10.56
Finishing filter (2 at $14.70) pressure cartridge	29.40	10	2.29	.76
Finished sirup holding tank with heating device	75.00	10	6.75	2.25
Finshed sirup storage tank (3,940 gal. at $0.25 per gal.)	985.00	20	44.32	29.55
Steam boiler (20 h.p.), installed	1,485.00	20	201.83	134.55
Oil tank (8,000 gal.)	1,000.00	20	45.00	30.00
Automatic sirup drawoff	100.00	10	9.00	3.00
Gravity filter	140.00	10	12.60	4.20
Pumps and motors to filter and to finishing evaporators (2 units at $75)	150.00	10	13.50	4.50
Can filling equipment	50.00	10	4.50	1.50
Thermometers (2 at $50)	100.00	10	9.00	3.00
Testing equipment (refractometer, $100; hydrometer, $48; scales, $150; thermometers, $10)	308.00	10	27.72	9.24
Portable power-stirring device	300.00	10	27.00	9.00
Water supply (well) plumbing, sink	1,000.00	20	45.00	30.00
Restroom furnishings	500.00	30	15.00	15.00
Office equipment	500.00	10	45.00	15.00
Other installation charges (burners, tanks, pumps, etc., besides cost of equipment)	912.00	10	82.08	27.36
Miscellaneous	800.00	10	72.00	24.00
Total	25,791.48		1,502.53	752.74

[1] About 8,800 gal. per year. 1962 dollars.

Source: Pasto and Taylor (*86*).

can be picked up at the farm; or (3) it can be delivered to the plant (figs. 129 and 130).

The quality of sap is not easy to judge by visual inspection. But the buyer must guard against purchasing spoiled or unsound sap, since a small amount could contaminate a large amount of sound sap when added to it. The plant operator must therefore exercise some control over the production of sap by the sap suppliers. He therefore should set certain minimum standards.

Production Standards for Sap Collected in Buckets

(1) All buckets must be covered.

(2) Buckets must be clean and sanitized before use.

(3) In midseason or after a warm period, buckets must be washed again.

(4) Collecting buckets and tanks must be kept clean and sanitized.

(5) Sap (even a very small amount) that has remained in buckets between runs must be discarded.

Production Standards for Sap Collected in Plastic Tubing

(1) Only clean tubing must be installed.

(2) All collecting or venting equipment must be washed and sanitized.

Standards for Storage Tanks on Sap Farms

(1) All tanks must be washed and sanitized before the start of the sap season.

(2) Tanks must be completely emptied, washed, and sanitized at least twice each season and preferably between each run of sap. Production of a darker grade of sirup indicates that the tank needs washing and sanitizing.

(3) Tanks should be covered with clear, transparent plastic that transmits the sanitizing ultraviolet radiation of sunlight.

(4) Tanks must be constructed with smooth, easily cleaned surfaces.

Metal tanks best meet the requirements.

PN-4825

Figure 129.—Sap is delivered to a central evaporator plant in a variety of vehicles. These vehicles are waiting to unload.

PN-4826

Figure 130.—Sap is delivered in all types of containers (including milk cans) and by every available type of conveyance ranging from the trunks of passenger cars to trailers drawn by farm tractors.

Purchase of Sap

Sap is bought on the basis of the total weight of solids (sugar) it contains. It is necessary to measure with precision the volume of the sap to the nearest gallon, its density to the nearest 0.1° Brix, and its temperature to the nearest ° F.

The volume of sap can be determined in several ways, as follows:

(1) By means of a meter through which the sap can be pumped or can flow by gravity. This is the most precise and direct method, provided the meter is calibrated carefully and is checked frequently. Be sure the meter is designed for operation at low pressures.

(2) By use of tanks of standard sizes calibrated in gallons for different depths of liquid. The calibrations are usually made on a "dip stick" calibrated for a specific tank size. The stick is lowered vertically to the bottom of the tank and the height of the sap in the tank is noted by the wet line on the stick. This line indicates the depth and volume of the sap. Usually, when sap is delivered to the plant, it is run into a receiving tank that can be calibrated precisely. The calibrations should be accurate to ± 1 gallon.

(3) By its weight. The tank of sap is weighed before and after emptying. The empty (tare) weight is subtracted from the weight of the tank and sap to obtain the weight of sap. The weight of sap is divided by 8.39 (the weight of 1 gallon of sap).

