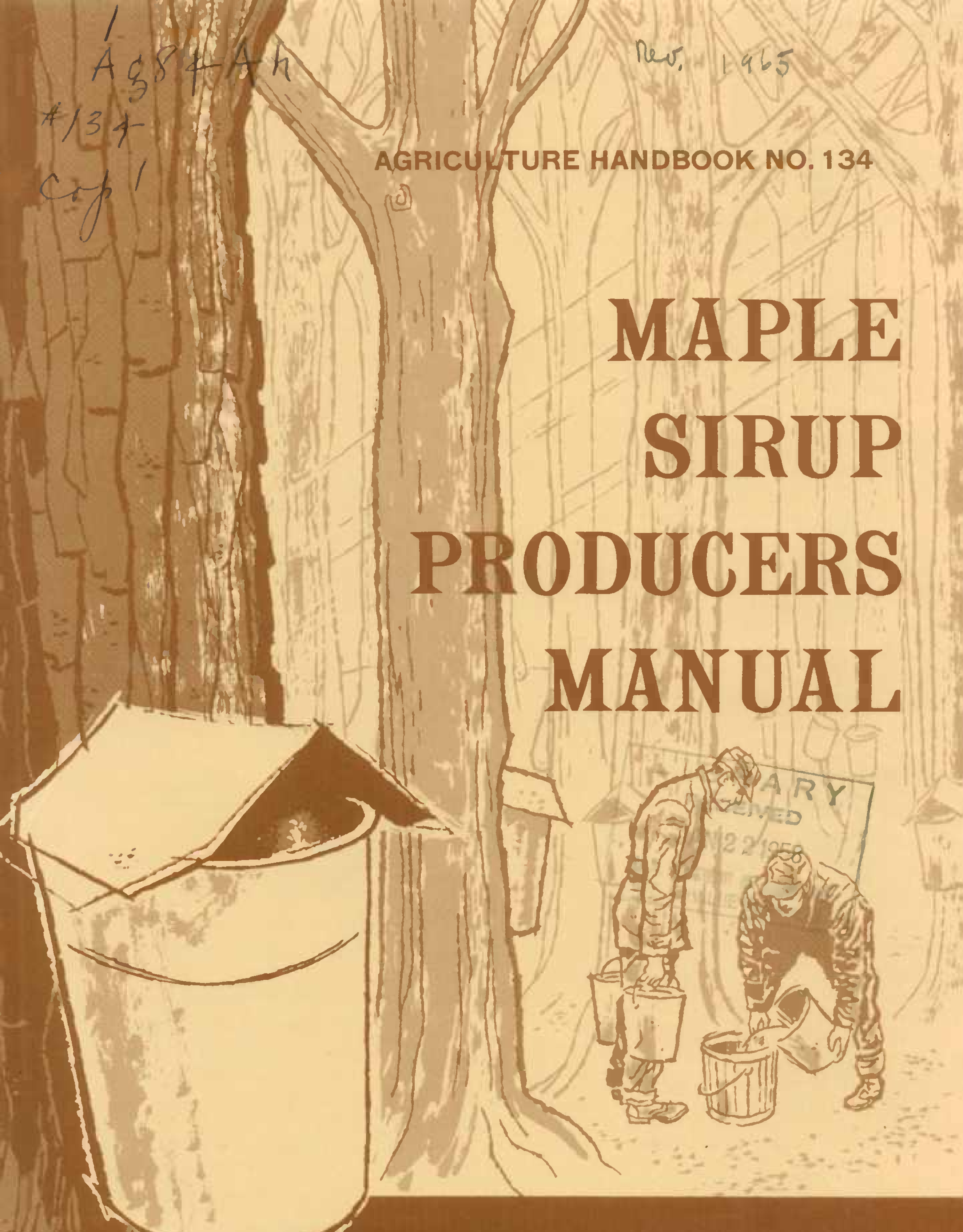
AGRICULTURE HANDBOOK NO. 134

MAPLE SIRUP PRODUCERS MANUAL



U. S. DEPARTMENT OF AGRICULTURE

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MAPLE-SIRUP PRODUCERS MANUAL

By C. O. Willits,

Eastern Utilization Research and Development Division, Agricultural Research Service

No one knows who first discovered how to make sirup and sugar from the sap of the maple tree. Both products 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 (*11, 37*).[1 2]

The maple crop has three claims to distinction: (1) It is one of our oldest agricultural commodities; (2) it is one of the few crops whose production is solely American; and (3) it is the only crop that must be processed on the farm before it is in suitable form for sale.

Although maple-sirup production is recognized as one of our oldest industries, relatively little scientific work has been done to improve it. The sap has been collected and converted to sirup in much the same way since the development of atmospheric evaporation equipment about 1900. This equipment was developed by Yankee ingenuity, not engineering studies. Today, a strong research program dealing with the different phases of maple-sirup production is being conducted by the Eastern Utilization Research and Development Division of the United States Department of Agriculture and by the experiment stations and agricultural colleges of Michigan, New Hampshire, New York, Ohio, and Vermont. As a result of this research a noticeable change is occurring in the maple-sirup industry, and this will be described throughout this handbook.

Maple sirup is a woodland crop. The trees grow best at altitudes of 600 feet and above; therefore, maple sirup is usually produced in the 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.

Annual production of maple sirup, like other crops, is subject to yearly fluctuations caused by 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 and so did production of maple sirup, reaching 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. An increase occurred also during World War II. Since then, there has been a decrease in production (table 1) (*46, 47*).

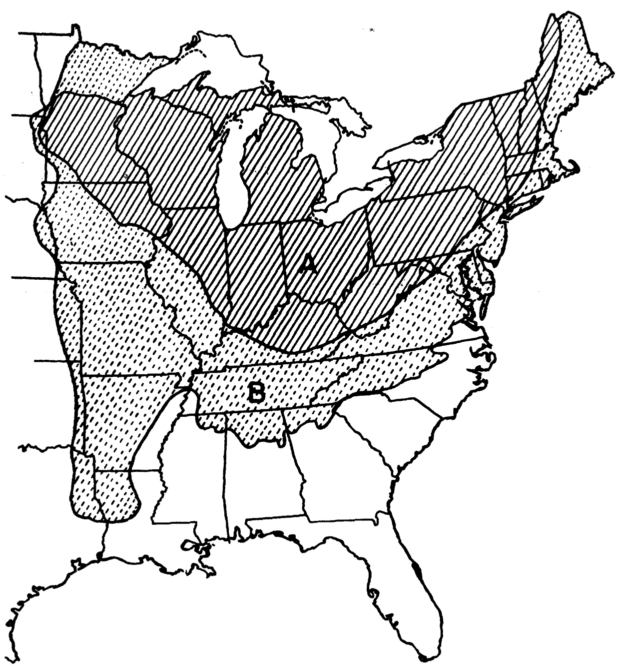

Chart 1.—*A*, Range of commercial production of maple sirup; *B*, range of hard maple trees.

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[1] Also communication from J. A. Mason, the University Museum, University of Pennsylvania.

[2] Italic numbers in parentheses refer to Literature Cited, p. 50.

TABLE 1.—*Production of maple sugar and sirup, trees tapped, average price received by farmers, and imports, selected years, 1918–54*

Year	Trees tapped	Production					Price		Imports for consumption	
		Sugar	Sirup	Total product in terms of sugar [1]	Average total production per tree		Per pound of sugar	Per gallon of sirup	Sugar [2]	Sirup [3]
					As sugar [1]	As sirup [1]				
	Thousand trees	*Thousand pounds*	*Thousand gallons*	*Thousand pounds*	*Pounds*	*Gallons*	*Cents*	*Dollars*	*Thousand pounds*	*Thousand pounds*
1918	17, 053	11, 383	4, 141	44, 511	2. 61	0. 33			3, 807	
1922	15, 198	5, 227	3, 370	32, 187	2. 12	. 26			3, 201	[4] 1
1926	13, 948	3, 585	3, 504	31, 617	2. 27	. 28	29. 3	2. 12	3, 446	203
1930	13, 158	2, 134	3, 712	31, 830	2. 42	. 30	30. 2	2. 03	9, 735	1, 575
1934	12, 099	1, 044	2, 444	20, 596	1. 70	. 21	24. 9	1. 33	2, 976	1, 316
1938	11, 380	705	2, 770	22, 865	2. 01	. 25	28. 4	1. 61	3, 946	39
1942	10, 046	560	2, 987	24, 456	2. 43	. 30	37. 7	2. 26	7, 121	4, 791
1946	8, 257	310	1, 351	11, 118	1. 35	. 17	65. 5	3. 30	4, 207	2, 221
1950	8, 146	257	2, 024	16, 449	2. 02	. 25	77. 8	4. 13	6, 549	5, 282
1954 [5]	6, 786	168	1, 730	14, 014	2. 07	. 26	85. 1	4. 66	6, 643	4, 096

[1] Assuming that 1 gallon of sirup is equivalent to 8 pounds of sugar.
[2] Includes maple sirup through Sept. 21, 1922.
[3] A gallon of sirup weighs about 11 pounds.
[4] Included with maple sugar through Sept. 21, 1922.
[5] Preliminary.

Agricultural Statistics, 1952 and 1955 (*46, 47*).

The decreased production since World War II is not necessarily a trend. Rather it is a reflection of the shortage of farm labor during this period. Although the downward trend tends to exist in the country as a whole, production of maple sirup in Minnesota, Wisconsin, and Michigan has shown a definite increase. 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.

Current surveys in the eastern maple-producing areas (*47*) [3] of the number of maple trees that are tapped as well as the total number that are of

[3] Also unpublished estimates for 1948–52 of the Northeastern Forest Experiment Station (U. S. Forest Service), Upper Darby, Pa.

TABLE 2.—*Number of tappable maple trees, and number and percentage tapped, Eastern States, 1951*

State	Tappable trees [1]	Tapped trees	
	Number	*Number*	*Percent*
Maine	53, 553, 000	136, 000	0. 25
Maryland	1, 660, 000	28, 000	1. 7
Massachusetts	11, 913, 000	166, 000	1. 4
New Hampshire	12, 103, 000	261, 000	2. 2
New York	73, 128, 000	1, 960, 000	2. 7
Pennsylvania	33, 553, 000	422, 000	1. 3
Vermont	25, 840, 000	3, 118, 000	12. 1
West Virginia	13, 031, 000		

[1] Larger than 10 inches d. b. h.

TABLE 3.—*Rank of States in production of maple sugar, selected years, 1916–54*

Rank	1916	1921	1926	1931	1936	1941	1946	1951	1953	1954
1	N. Y.	Vt.	N. Y.	Vt.	Vt.	Vt.	Vt.	Vt.	Vt.	Vt.
2	Vt.	N. Y.	Vt.	N. Y.	N. Y.	N. Y.	N. Y.	N. Y.	N. Y.	N. Y.
3	Ohio	Ohio	Ohio	Ohio	Ohio	Ohio	Ohio	Pa.	Ohio	Pa.
4	Pa.	Mich.	Pa.	Pa.	Pa.	Pa.	Mich.	Mich.	Pa.	Mich.
5	N. H.	N. H.	Mich.	Mich.	Mich.	Mich.	Pa.	Mass.	Wis.	Ohio
6	Mich.	Pa.	N. H.	Wis.	Wis.	Mass.	N. H.	N. H.	Mich.	N. H.
7	Wis.	Wis.	Mass.	N. H.	N. H.	N. H.	Mass.	Wis.	N. H.	Wis.
8	Mass.	Mass.	Wis.	Mass.	Mass.	Wis.	Wis.	Maine	Mass.	Mass.
9	Maine	Maine	Maine	Md.	Md.	Maine	Maine	Md.	Minn.	Maine
10	Md.	Md.	Md.	Maine	Maine	Md.	Md.	Ohio	Md.	Md.
11								Minn.	Maine	Minn.

tappable size show that the industry is not suffering from too few trees. Although many sugar maples have been cut for lumber, vast stands still exist and these can supply our maple-sirup needs. Table 2 shows the number of maple trees of tappable size and the percentage that were tapped in 1951.

Table 3 shows the production of maple sirup by the 11 principal States for selected years, 1916–54.

ECONOMICS

The maple season is short and comes in the early spring when most other farm activities are slowest, so it does not compete with them. Maple sirup can be considered a byproduct of the farm. However, surveys in New York (*2, 4*), Ohio (*18*), Michigan (*34*), and Wisconsin (*42*) have shown that production of maple sirup is one of the farmer's most profitable enterprises, paying him as much as $3 per hour for every hour spent, including time spent in cleaning the equipment and collecting and boiling the sap.

Modernization of equipment has done much to increase profits in maple-sirup production. This includes the use of flue-type evaporators, oil as fuel, mechanical tapping tools, and instruments for judging finished sirup. All these tend to reduce labor costs and contribute to the production of better grades of sirup that have a correspondingly greater value. Fixed costs, which normally represent about 35 percent of the total, may lower net income in groves where fewer than 500 buckets are hung.

The sirup can be sold immediately and so produce a ready source of cash, or it can be held for a more favorable market or to supply raw material for production of other 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. This in many instances has resulted in increased returns for him. 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 converting their sirup to confections such as "maple cream," pralines, and soft-sugar candies, which result in even larger returns. 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 products.

Also, the different States, in cooperation with the Agricultural Research Service and the Extension Service of the United States Department of Agriculture, have set up a strong extension program. This program has done much to bring the results of research directly to maple producers. In New York, which has taken a lead in this adult education program, it is not uncommon for more than a thousand producers to attend the "maple sirup" schools held annually throughout the State in the premaple season.

SUGAR MAPLES

Only 2 of the 13 species of maples (*Acer*) native to the United States are of importance in the production of sirup because of the sweetness (sugar content) of their sap (*3, 13, 45*).

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, *A* and *B*) the largest numbers are in the Lake States and the Northeast. The tree grows singly and in groups in mixed stands of hardwoods. The trunk of a mature tree may be 30 to 40 inches in diameter. It is a prolific seeder and endures shade well, but unfortunately it does not grow rapidly. The tree 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 *A. saccharum*. It does not grow as far north or south, but it 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).

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 and 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.

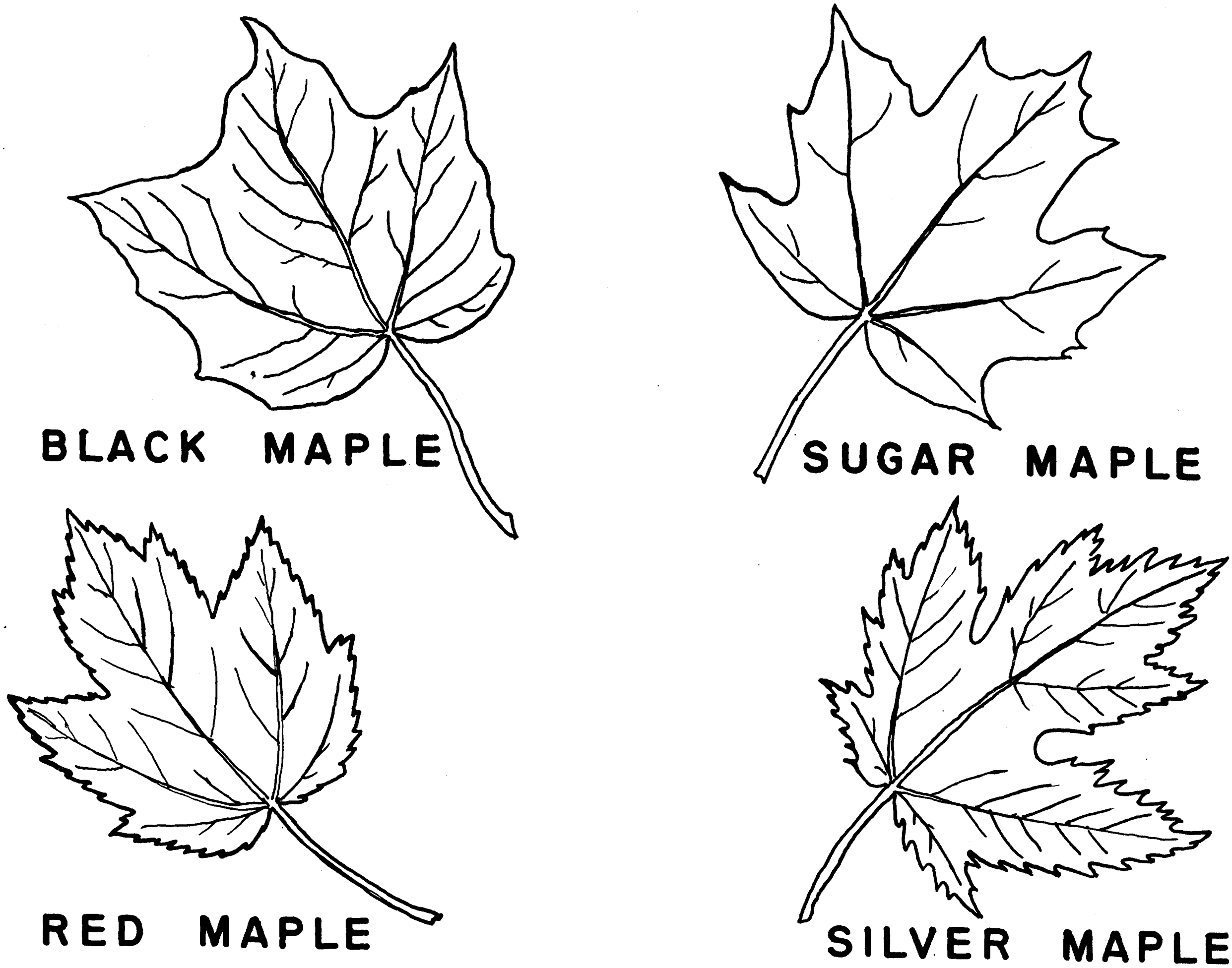

Chart 2.—Leaves of the sugar maple (*Acer saccharum* Marsh.), red maple (*A. rubrum* L.), silver maple (*A. saccharinum* L.), and black maple (*A. nigrum* Michx. F.).

THE SUGAR GROVE

Most maple-sugar groves, often 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. This 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 (*21*). As the number of trees per acre increases, the size of the crowns and boles and the yield per tree decreases, but the cost of labor for collecting sap increases.

Figures 1 and 2 show a maple grove (bush) 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 trees of tappable size, that is, 10 inches in diameter at breast height (d. b. h.). Groves with fewer than 10 maple trees per acre are not profitable; 25 to 30 trees to the acre is ideal (*19*).

Maples grown in the open, for example, along the roadside (fig. 3), have large crowns and are excellent sap producers (*20*). Because of their shorter boles, roadside trees do not make as good saw logs as trees that grow under crowded conditions. However, trees in a crowded stand have smaller crowns and consequently they are not good sap producers (figs. 4 and 5).

The ideal sugar grove requires not only a planned spacing of the trees but also a good understory to protect the ground, keep it moist, and permit the growth of seedling maples to replace trees that have matured and can be cut for lumber (figs. 6 and 7).

Sap Yields

The yield of sap in a sugar bush 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 tree and ranges from 5 to 15 gallons. It is not uncommon for a taphole to produce from 40 to 80 gallons of sap and as much as 3 quarts of sirup in a single year. The sugar content of the sap produced by the different trees in a grove varies considerably. The sap produced by the average tree has a sugar content of 2° to 3° Brix.[4] Frequently trees produce sap with a sugar content of less than 1° Brix, and occasionally a tree produces sap with as much as 9° or even 11° Brix.

The yield and sweetness of the sap produced by a tree varies 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. It is important to know the exact sugar content of the sap produced by each tree. Those trees that produce sap low in sugar (1 percent or less) should be culled. It is not difficult to measure the sugar content of sap. All that is needed is a sap hydrometer and a thermometer. These can be bought from any maple-sirup equipment house.

To make the reading, float the hydrometer in the sap bucket (fig. 8) or in a hydrometer can containing the sap (fig. 9). There should be no ice in the sap. The temperature of the sap must also be obtained so the hydrometer reading can be corrected. Subtract 0.4° Brix for temperatures of 32° to 50° F., 0.3° Brix for temperatures of 51° to 59° F., and 0.1° Brix for temperatures of 60° to 68° F.

The 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), with a refractometer, or by a quantitative chemical analysis.

A taphole that produces 15 gallons of sap with a sugar content of 2° Brix will yield 2.5 pounds of sugar or one-third of a gallon of sirup, whereas a taphole that produces 15 gallons of sap with a sugar content of 1° Brix will yield only 1.3 pounds of sugar, or less than one-fifth of a gallon of sirup. The cost of producing the sirup from both tapholes will be approximately the same. Trees producing sap with a sugar content of 10 percent would be especially profitable, as 15 gallons from 1 taphole will yield nearly 1¾ gallons of sirup.

Research is being conducted at the Universities of Vermont and New Hampshire on the propagation of maple trees from selected high-yielding trees (*7*). This research should eventually make possible the setting out of maple orchards or roadside trees that will produce sap with a high sugar content.

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. This plan should include removing defective, diseased, and weed trees to obtain maximum growth and sap production from crop trees.

TAPPING THE TREE

The sap of the sugar maple, from which sirup and sugar are made, appears to be different 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, being conducted at the University of Vermont, should lead to a better understanding of its nature, function, and source (*14*, *15*).

Maple trees will produce flows of sap any time from late fall after they have lost their leaves until well into the spring, each time a period of freezing is followed by a period of thawing. The sap will flow from a wound in the sapwood, whether the wound is from a hole bored in the tree or from a broken twig.

Date of Tapping

To establish a rule of thumb that can be used to set the date when sugar maples should be tapped is not a simple matter. The date should be early enough to assure the collection of large early flows of sap but not so early that only a small flow occurs followed by a long period of no flow. Michigan and New York provide sugarmakers with radio weather forecasts of the correct tapping dates (*9*), and a similar service is being set up in other maple-producing States including Massachusetts, Wisconsin, and Vermont. Generally, trees should not be tapped according to a calendar date. For example, in 1953 when this practice was followed, many producers failed to collect the

[4] The density of sap and sirup is due to a mixture of dissolved solids and not just 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.

early and largest flow of sap. In many instances a third of the crop was lost.

The best plan is to watch the weather maps, beginning about the first or middle of February. When the map shows a warm front moving across the country from West to East, which will cause the temperature to climb from below freezing at night to 40° or 50° F. in the daytime for a period of 2 or 3 days, the trees in a particular area should be tapped before the warm front reaches that area.

In 1954, favorable weather occurred in most sections of the country about February 18, 19, and 20, whereas records show that the normal tapping date for most areas is after the middle of March. To take full advantage of these early flow periods the sirup maker must be prepared. The trees must be selected, all of the equipment must be clean, sterile, and in order, and the evaporator house must be ready to put into operation on 1 or 2 days' notice.

Selection of Trees

The selection of the trees for tapping is of greatest importance and can be done at any time throughout the year. Culling low-yielding trees must be done during the period of sap flow (*19*).

Trees selected for tapping should measure 10 inches or more in diameter 4½ feet above the ground (10 inches d. b. h.) (fig. 10).

A good rule (*6*, *19*) 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.

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 result in serious damage to the tree. The extent of such damage is the subject of a study being conducted at Michigan State University.

Once the trees have been measured, it is well to mark them so they will not have to be remeasured each succeeding 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 the Taphole

The taphole is made by boring with either a ⅜-inch or 7/16-inch fast-cutting wood bit. This can be done either by hand, with a carpenter's brace or breast drill, or with a motorized tool. The brace (fig. 12) is slower than the breast drill but less fatiguing. Some prefer the faster acting machinist's drill (fig. 13).

For large operations, where the additional expense justifies its cost, a portable motor-driven drill (fig. 14) not only speeds up the operation but is far less fatiguing.

With a motorized tapping outfit one man can drill holes as rapidly as a crew of three can set the spouts and hang the buckets or bags. The development of this tool is one of the outstanding mechanizations that have occurred in the industry.

The hole is bored straight into the tree (preferably perpendicular to the tree) to a depth of 3 inches or until stained wood is reached. Studies at Michigan State University have shown that a taphole 3 inches deep (fig. 15) will produce 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 the plastic bag. The compass location of the hole is not important. Data obtained in New York (*43*) and in Michigan[5] have shown that the total yield per season is essentially the same regardless of the compass location of the hole. Data also show that the distance above ground level has little effect on yield. The best practice is to make the new hole on successive years 6 to 8 inches from the previous year's taphole, working up the tree in a spiral pattern until the hole is at breast height (fig. 16). 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.

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, as shown in figure 17. The hole itself remains open, but fungus growth (*39*) that may occur in the new hole stains the wood several inches above and below the hole and an inch or less to the sides, as shown in figure 18 (cross section of a maple log) and in figure 19 (longitudinal split of a log).

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 practice, this is seldom the case. Instead, the taphole usually "dries up" within 3 or 4 weeks after the hole is bored. This drying up is caused by growth of micro-organisms in the taphole rather than by air-drying of the wood tissue.

[5] ROBBINS, P. W. POSITION OF TAPPING AND OTHER FACTORS AFFECTING THE FLOW OF MAPLE SAP. 1948. [Unpublished master's thesis. Copy on file in Library, Mich. State Univ., East Lansing.]

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 (*24*).

In the past, a dried-up taphole was reamed to cause it to flow again, for it was assumed that this procedure would remove the air-dried wood tissue. Reaming was never successful and this can be readily explained. Research has shown that the reaming bit did not sterilize the hole. Only a layer of the microbial deposit was removed, with the result that the remaining bacteria kept on growing and soon sufficient numbers were again produced to stop sap flow. Investigations being conducted at Michigan State University on the problem of taphole infection may lead to ways by which the taphole can be maintained in a sterile condition throughout the sap season. Until such information is available the best practice is to keep the sap-collecting equipment sterile and clean.