The only tangible constituent of sap that can be used to establish its price is its solids content, which is measured and expressed as ° Brix. This measurement is made at the plant by using a quart sample taken when the sap was picked up at the farm or when it was delivered to the central plant (fig. 131). The sample identified with supplier's name and date can be stored a few hours before determining its Brix value. Or its Brix value can be determined at the time the sap is picked up or delivered provided its temperature is also determined at that time.

The observed Brix value of the sap is the value read to the nearest 0.1° from the test instrument (hydrometer or refractometer); this value, together with the measured temperature of the sap, is recorded. From these, the true Brix value of the sap is calculated.

Corrections to be applied to the observed Brix value to obtain the true Brix value of saps of various temperatures are as follows:

Temperature of sap, °F.	*Correction to subtract from observed Brix value (° Brix)*
32–42	0.4
43–53	.3
54–62	.2
63–66	.1

The value of sap is not constant but varies with its solids content (percentage of sugar), or Brix value. The higher the Brix value, the smaller the amount of sap required to produce 1 gallon of sirup. Less water has to be evaporated, less volume is handled, and less storage space is required. Sap with the highest Brix reading therefore has the highest value.

The base price for sap is usually for sap of 2° Brix. This base price is determined by a number of factors, the most important of which is the price of the finished sirup. For sirup selling at $9 to $12 a gallon, one New York producer reported in the National Maple Syrup Digest (*1*) the following prices paid for sap delivered at the evaporator plant in 1974. The prices can be adjusted up or down by such factors as efficiency of the plant, hours of operation, and wage scales.

True Brix value of sap [1]	*Price per gallon (cents)*
1.5°	2.9
1.6°	3.9
1.7°	4.9
1.8°	5.8
1.9°	6.6
2.0°	7.3
2.1°	7.9
2.2°	8.5
2.3°	9.1
2.4°	9.7
2.5°	10.2
2.6°	10.7
2.7°	11.2
2.8°	11.7
2.9°	12.2
3.0°	12.7
3.1°	13.2
3.2°	13.7
3.3°	14.2
3.4°	14.7
3.5°	15.2
3.6°	15.7
3.7°	16.2
3.8°	16.7
3.9	17.2
4.0°	17.7

[1] True Brix value is the observed Brix reading corrected for temperature.

Storing Sap

The central evaporator plant must provide facilities to store a full day's production of sap. There is no precise means for estimating the size. However, experience has shown that on days when sap flows well, from 4,000 to 20,000 gallons will be produced per 10,000 tapholes. Thus, a plant having a capacity of 8,800 gallons

PN-4827

Figure 131.—A sample of sap is taken for determining its Brix value and for judging its quality. The observed Brix value, temperature, and volume of the sap are recorded for each delivery.

of sirup annually would require sap from 10,000 to 35,000 tapholes, or 70,000 gallons of sap per day. Since the plant would be operating continuously after the first delivery of sap, the required storage facilities would be somewhat less than the daily requirement of sap.

Storage tanks can be made of several materials and in several shapes. Metal-lined tanks are preferred because their surfaces are smooth, easily cleaned, and sanitary. Concrete tanks are the most difficult to keep clean because droplets of sap, in which micro-organisms can grow, can lodge in the rough surfaces. Concrete walls can be made smooth with different types of coatings; however, before the walls are coated, clearance for the use of the particular coating should be obtained from State and Federal food agencies. Plastic tank liners also have been used successfully, especially in wooden tanks.

The storage tanks should be located in a cool place. Aboveground storage is preferable because of ease in making repairs and cleaning. All tanks must be covered. If the tanks are not equipped with germicidal lamps, they should have transparent plastic covers and should be located to receive as much sunlight as possible.

Because of the depth of the sap in the tanks, the efficiency of daylight sterilization is low. It is recommended that germicidal lamps be used. One or more lamps should be arranged to illuminate the entire surface of the sap. The lamp fixture should be provided with a bright metal reflector so that most of the ultraviolet radiation will be used. These lamps are also effective in sanitizing empty or partly empty tanks, provided no buildup of foam or solids has occurred on the tank walls.