Summary

1. Don't tap by the calendar. Follow your State's maple weather reports.
2. Make 1 taphole in a tree 10 inches in diameter, and 1 additional hole for each additional 5 inches of the tree's diameter.
3. Make the taphole with a $\frac{3}{8}$-inch or $\frac{7}{16}$-inch fast-cutting (special) wood bit.
4. Bore the hole straight into the tree to a depth of 3 inches.
5. The location of the taphole in respect to compass position and roots is unimportant.
6. Space the holes at least 6 inches apart (circumference of tree) and in a spiral pattern.
7. Use a power tapper if the grove is large enough to justify the expense.

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 serves as a support on which to hang the sap bucket or bag; (3) it keeps adventitious (wild or stray) bacteria from gaining access to the moist taphole, which should reduce infection.

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. 20).

There are only a few basic differences in the design of the various sap spouts or spiles. 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. A few spouts are shown in figure 21. 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 (fig. 15). In setting the spout (fig. 22) care must be exercised not to split the tree at the top and bottom of the taphole. Such a split results in leakage of the sap and often causes complete loss of sap from that hole.

Rainguards

Heavy rains often occur during the sap season. Rainwater picks up dirt and leaches tannins from the bark. Both the dirt and the tannins, if permitted to get into the sap bucket, will 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. 23) will make it impossible for the heaviest runoff rainwater to enter 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. Cut a $\frac{5}{16}$-inch hole in the center of the square with a leather punch. 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 $\frac{1}{4}$ to $\frac{3}{8}$ inch between the rubber guard and the bark of the tree.

Sap Buckets

Three different 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 metal buckets of 15-quart capacity are the most commonly used. Lead-coated metal (terneplate) or lead-soldered buckets or buckets painted with a lead paint should not be used because the lead may be dissolved by the sap, and the sirup may contain illegal amounts of lead. Aluminum buckets, use of which is being subsidized in Canada, tend to eliminate most of the objections to metal buckets.

All buckets should be provided with a cover to keep out rain and falling debris. Covers are of two general types: (1) Those that are attached to the spout (fig. 24), and (2) those that are clamped to the bucket (fig. 25).

The plastic sap bag (fig. 26), a recent development, is too new to be fully evaluated. Some of its advantages and disadvantages are as follows:

Advantages: (1) Because of their small bulk, they require minimum storage space, and they are easily transported to the woods and hung. (2) The bags have an adequate self-cover. (3) Emptying the sap is a one-handed operation (fig. 27). The bags need not be removed from the spout; they can be rotated on the spout. (4) Because the plastic bags are transparent to sunlight radiation, which is lethal to micro-organisms (fig. 28), they tend to keep the sap sterile (*23*). Sterile sap contributes to the production of high-quality sirup.

Disadvantages: (1) The bags have not been in use long enough to establish their life expectancy. (2) The capacity of the bag may be inadequate for a day's run. (3) The bags are subject to damage by rodents. (4) Washing and rinsing the bags may be a problem.

Summary

1. Any of the commercially available spouts are 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 cause a split in the bark and wood.
4. Use a 2- x 2-inch rubber runoff rainguard on the spout.
5. Do not use buckets coated with lead paint or with terneplate.
6. Use a bucket that will hold a normal day's run of sap.
7. Use only covered sap buckets or bags.

GATHERING THE SAP

Gathering the sap (fig. 29) is the most expensive and laborious of all maple-sirupmaking operations. Sap collection is handwork and accounts for one-third or more of the cost of sirup production.

Much time can be saved if the trees on both sides of a roadway that are to be serviced from that roadway bear a distinguishing mark and the trees to be serviced from an adjacent roadway bear another mark. This prevents visiting 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 first hole, and painting a stripe from the 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); then after they are emptied, they are hung from the opposite hole. This makes it easy for the sap collector to tell whether or not a bucket has been emptied and keeps him from skipping full buckets as well as revisiting emptied buckets. The only objection to this scheme 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.

Collecting Tanks

Collecting tanks vary in size with the needs of a particular sugar bush. 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 bush. 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 (figs. 30–34, incl.).

High mounting of the tank (figs. 31, 32, and 33) should be avoided, because of the labor required to lift the sap. Usually an additional worker is needed. The lowest mounting, such as on a stoneboat or skids (fig. 30), requires the least labor. A rig of excellent design is one with a low-mounted sump tank (fig. 35) provided with a self-contained power-driven pump to lift the sap up to the large tank (fig. 36).

Pipelines

To eliminate the costly labor of collecting sap by hand and to avoid the bad roads of the sugar bush, some producers have installed pipeline systems. In these systems the sap is piped directly from the tapholes to a storage tank. The first pipeline systems did not become popular because of the excessive cost of installing the intricate piping system and also because poor-quality sirup resulted if the sap fermented in the pipeline.

One factor that has made pipelines practical is the development of plastic tubes. These can be laid directly on the ground because sap trapped in a low spot or sap in the line will not burst the tube on freezing (fig. 37). The phenomenal growth in the use of pipeline systems since the development of today's lightweight plastic tubing can be attributed to: (1) The initial cost of plastic tubing is comparable to the cost of buckets or plastic bags, (2) the cost of collecting the sap and transporting it from the tree to the storage tank is reduced, (3) seasonal (daily) labor requirements are reduced, and (4) no sap is lost by spillage or by dumping small intermittent runs.

Because of the short time plastic pipeline systems have been in operation, no data are available to show: (1) The life expectancy of the tubing as affected by weathering either during the sap-flow season or throughout the year, (2) whether fermentation will be retarded in the tubing, (3) how the tubing can be sterilized if it becomes contaminated, (4) whether the tubing imparts any flavor to or has any other harmful effect on the finished sirup, and (5) how the tubing will perform if it becomes covered with snow. These and many other questions can be answered only after intensive studies have been made.

The use of pipelines is not limited to bushes located at an elevation above the evaporator house; they are equally useful for bushes at the same level or at a level below the evaporator house. In the latter, a pump is used. Several pump-operated pipelines are in use in Ohio.

In installations where the sap must be pumped, provision must be made for draining the pump and the pipeline. The amount of trapped sap should be kept as small as possible because it may ferment during the period between runs and so contaminate the next run. To prevent this, the pipeline should be flushed with 5 to 10 gallons of sap or water each time it is used, particularly if it has been inactive for a day or more. The sap or water used to flush the line must be discarded.

Some producers favor a partial pipeline system. In one system of this kind, storage tanks are connected by pipelines to a large number of sap-dumping stations throughout the sugar bush, where the collecting pails are emptied. Another type has fewer stations where gathering tanks are emptied. Where tanks are used to transport the sap to the evaporator house, they should be as large as possible to reduce the number of trips that must be made.

Storage Tanks

Storage tanks should be at least twice the capacity of collecting tanks. Where possible, the collecting tanks should empty into the storage tank by gravity flow, as shown in figure 38. When this is not practical, a sump tank from which the sap is pumped to the storage tank can be used (fig. 39).

Summary

1. Use two gathering pails, one in each hand.
2. Mark all trees to be serviced from each roadway or mark buckets and punch a second hole so that they can be rotated 180° each time after emptying.
3. Use a large collecting tank.
4. Mount the collecting tank on low-riding gear.
5. Use plastic pipelines to transport sap whereever possible.
6. Use a ramp to elevate the collecting tank above the storage tank, OR
7. Use a sump or receiving tank and pump the sap up to the storage tank.

THE EVAPORATOR HOUSE

Location of Building

Originally, most evaporator houses were located near the center of the sugar bush, to shorten the distance the sap had to be hauled (fig. 40). 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. 41). 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, and (3) full family participation is encouraged.

Function of the Evaporator House

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. With the advent of the closed fire pit and chimney, a lean-to type of shed was used to protect both the sugarmaker and the boiling sap from the inclement weather which so often occurs during the sirup season. The shed shelter immediately introduced a new problem—how to get rid of the steam from the boiling sap. This was solved by completely enclosing the evaporator and installing ventilators at the top. These crude shelters were the forerunners of today's evaporator houses.

As the evaporator house is used only 4 to 6 weeks of the year, its cost must be kept low; otherwise, the interest on the capital investment is out of proportion to its use. Today the trend is toward the construction of an evaporator house that not only will permit the sanitary handling of the sap and sirup, but in addition will provide a place to process and package the sirup, to make confections, and to serve as a salesroom for maple products.

Requirements of the Evaporator House

The evaporator house need not be elaborate. It should be large enough to allow plenty of free space (4 feet or more) on all sides of the evaporator, and it should be set on a foundation that extends below the frostline. The house should be of tight construction with provision for venting the steam and should have 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.

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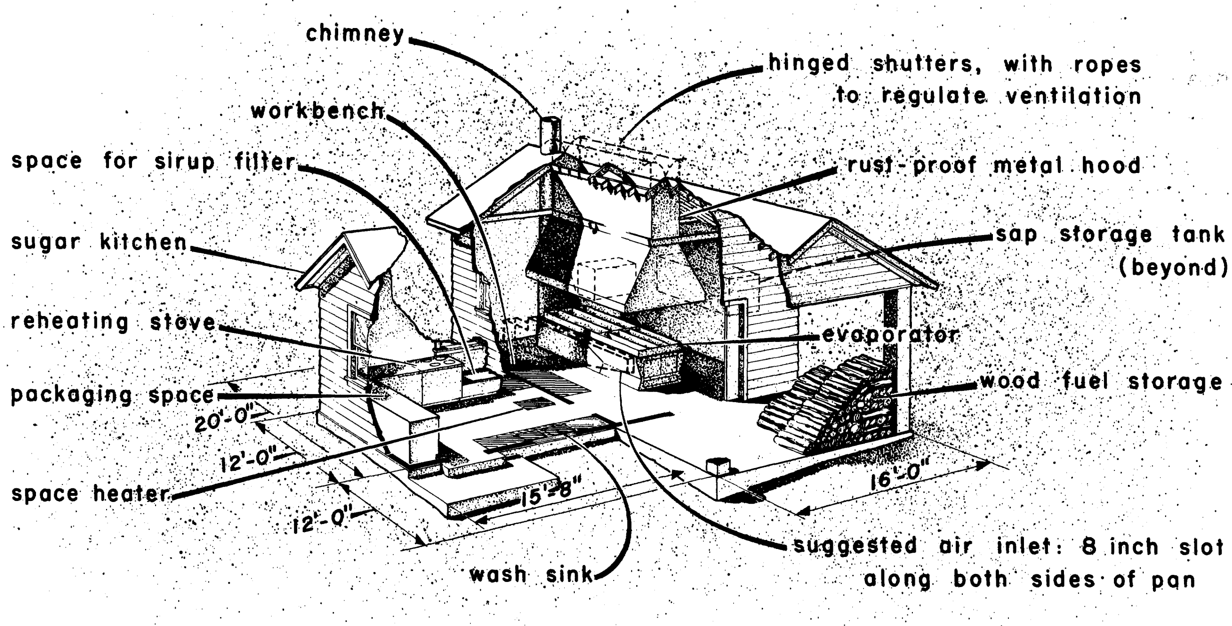

Chart 3.—A perspective drawing of an evaporator house with "L" to provide space for filtering and packaging sirup and making maple confections.

Design of the Evaporator House

Chart 3 shows a suggested plan for an evaporator house with a wing in which the sirup can be processed and maple products made.

The house itself is designed to contain only the evaporator and workbench. 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. The house is equipped with a workbench along one wall. The roof opening for the ventilator is two-thirds the width and the same length as the evaporator. The opening is provided with hinged shutters (sections of the roof), which can be raised or lowered to get the required ventilation.

Steam Ventilation

The steam hood.—The steam hood has nothing to support so can be made of lightweight noncorroding material, such as aluminum or galvanized sheets. The section between the stringers and the roof openings is rectangular, with perpendicular walls, and serves as a chimney. The dimensions are the same as the roof opening. Below the stringers the hood is flared out to project 1 foot beyond the evaporator on all sides. The lower edge of the hood is 6 feet from the floor to provide adequate headroom. The flanged sections of the hood are hinged to the chimney sections so they can be raised or lowered to take care of the steam. A strip of lightweight canvas, 1 to 3 feet wide, attached to the lower edge of the hood (fig. 42) will increase its efficiency. A small gutter ½-inch deep is attached to the lower edge of the hood to collect the water that condenses on it. To make the hood most effective, the distance between the top of the evaporator pans and the bottom of the hood curtain is narrow, about 2 feet. This requires that the evaporator arch be set higher from the floor than has been the practice in the past.

Evaporator cover and steam ventpipe.—Instead of a steam hood, which requires large amounts of outside air and a large opening in the roof, an evaporator cover and steam ventpipe can be used to remove steam from the evaporator house. This simple and efficient system employs the principal of the covered steam kettle. The cover is fitted over the entire evaporator, with the possible exception of the last section of the sirup pan, and is connected with a steam ventpipe.

The cover is made of lightweight metal, and it can be of arch, gable, or flattop design. If the latter, the sides should be raised 4 to 6 inches to provide free interconnecting space over the entire top of the evaporator, as in the other designs. Inspection holes with covers should be provided in the different areas of the cover, and especially over the sap pan, to permit skimming of the sap.

The steam ventpipe should be 8 to 10 inches in diameter. It can be made of air-duct pipes similar to those used in domestic heating systems. It should be mounted in the cover over the sap pan adjacent to the arch stack, and carried up through the roof. It must be lagged with insulating material to prevent steam from condensing in the pipe. Failure to do this will result in large amounts of condensed steam running back into the evaporator.

Location of the Evaporator

The evaporator is located directly under the ridge of the roof and the opening of the hood. The foundation for the evaporator arch is extended below the frostline; it is extended above floor level sufficiently high so that the top of the pans is at least 4 feet above the floor when the arch and pans are in place. Setting the evaporator at this height, close to the hood, aids in removal of steam, makes it easier to fire when wood is the fuel, and brings the thermometers closer to eye level. The house is floored, preferably with concrete.

In older installations, the foundation on which the evaporator was mounted was much lower. To make wood firing more convenient or to mount the oil burner, a pit was dug in front of the firebox. To aid in reading the thermometers and to provide depth below the sirup drawoff cocks, pits were also dug on each side of the sirup pan.

If the sirup is only partly finished in the evaporator and evaporation is completed in a finishing pan, the finishing pan should also be in the evaporator house.

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. Removal of the steam through the ventilator will require an additional 10 cubic feet of air per minute per square foot of evaporator. For example, an evaporator 4 feet wide and 12 feet long requires 480 cubic feet of air per minute to remove the steam through the 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 make provision for delivering it where it is needed, as indicated in chart 3. Ducts along both sides of the evaporator supply the hood ventilation and the combustion air. These ducts are 8 inches wide and are open at the top and at the ends toward the firebox. They run the entire length of the evaporator. The incoming air supplied through these ducts tends to keep the steam under the hood. If the evaporator is covered and a steam ventpipe is used, the fresh-air ducts will need to supply air for combustion only.

Sirup Processing Room

If the evaporator house consists of a single room, it must have space for the filters and for canning the sirup. A better plan is to process the sirup in a second room built as an "L" to the evaporator room (chart 3). This arrangement does not add appreciably to the cost of construction, and the sirup can be processed under more ideal working and sanitary conditions.

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

There should be a dishwashing sink and a trough with cold running water in which sirup that has been cooked for making maple cream can be cooled rapidly. The room should be provided with adequate storage space for the cooking utensils and the containers for the products.

If the evaporator house is to serve as a salesroom, space should be provided for the attractive display of the products as well as for storage of these products.

Wood Storage

When wood is the fuel, sheltered storage must be provided in a convenient location so the wood can be readily obtained by the fireman. Figure 44 shows a space for wood storage in front of the evaporator house, which is the point closest to the evaporator fire doors. This storage space will hold 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 by means of a truck mounted on rails. Such an installation is shown in figure 43.

Storage Tanks

Storage tanks for sap must be located in a cool place, never in the evaporator house where the sap would be too warm. Warm sap favors the growth of micro-organisms that produce unwanted fermentation.

When the contour of the ground will permit it, the location of the tank underground has become popular. However, it may be difficult to keep sanitary. If placed aboveground, the tank should be insulated and covered (fig. 44). It should be built so that its interior is readily accessible and can be easily cleaned and rinsed. After each run of sap the tank should be washed with a detergent and thoroughly rinsed by hosing with clean fresh water.

There must be some indicating device inside the house to show the level (supply) of sap in the tank. This device may be a 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 pullies as the level of the sap varies.

If the feed line from the tank to the house is aboveground, it too must be well insulated. Numerous cases have been reported where 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. 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 and sanitary.
4. Provide a workbench along one wall.
5. Provide a steam vent.
6. Build a steam hood directly over the evaporator OR
7. Provide the evaporator with a cover and steam ventpipe.
8. Elevate the evaporator arch on a foundation which extends into the ground below the frostline.
9. Make floor of concrete or other easily cleaned surface.
10. Provide ducts in the house for intake of outside air.
11. If possible, provide a separate but adjoining room for processing the sirup and making other maple products.
12. If possible, equip the house with running water, electricity, and a gas fuel supply.
13. When wood is the fuel, provide adequate storage room for supplies of dry wood.
14. If possible, provide means for transporting the wood to the evaporator.
15. Locate the sap-storage tanks outside the building.

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 that is being made.

Maple-sirup evaporators have gone through an evolution in design. The first, used by the Indians, was a hollowed log in which water was evaporated from the sap by the addition of hot stones. Later they used earthen vessels set in the fire. These were followed by the metal kettles of the white settlers. All 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, with sap both high and low in sugar content being 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 was the use of multiple kettles (fig. 45).

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 to a fourth kettle where evaporation was completed. The multiple-kettle method was a semicontinuous operation and resulted in an improved (lighter colored) sirup, as the time of heating at near-sirup density could be shortened.

The source of heat for all the early evaporators was the 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. The increased heating surface of the pan and the confined fire both increased the efficiency of the fuel. This design was quickly followed by partitioned pans which were the forerunner of flue-type evaporators.

A modern flue-type evaporator, the last major change in design, was developed about 1900 (fig. 46). 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 and resulted in increased fuel economy. Also, the rate of evaporation was increased, which shortened the evaporation time, improved the quality of the sirup, and lowered the cost of production.

Design

The 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. Originally, a siphon was used to connect the two pans (fig. 47). More recently, rigid and semirigid pipe or tubing has been used (fig. 48). 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 sirup pan, often called the front pan, usually is located over the firebox. It is the pan in which the concentration to sirup is completed. This pan has a flat bottom to facilitate cleaning and to permit evaporation of shallow layers of sirup with less danger of burning.

The channels or flues in the sap pan can be narrower than in the sirup pan because the sap is never concentrated enough to become viscous and 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, which is adjusted to

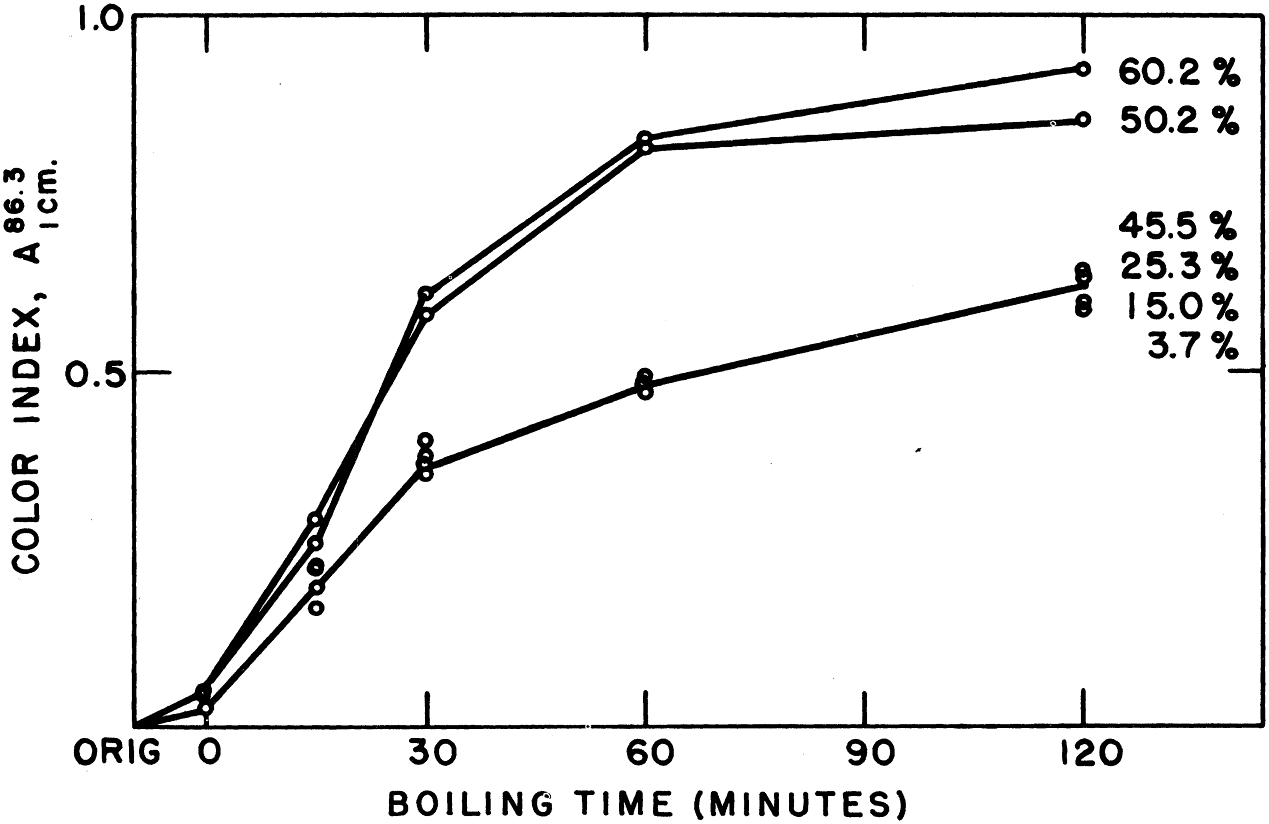

Chart 4.—Effect of length of boiling period on color formation (color index) in sap of different solids concentrations.

maintain the desired depth of liquid in the evaporator.

Rule of 86

The amount of water that has to be removed to reduce sap to sirup varies with the density 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 (65.5° Brix). Standard-density sirup contains 86.3 percent of solids (as sugar) on a weight-volume basis. Since the density 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. In practice the value of 86 can be used rather than 86.3, and the equation is: $a=\frac{86}{X}$.

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

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

where a = the number of gallons of water that must be removed from sap to produce standard-density sirup.

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

Example: With sap having a density of 2.4° Brix, $a=\frac{86}{2.4}-1$, or $36-1=35$, the number of gallons of water that must be evaporated.

Changes in Sap During Its Evaporation to Sirup

Development of the desired maple flavor and color as well as undesirable flavors are the result of browning reactions that occur while the sap is boiling in the evaporator. (This is discussed more fully on p. 23.) The extent to which these reactions occur is determined in part by the length of time the sap is boiled.

Chart 4 shows the effect of the length of the boiling period on the amount of color (*52*) produced in sap of different solids concentrations (° Brix).[6] At low concentrations of sugar the

[6] To provide a basis for comparing color of maple saps of different concentrations, color is expressed as "color index." Measurements to determine color index are

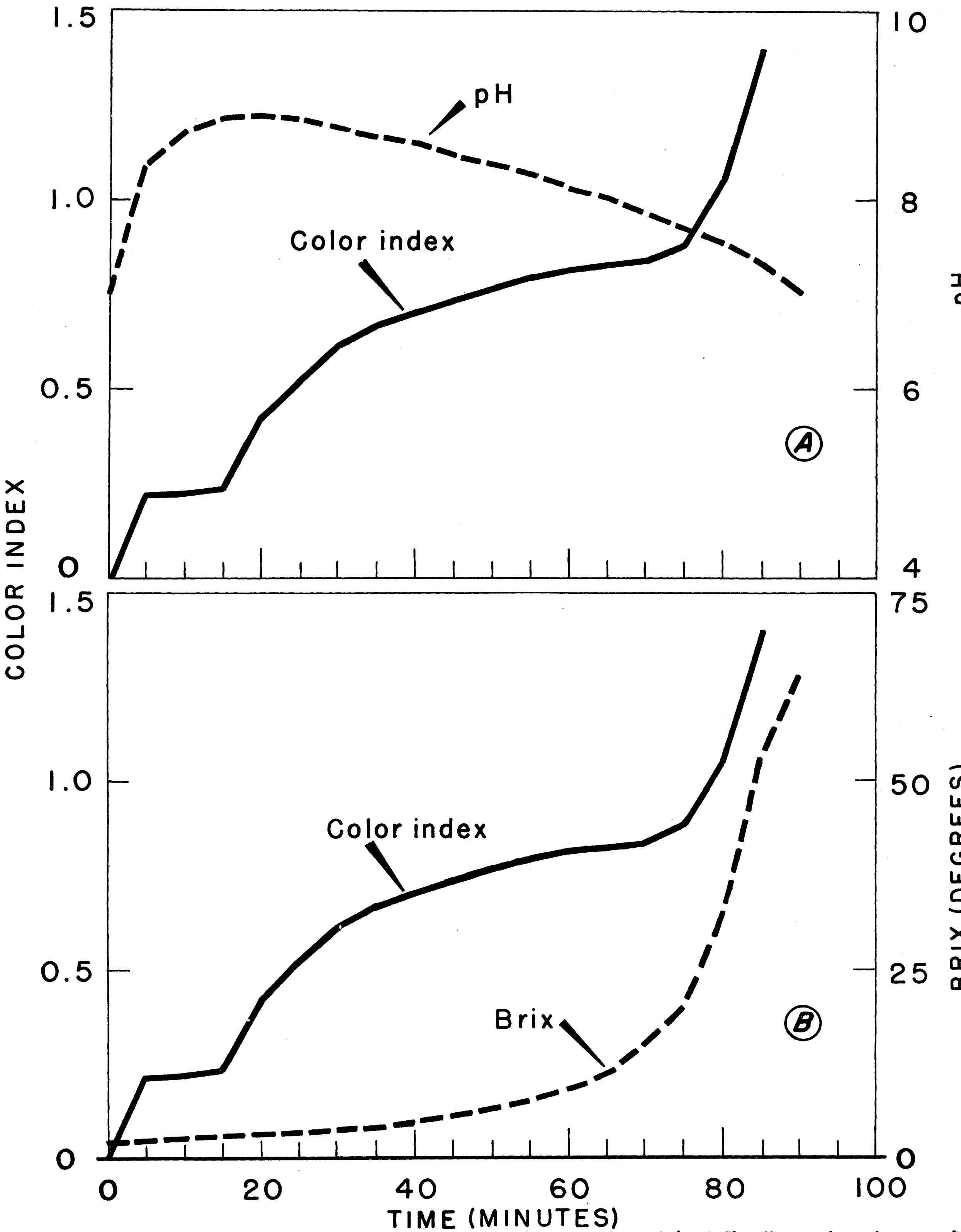

Chart 5.—Changes in Brix value, color, and pH that occur in sap during the evaporation period. *A*, The pH curve shows that soon after evaporation begins the sap becomes alkaline, reaching a pH of 8 to 9; it then decreases in alkalinity until at the end of the period it is about neutral. Little color is produced until after the sap reaches a pH of 8, at which point the rate of color production becomes rapid. It becomes still greater 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.