CAUTION

Care must be exercised not to expose the eyes to direct ultraviolet radiation. Always turn the lamps off when the tanks are cleaned or when they are opened for entering or for inspection. Ultraviolet rays can do irreparable damage to the eyes.

The receiving tank (fig. 132) should be placed alongside a ramp so that the sap in the hauling tanks can be emptied into it by gravity. In some localities it is possible to have the receiving tanks installed higher than the storage tanks so that they also can be filled by gravity.

PN-4828

Figure 132.—The sap is filtered as it is run into the receiving tank.

However, the more common method is to move sap from the receiving tanks to the storage tanks by pumps.

Sap obtained from pipelines is usually free of foreign matter and does not need to be filtered. However, sap obtained by other collecting methods must be filtered to remove fine particles of bark and other foreign matter from the sap. If not removed, this foreign matter may serve as an unwanted source of color and cause the production of dark, low-grade sirup. The filter may be either a presscloth prefilter or several thicknesses of muslin (fig. 133).

It is desirable to use two or more sap-storage tanks. This permits better control of sanitation, plant operation, and production records. The Brix value of the sap in each tank must be determined since it may be a composite of sap obtained from two or more sources that may be of different sugar contents. If the volume of sap in the tank and its Brix value are known, the yield of finished sirup can be calculated (see p. 48).

The evaporator house must be provided with a gage to show the volume of sap in the storage tank being used to supply sap to the evaporator. Without a gage, the plant operator may unexpectedly find the supply of sap exhausted, and the evaporator pans may go dry and be damaged by burning. A simple type of gage can be installed in the sap feed line from the tank to the evaporator. This gage consists of a tee with a long, upright, glass sight tube, the top of which is open and above the level of the top of the storage tank. The level of the sap in the tube indicates its depth in the storage tank. The tube can be calibrated in units such as full, 1/2-full, etc., or in gallons.

PN-4829

Figure 133.—Several layers of muslin or presscloth can be used to filter sap.

Handling and Storing Sirup

Sirup tends to become darker each time it is heated above 180° F. Therefore, sirup should be reheated as few times as possible. To insure a sterile package, all sirup must be packaged at temperatures above 190°. It is advisable to package the sirup immediately after it leaves the filter or the finishing pan while it is still above 190°. If the temperature of the sirup drops below 190° before it can be packaged, a small amount of heat furnished by a steam coil with high-pressure steam, an electric immersion heater, or a heat lamp will bring it back to the desired 190° with a minimum of darkening.

Sirup not immediately packaged can be put in bulk storage. If it is stored in drums, they must be completely filled with hot sirup (190° F.). Large tanks holding several hundred or several thousand gallons can be used. Sirup storage tanks, like sap storage tanks, should be provided with germicidal lamps mounted to illuminate the entire surface of the sirup when the tank is filled. These lamps must be kept in operation continuously from the time the tanks are cleaned prior to filling until the last of the stored sirup has been removed. If the sirup is run into these tanks hot and sterile, there is little chance that any microbial growth will occur below the sirup surface, and the germicidal lamps will keep the surface sterile. Sirup stored in this way can be held indefinitely and sirup can be added or withdrawn at any time. It is not necessary to keep the tank cool. Tanks with sterile lamps can be mounted outside, for the ambient temperature has little or no effect on keeping quality of the sirup. The sirup withdrawn for packaging must be heated to sirup-pasteurizing temperature (190° F.).

The large storage tank also serves as a settling tank. After several weeks of storage, the sirup will be sparkling clear.

Sanitation

The central evaporating plant is a food processing plant. It must be maintained in the same clean and sanitary manner that is required of all food plants.

The evaporator room and any other rooms in the plant should be kept free of steam. Moist surfaces are sites for microbial growth. Steam is easily removed from the evaporators by using the closed venting system described on page 40.

The floors should be constructed of smooth masonry for ease of cleaning.

The sirup should be packaged in a separate room or area that can be kept clean and free of dust. Clean all equipment at frequent intervals. When detergents and scale-removing chemicals are used, they must be completely removed by at least three successive rinses with clean, clear water.

Only clean utensils should be used and instruments should be kept free of sugar sand.