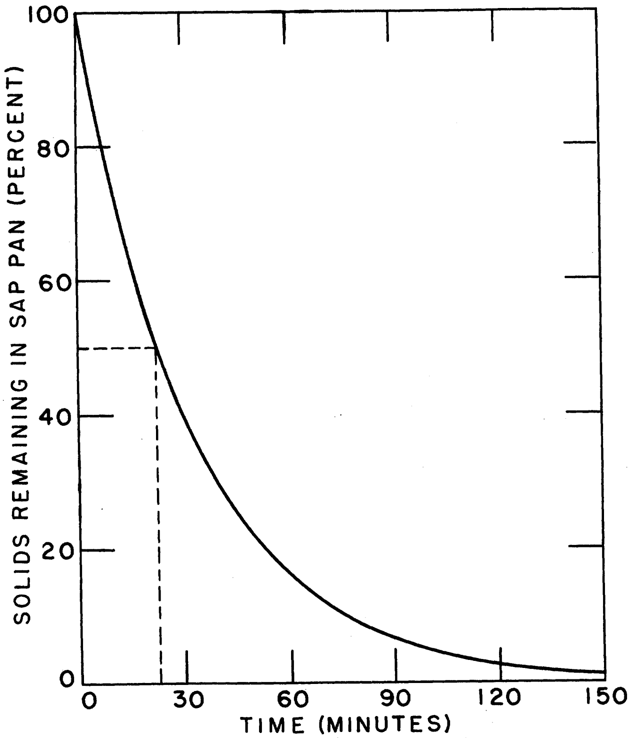

Chart 6.—The average length of time (the time required to remove 50 percent of the water) that any lot of sap remains in the sap pan (see dotted lines) is slightly less than 30 minutes. The time can be shortened or lengthened by using sap of lower or higher solids content (° Brix), by varying the depth of sap in the evaporator, and by varying the intensity of the heat.

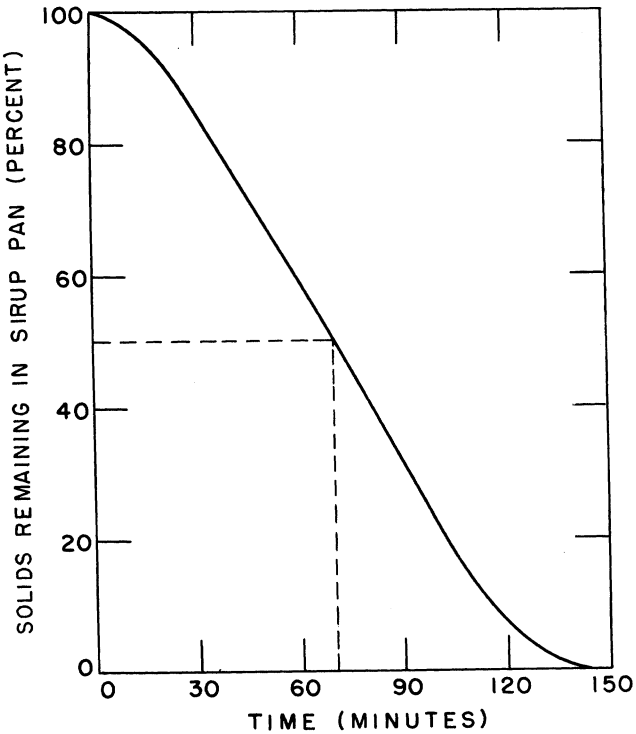

Chart 7.—The average length of time (the time required to remove 50 percent of the water) that any lot of sap remains in the sirup or front pan (see dotted lines) is a little more than 60 minutes. The time in this pan can also be shortened or lengthened by changing the Brix value of the sap entering the sirup pan, by varying the depth of the sap, and by varying the intensity of the heat.

amount of color produced in a given boiling time is small, whereas at higher concentrations it is very much larger. The increasing rate of color formation does not become appreciable until the Brix value of the sap reaches 25° or more, and this occurs after the sap reaches the sirup pan. (See table 4.)

Other changes that occur in the sap as it boils are shown in chart 5. The rate of color formation (*52*) is greatest as the sap approaches the concentration of finished sirup. 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 development increases rapidly as concentration increases. The effect of holding the boiling sap (sugar) in the sap and sirup pans for different periods of time is shown in charts 6 and 7.

The curves show the average time (time required to remove 50 percent of the water) that a lot of sap with an initial solids content of 2.5° Brix remains in the sap pan is a little less than 30 minutes and in the sirup pan slightly more than 60 minutes. The average time the sap is in the evaporator is approximately 1½ hours. 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, (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 the boiling sap.

The Evaporation Time

From the time a unit of sap enters the sap pan until it is removed from the sirup pan as sirup is the evaporation time. Measurements of evaporation time should not be made until the evapo-

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made 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 absorbence at 450 ml. using distilled water as the blank, b is the depth of the solution in centimeters, and c is the grams of solids as sucrose per 100 ml. of solution as determined on a 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).

rator is operating steadily and sirup is being drawn off. The evaporation time can be lengthened by increasing the level of liquid in the pans. The lowest level of liquid will have the shortest holdup time.

Liquid Level in the 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 prevent scorching the pans. 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 being 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, with the sap merely simmering, this gradient is lost and the depth of the sap tends to become the same and higher throughout the evaporator. This also causes an intermixing of sap of different concentrations which, together with an average increase in the depth of sap, results in a longer holdup time and production of darker sirup. The lower the Brix value of the sap the longer the holdup time becomes, since there must be greater gradient in the sap levels. As the minimum level at the point of sirup drawoff is fixed to prevent burning the pans, the level at the sap intake must be adjusted to keep the sap proportionately deeper.

Rates of Evaporation

Recent studies (*40*, *50*) indicate the changes in density that sap undergoes in different parts of the evaporator.

The solids concentration of the sap is about doubled in the sap pan, that is, nearly 50 percent of the water that is to be removed has been evaporated. By the time the sap reaches a concentration of only 19° Brix, 90 percent of this water has been removed.

The changes in the concentration of a typical sap (with a solids content of 2.5 percent) during its evaporation are given in table 4. Chart 8 shows a 2-section evaporator with 3 channels in the sap or flue pan and 4 in the sirup or front pan and the points at which the concentration measurements (table 4) were made.

To make 1 gallon of standard-density sirup from this sap required $\frac{86}{2.5}$, or 34.3 gallons of sap, and 33.3 gallons of water had to be evaporated. The sap concentration was doubled (from 2.5° to 5.0° Brix) in the sap pan. This removed 17.4 gallons of water or more than 52 percent of the 33.3 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 this occurred by the time 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 evaporation is accomplished 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.

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

Section of evaporator	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	17.34
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	33.97	99.16
Finished sirup	65.5	.28	.84	33.25	100.00

[1] Percentage of sugar.

Summary

1. Evaporators are of atmospheric or open-pan design, usually with sections, and are made for continuous or semicontinuous operation.
2. Rule of 86: $a=\frac{86}{X}$,

   where a=the number of gallons of sap, with an initial Brix value of X, required to produce 1 gallon of standard-density sirup.
3. Formation of color and flavor in maple sirup occurs during evaporation of the sap. The amount of these is related to the length of time the sap is boiled in the evaporator, especially in the sirup section.
4. The length of time the sap is in the evaporator depends largely on the depth of the sap in the evaporator. The depth of the sap in turn depends on the initial Brix value of the sap. The higher the Brix value, the shallower is the depth of sap required and the shorter is the required holdup time.
5. The rate of evaporation diminishes as the sap approaches the solids concentration of standard-density sirup.

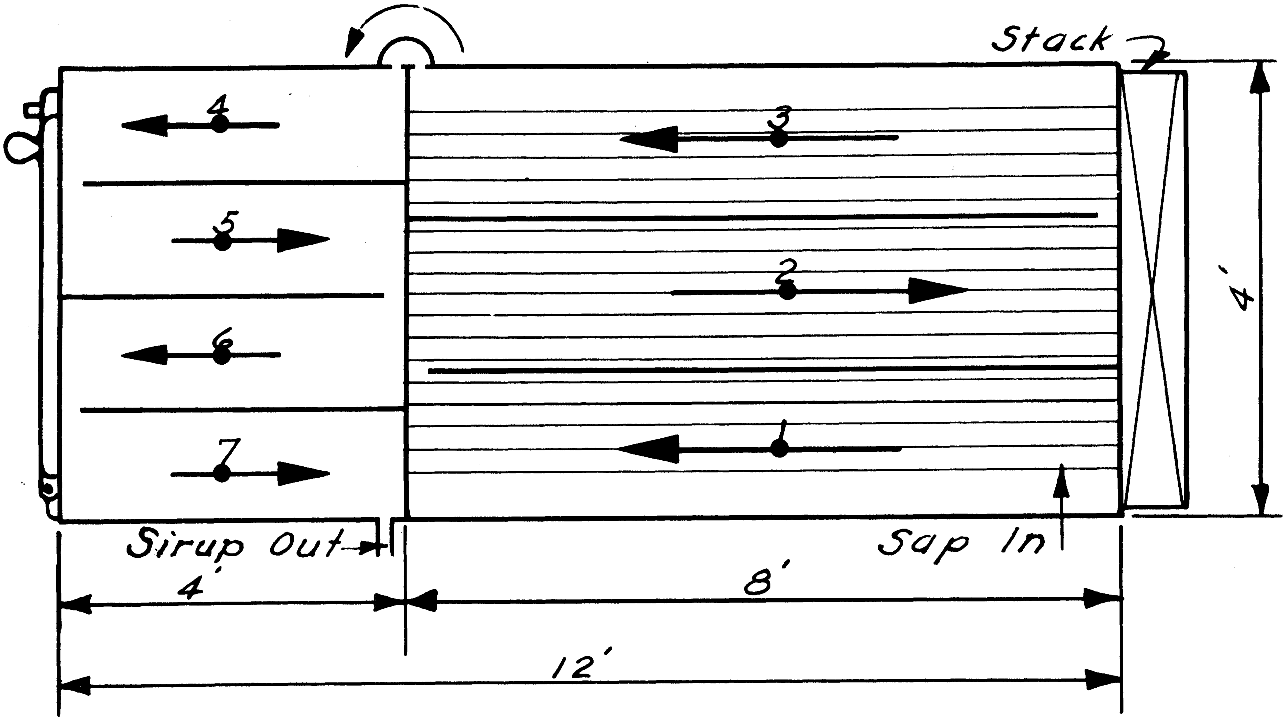


Chart 8.—Top view of a simulated maple-sap evaporator having 3 channels in the sap pan and 4 channels in the sirup pan. Arrows show direction of flow of the sap and the solid circles show the location of sap of different sugar percentages (° Brix), as indicated in table 4.

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 (½ to 1 inch) in the sirup pan. As water is evaporated, the float valve will admit more sap (fig. 49).

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 is always maintained at a depth of ½ to 1 inch at the point of drawoff.

The constant addition of sap keeps the sap in the sap 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 solids content of the sap in the storage tank it is possible to set the float valve to maintain the desired depth of sap in the evaporator. The solids content of the sap should be checked with a hydrometer every half hour or whenever a new lot of sap is run into the storage tank.

Drawing Off the Sirup

The best way to determine when sap has been evaporated to standard-density sirup is by its boiling point. 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 the Boiling Point," page 26.

Any thermometer with a range of temperature up to 225° F. can be used to determine the boiling point of sirup, if it has a sufficiently open scale and is calibrated at intervals of 1°.

As soon as the boiling sirup reaches the proper temperature, the drawoff valve is opened and the finished sirup is removed. The temperature of the boiling sirup should be watched closely to be sure it neither rises above nor falls below the proper temperature, and the rate of removal should be regulated to maintain that temperature. If the boiling sirup falls below the proper temperature, the drawoff valve should be closed immediately.

Automatic Drawoff Valve

An automatic sirup drawoff valve is now available. It opens automatically when the sirup reachers the proper temperature (7° F. above the boiling point of water). The valve is operated by a solenoid, which in turn is activated by a thermoregulator. The thermoregulator is set by hand to open or close the valve when the boiling sirup goes above or below the proper temperature, and must be reset to compensate for changes in barometric pressures.

This type of drawoff valve may be purchased assembled and ready for use, or the various parts may be purchased separately and assembled by the user.

At the time of this writing, the author has had insufficient experience with the automatic drawoff valve to make any recommendations regarding its use.

Finishing Pan

Because of the difficulty of maintaining the boiling sirup at *exactly* the right temperature for continuous drawoff of standard-density sirup (7° F. above the *exact* boiling point of water), the use of a finishing pan is recommended. When a finishing pan is used, the sap is drawn from the evaporator at a concentration of 55° to 60° Brix (4° to 5° F. above the boiling point of water). At this concentration, the density is not critical and drawoff can be continuous. An automatic drawoff valve can be used. Evaporation is then completed in a separate pan called the finishing pan.

The dimensions of the finishing pan should be approximately 2 feet by 3 feet. (The sugaring-off pan listed by most equipment manufacturers is adequate.) The use of the finishing pan provides a means for the exact control of the finishing of the sirup without extending the total time the sap is heated. 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 has reached the proper temperature (7° F. above the exact boiling point of water) remove the pan from the heat immediately, either by lifting the pan free of the firebox, or, if it is heated by gas or oil, by extinguishing the flame or by means of a damper arrangement bringing a current of cold air across the bottom of the pan. A gas-fired burner is preferred since the heating can be stopped immediately.

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

Completion of Run of Sap

When the evaporation of a given 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. This permits the evaporation of all of the sap to sirup without any loss of sap, and the pans can be flooded with 3 to 5 inches of water before the fire is extinguished.

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, because enough heat will remain in the firebox and arch to melt the solder and the thin metal of the pans if the pans become dry before the firebox has cooled.

Cleaning the Evaporator

During the evaporation of sap to sirup, the salts of calcium and magnesium are concentrated to a point where they can no longer be held in solution. They are then deposited as a precipitate called sugar sand, mostly in the sirup pan. Like boiler scale, sugar sand forms a hard, impervious layer on the bottom and sides of the evaporator, and this layer builds up with continued use. The scale cuts down transfer of heat, which reduces the efficiency of the evaporator, wastes fuel, and causes an undue holdup of sirup in the evaporator. Sugar sand also contains entrapped caramelized sugar, which contributes to the production of dark-colored sirup.

To remove sugar-sand scale is not easy and to do so by physical means (scraping, scrubbing with steel brushes, or chiseling) is almost impossible. Removal becomes more difficult as the layer of scale becomes thicker.

Because of the chemical similarity of sugar sand to milkstone—both are deposits of insoluble calcium salts—the same commercial preparations used for removing milkstone from milk-processing equipment can be used to remove sugar-sand scale. One of the best of these is sulfamic acid, either commercial grade or with modifier. Sulfamic acid should be used on galvanized equipment only with extreme care as it readily attacks the zinc coating.

Caution: The milkstone remover should be used as directed by the manufacturer. Extreme care should be taken to be sure that the remover has been completely rinsed out of the evaporator pans with water before they are used to evaporate more sap. If rinse water is not available at the evaporator house, the evaporator pans should be taken to a source of water supply.

If the pans have a heavy incrustation of scale, a time should be selected when the milkstone remover (diluted according to the manufacturer's directions) can be put in the pans to soak until the scale softens. If the weather is cold, the pans with the diluted solution should be set on the arch and the solution should be heated but not boiled. Use of excessively strong solutions of milkstone remover or leaving it in the evaporator longer than is required to soften the scale may damage the tinned surface of the evaporator.

The best maintenance practice is to remove the sugar-sand scale between each run. The deposit will be thin, and swabbing the milkstone remover on the pan with a cloth, allowing it to remain a short time, and then completely rinsing the pan with water will be sufficient to keep it clean and bright.

The practice of periodically reversing the flow of sap through the evaporator, according to the manufacturer's directions, is recommended. This practice will not prevent the formation of sugar-sand scale, especially in the sirup pan, but it will retard its formation. Another practice for cleaning the evaporator that has been used with some success is that of running water through the entire evaporator for a long period of time.

At the end of the season the evaporator should be cleaned and rinsed; it should be stored in an upside-down position preferably by mounting it on sawhorses, or it can be leaned against the wall of the evaporator house. An evaporator that is stored in a dry place will not rust or deteriorate.

Summary

1. Use a flue-type open-pan evaporator.
2. Choose an evaporator of sufficient capacity to handle a day's run of sap in 16 hours. (Consult manufacturer's rated capacities.)
3. Operate the evaporator with a minimum depth of sap. (Keep the depth of sirup at point of drawoff between ½ and 1 inch.)
4. Keep the sap boiling rapidly at all times.
5. Keep the fire uniform.
6. Keep the fire doors closed except when adding fuel.
7. Draw off the sirup as soon as it reaches the proper temperature (7° F. above the boiling point of water for that day).
8. Regulate the rate of sirup drawoff to the rate of evaporation. Keep the temperature at exactly 7° F. above the boiling point of water.
9. With evaporators that cannot be operated so that standard-density sirup can be drawn continuously, draw the sirup when it is 50° to 60° Brix (4° or 5° F. above the boiling point of water). This will permit continuous drawoff. Finish the low-Brix sirup by evaporating to standard density (65.5° Brix) in batches in a finishing pan.
10. Clean the evaporators often to remove sugar sand as it accumulates.
11. Be sure to rinse the evaporator pans thoroughly with water after using a chemical cleaner to remove sugar-sand scale.
12. 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), the vacuum evaporator, and a newly developed rapid atmospheric evaporator (R. A. E.). They are best suited to large-scale or central-station (cooperative-plant) operation.

Steam Evaporator

The evaporation of maple sap with high-pressure steam is practiced by a few producers. Its use, however, has never become widespread. Steam evaporators have certain advantages as well as some disadvantages, as follows:

Advantages: (1) The heat is steady so that evaporation of the sap can be maintained at a continuous and even rate. (2) The heat can be supplied in steam coils, manifolds, or a jacketed kettle. (3) The evaporator can be of smooth wall construction; flues are unnecessary. (4) Scorching of sirup is minimized. (5) The evaporator room can be separated from the boiler room and so is easier to keep clean at all times.

Disadvantages: (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 steam boiler (boiler horsepower, b. h. p.) required to evaporate sap to sirup can be calculated, as 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 water as it enters the boiler, the operating pressure of the boiler, and the initial temperature of the sap. 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. This will require $33.25 \div 3.25$, or approximately 10 b. h. p. 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 evaporate the sap to about 30° or 40° Brix in flue pans, and steam is 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 evaporation plants in maple-producing areas can be adapted for use in evaporating maple sap. This was done during the 1930's at Antigo, Wis., where a milk plant was used for making sirup during part of the day in the spring sirup season.[7]

A practical procedure, and the one which was used at Antigo, is as follows: The sap is concentrated in the conventional open-pan evaporator at the farm site to between 25° and 30° Brix. Evaporation is completed in the vacuum evaporator at a central or cooperative sirup-finishing plant. This two-stage method of evaporation results in a nearly colorless and flavorless maple sirup. Such sirup would hardly find a market for direct use, but it would be ideal for the production of high-flavored sirup, as described on page 45.

A study at Cornell on the use of milk-plant equipment during off-peak seasons for evaporating maple sap showed that this use was practicable but that the sirup produced had to be treated by the high-flavoring process to obtain marketable maple sirup (*12*). The fixed costs chargeable to the use of the milk-plant equipment would be negligible. However, means of transporting the perishable, partly concentrated sap to the milk-concentrating plant would be required, and the use of a central sirup-finishing plant would require a new procedure of maple-sirup production.

High-Speed Tube-Type Evaporator

The rapid atmospheric evaporator (R. A. E.), which is designed to be operated with high-pressure steam, is a new development (*41*). Sap that has been concentrated to a density of about 20° Brix can be converted to sirup in this high-speed tube-type evaporator in a few seconds. Because of the short heating time, little or no color is developed in the final and critical stage of evaporation. Poor-quality sap, that would make a dark-colored sirup in the conventional open-pan evaporator, makes a lighter colored (higher quality) sirup when finished in the R. A. E. High-quality sap finished in the R. A. E. may make sirup too light in color and too delicately flavored. However, color and flavor can be developed by holding the hot sirup for a short time in an insulated chamber attached near the outlet of the R. A. E., or by the high-flavor process described on page 45.

The R. A. E., like the vacuum evaporator, is best suited to central-station or cooperative-plant operation and its adoption by the maple industry would require new marketing methods. The R. A. E. is not a substitute for the open-pan evaporator; in fact, it functions best when used to complete the evaporation of sap that has been previously concentrated to a density of at least 20° Brix. Concentrating sap with an initial density of 2.5° Brix to a density of 20° Brix removes approximately 90 percent of the water that has to be evaporated to make standard-density sirup. In performing this important function the farm-operated open-pan evaporator would still do a major part of the evaporation. However, finishing the sirup in the R. A. E. insures a better quality sirup from poor-quality sap.

Summary

1. The steam evaporator is expensive to install. It provides a steady source of heat, and danger of scorching is minimized. The sirup produced is light colored and delicately flavored. 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 is bland with essentially no maple flavor, but it is excellent for use in making high-flavored sirup.
3. A new rapid atmospheric evaporator (R. A. E.) has been developed for use in the second stage in a two-stage method of evaporation. This evaporator is also limited to large-scale central-plant operation. The heating time required by this high-speed tube-type evaporator for the *last* and *critical* stage of evaporation is so short that little color is imparted to the finished sirup, even sirup made from late season or low-quality sap.

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 that portion which lies over the firebox are heated by radiant as well as by convection heat that is liberated by the burning gases. The wood may be sound cordwood, defective trees removed in improvement cuttings, or sawmill wastes—either culls or slab.

In the evaporation of sap to sirup, the object is to evaporate 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 the same amount of dry wood. Poor-burning fuel results

[7] Interdepartmental communication of Michigan College of Mining and Technology: Baggley, G. F., and Machwart, G. M. MAPLE SIRUP MANUFACTURE, USING A VACUUM EVAPORATOR. 28 pp. 1947. [Processed.]

in a slower boiling rate, which 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 the other, keeping the fuel in the firebox at almost constant volume. The fire doors should be closed immediately after each charging of wood to reduce the intake of cold air, which reduces the boiling rate of the sap and increases its holdup time in the evaporator. Likewise, 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.

The cost of wood fuel to produce a gallon of sirup, based on data obtained in 1953 and 1955, ranged from 15 to 65 cents, with an average of 45 cents. This represents less than 10 percent of the cost of sirup production (*2*, *42*).

Oil

The use of oil for heating the evaporators has been increasing steadily during the past few years. Unquestionably, one factor has been the shortage of labor; this would be a factor even if the cost of oil were not favorable compared with the cost of wood. Use of oil not only eliminates the need of a fireman, but also eliminates the preseason preparation of wood. Surveys in Wisconsin (*42*) and New York (*2*) show that 35 percent of the total labor in making maple sirup is spent in boiling the sirup; therefore, elimination of a fireman offers a real opportunity for economy. Surveys (*29*) also show that the cost of oil (43 cents per gallon of sirup produced) compares favorably with the cost of wood.

Once oil-firing equipment has been installed and put to use, its real advantage becomes apparent. An oil fire provides the even, high temperature so necessary for the production of high-quality sirup.

Present-day evaporators were designed for wood, and conversion to oil merely by putting a burner in the firebox of the evaporator has been unsatisfactory in some instances because the two fuels burn in different ways. The luminous flame from wood extends the entire length of the arch, whereas the flame from oil extends only a short distance from the burner nozzle. Consequently, the more successful installations of oil burners have included specially built or rebuilt fireboxes and arches. Such an installation is shown in figure 50.

The evaporator pans are heated principally by radiant heat, which travels in straight lines as heat waves from its source. In oil firing, the heat is propagated in the firebox and all of the luminous flame is limited to that area. To make full use of the radiant heat, the firebox and the arch must be rebuilt. The bed and slope of the arch must be dropped so that most or all of the underside of both sap and sirup pans are in line with the flame (chart 9).

The approximate size of oil burner (gallons of No. 2 oil per hour) to use with a flue-type evaporator can be calculated by dividing the manufacturer's rated capacity of the evaporator (gallons of sap per hour) by 10. Experimental data have shown that under average operating conditions 1 gallon of oil will evaporate 10 gallons of water (sap) in a flue-type evaporator.

Phillips and coworkers (*29*) found that use of the flues in the sap pan as economizers is desirable if maximum utilization of the B. t. u.'s of the oil is to be achieved. Further, a perpendicular wall at the back of the firebox is advisable. Unburned oil droplets impinge on this wall and ignite, instead of being drawn up the stack. Also, the wall deflects the hot gases from the burner upward toward the pans. The burner is located well below the pans to prevent insulating soot from being deposited on them.

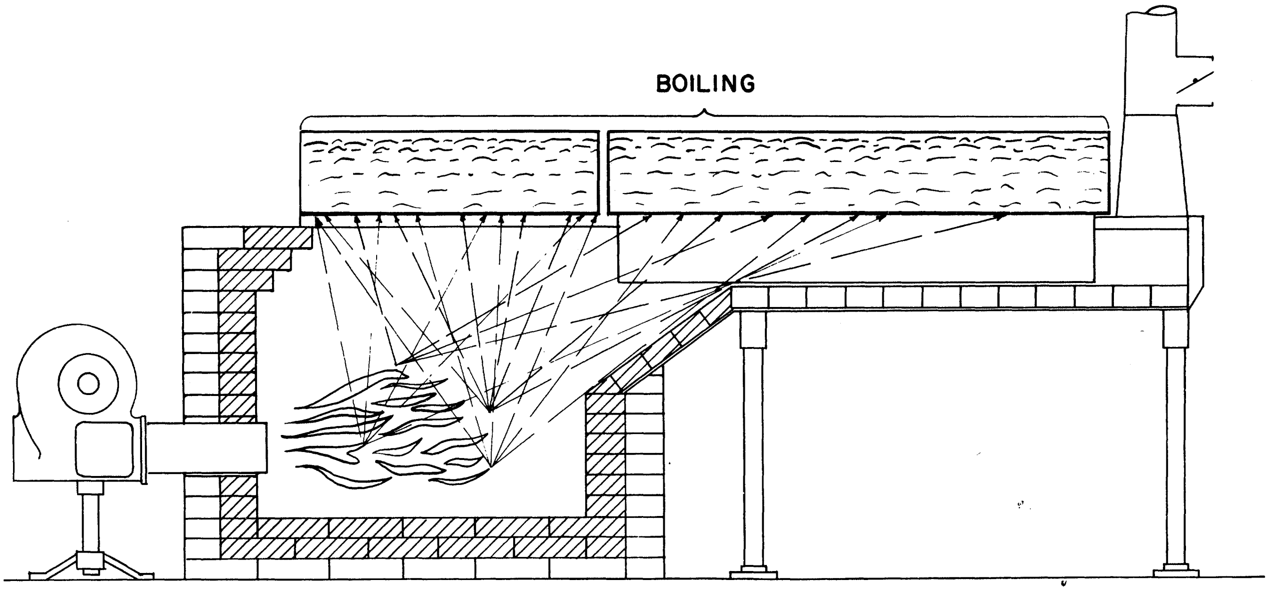
In other installations, the oil burner has been mounted just a few inches below the pans. This is satisfactory if sufficient air is supplied to permit complete combustion.

The brick used to line the arch must be a fire-resistant type, and it must be nonporous, otherwise it will take up moisture during inactive periods. This moisture may freeze and crack the brick.

With either oil or wood, fuel costs are a small part of the total cost of making sirup. Therefore, it is not good practice to make fuel economy the major consideration. Rather, use the amount of fuel that will evaporate the greatest number of gallons of sap per hour. This will contribute to the production of high-quality sirup.

Summary

1. Use only well-seasoned dry wood, either cord or slab.
2. Keep a steady fire.
3. Fire first on one side of the firebox and then on the other.
4. Keep the fire doors open only long enough to charge the firebox.
5. Open the dampers and draft doors only enough to furnish the air for combustion.
6. The use of oil as fuel is recommended if there is a shortage of labor.
7. To use oil, the firebox and arch must be specially built or rebuilt.
8. Use only fire-resistant brick for lining the firebox.
9. The cost of fuel for making sirup is approximately the same for oil and wood.



OIL BURNING FURNACE

Chart 9.—Diagram showing an arch for oil-burner installation. With this design the radiant rays of the oil fire strike the underside of the flues in the sap pan as well as the underside of the sirup 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

The composition of maple sap and sirup is given in table 5. The analyses in this and subsequent tables are not average values; they are analyses of typical saps and sirups. Usually the composition of the sirup and sap are essentially the same, except that on an "as is" basis the constituents of the sirup show a 30- to 50-fold increase as a result of the concentration of the sap to sirup. The amounts of some of the constitutents, 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 (*33*). 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 6). The other 0.05 percent is composed of raffinose together with 3 unidentified oligosaccharides. Unfermented sap does not contain any simple or hexose sugars.

The sap contains a relatively large number of nonvolatile organic acids (table 7), even though they account for only a small proportion of the solids (*31*). Malic acid exceeds all others by 10 times. One or more of these acids may play an important role in the formation of "maple flavor."

The ash or mineral matter (table 8) 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 hard scale, calcium malate, which forms on the pans and is known as sugar sand. The low sodium and high potassium content of the ash suggests the use of maple in dietary foods.

TABLE 5.—*Composition of maple sap and sirup* [1]

Item	Sap	Sap (dry weight)	Sirup (dry weight)
	Percent	*Percent*	*Percent*
Sugars	2.00	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 varies in composition betweeen rather wide limits.

Table 6.—*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	---------
Oligosaccharide I [2]	. 00018	. 013	---------
Oligosaccharide II [2]	. 00020	. 014	---------
Oligosaccharide III [2]	. 00042	. 028	---------

[1] Typical values, not averages.
[2] Oligosaccharides I, II, and III have been isolated by chromatography but have not been identified.

Table 7.—*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 dihydroxy-butyric	. 000	. 00	. 006
Unidentified acids I, II, III, IV [2]	Trace	Trace	Trace
Unidentified acids V, VI, VII [3]	0	0	Trace

[1] Typical values, not averages.
[2] These occur in both sap and sirup.
[3] These occur only in sirup.

Table 8.—*Mineral composition of maple sap* [1]

Item	Sap	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 (*30*).[8] 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; nitrogen occurs only in the form of peptids. Whether or not the nitrogenous matter enters into the formation of maple color or flavor is an open question.

[8] Also unpublished data of Eastern Utilization Research and Development Division, U. S. Agricultural Research Service.

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 so obtained is white 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 (*51*). 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 1 or more of the 6 sugars and 1 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 sugars. 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 10.

FORMATION OF TRIOSES FROM SUCROSE

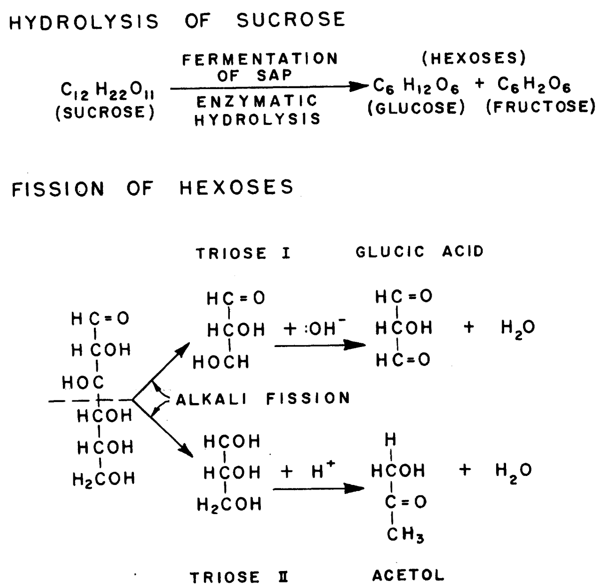


Chart 10.—Chemical reactions showing the formation of trioses from the sucrose of sap. In the first reaction, 1 molecule of sucrose is hydrolyzed by enzymes to yield 2 molecules of hexose sugars. In the second reaction, these hexoses are broken by alkaline fission into trioses.

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. The second reaction is the alkaline degradation of the fructose and dextrose to trioses (*35*). The latter 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.

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

Factors Controlling Color and Flavor

Factors that control color and flavor are: (1) amount of fermentation, (2) pH of the boiling sap, (3) concentration of the solids (sugars), (4) time of heating (the time necessary to evaporate sap to sirup), and (5) temperature of the boiling sap (*52*). The most important of these factors are the time required to boil sap to sirup and the amount of fermentation products in the sap. 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 the pH changes in the boiling sap. At the beginning of the 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 length of time the sap is boiled (the time that it takes a unit of sap to traverse the evaporator and be drawn as sirup) is the most important factor in development of color and flavor (*52*). The longer the boiling time the darker the sirup and, conversely, the shorter the boiling time the lighter the sirup. The effect of the boiling-point factor is further augmented by the increasing solids concentration as the sap is evaporated. This was discussed previously in the section on evaporation. The relationship 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 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 in color.

Rules of Sirupmaking

This leads to the following axioms that should be followed in sirupmaking:

(1) Don't use fermented sap. To keep the sap from fermenting, collect it often, don't 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. Wash the sap-gathering equipment (buckets, pails, and tanks) at least once during a season.

(2) Speed should be the sirup producer's watchword, for speed has much to do with the color of the finished sirup. The sooner sap is evaporated after it has been obtained from the tree, the higher the grade of sirup that will be produced. The faster sap is evaporated to sirup, especially during the last stages of the evaporation when the solids concentration is highest, the lighter will be the color and the higher the grade of the sirup.

(3) Cleanliness is a must in maple sirupmaking for, aside from its esthetic aspects, cleanliness is the only way that microbial contamination and subsequent growth in the sap can be controlled. Sirup made from sap in which growth of microorganisms has occurred tends to be dark-colored and low in grade.

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

Grades of Sirup

It is generally believed that the best sirup (that is, sirup lightest in color and flavor) is made early in the season during the first or second sap runs. However, this is not always true, as was demonstrated in 1954 when sirup made early in the season was darker than some made later. The important factor is the 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 little care is needed to produce a light-colored, light-flavored, fancy sirup. Sometimes, as in 1954, the weather at the onset of the season is warm in most areas and fermentation occurs. The result is that the first-run sirup is darker than expected. Later in the season, conditions reverse themselves and fancy sirup is the rule, for with the 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.

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.
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 is 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.

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 will be either too high or too low. To conform with minimum Federal and State requirements, sirup must have a solids content (density) of not less than 65.46° Brix at a temperature of 68° F. In this region, a little more or a little less evaporation has a relatively big effect on the concentration (table 4). 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 difficult.

Viscosity of Maple Sirup

Maple sirup with a density only 0.5° to 1° Brix below standard-density sirup tastes thin. This is due to the pronounced change in the viscosity of sugar solutions with only slight change in concentration, especially in the range of standard-density sirup. At a temperature of 68° F., an increase in the density of sirup from 0° to 20°

TABLE 9.—*Viscosity of sucrose solutions of various densities at temperatures of 68° and 140° F.*[1]

Density of solution (° Brix)	Viscosity at—	
	68° F.	140° F.
	Centipoises	*Centipoises*
20	2. 0	0. 8
60	58. 9	9. 7
61	69. 7	10. 9
62	83. 0	12. 2
63	99. 8	13. 8
64	121. 0	15. 7
65	148. 2	18. 0
65.5	164. 3	19. 4
66	193. 3	20. 7
67	229. 4	24. 0
68	290. 5	28. 0
69	372. 7	33. 0

[1] Data from pp. 671, 674 of Circular C440 issued by the National Bureau of Standards, U. S. Department of Commerce.

Brix increases its viscosity only 2 centipoises (table 9), whereas in the range of standard-density sirup an increase of only 9° Brix (from 60° to 69°) increases its viscosity 313.8 centipoises (from 58.9 to 372.7). Thus, in this range only a slight difference in density changes the viscosity of the sirup sufficiently to be detectable to the tongue.

As shown in the table, the viscosity of sirup is lowered 16.1 centipoises if its density is only 0.5° Brix below standard density, and 43.3 centipoises if is is 1° Brix below standard density. The tongue is sensitive enough to detect these differences. The lowered viscosity has a marked effect on the keeping quality of the sirup and on its acceptance by consumers.

Likewise, the tongue is sensitive to slight increases in the density of sirup above standard density. An increase of only 0.5° Brix above standard density increases the viscosity of sirup 19 centipoises, and the sirup acquires a thick, pleasant feel to the tongue. 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, and 67° Brix therefore becomes the upper permissible density.

Sirup tastes best, based on its density, between 66° and 67° Brix at a temperature of 68° F.

At higher temperatures the viscosity of a sirup solution is much lower, as shown in table 9, and this accounts for the fact that all warm or hot sirup appears and tastes thin.

Old Standards of Finished Sirup

In the past, the finishing point of sirup was determined by a number of methods, none of which was highly accurate, and their use required skill and artfulness. For that reason comparatively few men have won the title of "sugarmaker."

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Typical of these methods was the "blow" test. In this test, a small loop of wire was dipped into the "sirup." When the film of sirup that formed across the loop required a certain puff of breath to blow it off, the sirup was considered finished. Another method in more common usage was the "apron" test. In this, a scoop was dipped into the sirup and then held in an upright position to allow the sirup to drain off. 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 with a thermometer, a hydrometer, and a refractometer, respectively. However, only the measurement of the elevation of the boiling point is applicable to a sugar-water solution, such as sap, while it is actively boiling.

Elevation of the Boiling Point

Chart 11 shows 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 (65.46 percent of sugar or 65.46° Brix), its boiling point has been elevated 6.85° F. above the boiling point of water. Between 0° and 27° Brix, there is only a slight 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° F. Hence, in this region the boiling-point method 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.

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 mm. mercury. Under actual conditions of sirupmaking the barometric pressure is seldom at 760 mm.; therefore, it is best not to associate the fixed value of 212° F. with the boiling point of water.

A much safer and 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

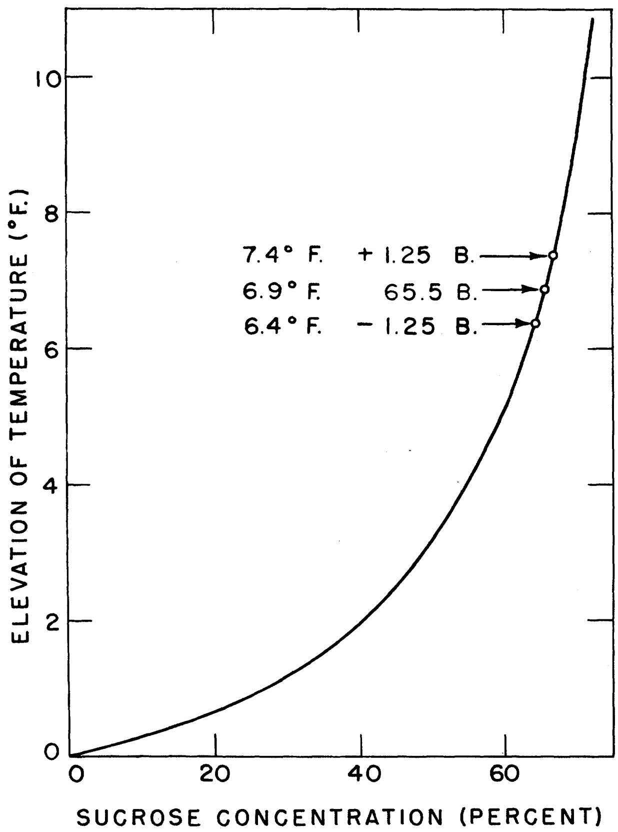


Chart 11.—Curve showing the relationship between the concentration of a sugar solution (sap) and the elevation of its boiling point above the boiling point of water.

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 11, 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 as noted by a change in the weather. The result of failure to make 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

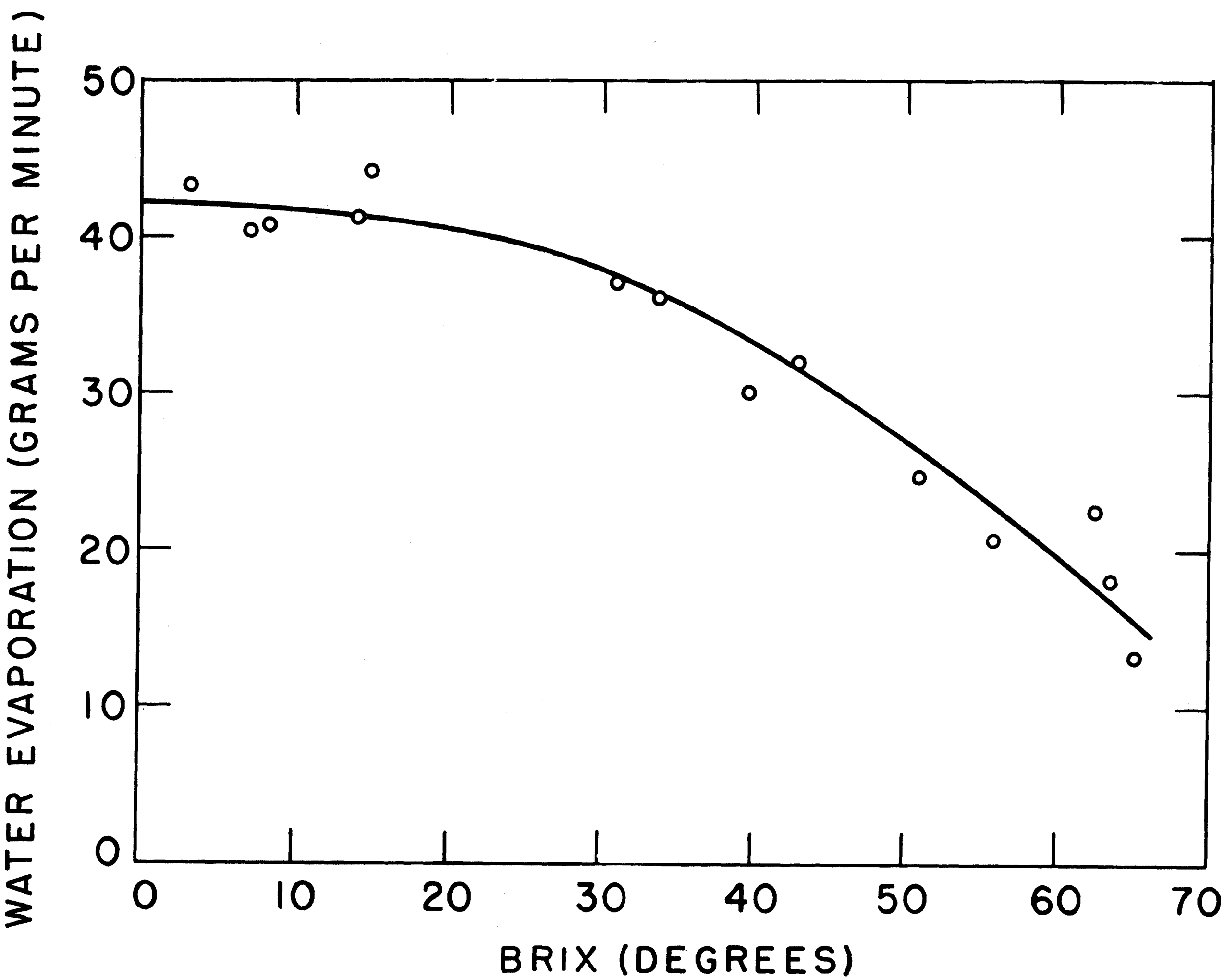


Chart 12.—Change in the rate of loss of water by evaporation, with constant heat, as the concentration of sap increases. Boiling sap with an initial density of 22° Brix loses 42 grams of water per minute, whereas sirup with a density of 65° loses only 15 grams of water per minute, a threefold decrease in rate.

2° too high, and the sirup contained 69.5 percent of solids instead of 65.4 percent (chart 11). This high-density sirup not only resulted in fewer gallons of sirup made, but 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. Such sirup would contain only 59.4 percent of solids as 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.

Special Thermometers

In sirupmaking, a knowledge of the boiling point of standard-density sirup in ° F. is unimportant providing 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, two special thermometers have been developed for use in making sirup. One is a liquid-stem thermometer with movable target and the other is a dial thermometer with movable dial.

Target thermometer.—The target thermometer (fig. 51) 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.

This 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 day and place. After adjustment, the thermometer is placed in the sirup pan adjacent to the place where the sirup is drawn off. Unfortunately, at this position, it is surrounded by steam and is difficult to read (fig. 52).

Use of a flashlight to illuminate the thermometer and a large funnel to divert the steam will make 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. For maximum accuracy it is desirable for any thermometer to have as great a distance as possible between the "water boils" line and "sirup" line. Since this is only 7° F. the thermometer will have a very fine column of liquid.

Dial thermometer.—The degree lines of the dial thermometer (*10*), like the target thermometer, refer to the boiling point of water (fig. 53). 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 easy to read (fig. 53).

The physical factors that affect the finishing of the sirup are in the sirupmaker's favor. These are the rapid change in elevation of the boiling point and the decrease in the rate of water loss (by evaporation) as the sap approaches the concentration of standard-density sirup. The elevation of the boiling point, as has been discussed, makes it possible to follow small changes in concentration by means of a thermometer. Also, as shown in chart 12, with constant heat, the loss of water per minute from boiling sap decreases as the concentration increases. Therefore, as the sap approaches the concentration of standard-density sirup, loss of water per minute slows down and the sirupmaker has a reasonable time in which to adjust the drawoff valve.

Hydrometers

A hydrometer is not the ideal instrument for judging the finishing point of sirup because it is not calibrated 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. 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.

A special hydrometer, the hydrotherm (chart 13), has a liquid thermometer built into it that automatically locates the point on the hydrometer (top of thermometer liquid column) for standard-density sirup. The accuracy of this instrument depends on the relationship of lineal expansion of the thermometer liquid to lineal displacement of the hydrometer stem by standard-density sirup at different temperatures. In use, sufficient time must be allowed for the thermometer of the hydrotherm to warm to the temperature of the sirup.

Many sirupmakers use hydrometers successfully by standardizing their technique so exactly that they can reproduce the empirical conditions of the test each time, and so can test the density of sirup that is near its boiling point (210° F., hot test). For example, each mechanical operation (filling the hydrometer can, inserting the hydrometer, etc.) is standardized so

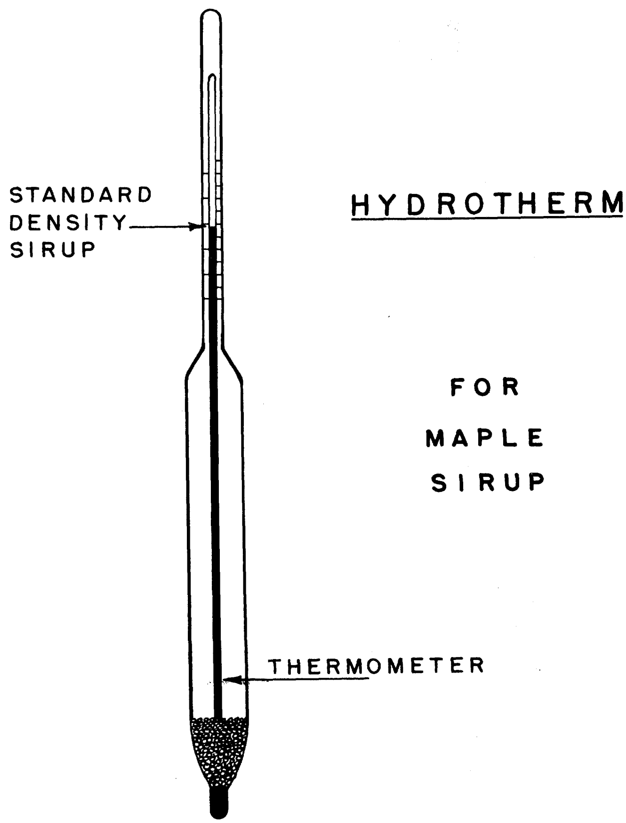


Chart 13.—The hydrotherm, a special type of hydrometer. When this instrument is placed in sirup, the top of the mercury column of the built-in thermometer automatically locates the point on the hydrometer stem that corresponds to standard-density sirup.

the same length of time is always used to make the test and consequently the sirup cools for the same length of time and to the same temperature (approximately 210°) each time the test is made.

For those who prefer the hydrometer to test the finishing point of sirup, the data in table 10 (p. 34) may be used. This table shows that standard-density sirup at a temperature of 210° F. (hot test) is 58.8° Brix and 31.9° Baumé.

Summary

1. Finished sirup must contain not less than 65.46 percent of solids (65.5° Brix) at a temperature of 68° F.
2. Table sirup that is between 66° and 67° Brix will have the best taste. Table sirup that is below standard density will taste 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 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.
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.

CLARIFICATION OF SIRUP

Sugar Sand

Sirup as it is drawn from the evaporator contains suspended solids, commonly known as sugar sand. The amount and color of these solids vary widely and depend on many factors. They are primarily the calcium salts of malic acid. These salts are precipitated because they become less soluble (1) as the temperature of the sirup solution increases and (2) 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, whereas white sugar sand will often cause it to appear lighter in color.

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

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 sedimentation, filtration, or centrifugation. On the farm, sedimentation and filtration are the methods generally used.

Sedimentation

The sedimentation or settling method is the simplest method of clarifying maple sirup, but unfortunately it has several serious disadvantages. It cannot be used to clarify all sirup. Some sirups contain suspended particles the size and nature of which make them resistant to settling. Clarification by sedimentation requires a long time—days and sometimes weeks. The sirup cools to room temperature and must be reheated to 180° F. before packaging to insure a sterile pack.

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, heated, 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.

Filtration

Filtration of maple sirup is not a simple procedure. As with sedimentation, the success and ease of clarification by filtration depends on the nature of the particles 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. Following the prefilter the sirup is run through a thicker filter, usually a layer of wool felt.

The most common filtration assembly is a large milk can in which is inserted a cone-shaped wool felt bag (fig. 54) supported at the top of the can with clothespins. Over this is placed the prefilter, also supported with clothespins and arranged to form a smaller cone within the felt.