Economics

The central evaporator plant is primarily for concentrating sap to sirup and for filtering and packaging sirup. When used for this, it will be operated only 6 to 8 weeks a year. Yet even with this short period of use, Pasto and Taylor (*86*) found in 1962 that such a plant could pay an excellent return on the invested capital. The following calculations, based on Pasto and Taylor's data, show how profitable such an operation could have been at that time. By recalculating, using current costs and prices, one could determine whether the return to be expected would be higher or lower than that shown here.

Returns on capital investment in small central evaporator plant used only for processing sap and filtering and packaging sirup[1]

A. Investment in plant and equipment[2]	$25,291
Costs (operating):	
B. Fixed (management, interest on borrowed capital, depreciation, repairs, insurance, property taxes)[3]	6,277
Variable:	
C. Sap supplies (322,292 gal. (2.4° Brix) at $0.052 per gal.)[4]	16,759
D. Fuel (26,136 gal. oil at $0.15)	3,920
E. Labor (supervisor plus hourly wages at $1.50 per hour)	1,255
Total	28,211
F. Income (8,800 gallons of sirup produced; price received per gallon, $4.33)[5]	38,104
Net profit, F − (B+C+D+E), or $38,104 − $28,211	9,893
Return on capital investment: $\frac{\$9,893}{\$25,291} \times 100 = 39$ percent[6]	

[1] Except for average price per gallon of sirup, these data are adapted from Pasto and Taylor (*86*).

[2] See table 18 for itemized capital expenditure.

[3] Fixed costs, with the possible exception of salaries paid to management, remain constant irrespective of production.

[4] Cost of sap. This depends on two variables: (1) The volume of sap processed, and (2) the Brix (percent of sugar) of the sap. $0.05 was the common price paid for sap of 2.4° Brix in 1963.

[5] The price received for a gallon of sirup is based on an assumption that $\frac{1}{3}$ will be sold in bulk at $3 per gallon, $\frac{1}{3}$ at a bulk price of $4, and $\frac{1}{3}$ sold retail at $6 per gallon.

[6] Return on capital for sirup at the plant; does not include marketing costs.

The previous data assume maximum production for a small plant. Less production would reduce net profit and income from invested capital.

Material Balance

Seldom will the actual amount of sirup produced equal that calculated from the amount of sap purchased and the Brix value of the sap. Pasto and Taylor (*86*) suggested that there is a 2-percent loss in sirup. They suggested that this is due to sirup left sticking to the walls of the evaporators, holding tanks, and felt filters. This apparent loss is caused (1) by making sirup that is too heavy (a Brix value above 66.0°), and selling this heavy sirup on a volume basis rather than on a weight basis; (2) by overfilling sirup containers; as little as 5-percent overfill in the retail package results in only 950 gallons of sirup for each 1,000 gallons handled—a loss of 50 gallons; and (3) by removing during filtration sugar sand that was measured in sap as sugar.

The longer the plant is in productive operation (hours and days) and the greater the volume of sirup produced, the greater will be the profits and returns on the investment.

Increasing Returns

Use of central plant facilities need not be limited to the 6 or 8 weeks of sap evaporation. Instead, the facilities can be put to a number of other uses that not only produce more income from the invested capital but also furnish profitable employment.

Additional uses for the plant are: (1) Mixing of sirups to obtain a standard grade and density; (2) custom packaging of sirup; (3) preparing gift packages; (4) reprocessing sirup to remove buddy flavor; (5) making high-flavor sirup; (6) preparing high-density sirup; and (7) manufacturing confections.

Some additional equipment would be required. This includes a steam kettle for use in processing sirup and in manufacturing confections and a candy machine and facilities for manufacturing confections.

Standardizing Sirup for Color and Density

Today, the consumer expects uniformity in food products. The public, therefore, expects uniformity (year after year) in the color (grade) and density of maple sirup. The color and density can easily be adjusted to meet specific customer demands by mixing sirup of different grades and different densities. This must be done after the sirupmaking season so that the amount of different sirup stocks will be known.

Adjusting Color

To adjust the color, measure 1 cup of either the lighter sirup or the darker sirup in a 2-cup measurer. Then add the other with constant mixing until the desired color (grade) is reached. Note the amount of sirup added in ounces. This will give the ratio of the light and dark sirups to be mixed to produce the desired grade.

Stirring sirup in 5-gallon tins makes it easier to select different grades for mixing.