Because sirup filters best when it is hot, it is customary to set the milk can with its filters directly under the sirup drawoff valve of the evaporator or finishing pan so that the hot sirup runs directly onto the filter. If the sirup cools off before it has all passed through the filters, the rate of filtration will be slowed down. Several manufacturers of sirup equipment have developed insulated boxes fitted with covers so that the sirup will stay hot while filtering. Usually the boxes are made to hold two or more filters to be used in rotation.

Even when a prefilter is used, the felts soon become heavily coated with sugar sand or filter cake. This filter cake usually appears as a dark-brown mudlike substance and slows down the rate of filtration. The filters have to be cleaned often to maintain filtration at a rapid rate.

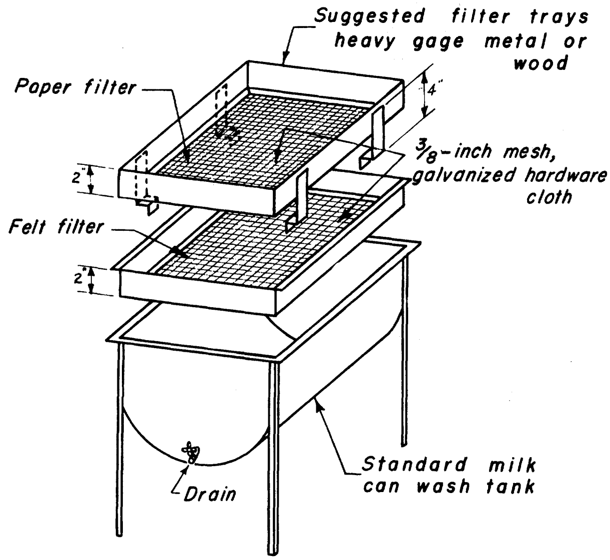
To clean the filters, the filter cake is scraped off and the entrapped sirup is dissolved by dipping the bag in a pail of hot water or hot sap taken from the evaporator. The water or sap can be returned to the sap pan. Washing is completed by turning the bag inside out and washing it several times in hot water. Soap or other detergent should not be used because they add flavor to the sirup if they are not completely rinsed out. The bag is then turned right side out and the water is removed by passing it through a clothes wringer. Prefilters can be cleaned in a similar manner.

Flat Filters

A flat-type filter consists of a square felt filtering surface (fig. 55) instead of the cone. It was first used in New York, and its use is gaining in popularity elsewhere. The flat filter provides a larger filtering area than the cone-shaped filter during the entire filtering period; distribution of the filter cake over this larger area results in a thinner layer, so the filters can be used for longer periods before cleaning becomes necessary.

The felt sheet is supported in a shallow basket of hardware cloth with 2-inch walls. 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. The felt can be used 2 or 3 times longer between cleanings if the sirup is first put through a prefilter, as described previously. The prefilter is mounted above the felt and it is supported on a wire-screen basket the same size as that used for the felt (chart 14). 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 part way across the basket (fig. 56).

The filters can be built in multiples over a common tank, as shown in figure 57. As one becomes clogged with sugar sand, the assembly can be moved so as to place a clean filter under the spigot.



SIRUP FILTER

Chart 14.—A flat-type 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 castors or wheels permits the assembly to be moved easily into place under the sirup drawoff spigot.

The flat prefilters and felts are cleaned in the same way as the cone filters.

Summary

Sedimentation

1. Strain the sirup through a paper prefilter, or cheesecloth.
2. Place 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) or cone-shaped 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.

STANDARDS FOR MAPLE SIRUP

For Retail Sale

The maple-sirup producer often finds it profitable to sell his sirup directly to the consumer. In doing so, the farmer is not only a producer but he is a food processor as well. As a food processor he is expected to offer for sale a product that meets Federal and State requirements, and he must package his 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 and has enacted regulations governing the sale and labeling of maple products (*48*). Wisconsin (*53*) and New York (*26*) are among the other States that 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 the product he has purchased meets certain minimum standards, and they also protect the producer against unfair competition.

The United States Standards for table maple sirup (*44*) are as follows:

UNITED STATES STANDARDS FOR TABLE MAPLE SIRUP

Effective February 15, 1940

INTRODUCTION

Numbers in parentheses following grade terms indicate where such terms are defined under Definition of Terms.

These standards 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.

GRADES

U. S. Grade AA (Fancy) Table Maple Sirup shall consist of maple sirup (1) which meets the following requirements:

The color shall not be darker than light amber as represented by the color standards of the United States Department of Agriculture.

The sirup shall not be cloudier than light amber cloudy standard as represented by the standards of the United States Department of Agriculture for cloudiness (2).

The weight shall be not less than 11 pounds per gallon of 231 cubic inches at 68° F. corresponding to 65.46° Brix or 35.27° Baumé (Bureau of Standards Baumé scale for sugar solutions, modulus 145).

The sirup shall possess a characteristic maple flavor, shall be clean (3), free from fermentation, and free from damage (4) caused by scorching, buddiness, any objectionable flavor or odor or other means. (See Tolerance.)

U. S. Grade A Table Maple Sirup shall consist of maple sirup (1) which meets the requirements for U. S. Grade AA (Fancy) Table Maple Sirup except for color and cloudiness (2).

The color shall not be darker than medium amber as represented by the color standards of the United States Department of Agriculture.

The sirup shall not be cloudier than medium amber cloudy standard as represented by the standards of the United States Department of Agriculture for cloudiness (2). (See Tolerance.)

U. S. Grade B Table Maple Sirup shall consist of maple sirup (1) which meets the requirements for U. S. Grade AA (Fancy) Table Maple Sirup except for color and cloudiness (2).

The color shall not be darker than dark amber as represented by the color standards of the United States Department of Agriculture.

The sirup shall not be cloudier than dark amber cloudy standard as represented by the standards of the United States Department of Agriculture for cloudiness (2). (See Tolerance.)

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 these standards but is provided as a designation to show that no definite grade has been applied to the lot.

Tolerance 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 (5) 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

Containers shall be clean and new in appearance. Tin containers shall not be rusty.

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.

Definition of Terms

As used in these standards:

1. "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).

2. "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.

3. "Clean" means that the sirup shall be practically free from foreign material such as pieces of bark, soot, dust, and dirt.

4. "Damage" means any defect that materially affects the appearance or the edibility or shipping quality of the sirup.

5. "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.

Issued: February 7, 1940.

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 governing the retail sale of maple products.
4. Federal specifications for table sirup are given in this section.

CHECKING AND ADJUSTING THE 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 11 pounds per gallon of 231 cubic inches at a temperature of 68° F., which corresponds to 65.46° Brix or 35.27° Baumé (Bureau of Standards Baumé scale for sugar solutions, modulus 145).

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

Weight Method

Determination of the density of sirup by the weight per unit of volume is not recommended as a general 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 (volume, temperature, or weight) 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, 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.

Refractometry Method

The determination of the density of sirup by measuring its refractive index is the simplest of the three methods. This method is not in general use because it requires the use of a refractometer, an expensive optical instrument. However, the precision of the density measurement that can be made with the refractometer makes it well suited for use by Federal and State inspection services and by judges of sirups placed in competition.

Hydrometry Method

Hydrometry is the most generally used method for measuring the density of cold sirup, 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. The density of a liquid is measured by means 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. The level of the liquid surface on the stem of the hydrometer is noted when the hydrometer is at rest and floating freely in the liquid, as shown in chart 15. The density value

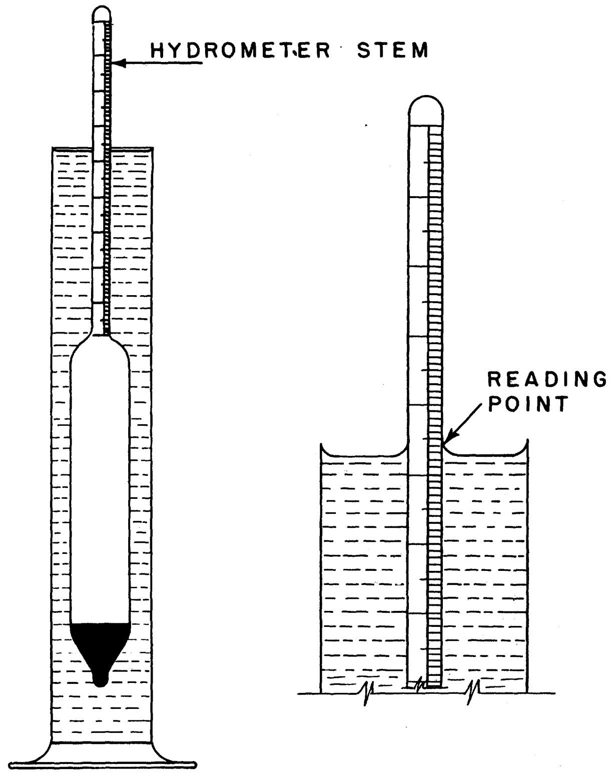


Chart 15.—Hydrometer, an instrument for measuring density. The hydrometer can should be filled to the top and the hydrometer should be read by holding the top of the can at eye level.

is read from a scale sealed in the stem. The precision or 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 (more open the scale) and the greater the accuracy of the density measurements. Hydrometers for measuring density of sirup may have the enclosed scale marked and calibrated with 1 of 3 systems or combination of these systems: (1) Specific gravity, (2) Baumé scale, or (3) Brix scale (chart 16).

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

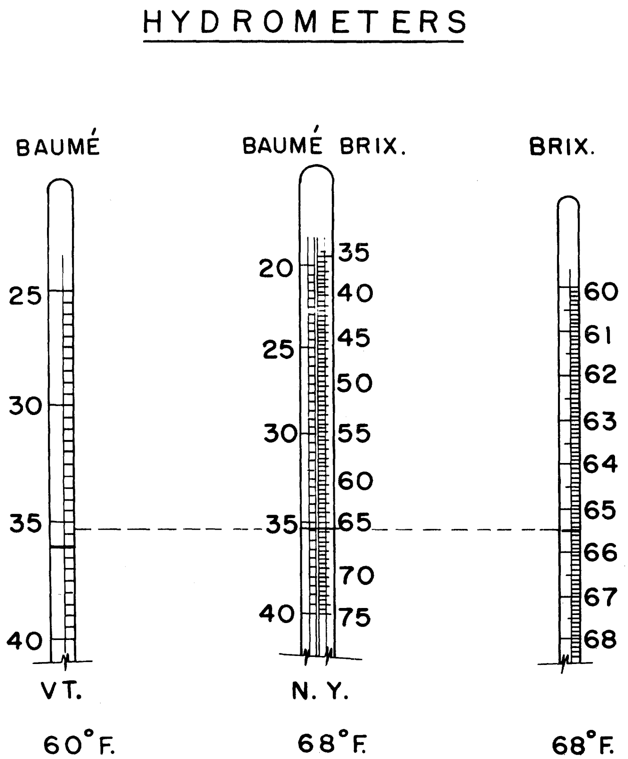


Chart 16.—The three hydrometer scales used in testing sirup. *Left,* Vermont Baumé scale, marked for testing sirup at a temperature of 60° F.; standard-density sirup at this temperature is indicated by the heavy line at 36°. *Right,* Brix scale, marked for testing sirup at 68°; standard-density sirup at this temperature is indicated by the heavy line at 65.46°. *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.

The 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, and for practical purposes the Brix value (°Brix) equals the percentage of sugar in the sirup.

The approximate 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 of great importance to the producer who sells his sirup wholesale, since the price is based on its solids (sugar) content. Thus, 100 pounds of sirup at 64° Brix contains 64 pounds of sugar whereas 100 pounds of standard-density sirup (65.5° Brix) contains 65.5 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 in 100 pounds of standard-density sirup, and it has a greater value.

To obtain the weight of sugar in sirup when density is measured by a hydrometer whose scale is in specific gravity or ° Baumé requires more involved calculation, as neither scale has a direct relationship to the amount of sugar present.

The 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 usage by the maple industry justifies the following explanation:

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, $° \text{Baumé} = \text{sp.g.} \frac{(\text{sp.g.})}{(\text{M})}$, where M=the modulus.

In the past, unfortunately, neither the temperature for which the Baumé scale was calibrated nor the modulus 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 will have a Baumé reading of 36° when measured at a temperature of 60°. In other States and for Federal specifications the scale is marked at 35.3° (for use at 68° F.). When this scale is used, standard-density sirup will have a Baumé reading of 35.3° at a temperature of 68°. When using a Baumé hydrometer, caution must be exercised in observing the temperature at which the scale is to be used.

Making the Density Measurement

To make the measurement, fill the hydrometer can to the top with sirup and hold it above the finishing pan so that any sirup displaced by the hydrometer will fall back in the finishing pan. Hold a clean, dry hydrometer lightly in the hand

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and let it sink into the sirup until it comes to rest (fig. 58). Take care not to get any sirup on that portion of the stem extending above the surface of the sirup. This would add to the weight of the hydrometer and make the sirup appear to be of lower density.

After the hydrometer has come to rest, raise the hydrometer can to eye level and obtain the density reading by sighting across the top of the jar or cylinder and noting the point on the scale of the hydrometer that is at the surface of the sirup. This hydrometer reading is the *apparent* density of the sirup.

However, maple sirup is a sugar–water solution and it behaves like water, contracting and expanding with changes in temperature. Therefore, standard-density sirup has different densities at different temperatures. Table 10 shows the weight per gallon, the Brix value, and the Baumé value of standard-density sirup at temperatures from 50° to 210° F. (*38*).

To determine whether or not the sirup is standard density, carefully measure the temperature of the sirup in the hydrometer can; then locate the hydrometer reading for standard-density sirup at that temperature in table 10. If the observed hydrometer reading is less than the value in the table, the sirup is too thin; if the reading is greater than that value, the sirup is too thick.

TABLE 10.—*Weight and hydrometer reading of standard-density sirup at different temperatures*

Temperature (° F.)	Weight per gallon [1]	Hydrometer reading	
	Pounds	° *Brix*	° *Baumé* [2]
50	11. 043	66. 32	35. 70
52	11. 038	66. 22	35. 65
54	11. 035	66. 13	35. 61
56	11. 028	66. 04	35. 56
58	11. 024	65. 94	35. 51
60	11. 019	65. 85	35. 46
62	11. 014	65. 75	35. 41
64	11. 009	65. 65	35. 37
66	11. 005	65. 55	35. 32
68	11. 000	65. 46	35. 27
70	10. 995	65. 37	35. 22
72	10. 991	65. 27	35. 17
74	10. 986	65. 18	35. 13
76	10. 981	65. 08	35. 08
78	10. 976	64. 99	35. 03
80	10. 972	64. 90	34. 98
85	10. 959	64. 66	34. 86
90	10. 948	64. 43	34. 74
95	10. 936	64. 19	34. 62
100	10. 923	63. 96	34. 50
105	10. 912	63. 72	34. 38
110	10. 900	63. 49	34. 26
115	10. 888	63. 25	34. 14
120	10. 878	63. 02	34. 02
125	10. 865	62. 78	33. 90
130	10. 855	62. 55	33. 78
140	10. 830	62. 08	33. 44
150	10. 807	61. 61	33. 30
160	10. 783	61. 14	33. 06
170	10. 760	60. 67	32. 82
180	10. 737	60. 20	32. 58
190	10. 715	59. 73	32. 34
200	10. 692	59. 26	32. 10
210 (hot test)	10. 669	58. 79	31. 86

[1] 231 cubic inches.
[2] M=145.

Correcting for Temperature

To determine the density (Brix or Baumé value) of sirup that is either warmer or colder than the temperature for which the hydrometer is marked for use, a correction must be made by

TABLE 11.—*Amount to add to* (+) *or subtract from* (−) *the observed reading on a hydrometer marked for use at 68° F.* (*Brix or Baumé*) *and on a hydrometer marked for use at 60°* (*Baumé*) *to obtain the true density of maple sirup tested at various temperatures*

Temperature of sirup tested (° F.)	Hydrometer with Brix scale—	Hydrometer with Baumé scale—	
	For use at 68° F.	For use at 68° F.	For use at 60° F.
	° *Brix*	° *Baumé*	° *Baumé*
50	−0. 86	−0. 43	−0. 24
55	−. 61	−. 31	−. 12
60	−. 39	−. 19	0
65	−. 14	−. 07	+. 12
68	0	0	----------
70	+. 09	+. 05	+. 24
75	+. 33	+. 17	+. 36
80	+. 56	+. 29	+. 48
85	+. 80	+. 41	+. 60
90	+1. 03	+. 53	+. 72
95	+1. 27	+. 65	+. 84
100	+1. 50	+. 77	+. 96
105	+1. 74	+. 89	+1. 08
110	+1. 97	+1. 01	+1. 20
115	+2. 21	+1. 13	+1. 32
120	+2. 44	+1. 25	+1. 44
125	+2. 68	+1. 37	+1. 56
130	+2. 91	+1. 49	+1. 68
135	+3. 15	+1. 61	+1. 80
140	+3. 38	+1. 73	+1. 92
145	+3. 62	+1. 85	+2. 04
150	+3. 85	+1. 97	+2. 16
155	+4. 09	+2. 09	+2. 28
160	+4. 32	+2. 21	+2. 40
165	+4. 56	+2. 33	+2. 52
170	+4. 79	+2. 45	+2. 64
175	+5. 03	+2. 57	+2. 76
180	+5. 26	+2. 69	+2. 88
185	+5. 50	+2. 81	+3. 00
190	+5. 73	+2. 93	+3. 12
195	+5. 97	+3. 05	+3. 24
200	+6. 20	+3. 17	+3. 36
205	+6. 44	+3. 29	+3. 48
210 (hot test)	+6. 67	+3. 41	+3. 60

adding to or subtracting from the observed density reading.

If the temperature of the sirup is between 50° and 210° F. when tested, its approximate density may be obtained by using the data in table 11. The data show the amount that must be added to (+) or subtracted from (−) the observed reading on a hydrometer marked for use at 68° F. (Brix or Baumé) and on a hydrometer marked for use at 60° (Baumé), to obtain the true density of the sirup.

The approximate density of maple sirup can also be obtained by the following simple calculation: Determine the difference (° F.) between the temperature of the test sirup in the cylinder and the temperature at which the hydrometer is marked for use (60° or 68°). Multiply this difference by 0.047 if the hydrometer has a Brix scale (0.024 for Baumé). *Add* the result to the observed density for sirup *warmer* than the temperature for which the hydrometer is marked; *subtract* the result from the observed density for sirup that is *colder*.

Example 1.—Suppose the temperature of the sirup at the time of testing is 78°, and it is tested with a hydrometer marked for use at 68° F.—a difference of 10°. The observed hydrometer reading is 65.0° (Brix scale) and 35.0° (Baumé scale).

The correction for the Brix scale is $0.047 \times 10 = 0.47°$. Since the temperature of the test sirup is *higher* than 68° F., the correction is added to the observed reading. Therefore, the true density of the sirup is $65 + 0.47 = 65.47°$ Brix.

The correction for the Baumé scale (marked for use at 68° F.) is $0.024 \times 10 = 0.24°$. The true density would be $35.0 + 0.24 = 35.24°$ Baumé.

Suppose the same sirup (at a temperature of 78°) is tested with a hydrometer with a Baumé scale marked for use at 60° F., a difference of 18°. The correction is $0.024 \times 18 = 0.43°$ Baumé. The true density of the sirup is $35.0° + 0.43 = 35.43°$ Baumé.

TABLE 12.—*Amount to add to (+) or subtract from (−) the observed reading on a hydrometer with a Brix scale marked for use at 68° F. (or 20° C.) to obtain the true density of sirup tested at different temperatures* [1]

Temperature of sirup tested	Observed hydrometer reading													
	0	5	10	15	20	25	30	35	40	45	50	55	60	70
32.0° F. (0° C.)	−0.40	−0.49	−0.65	−0.77	−0.89	−0.99	−1.08	−1.16	−1.24	−1.31	−1.37	−1.41	−1.44	−1.49
41.0° F. (5° C.)	−.36	−.47	−.56	−.65	−.73	−.80	−.86	−.91	−.97	−1.01	−1.05	−1.08	−1.10	−1.14
50.5° F. (10° C.)	−.32	−.38	−.43	−.48	−.52	−.57	−.60	−.64	−.67	−.70	−.72	−.74	−.75	−.77
51.8° F. (11° C.)	−.31	−.35	−.40	−.44	−.48	−.51	−.55	−.58	−.60	−.63	−.65	−.66	−.68	−.70
53.6° F. (12° C.)	−.29	−.32	−.36	−.40	−.43	−.46	−.50	−.52	−.54	−.56	−.58	−.59	−.60	−.62
55.4° F. (13° C.)	−.26	−.29	−.32	−.35	−.38	−.41	−.44	−.46	−.48	−.49	−.51	−.52	−.53	−.55
57.2° F. (14° C.)	−.24	−.26	−.29	−.31	−.34	−.36	−.38	−.40	−.41	−.42	−.44	−.45	−.46	−.47
59.0° F. (15° C.)	−.20	−.22	−.24	−.26	−.28	−.30	−.32	−.33	−.34	−.36	−.36	−.37	−.38	−.39
60.8° F. (16° C.)	−.17	−.18	−.20	−.22	−.23	−.25	−.26	−.27	−.28	−.28	−.29	−.30	−.31	−.32
62.6° F. (17° C.)	−.13	−.14	−.15	−.16	−.18	−.19	−.20	−.20	−.21	−.21	−.22	−.23	−.23	−.24
63.5° F. (17.5° C.)	−.11	−.12	−.12	−.14	−.15	−.16	−.16	−.17	−.17	−.18	−.18	−.19	−.19	−.20
64.4° F. (18° C.)	−.09	−.10	−.10	−.11	−.12	−.13	−.13	−.14	−.14	−.14	−.15	−.15	−.15	−.16
66.2° F. (19° C.)	−.05	−.05	−.05	−.06	−.06	−.06	−.07	−.07	−.07	−.07	−.08	−.08	−.08	−.08
68.0° F. (20° C.)	------	------	------	------	------	------	------	------	------	------	------	------	------	------
69.8° F. (21° C.)	+0.04	+0.05	+0.06	+0.06	+0.06	+0.07	+0.07	+0.07	+0.07	+0.08	+0.08	+0.08	+0.08	+0.09
71.6° F. (22° C.)	+.10	+.10	+.11	+.12	+.12	+.13	+.14	+.14	+.15	+.15	+.16	+.16	+.16	+.16
73.4° F. (23° C.)	+.16	+.16	+.17	+.17	+.19	+.20	+.21	+.21	+.22	+.23	+.24	+.24	+.24	+.24
75.2° F. (24° C.)	+.21	+.22	+.23	+.24	+.26	+.27	+.28	+.29	+.30	+.31	+.32	+.32	+.32	+.32
77.0° F. (25° C.)	+.27	+.28	+.30	+.31	+.32	+.34	+.35	+.36	+.38	+.38	+.39	+.39	+.40	+.39
78.8° F. (26° C.)	+.33	+.34	+.36	+.37	+.40	+.40	+.42	+.44	+.46	+.47	+.47	+.48	+.48	+.48
80.6° F. (27° C.)	+.40	+.41	+.42	+.44	+.46	+.48	+.50	+.52	+.54	+.54	+.55	+.56	+.56	+.56
82.4° F. (28° C.)	+.46	+.47	+.49	+.51	+.54	+.56	+.58	+.60	+.61	+.62	+.63	+.64	+.64	+.64
84.2° F. (29° C.)	+.54	+.55	+.56	+.59	+.61	+.63	+.66	+.68	+.70	+.70	+.71	+.72	+.72	+.72
86.0° F. (30° C.)	+.61	+.62	+.63	+.66	+.68	+.71	+.73	+.76	+.78	+.78	+.79	+.80	+.80	+.81
95.0° F. (35° C.)	+.99	+1.01	+1.02	+1.06	+1.10	+1.13	+1.16	+1.18	+1.20	+1.21	+1.22	+1.22	+1.23	+1.22
104.0° F. (40° C.)	+1.42	+1.45	+1.47	+1.51	+1.54	+1.57	+1.60	+1.62	+1.64	+1.65	+1.65	+1.65	+1.66	+1.65
113.0° F. (45° C.)	+1.91	+1.94	+1.96	+2.00	+2.03	+2.06	+2.07	+2.09	+2.10	+2.10	+2.10	+2.10	+2.10	+2.08
122.0° F. (50° C.)	+2.46	+2.48	+2.50	+2.53	+2.56	+2.57	+2.58	+2.59	+2.59	+2.58	+2.58	+2.57	+2.56	+2.52
131.0° F. (55° C.)	+3.05	+3.07	+3.09	+3.12	+3.12	+3.12	+3.12	+3.11	+3.10	+3.08	+3.07	+3.05	+3.03	+2.97
140.0° F. (60° C.)	+3.69	+3.72	+3.73	+3.73	+3.72	+3.70	+3.67	+3.65	+3.62	+3.60	+3.57	+3.54	+3.50	+3.43
149.0° F. (65° C.)	+4.4	+4.4	+4.4	+4.4	+4.4	+4.4	+4.3	+4.2	+4.2	+4.1	+4.1	+4.0	+4.0	+3.9
158.0° F. (70° C.)	+5.1	+5.1	+5.1	+5.0	+5.0	+5.0	+4.9	+4.8	+4.8	+4.7	+4.7	+4.6	+4.6	+4.4
167.0° F. (75° C.)	+6.1	+6.0	+6.0	+5.9	+5.8	+5.8	+5.7	+5.6	+5.5	+5.4	+5.4	+5.3	+5.2	+5.0
176.0° F. (80° C.)	+7.1	+7.0	+7.0	+6.9	+6.8	+6.7	+6.6	+6.4	+6.3	+6.2	+6.1	+6.0	+5.9	+5.7

[1] Adapted from a table on p. 624 of Circular C 440 issued by National Bureau of Standards, U. S. Department of Commerce.

Example 2.—Suppose the temperature of the sirup at the time of testing is 50° F. The observed hydrometer readings are 66.22° on the Brix scale and 35.70° on the Baumé scale.

The correction for the Brix scale marked for use at 68° F., is $18 \times 0.047 = 0.85°$. The correction is *subtracted* from the observed reading, since the temperature of the test solution is below the temperature (68° F.) marked on the hydrometer. The true density of the sirup is $66.22° - 0.85° = 65.47°$ Brix.

The correction for the Baumé scale (marked for use at 68° F.) is $0.024 \times 18 = 0.43°$. The true density of the sirup is $35.70° - 0.43° = 35.27°$ Baumé.

If the same sirup (at a temperature of 50° F.) is tested with a hydrometer with a Baumé scale marked for use at 60° F., the correction is $10 \times 0.024° = 0.24°$ Baumé. The true density of the sirup is $35.70 - 0.24 = 35.46°$ Baumé.

For more exact measurements, some people may prefer to use the corrections given in table 12. Although this table was prepared for a hydrometer marked with a Brix scale for use at 20° C., it has been adapted for a hydrometer marked with a Brix scale for use at 68° F.

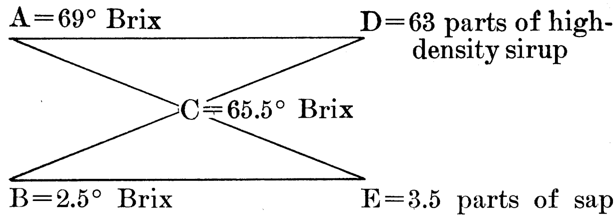
Adjusting the Density of the Sirup

Sirup with a density of more than 67° Brix at a temperature of 68° F. (or more than 36° Baumé at 68° or 36.27° Baumé at 60°) will crystallize on storage and must be diluted. This can be done by adding either sap or low-density (thin) sirup to the high-density (thick) sirup. The amount of sap or thin sirup to add can be calculated either by alligation (Pearson's square) or by the trial and error method. In the latter method, the diluent (sap or low-density sirup) is added a little at a time. After each addition the mixture is stirred thoroughly, and the density is checked. The need for thorough stirring cannot be overemphasized, because sirups of different densities are not easily mixed. This addition and mixing is repeated until the sirup reaches standard density (table 10).

Alligation (Pearson's Square)

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. A simple method for doing this is by alligation (Pearson's square).

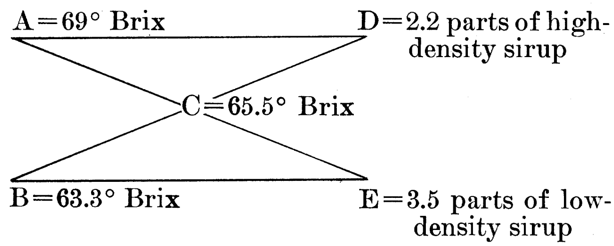
Example 1.—Suppose sirup that tests 69° Brix at 68° F. is to be diluted with sap (2.5° Brix) to make standard-density sirup. The quantity of each sirup to use can be determined by alligation, as follows:



A=density of sirup; B=density of sap; C =density of standard sirup (always the central figure).

The difference between C and B=D ($65.5 - 2.5 = 63$). The difference between A and C=E ($69 - 65.5 = 3.5$). If 63 parts by weight of 69° Brix sirup and 3.5 parts by weight of 2.5° sap are mixed, the density of the mixture will be exactly 65.5° Brix (standard density).

If the dense sirup in the above example is to be diluted with thin sirup (63.3° Brix), the mixture of the two sirups which will be of standard density (65.5° Brix at a temperature of 68° F.) can be calculated by alligation as follows:



The difference between C and B=D ($65.5 - 63.3 = 2.2$). The difference between A and C=E ($69 - 65.5 = 3.5$). Thus, if 2.2 parts by weight of the 69° Brix sirup and 3.5 parts by weight of the 63.3° Brix sirup are mixed, the density of the mixture will be 65.5° Brix (standard density).

Baumé data may be used in the same way.

In practice, the density of sirup to be sold to the consumer should be a little higher than the minimum that meets specifications of standard-density sirup (65.5° Brix at 68° F.). Sirup that has a density of 66° Brix is more pleasing to the taste because it has more body (viscosity) than standard-density sirup and, since it is below 67° Brix, it will not crystallize in storage.

Thin sirup can be used to dilute heavy sirup, but this usage of thin sirup is limited, and the best practice is to boil it until it reaches standard density. If considerable boiling is required, more sugar sand may form, which will require refiltering the sirup. This reboiling may also cause darkening and hence lowering of grade.

Summary

1. Do not check the density of sirup by weighing, unless precision instruments are available.
2. The minimum allowable density is 65.46° Brix (at 68° F.) or 35.27° Baumé (at 68° F.) Bureau of Standards Baumé scale for sugar solutions, modulus 145. Sirup that has a density of 66° to

66.5° 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. Determine the true density (° Brix or ° Baumé) of sirup tested at temperatures *warmer* than the temperature at which the hydrometer is marked for use by calculation, as follows:

$$TD\ (°\text{Brix}) = OD + [0.047 \times (T - T_0)]$$
$$TD\ (°\text{Baumé}) = OD + [0.024 \times (T - T_0)]$$

and for sirup tested at temperatures *colder* than the temperature at which the hydrometer is marked for use, as follows:

$$TD\ (°\text{Brix}) = OD - [0.047 \times (T_0 - T)]$$
$$TD\ (°\text{Baumé}) = OD - [0.024 \times (T_0 - T)]$$

where TD = true density; OD = observed density; 0.047 = correction factor for Brix reading; 0.024 = correction factor for Baumé reading; T = temperature of sirup tested; and T_0 = temperature at which hydrometer is marked for use.

GRADING THE 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 (*48*). The principal grade-determining factor is color.

The United States Department of Agriculture color standards are designated "Light Amber," "Medium Amber," and "Dark Amber." These correspond to the Bryan Color numbers 6, 8, and 10.

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

U. S. Color Comparator

The United States Department of Agriculture has developed a simple type of color comparator with permanent standards of colored glass (*5*). These became the official USDA color standards for maple sirup in 1950. The colors of the different grades of sirup are given in table 13. A thick layer of the sirup to be tested is used in the comparator (fig. 59). This aids in precise grading because the standards are widely spaced on a color scale when viewed in this thickness. The square shape of the container provides a field of view of uniform thickness and color, a feature that was not possible with the cylindrical bottles used heretofore.

TABLE 13.—*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.	.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. 15.

Use of the Color Comparator

The 3 clear blanks supplied with the kit are placed in the compartments, in the back of the 3 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 1 of the 2 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. 60). The color grade (classification) of the sirup is determined by comparing the sample with the standards. If the sample of sirup is cloudy, its true color classification may be difficult to determine as its brightness will be lowered. This cloudy effect can be compensated for if the clear blank used behind the colored glasses is replaced by one of the cloudy blanks (A, B, or C).

Information concerning the complete color comparator kit, including the comparator block with glass standards and clear and cloudy blanks, may be obtained by writing to the Eastern Utilization Research and Development Division, U. S. Department of Agriculture, Philadelphia 18, Pa., or to the Processed Products Standardization and Inspection Branch, Agricultural Marketing Service, Washington 25, D. C.

Summary

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

PACKAGING

The graded and clarified sirup of correct density (between 65.5° and 67° Brix at a temperature of 68° F.) is ready for packaging. 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, a given quantity of sirup (by weight) expands and contracts with changes in temperature. For this reason it is difficult to package sirup accurately by volume. When the package of hot sirup has cooled it may not contain exactly the specified volume.

On the other hand, the weight of a given quantity of sirup of standard density is the same regardless of the temperature of the sirup. For this reason 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 scale before it is 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. The net weights most commonly used for standard-density sirup are:

1 gallon weighs 11 pounds; 1 quart weighs 2 pound, 12 ounces; and 1 pint weighs 1 pound, 6 ounces.

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

Stack Burn

If packaged sirup is stacked while it is still hot the same browning reaction that occurred in the evaporator will continue and cause a darkening of the sirup by as much as 1 or 2 grades. This development of color in hot packaged sirup is called "stack burn." To prevent stack burn, the containers should be placed in cold water or spaced 3 or 4 inches apart to cool before stacking.

Control of Micro-Organisms

Standard-density sirup will not support active growth of micro-organisms with the exception of one type of yeast. Because of the possible contamination of sirup with this yeast no sirup that is offered for sale to the consumer should be packaged cold. Instead the sirup must be heated to at least 180° F., to destroy the yeast, and packaged immediately.

Although everyone has seen mold growing *on* sirup, mold will not grow *in* standard-density sirup. These apparently contradictory statements are explained as follows: Maple sirup that is cold-packed may contain mold spores. The mold spores 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 becomes warm, some of the water of the sirup is distilled up into the head space. When the storage temperature falls this vapor condenses into small drops of water that run down onto the surface of the sirup, producing a layer of low-density sirup in which mold spores can vegetate and grow.

Even though the sirup contains mold spores, growth of mold can be prevented by momentarily inverting the packaged sirup once or twice weekly (*22*). This destroys the layer of dilute sirup and therefore inhibits germination of the mold spores.

Even though 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 a 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.

Size and Type of Package

The size and type of package is important when sirup is made for retail sale. The housewife dislikes to repackage sirup from a gallon container to smaller ones which can be used 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 consumer expects sirup to be as attractively packaged as other foods (fig. 61). The day is gone when leftover mayonnaise jars, soft-drink bottles, and the like are acceptable containers. When sold at roadside stands, sirup packaged in tin is attractive to the tourist regardless of the size of the container, because he does not have to take special care in storing it in the car as with glass containers. Either glass or tin packages must 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. Package the sirup neatly in attractive containers.
10. Use quart and pint, as well as gallon, containers for packaging the sirup.

MAPLE SUGAR

Many producers are finding that the gross returns of their maple crop can be increased 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 75 cents a pound based on sirup selling at $6 per gallon. This same weight of sugar, if converted to sugar products can be sold at prices ranging from $1 to $2 per pound or a gross of $8 to $16 per gallon of sirup. This increase in gross returns is commensurate with the additional labor involved in converting sirup to sugar products.

The Equipment

The making of the different maple-sugar products is not difficult, nor does it require the use of expensive or unusual equipment. It does require the same type of care and sanitation that is expected of any candy company. Maple confections can be made on a small scale in the home kitchen; for a larger operation a special room, either in the home or a part of the evaporator house, is preferable (fig. 62). Gas is the preferred fuel, as it is easily controlled to give the right amount of heat (fig. 63); 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. is an absolute necessity; this can be either the maple-sirup target or dial thermometer, or a candy thermometer. Other equipment includes measuring cups, wooden ladles, wooden paddles, and a household scale. Provision should be made for cooling the sugar products. This is especially desirable when making maple cream or fondant. The cooler can be a trough with circulating cold water into which the pans of cooked sirup are placed (fig. 64). A pan of chipped ice or ice water may also be used.

The 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. Hot solutions can contain more and cool solutions less sugar.

Maple-sirup solutions containing 67 percent of sugar (67° Brix at 68° F.) are saturated at room temperature. That is, no more sugar can be dissolved in the solution at that temperature. Sirup that has been heated to 7.5° F. or more above the boiling point of water will be supersaturated when it cools to room temperature, that is, 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 become normal again by ridding itself of the excess sugar. The excess sugar is thrown out of solution (precipitated), and sugar crystals are formed.

To make any of the maple-sugar products it is necessary first to make supersaturated sirup. The degree of supersaturation increases 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 accompanied by little or no agitation, the state of supersaturation may persist for a long time and very little sugar will be precipitated. When the amount of supersaturation is appreciable (such as occurs when sirup is boiled to 18° F. or higher above the boiling point of water), 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 noncrystalline nature of the precipitated sugar is determined by a number of factors, all of which are influential in making the desired type of confection (*27*). These factors include the degree of supersaturation, seeding, the rate of cooling, and the amount and time of stirring.

Large crystals, 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 (elevation of the boiling point, 18° F. or more) is cooled rapidly 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 of the stirring causes crystal nuclei to form. Continued stirring mixes the crystals throughout the thickened sirup causing them to grow. When the number of crystals is relatively few, the large crystals tend 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 a fine crystalline structure, free of grittiness, all of the crystals must be kept very small, even microscopic in size. This is accomplished by suddenly cooling the hot, highly supersaturated sirup so that a viscid, noncrystalline, glasslike mass is obtained. Then, while it is still in this supersaturated state, fine crystals, called seed, are added to serve as nuclei, and stirring is begun. Since the mass is so highly supersaturated not just a few crystals but literally millions of tiny ones 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.

The presence of some invert sugar in maple sirup to be made into maple sugar and maple confections is desirable. Invert sugar tends to reduce supersaturation, that is, more sugar can be held in solution before crystallization occurs. This helps to keep the product moist (*17*). Also it helps in the promotion of exceedingly small sugar crystals. The degree of these effects depends on the amount of invert sugar in the sirup. Fortunately, most maple sirup contains an adequate amount of invert sugar. Occasionally, however, maple sirup is found that has either too little or too much invert sugar to permit making a sugar product of the best quality. Too little invert sugar in the sirup will cause the product to be grainy; too much will prevent formation of crystals (creaming). A simple chemical test for use in determining the amount of invert sugar in maple sirup is described on page 48. If the amount of invert sugar in the sirup is so low that a fine crystalline product cannot be made, a "doctor" solution is required (*16*).

Doctor

The "doctor" solution usually used is sirup rich in invert sugar (more than 6 percent, as determined by the chemical test described on p. 48). Sirup made from sap produced during a warm spell usually contains a high percentage of invert sugar. The addition of 1 pint of doctor sirup to 6 gallons of maple sirup low in invert sugar usually will correct the condition of coarse grain.

When sirup with a high content of invert sugar is not available, the doctor solution can be prepared as follows: Two and one-half fluid ounces of invertase (an enzyme that causes the inversion of sucrose to invert sugar) is added to 1 gallon of standard-density maple sirup; the mixture is stirred thoroughly and allowed to stand at room temperature (65° F. or above) for several days during which 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 larger candy companies.

Another type of doctor is an acid salt, such as cream of tartar (potassium acid tartrate). One-half teaspoon of cream of tartar added to 1 gallon of low-invert sirup just before it is boiled will cause sufficient acid hydrolysis or inversion of the sucrose to form the desired amount of invert sugar.

Summary

1. Converting maple sirup to maple sugar is not difficult nor does it require special equipment, with the exception of a thermometer having an upper range of 250° to 300° F.
2. Sirup that is saturated in respect to 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 precipi-

tated sugar usually is in the form of crystals, and the amount formed depends on the degree of supersaturation.

4. The crystallinity of the precipitated sugar depends on the degree of supersaturation, the rate of cooling the sirup, and the amount and time of stirring.
5. Invert sugar, a product of fermentation of sucrose, is a noncrystallizing sugar. Its presence in maple sirup influences the crystallization of maple sugar. Too much invert sugar will tend to prevent crystallization of sugar from a supersaturated sirup and too little will cause the maple sugar to be coarse and gritty.

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 that they convert their entire crop to cream. In 1954, one New York producer made more than 2½ tons of this confection.

Maple cream (*27*, *28*), a fondant type of confection, has a butterlike consistency. It is made up of millions of microscopic-size 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. To make maple cream, it is necessary first to make a supersaturated sugar solution. This is cooled to room temperature so quickly that crystals have no chance to form. The cool glasslike mass is then stirred, which produces the mechanical shock necessary to start the crystallization. All of the crystals formed are about the same size and very small.

Sirup for Creaming

For best results, U. S. Grade AA (Fancy) or U. S. Grade A (No. 1) maple sirup should be used; it should contain 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 test, as described on page 48. 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 24° or 25° F. above the boiling point of water (instead of the usual 20°). Sirup with more than 4 percent of invert sugar is not suitable for creaming. If used, 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.

For years, many people throughout the maple-producing area have believed that maple cream should be made only from first-run sirup and that all first-run sirup will yield a good cream. This is not the case. The amount of invert sugar in the sirup 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, and 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.

As maple sirup for creaming normally contains an adequate amount of invert sugar, the use of a "doctor" solution is not recommended. The addition of or the formation of too much invert sugar will ruin the sirup. Instead, select the sirup for creaming on the basis of the quick test for invert sugar.

Cooking and Cooling

The sirup is heated to a temperature 20° to 23° F. above the boiling point of water. (The temperature of boiling water must be established at the time the sirup is boiled for creaming.) The boiling temperature determines the amount of sirup (mother liquor) surrounding the crystals, and this in turn governs the stiffness of the final product. As soon as the sirup reaches the proper 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 more water will be evaporated to produce a more concentrated sirup than desired. Rapid cooling prevents crystallization. To facilitate cooling, the sirup is poured into large, flat-bottom pans (the layer of sirup should be not more than 1 to 3 inches deep), and the pans are set in a trough through which cold water (35° to 45° F.) is flowing (fig. 65).

The thickened sirup is cooled to at least 70° F., and preferably to 50° or below. The sirup is sufficiently cool when the surface is firm to the touch. Appearance of crystals during the cooling process indicates either that cooling is too slow or that the invert-sugar content of the sirup was too low for the conditions of cooling used. This situation can be corrected either by more rapid cooling (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 as previously described.

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. 66), and there are a number of inexpensive ones on the market.

The homemade maple-cream beater (fig. 67) consists of a pan approximately 13 inches in diameter that holds about 1½ gallons of cooked sirup. In this beater, the scrapers are held stationary and the pan revolves. In other beaters, this procedure is reversed. Both types work equally well.

A hardwood paddle having a sharp edge 2 or 3 inches wide is used for hand beating. The cooked sirup is poured into a large flat pan, such as a cookie tin. This is held firmly, and the thick sirup is scraped first to one side of the pan and then the other, mixing continuously so that no portion is allowed to stay at rest. If stirring is stopped some of the crystals will grow and cause the product to be gritty.

During the stirring operation the chilled sirup will first tend to become fluid and then begin to stiffen showing a distinct tendency to set. At this time the batch will lose its shiny surface (fig. 67). 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. Creaming 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 of 1 day to several weeks in tightly covered glass or earthen vessels, preferably under refrigeration. Many candymakers believe that aging of a fondant is desirable because it permits an equalization of the crystals in the saturated sirup. After aging, the cream is remelted for pouring and packaging by careful heating in a double boiler (*36*). The temperature of the cream during this reheating must not go above 150° F. This can be controlled by not permitting the water in the double boiler to go above that temperature. 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.

Packaging and Storing Maple Cream

Maple cream can be packaged in tin, glass, or wax paper cups. Containers with wide mouths are best for ease of filling. Care must be taken to keep air bubbles from forming. This precaution is of particular importance 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. Further, 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. 68). 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 the cream at temperatures above the 70° F. used for creaming will cause more sugar to go into solution, and this increased volume of sirup will tend to separate as an unattractive dark liquid layer on the surface of the cream. This sirup layer will also be formed if the cream is stored at uneven temperatures.

For the best storage conditions keep the cream at low temperature and constant humidity. If the cream is packaged in moisture-proof containers, glass, tins, or heavy waxed boxes, it can be stored in refrigerators for long periods of time prior to use, with little danger of the saturated sirup in the cream separating.

Summary

1. Use U. S. Grade AA (Fancy) or U. S. Grade A (No. 1) sirup.
2. The sirup must not contain more than 4 percent of invert sugar.
3. Heat the sirup to a temperature 20° to 23° F. above the boiling point of water.
4. Cool the sirup rapidly to about 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 temperatures not exceeding 150° F.
8. Store 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 a gritty texture.
   - (b) If the sirup contains too much invert sugar, it will not cream (crystallize).

SOFT-SUGAR CANDIES

Next to maple cream the making of soft-sugar candies is gaining in popularity. Eight 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 of stiffer consistency than cream. Although the crystals in soft-sugar candies are larger than in cream and are palpable to the tongue, 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), and U. S. Grade B (No. 2).

Cooking, Cooling, and Stirring

The sirup is cooked to a temperature 27° F. above the boiling point of water (established for that time and place). The pans of cooked sirup should be cooled slowly (on a wooden-top table) to a temperature of 155° F. (measured with a thermometer). The thick sirup is then stirred, either by hand with a large spoon (fig. 69) or with a mechanical mixer (fig. 67).

While the sugar is still soft and plastic it is poured or packed into rubber molds of different shapes. This operation of packing the molds is best done with a wide-bladed putty knife or spatula (fig. 70). Rubber molds for use in making candies of different sizes and shapes can be purchased from any maple-equipment supplier.

The Bob

Another method of preparing the sugar so that it can be run into the molds is used by commercial confectioners. The soft sugar is set aside after stirring to firm and age for a day. On the following day, it is mixed with an equal amount of "bob," the two are stirred together, and the mixture is run into the rubber molds while it is still fluid.

The bob (*27*) is sirup that is boiled to *exactly* the same boiling point (27° F. above the boiling point of water) as used in making the soft sugar. 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.

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. 71) from which the cooled sirup is dispensed to a small mechanical agitator (fig. 72).

Here the sirup is crystallized; while it is still fluid it is run into the rubber molds, where it sets up in 30 minutes to 1 hour. Candies formed by pouring, rather than packing, have an attractive glazed surface.

Crystal Coating of Candies

The candies can be prevented from drying by coating them with a moisture-impervious shell made from crystalline sucrose (*36*). The effect of crystal coating soft-sugar candies is shown in figure 73. The crystallizing sirup is made as follows: Fancy maple sirup low in invert sugar is heated to a temperature 10° 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° F. One gallon of standard-density sirup (65.5° Brix) will make 7 pints of crystallizing sirup (70° to 73° Brix).

The hot, heavy sirup, in the vessel in which it was boiled, is set aside to cool where it will not be disturbed by jarring or shaking. To retard surface crystallization, the surface is 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 be attached to the cover and can be removed along with the covering. These sugar crystals can be recovered by rinsing the cover in hot water.

The candies to be coated should be dry (24 hours old), and they can be coated by either of two methods. In the first method, the candies are loosely packed 2 or 3 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 if all the crystals are not removed with the cover they are skimmed off. Enough of the crystallizing sirup is poured over the candies to cover them completely, and a paper cover is placed on the surface.

The pans are gently set aside in a room with a temperature of 65° to 80° F. for 6 to 12 hours, or overnight. This is the crystallizing period. Sugar comes out of the thick sirup and is deposited and grows on the millions of tiny crystals on the surface of the candies. When sufficient sugar has been deposited on the candies, the paper cover is removed and the thick sirup is drained off. This is done by covering the pan with a second piece of hardware cloth and inverting the pan over a kettle to catch the sirup. The candies must be well drained because any drops of sirup left on the candies will dry as a glaze rather than as crystals. After draining, the candies are spread out on paper to dry. To facilitate even drying, each piece is turned over at intervals of 1 or 2 hours. Crystal coating of candies should not be attempted on a damp or rainy day since the candies will not dry properly.

In the second method the candies are packed loosely in a shallow wire basket, the basket is submerged in the crystallizing sirup, and a paper cover is placed on the surface, as in the first method. Following the crystallizing period, the cover is removed, the basket is raised from the sirup and is held above the sirup by means of a rack or other device until the candies have drained. They are then spread out on paper to dry as before. A French fryer or blanching assembly of kettle and wire basket is well adapted to this use (fig. 74).

Packaging Candies

The packages have two functions: (1) To make the candies as attractive as possible, and (2) to keep them in good condition (fig. 75). Boxes, individual wrappings, and candy cups can be obtained from a confectioner's supply house. It is of greatest importance that the net weight of the candies be stated on the outside of the package. This requires that the tare (weight of box) and the net weight of the candies be determined for each box, as shown in figure. 76.

Candies that have been crystal-coated have relatively good shelf life, tending neither to take up moisture nor to dry out. Candies that are not crystal-coated may do either, depending on the humidity of the room in which they are stored. In a room of low humidity, they will lose moisture and the dried-out areas will appear as white spots. If the humidity is high the candies will take up moisture, and moist areas or droplets of water will appear on the surface of the candies. The droplets become dilute sugar solutions and are good sites for growth of mold.

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, because a moistureproof wrapper tends 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.

Summary

Soft-sugar candies

1. Use any of the top three grades of sirup.
2. Heat the sirup to a temperature 27° 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 (27° F.) is reached add the hot concentrated sirup (bob) to the aged soft sugar.
9. Stir only enough to mix and pour the semi-fluid sugar into the molds.

Crystal coating of candies

1. Make crystallizing sirup from top grades of maple sirup.
2. Concentrate the sirup to 70° to 73° Brix by heating it to a temperature 10° or 11° F. above the boiling point of water.
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.
8. Don't attempt to crystal-coat candies during damp or rainy weather.

MAPLE SPREAD

Maple cream, described on page 41, is not a stable product 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 which avoids this separation of sirup. Also, it requires no beating or stirring. The process for making the spread consists of three simple steps: (1) The sirup is concentrated, by heating, 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 (65.5° Brix) is heated to a temperature about 10° F. above the boiling point of water (approximately 76° Brix), and then cooled to 150° F. or below (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. It 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 use in seeding the first batch. For subsequent 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 uniform 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 is formed. 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.

Summary

1. Use any of the three top grades of sirup.
2. Heat the sirup to a temperature 10° or 11° F. above the exact 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.

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 the boiling process. Experiments have shown that all of the potential flavor is not developed under these conditions (*51*). To develop maximum flavor, the browning reaction must be carried further; that is, the sirup must be heated to a high temperature and for a longer time.

Unfortunately, high temperatures favor the formation of "caramel" flavor. The presence of large amounts of water favor caramel formation and the presence of some caramel in the initial sirup accelerates it (*32*). Therefore, only light-colored sirup of the two top grades—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 either the atmospheric process or by the pressure-cooking process.