Adjusting Density

To adjust the density, preferably to between 66° and 67° Brix, the method of Pearson's Square can be used. Considerable time can be saved by calculating the number of parts (by weight) of the heavy sirup to mix with sap or thin sirup to obtain standard-density sirup.

Example 1. If a dense sirup of 70° Brix is to be mixed with a thin sirup of 64.4° Brix to make a standard-density sirup of 66.0° Brix, the quantity of each sirup to be used can be determined by alligation as follows:

A = 70 D = 1.6 (calculated)

C = 66.0

B = 64.4 E = 4.0 (calculated)

where A = density of heavy sirup in ° Brix
B = density of light sirup in ° Brix
C = density desired as the result of mixing A and B

This is always the center figure. D = the difference between C and B, which in this case = 1.6. E = the difference between A and C, which in this case = 4.0. D and E give the ratios of sirup A and B to mix to produce standard-density sirup (66.0° Brix), which in this case would be 1.6 parts of A (heavy sirup) to 4.0 parts of B (light sirup).

Example 2. If sirup with a density of 66.5° Brix is desired (it will feel better to the tongue) using the same two sirups, the Pearson Square would become

A = 70 D = 2.1

C = 66.5

B = 64.4 E = 3.5

The ratio of these two sirups mixed to give a sirup having a density of 66.5° Brix (C) would be 2.1 parts of A (heavy sirup) to 3.5 parts of B (light sirup).

Custom Packaging and Gift Packages

Many customers want sirup packaged in containers of special design and shape. This requires special handling, and is usually done after the sap season.

Many companies and some individuals are using gift packages for a selected clientele. These gift packages consist of a variety of maple products attractively packaged. Orders are usually received and made up for special occasions, particularly for the Christmas season.

High-Flavored and High-Density Sirup

To meet ever-increasing demands for high-flavored sirup (described on p. 106) for use in making some maple-blended table sirups, a considerable portion of bulk sirup will require high flavoring. Most of this will be done by the open steam-kettle process or by the new continuous process.

High-density sirup will also need to be made to meet consumer demands. The process is described on page 105.

Manufacture of Confections

All well-managed central evaporator plants should have a candy kitchen for manufacturing confections (figs. 134–136). The cost of converting standard-density sirup to confections is small compared to the selling price of the confections; confection manufacture is the most profitable enterprise of the central plant. The principal confections made are maple cream, maple candies (soft sugar), block sugar, and stirred sugar.


PN–4830

Figure 134.—A well-equipped candy kitchen with dehumidifier and air-conditioner is an essential part of a central evaporator plant. The candy kitchen furnishes employment a major part of the year.

PN–4831

Figure 135.—A central evaporator plant must have a salesroom for displaying and selling the products manufactured.

PN–4832

Figure 136.—A large, easily read sign advertising the central evaporator plant is essential for directing the public to the plant for the purchase of maple products.

The candy kitchen of the central plant will be in operation from 9 to 12 months of the year. The manufacture of confections may use more than half the plant's sirup production and will provide the largest source of income per gallon of sirup. A small central evaporator plant may produce more than 4 tons of confections a year.

Summary

(1) Theoretically, the central evaporator plant is sound economically for both the plant investor and the suppliers of sap.

(2) Locate it on an accessible, hard-surfaced, tourist-traveled road.

(3) The plant need not be large, but the larger the plant, the larger the returns. Central evaporator plants are readily expanded.

(4) The most common plant is one using oil fuel for the bulk of the sap evaporation and high-pressure steam for the last stage of the evaporation.

(5) Utilize automation where possible.

(6) Sap should be purchased on the basis of its Brix value and volume or weight. The price of sap should be on a sliding scale, varying with the ° Brix of the sap.

(7) Standards of production should be set for sap producers.

(8) Sap storage facilities must be adequate to handle a maximum day's run from all of the sap suppliers.

(9) Sap tanks should be located in a cool place, easily accessible for washing and sanitizing. Tanks should be provided with germicidal lamps to prevent sap deterioration by microbial spoilage.

(10) Bulk storage of sirup can be in large tanks protected by germicidal lamps or in 5-gallon tins or 30-gallon drums.

(11) Sirup for retail trade should be mixed to obtain a standard color and density and packaged at 190° F.

(12) Increased returns from the plant will result from extending its use throughout the year by manufacturing confections, custom-packaging sirup, and preparing gift packages of assorted maple products.

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