Atmospheric Process

The sirup is concentrated at amospheric 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 (fig. 77 and chart 17).

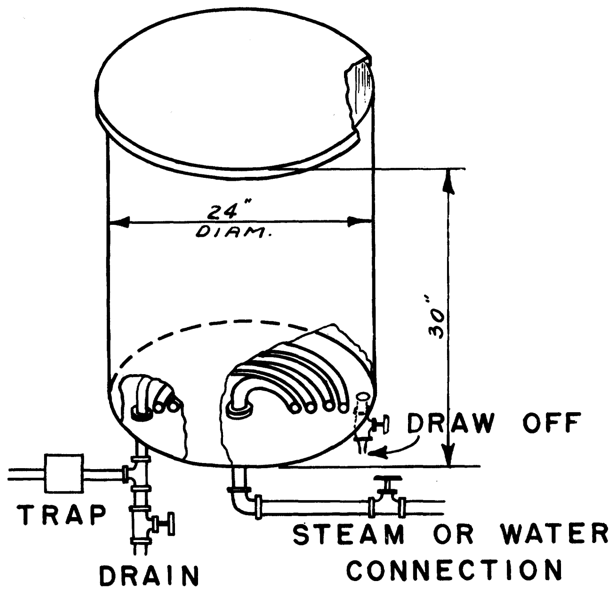


Chart 17.—Kettle with steam coil that can be built in any tin shop. It is not as convenient to use as a tilting-jacketed kettle, but very satisfactory results can be had with it. Like the steam-jacketed kettle, it must be operated with high-pressure steam and the condensed water must not be allowed to collect in the coils. Provision should be made for running cold water through the coils for cooling the sirup.

The first step of the process—removal of the water from the sirup—should be done as rapidly as possible. Steam pressures from 30 to 100 pounds should be used. As soon as the sirup reaches a boiling temperature of 252° F., the steam pressure is reduced until only enough heat is applied to maintain the temperature between 250° and 255°. Usually a steam pressure of 20 to 28 pounds is sufficient. A relatively tight cover is placed over the kettle to serve as a reflux condenser. Because of the high viscosity of the sirup very little water will be vaporized.

A thermometer calibrated in 1-degree intervals and with an upper range of 300° to 350° 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 pressure of the heating steam should be decreased and small amounts of water should be cautiously added. The sirup should not be stirred or agitated in any way during the high-flavoring process; to do so encourages the formation of crystals, and the whole batch may set into a hard cake.

At the end of the cooking period, the thick supersaturated sirup is cooled to 200° 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.

As flavor and color develop in sirup to the same degree, flavor development in the treated sirup may be measured 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 that has a density of 65.5° Brix as measured with a hydrometer or refractometer. The colorless sirup is added slowly, with thorough stirring, to the high-flavored sirup 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:

$$\frac{\text{Weight of the mixed sirup}}{\text{Weight of high-flavored sirup}}$$

This procedure can be used to follow the progress of the high-flavoring process, since different lots of sirup of the same grade will develop flavor at slightly different rates. A sample is removed periodically from the cooking sirup and weighed. Enough water is added to restore that sample to standard density (65.5° Brix), and it is tested as described above. The tests are easy to make using the 2-ounce French square bottles supplied with the U. S. Color Comparator described on page 37. If the color test shows a ratio of 4:1, the process is completed and the color and flavor has been increased fourfold. The high-flavor process and its end uses are shown graphically in figure 78.

Pressure-Cooking Process

Many maple producers do not have high-pressure steam equipment. They may make high-flavored sirup by the process described in U. S. Patent 2,054,873 (*49*).[9] 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.

In the pressure-cooking process the water content of the sirup is 34.5 percent during heating, rather than 10 percent, as in the atmospheric process. The higher water content favors the 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 one-half inch of the top. The lids are set loosely in place, and the jars are placed in the 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.

High-flavored maple sirup made from U. S. Grade AA or U. S. Grade A sirup by either of the above processes will have a strong full-bodied maple flavor that is 4 to 5 times that of the sirup from which it was made, and it will be essentially free from caramel.

Uses of High-Flavored Sirup

High-flavored sirup has a number of uses. Because it is rich 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 maple sirup with 3 parts of cane-sugar sirup with a Brix value of 65.5°. Blended sirup must be properly labeled when offered for sale. The percentage of each ingredient must ap-

[9] This patent, which was issued to George S. Whitby on Sept. 22, 1936, has expired. Therefore, the process is available for free use by the public.

pear on the label, with the one in greater amount appearing first.

Summary

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 a temperature 40° F. above the boiling point of water (250° to 255° F.). Use only a steam kettle, jacketed or with coils, for the processing.
2. Hold the thickened sirup at the final temperature of concentration for 1½ to 2 hours.
3. Cover the kettle with a close-fitting lid and reduce the steam pressure to keep the sirup simmering (approximately 24 or 26 pounds per square inch).
4. Turn off the steam at the end of the processing period and cool the thick sirup to between 180° and 200° F.
5. Add water with caution and in small amounts until the sirup is restored to standard density, as measured by the hydrometer test.

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, remove the high-flavored sirup, and seal the containers.

CRYSTALLINE HONEY-MAPLE SPREAD

The development of a maple-flavored crystalline honey spread has produced a new farm outlet for both maple and honey. This spread is made by mixing honey with high-flavored maple sirup. 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 N. Y. No. 2) sirup to high-density sirup by the enzyme treatment, as described on page 40, 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° F. 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.

The high-flavored, high-density maple sirup is added to mild strained honey at the rate of 33 parts of maple to 67 parts of honey, by weight. The mixture is crystallized by the Dyce process (*8*), 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 a temperature of 57° to 60° F. until crystallization is complete, usually 3 to 7 days. The resulting product is smooth with 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.

Summary

1. Use U. S. Grade B, Vermont B, or N. Y. No. 2 sirup.
2. Heat the sirup to a temperature 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 1 part of the high-density sirup to 2 parts of mild-flavored honey.
6. Add seed (dextrose crystals) at the rate of 1 teaspoonful per gallon of mixture. Use 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 (3 to 7 days).
8. Store under refrigeration.

OTHER MAPLE CONFECTIONS

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 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 easily eaten, hard sugar is not classified as a confection, and it is not often made for retail sale. It was popular in the past because it offered a convenient form for the safe and stable storage of maple sirup. The hard sugar cake could be broken up, melted in water, and the solution 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 boiling maple sirup to a temperature 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, when 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.

Hard sugar, often called maple "concrete," is the preferred form for holding commercial maple sirup in storage.

Granulated or Stirred Sugar

Granulated (stirred) sugar is made by concentrating the sirup to the same density as for making hard sugar (heating to between 40° and 45° F. above the boiling point of water). 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 days gone by, this form of maple sugar was made by stirring it in a hollowed log usually made from basswood.

Maple on Snow

This is a favorite of guests at a maple-sirup camp. As in making stirred sugar, the sirup is heated to a temperature 40° to 45° F. above the boiling point of water. As soon as it reaches the desired temperature it is poured immediately, without stirring, on snow or ice. Because it is so quickly cooled, the supersaturated solution does not have a chance to crystallize and it forms a thin, glassy taffylike sheet.

Summary

Rock candies

1. Use one of the top grades of maple sirup.
2. Heat the sirup to a temperaure 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 a temperature 40° to 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 a temperature 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 graunlation is completed.

Maple on snow

1. Use the top grades of sirup.
2. Heat the sirup to a temperature 40° to 45° F. above the boiling point of water.
3. Without stirring, pour the sirup immediately onto snow or ice; it will form a glassy, taffylike sheet of candy.

TESTING MAPLE SIRUP FOR INVERT SUGAR

A simple test for determining the invert-sugar content of maple sirup has been adapted from a standard test for determining the sugar in urine (*25*). Table 14 shows how much invert sugar can be tolerated in sirup from which good cream can be made. The table also shows the results of using sirup containing too much invert sugar.

The test to find the amount of invert sugar in sirup is made in 3 main steps: (1) Five sirup-and-water mixtures are prepared. In each mixture the sirup is diluted with a different amount of water. (2) Each dilution is color-tested for the presence

TABLE 14.—*The relation between the invert-sugar content of maple sirup and its suitability for making maple cream*

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.

of invert sugar. Clinitest[10] tablets and a color scale are used in making the test. (3) The invert-sugar content of the sirup is determined by comparing the results obtained in step 2 with a specially prepared key (table 15). The equipment required is shown in figure 79.

Preparing the Sirup-and-Water Dilutions

Stir the sirup to be tested thoroughly, and fill a standard 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.—Pour 2 measured quarts (8 cups) of water into a pail, and add the cupful of sirup. Be sure to let most of the sirup drain out of the cup. Use a third measured quart (4 cups) of water to rinse the remaining sirup from the cup: Fill the cup with water; stir with a small spoon, and then pour the water into the pail. Repeat this rinsing of the cup and pour each rinsing into the pail until the quart of water is used. Stir the sirup and water in the pail until thoroughly mixed. Then dip a 4-ounce glass into the dilute sirup and withdraw half a glassful. Label this glass "12" and set it aside.

1-and-20 dilution.—Add 2 measured quarts (8 cups) of water to the dilute sirup remaining in the pail, and stir 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 dilute sirup remaining in the pail and stir 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 contents of the pail and stir 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 contents of the pail and stir until well mixed. Remove half a glassful and label it "60."

Testing for Color

Make the color test as follows:

Place 5 test tubes in a test-tube holder. Fill a clean, dry medicine dropper with the dilute sirup from the glass labeled "60." Hold the dropper upright above the test tube in the hole marked "60" and drop *exactly* 5 drops of the dilution into the test tube. Similarly, fill a separate clean, dry medicine dropper with the dilute sirup from each of the other 4 glasses, and drop *exactly* 5 drops of each dilution into the test tube in the hole with the number corresponding to the number of the dilution. Then fill a clean medicine dropper with water, and add 10 drops to each of the 5 test tubes. Remove 5 Clinitest tablets from their container and place them on a clean piece of paper. Add 1

[10] Clinitest tablets (trade name) are inexpensive tablets stocked by most drug stores. Anyone can buy them. They are sold by the bottle or as part of a kit. A color scale on a small card comes with the tablets; this scale is also used in the test.

TABLE 15.—*Key table for interpreting results of color test of five dilutions*

[— indicates negative reaction; + indicates positive reaction; ± indicates doubtful reaction]

Reactions for 5 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	Do.
+	±	—	—	—	More than 2, less than 4	Suitable, if sirup is heated 2 to 4 degrees higher than usual in cream making.
+	+	—	—	—	More than 3, less than 4	Not suitable.
+	+	±	—	—	More than 3, less than 5	Do.
+	+	+	—	—	More than 4, less than 5	Do.
+	+	+	±	—	More than 4, less than 6	Do.
+	+	+	+	—	More than 5, less than 6	Do.
+	+	+	+	±	More than 5, less than 7	Do.
+	±	+	+	+	Above 6, may be 7 or more	Do.

tablet to each 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 tubes while the solutions are boiling. Fifteen seconds after boiling stops, add water to the test tube marked "60" until the tube is two-thirds full. Then add the same amount of water to the other 4 test tubes.

Interpreting the Color Test

To interpret the color test, compare the colors in the test tubes with the two colors of the color scale (supplied with the tablets) marked "trace" and "+." Disregard everything else on the color scale; the other colors and the labels on all the colors have no relation to this test.

The comparison must be made in a room lighted with an incandescent bulb. The colors cannot be judged properly with either sunlight or fluorescent light. Values for invert sugar are assigned to each tube according to the color developed, as follows: Positive (+), negative (−), or doubtful (±).

If the color in the tube is the same blue or more blue than the scale marked "trace," it is negative (−). If the color is the same yellow or more yellow than the scale marked "+," it is positive (+). If the color is between "trace" and "+," it is doubtful (±). The color value for each of the 5 tubes is written down in order with the value for the 1-and-12 dilution at the left.

To find the invert-sugar content of the sirup, find in the Key Table the line that contains the same combination of values as obtained in the color test. As the table shows, sirup is most suitable for making into cream if all dilutions are negative or if the first (1-and-12) dilution is positive and all others are negative.

Special note.—If the first sirup tested proves positive in some dilutions and negative in others, the difference between a positive and a negative reaction is easily seen. It is possible, however, that all dilutions will prove positive or all will prove negative. If this happens, and the interpretation of the results is doubtful, it will be helpful to have for comparison a solution that is known to test positive.

To make such a solution, add 3 drops of corn sirup to the 4-ounce glass containing the sample of the 1-and-60 dilution and place 5 drops of this mixture in a clean test tube, add 10 drops of water and 1 Clinitest tablet. After boiling has stopped, add water until the tube is two-thirds full. The color that develops will be the color that indicates a positive reaction.

The Simplified Test

After the complete test has been done a number of times, it may be desirable to shorten the process by making a color test of only the 1-and-20 dilution. As the Key Table shows, sirup that is negative for invert sugar in the 1-and-20 dilution is suitable for making into cream. Sirup that is positive in this dilution, contains too much invert sugar to make good cream. Sirup that is doubtful in this dilution can be made into cream if it is heated to a higher temperature than usual in creammaking.

Summary

1. Prepare 5 dilutions of the sirup to be tested: 1-and-12, 1-and-20, 1-and-30, 1-and-40, and 1-and-60.
2. With a clean, dry medicine dropper transfer 5 drops of each dilution to 5 test tubes labeled to correspond with the labels on the dilutions.
3. With a clean medicine dropper, add 10 drops of water to each test tube.
4. Add 1 Clinitest tablet to each test tube, beginning with the one labeled 1-and-60.
5. 15 seconds after boiling has stopped in the test tubes, add enough water to fill the tubes two-thirds full.
6. In a room illuminated with an incandescent bulb, compare the colors in the test tubes with the two colors of the color scale marked "trace" and "+."
7. Assign values to the color formed in each test tube to indicate the presence of invert sugar, no invert sugar, and doubtful.
8. Write down in order the values assigned to the 5 test tubes, beginning with the value for the 1-and-12 dilution on the left.
9. Compare the 5 values with the Key Table (table 15) to determine the invert-sugar content of the sirup.

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Figure 1.—Grove of maple trees with large crowns so important for large yields of sweet sap.

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

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

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.

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

Figure 6.—An ideal spacing of maple trees, favoring the growth of large crowns. However, the grove shows the effect of heavy grazing, a practice not to be recommended since it results in a reduction of sapwood production, stag-headness, loss of reproduction, and root damage due to compacting of the ground.

Figure 7.—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.

Figure 8.—Measuring the sugar content (° Brix) of the sap from a single taphole.

Figure 9.—Measuring the sugar content (° Brix) of sap with a precision hydrometer, one calibrated in 0.1°. When there is insufficient sap in the bucket to provide the necessary depth for such a measurement, the sap is transferred to a hydrometer can, where the measurement can be made.

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

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

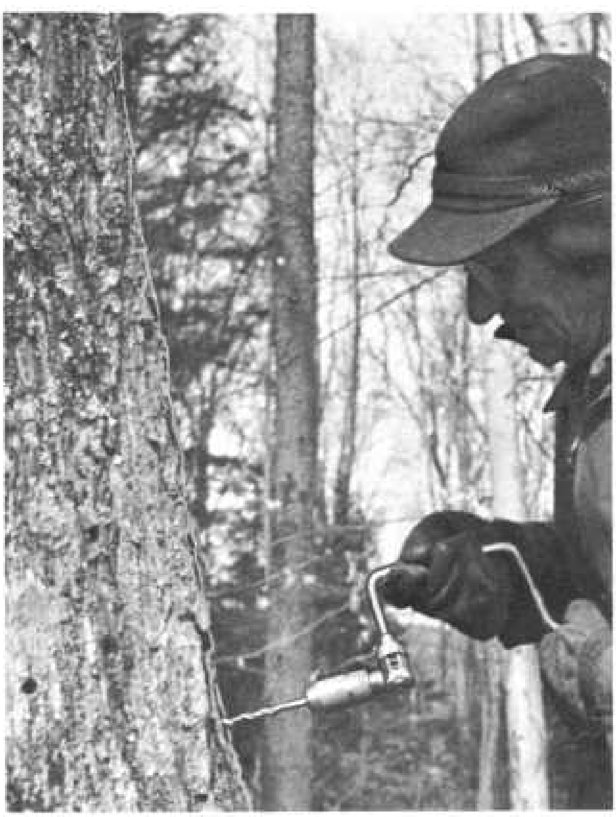

Figure 12.—Boring the taphole at convenient breast height. The hole is 6 inches from that of the previous season.

Figure 13.—To speed tapping operations, many producers prefer to use the faster acting machinist's breast drill.

Figure 14.—For large maple groves, the power-operated drill is preferred.

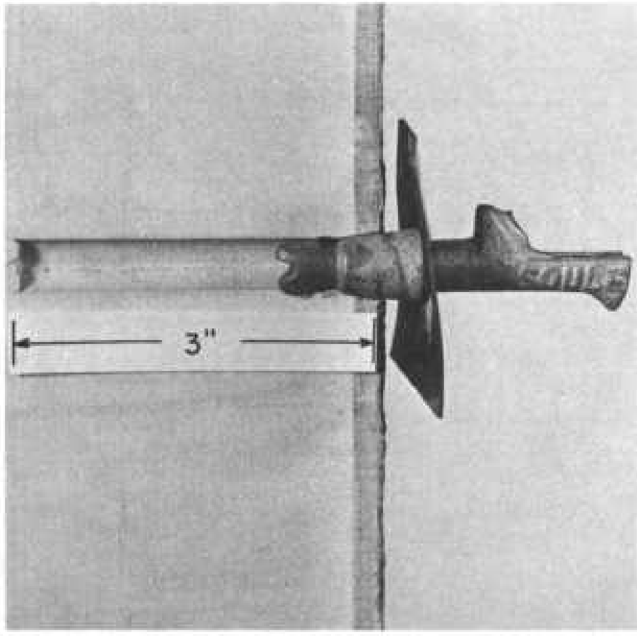

Figure 15.—The taphole is bored into the tree to a depth of 3 inches.

Figure 16.—Tapholes arranged in a spiral about the tree.

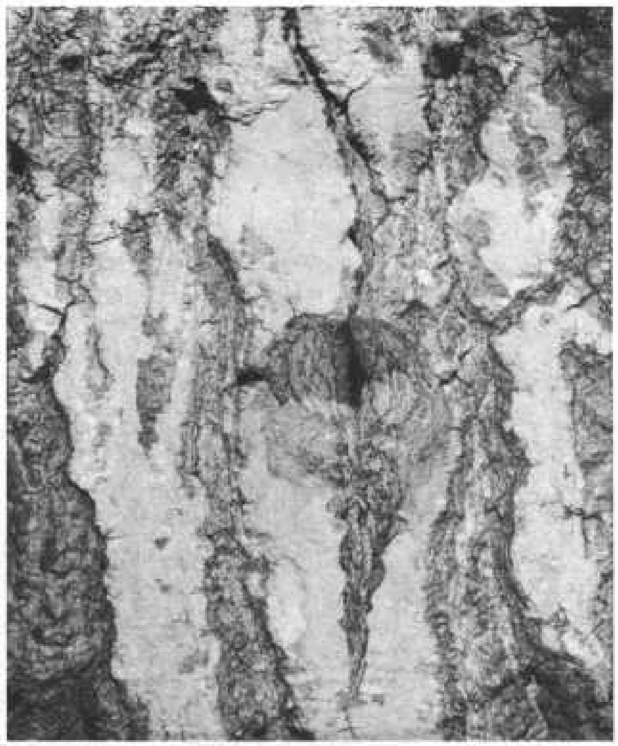

Figure 17.—In a healthy, vigorously growing tree, the taphole will be completely covered with new wood and bark in 1 year.

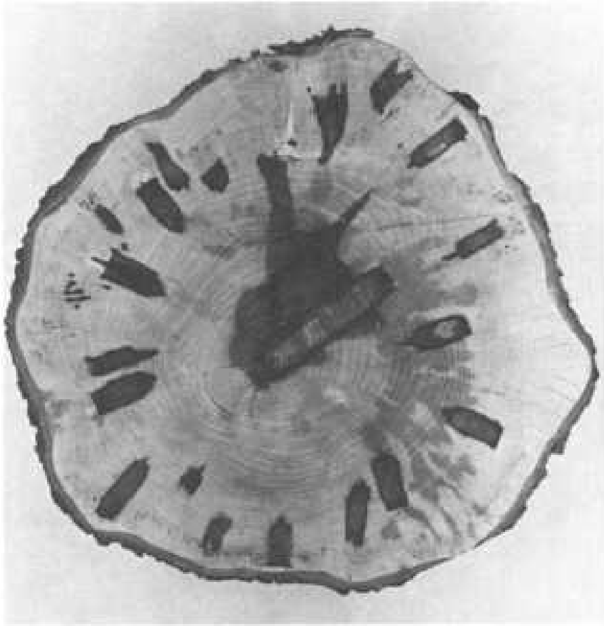

Figure 18.—Cross section of maple log showing stained area caused by fungus growth in old tapholes. The stains show the exact contour of the holes including the area entered by the screw of the bit. The stains do not indicate whether the holes lie above or below the plane of the cut. Note that the stain is confined to the width of the taphole, which indicates that lateral damage to the tree is restricted to within ½ inch of either side of the hole, but damage may extend several inches above and below the hole, as shown in figure 17.

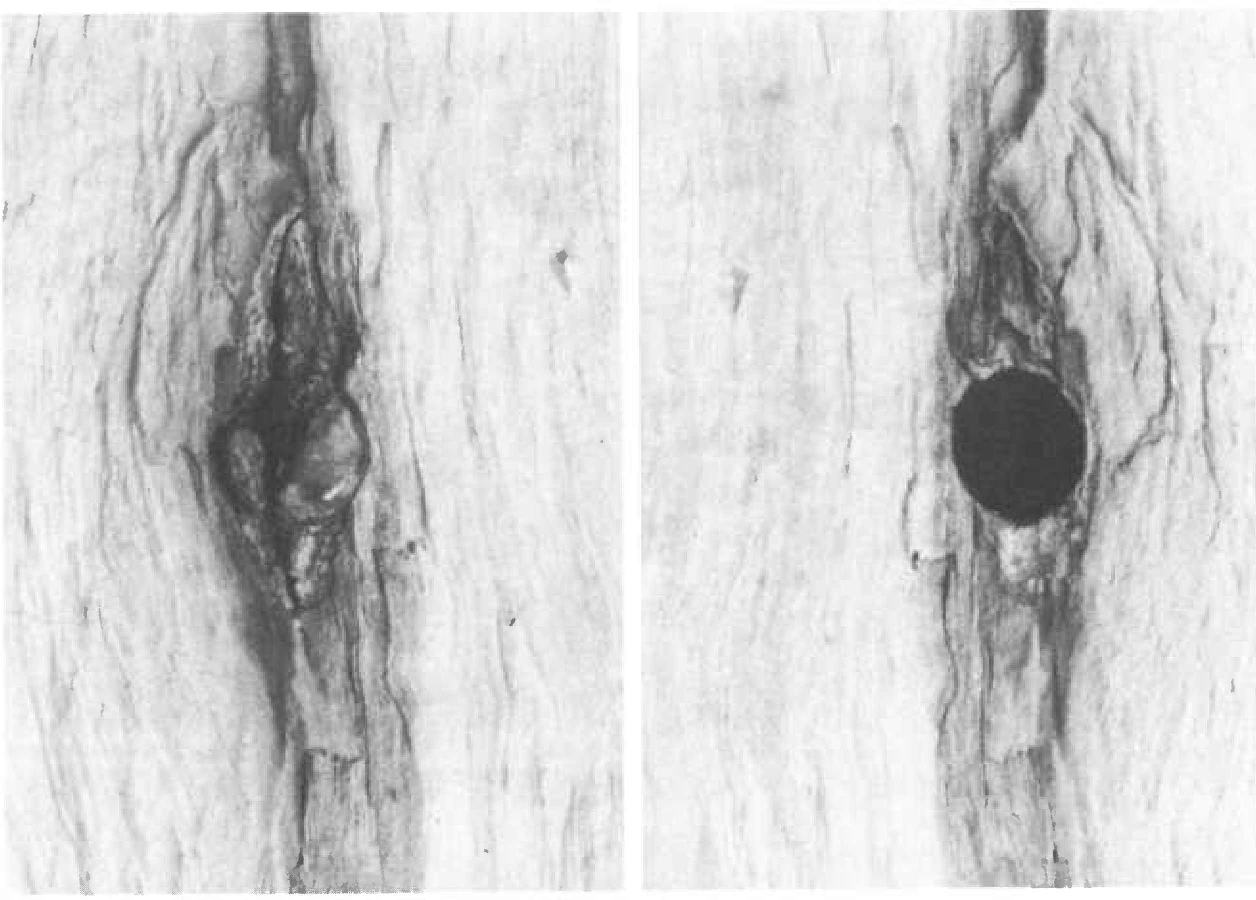

Figure 19.—A split section of a tapped maple log showing the longitudinal stain area above and below the taphole and the new growth of bark that covered the outside end of the hole (left-hand piece).

Figure 20.—Reed sap spauts, the forerunner of aur metal spauts.

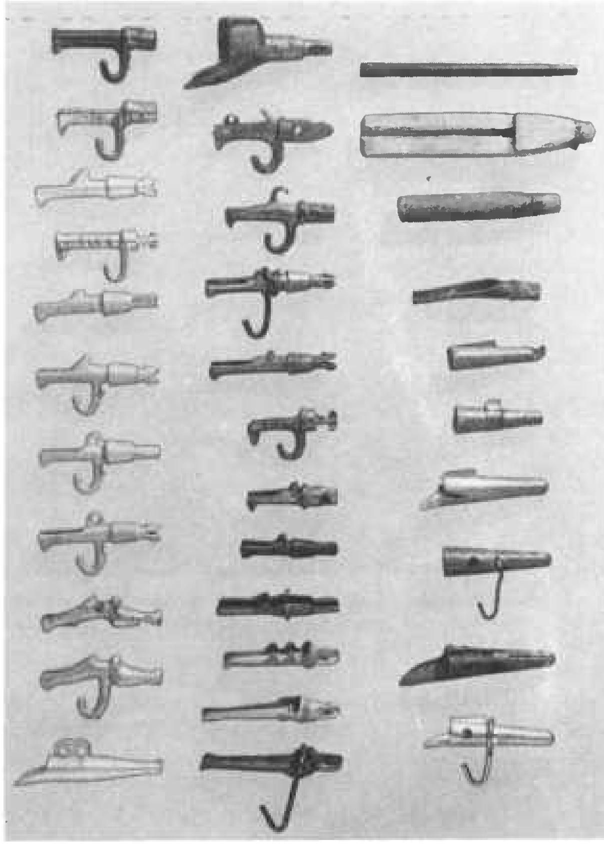

Figure 21.—Woad and metal sap spouts.

Figure 22.—Setting the sap spout; care must be taken to seat the spout firmly in the hole so that a watertight seal is made with the sapwood and bark. If the spout is driven in too deeply, the taper will split the wood and bark, and sap will be lost. To strike the bark a sharp blow will damage the tree and often kills an area for several inches.

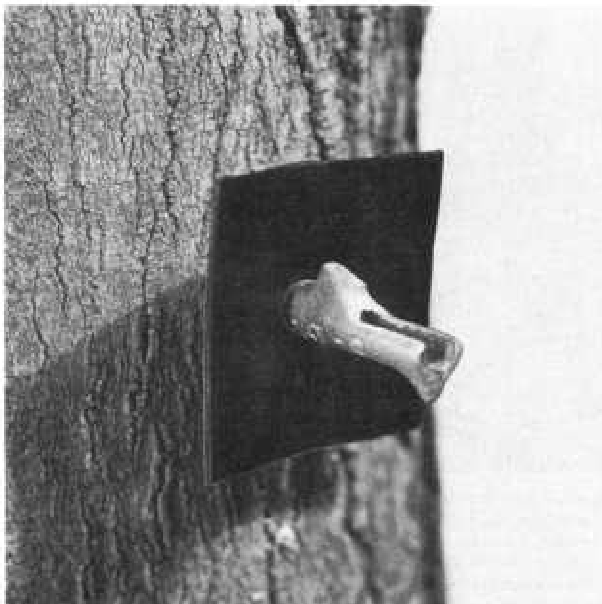

Figure 23.—Rubber rainguard to prevent water from reaching the sap bucket.

Figure 24.—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.

Figure 25.—The clamp-on type of 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.

Figure 26.—The 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 of the transmitted ultraviolet rays of daylight. The bag has its own plastic cover. Since the spout is completely covered it is free from contamination.

Figure 27.—Emptying the plastic bag by rotating it on the sap spout makes it a one-handed operation.

Figure 28.—Sap from a single taphole was diverted so that one-half ran into a plastic bag and the other half into a metal bucket. One week later samples of the sap from the two containers were taken. The sap in the bucket was cloudy because of 144 million bacteria per milliliter, whereas the sap in the plastic bag was clear and had less than 3,000 bacteria per milliliter.

Figure 29.—The collection of sap is the most expensive and laborious operation involved in maple-sirup production. Usually two gathering pails are used to collect the sap from the sap bags or buckets, and the sap is then carried by hand to the gathering tanks.

Figure 30.—Collecting tank mounted on a stoneboat. This low-type mounting avoids lifting of the pails for emptying, but a great deal of power is wasted in dragging the stoneboat.

Figure 31.—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.

Figure 32.—Collecting tank mounted on a trailer. Again, an additional man is required to empty the pails into the tank.

Figure 33.—Mounting the collecting tank on a wagon bed is the most common practice. Low wheels make filling of the tank easier. The wheels can be easily interchanged with runners for use under all ground conditions.

Figure 34.—For large operations or for collection from roadside trees extending along several miles of roads, the large tank trailer is desirable.

Figure 35.—Sap is easily poured from buckets into a low sump tank, from which it is pumped into the large tank.

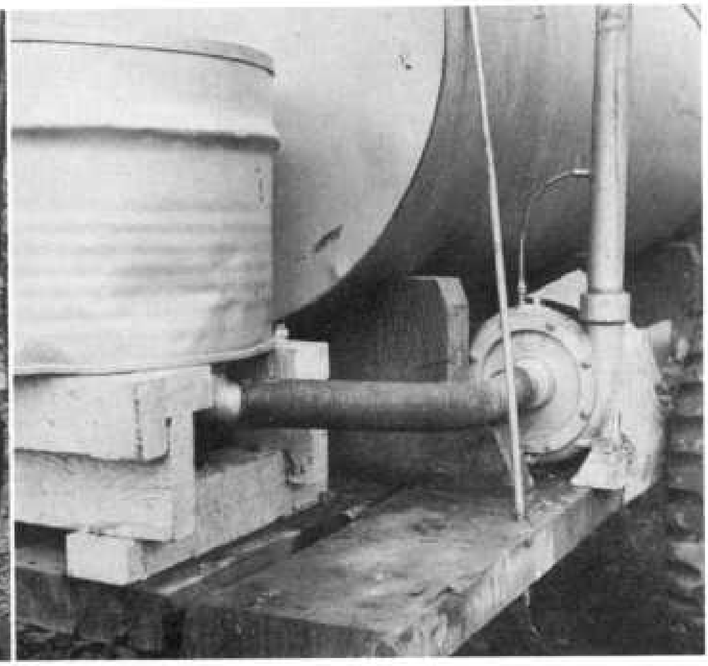

Figure 36.—The sap is lifted from the sump by means of a pump. Power for the pump can be supplied by a takeoff from the tractor or truck engine or by a small gasoline motor.

Figure 37.—The use of pipelines to carry sap to the evaporator house saves time. With a lateral system of dumping stations, the use of gathering tanks can be eliminated in some locations. The pipeline also makes accessible some maple groves that would be impossible to reach by tractor or truck.

Figure 38.—The ramp on which the collecting tank is hauled must be high enough to allow gravity emptying.

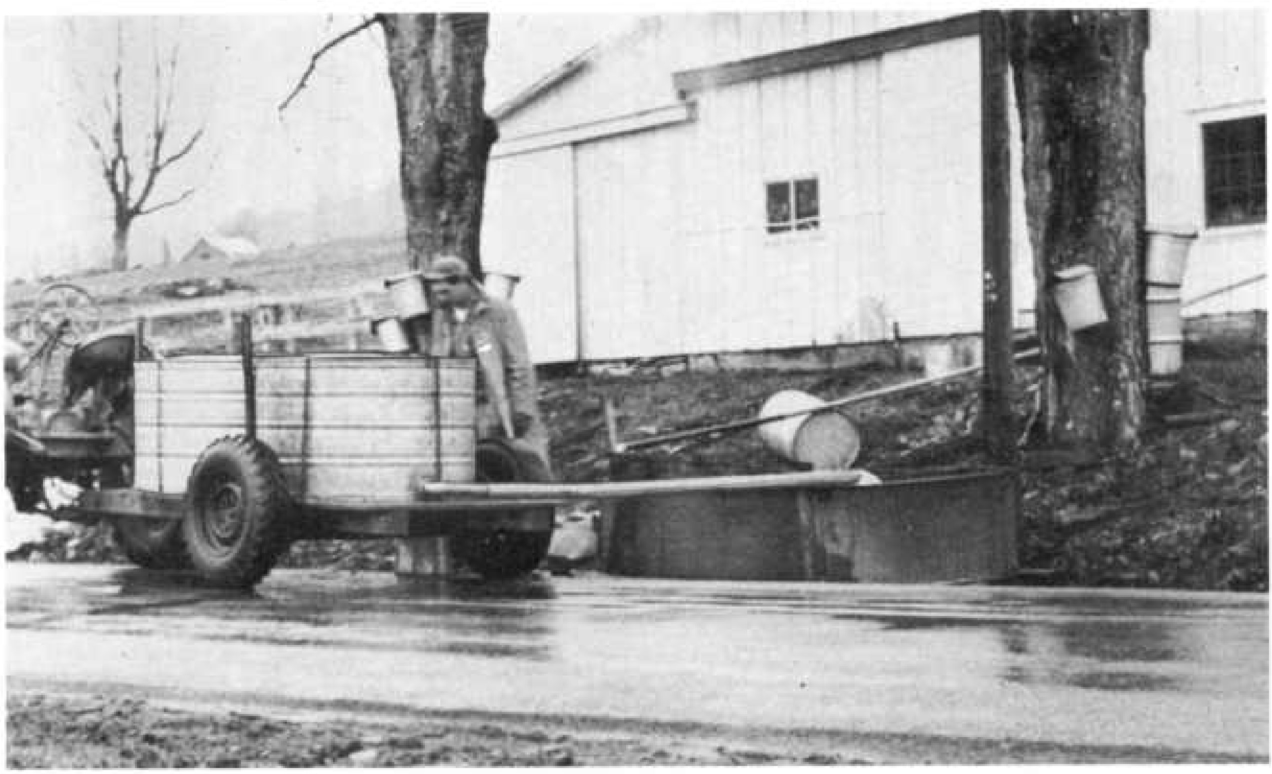

Figure 39.—When it is not practical to build a ramp for emptying the collecting tank by gravity, it can be emptied into a sump tank from which the sap can be pumped to the main storage tank.

Figure 40.—Evaporator house located in center of sugar bush. Before the days of pipelines and large hauling tanks, the house was built close to the sap supply to shorten the hauling distance.

Figure 41.—The trend today is to locate the evaporator house near the other farm buildings and on an improved road.

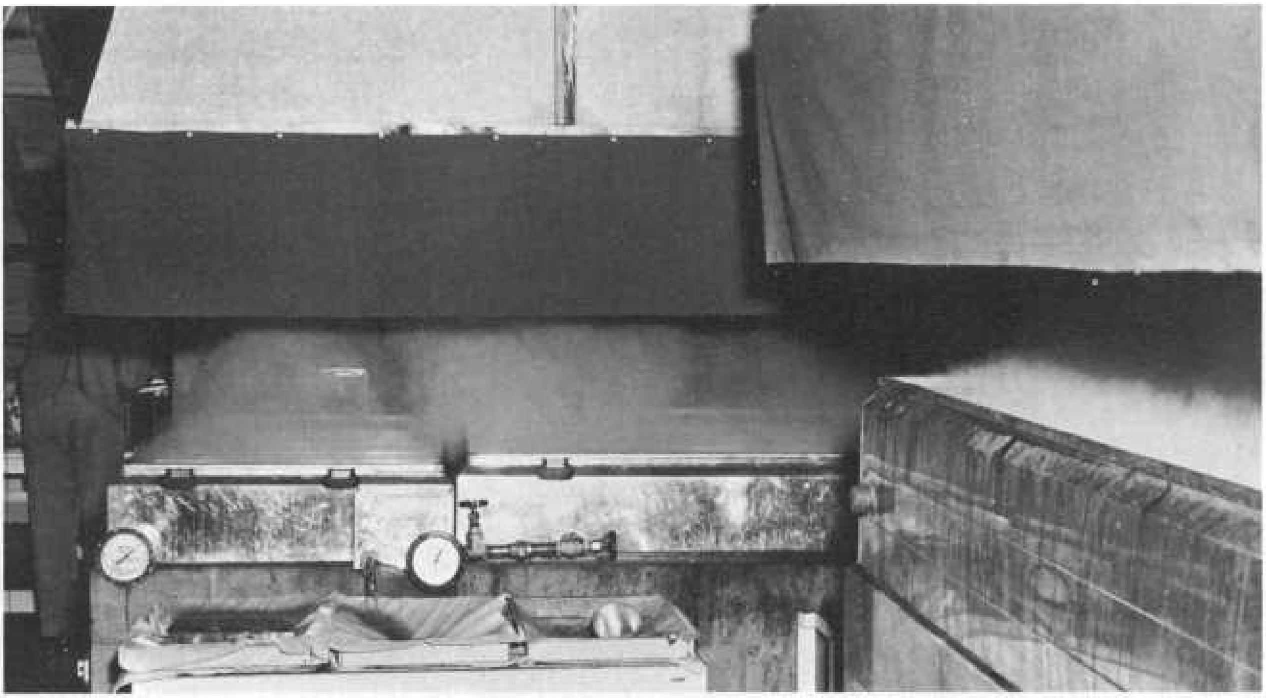

Figure 42.—Heavy cloth or canvas is attached to the lower edge of the hood to bring the hooded area closer to the evaporator.

Figure 43.—Wood truck with flanged wheels runs on rails to transport wood from large storage shed to the evaporator fire doors.

Figure 44.—Sap-storage tank, which is a converted milk-storage tank. When the storage tank is mounted outside aboveground it should be well insulated.

Figure 45.—Multiple-kettle method of making maple sirup. In this method, which was the forerunner of today's continuous evaporators, 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 Prof. W. W. Simonds of Pennsylvania State University.)

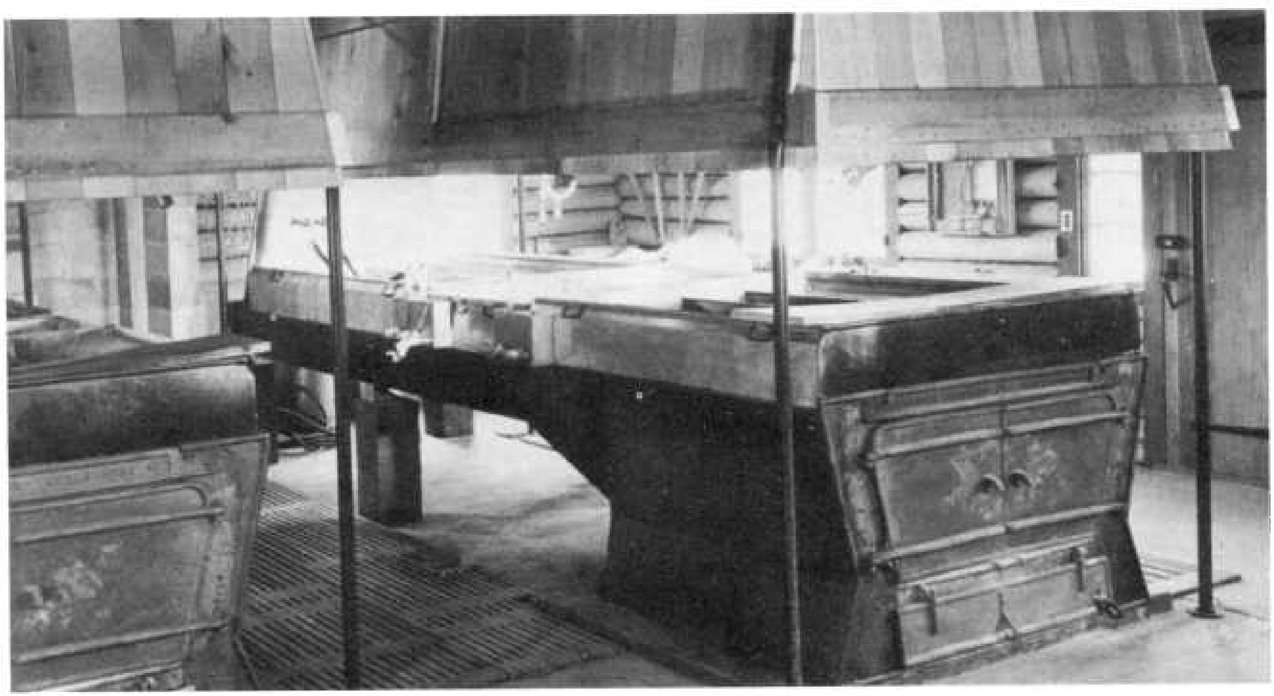

Figure 46.—A modern flue-type evaporator. These are made in sizes up to 6 by 20 feet and have evaporating capacities up to 200 gallons of sap per hour.

Figure 47.—The siphon used to move the sap from the sap (flue) pan to the sirup (front) pan.

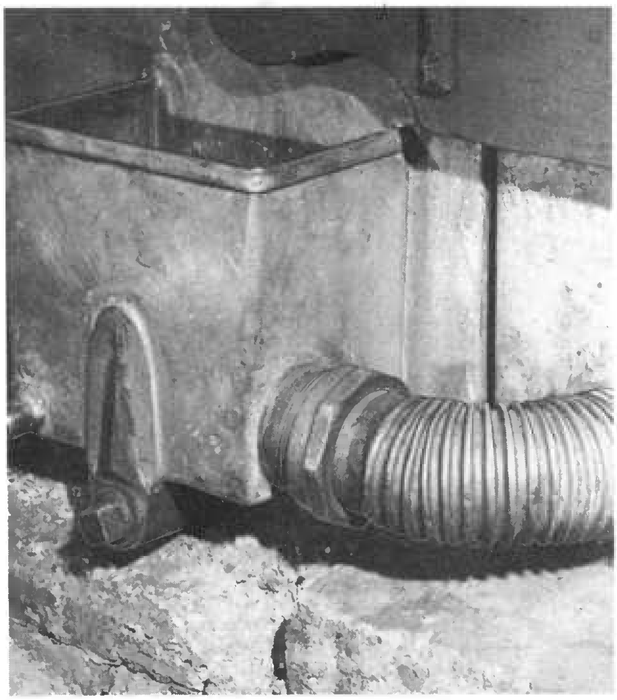

Figure 48.—A semirigid connection between the flue and sirup pans.

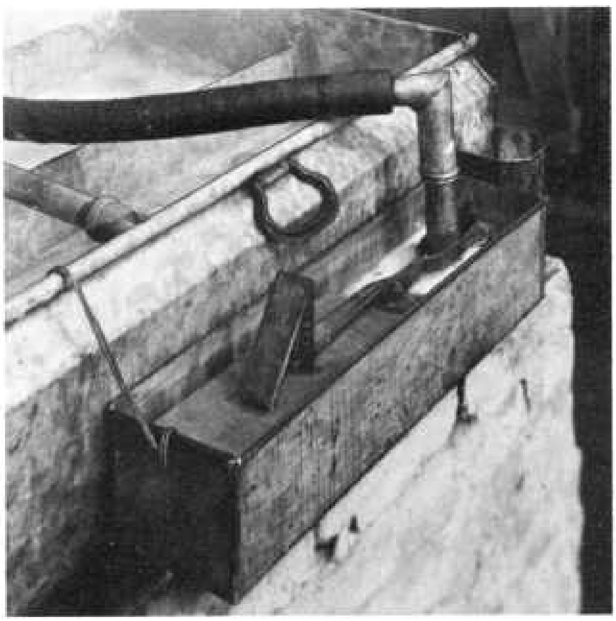

Figure 49.—The float valve, which adjusts the depth of liquid in the evaporator, is mounted on the sap pan. Different devices are used to obtain precise settings of the valve.

Figure 50.—The installation of oil as fuel for the evaporator usually requires reconstruction of the arch so that heat from the oil flame can be fully utilized.

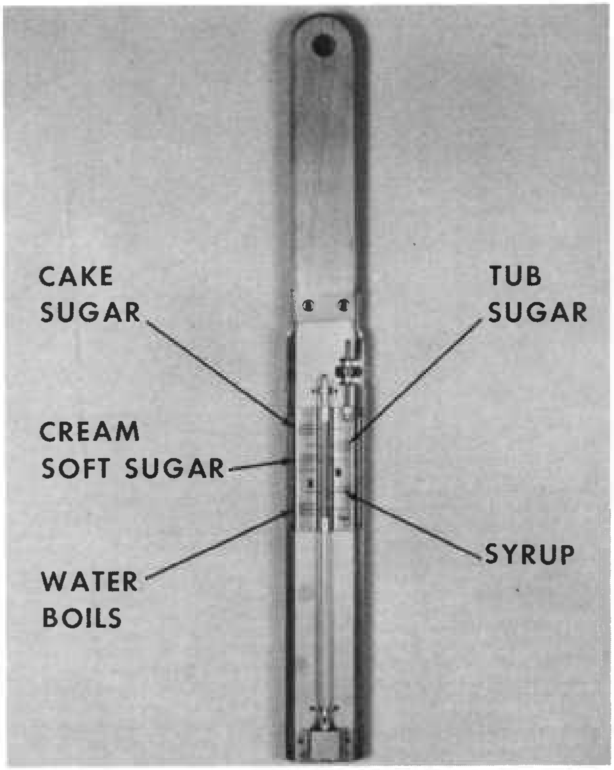

Figure 51.—Maple-sirup target thermometer showing the movable target on which are etched the markings "water boils," "sirup," and others.

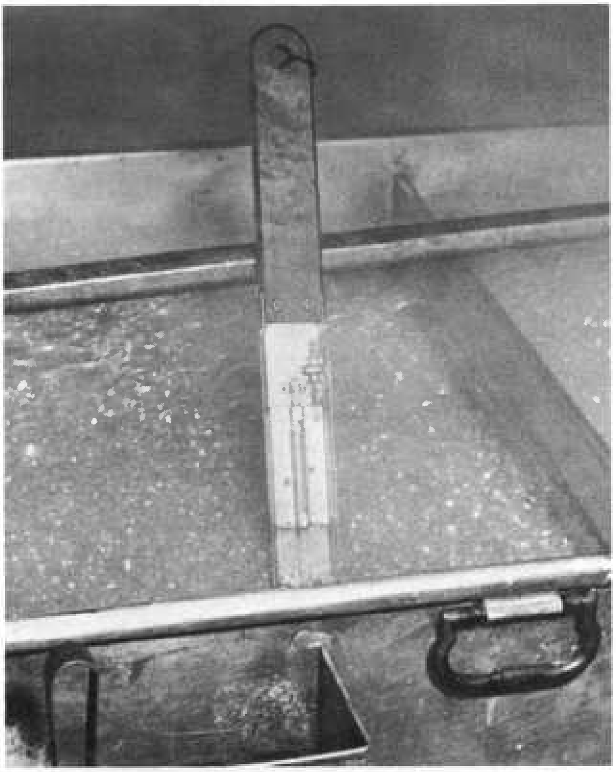

Figure 52.—The target thermometer in place in the boiling sirup. The fine mercury column is difficult to see because of the steam. The boiling sirup being tested must be deep enough to cover the bulb of the thermometer. The thermometer must be in boiling sirup and as close to the point of sirup drawoff as possible.

Figure 53.—The dial maple-sirup thermometer, like the target thermometer, has markings to indicate "O" or "water boils," "sirup," "soft tub," and "cake sugar." The sensitizing element that moves the needle is in the first 3 inches of the stem. The dial thermometer is mounted through the drawoff box on the outside of the evaporator with the stem and its sensitizing element projecting through the wall of the sirup pan. The stem is placed one-fourth inch above and parallel to the bottom of the pan. It must extend at least 3 inches into the area of boiling sirup, adjacent to the point of sirup drawoff.

Figure 54.—Flannel prefilter and felt filter for maple sirup, mounted on a milk can.

Figure 55.—A flat type of felt filter, with a flour bag used as a prefilter.

Figure 56.—The prefilter will clog with sugar sand before the felt filter; to replace the clogged area the prefilter is pulled forward until a clean area is in place.

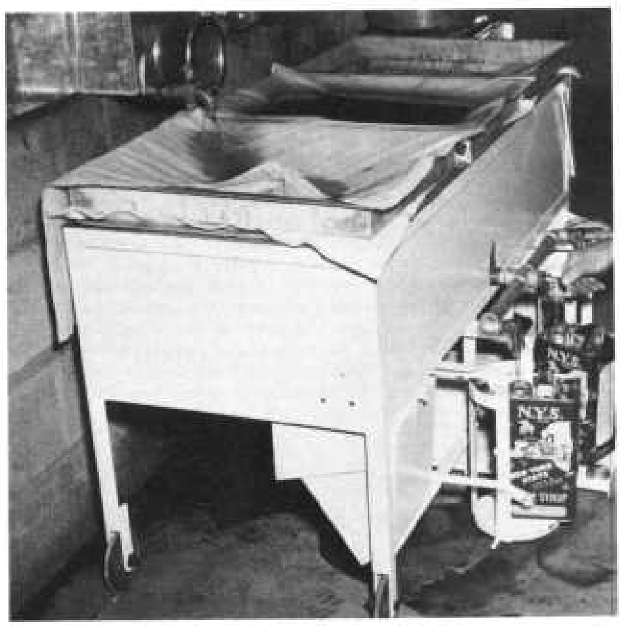

Figure 57.—The use of a multiple filter assembly permits moving a clean filter under the sirup drawoff as each one becomes clogged.

Figure 58.—Measuring the density of sirup: The hydrometer is carefully placed in the sirup and after it has come to rest the scale is read. This is the *apparent* density (Brix value or Baumé value). The temperature of the sirup is then obtained, so that the density reading can be corrected, if necessary.

Figure 59.—Color grading kit. The kit consists of the official USDA permanent glass color standards mounted in a comparator. The 3 clear blanks are in position in the comparator; 3 blanks (A, B, and C) of different degrees of turbidity, are on the right. The sirup sample (in the bottle to left of comparator) is inserted in 1 of the 2 openings in the comparator for viewing.

Figure 60.—Grading the color of maple sirup with the USDA permanent glass color comparator. The sirup is poured into a rectangular bottle and placed in one of the open chambers in the comparator. The sirup and color standards are viewed toward the sky (away from the sun, preferably toward the north sky), and the sample of sirup is moved from one viewing compartment to the other until a match or near-match with one of the color glasses is reached. If the sirup is cloudy, the clear blank behind the colored glass which most nearly matches the sirup should be replaced by the turbid blank (A, B, or C) that gives the best match both in brightness and in color. Because cloudiness in maple sirup can cause an apparent upgrading or downgrading of the sirup, failure to use the turbid blanks may result in grading the sirup incorrectly.

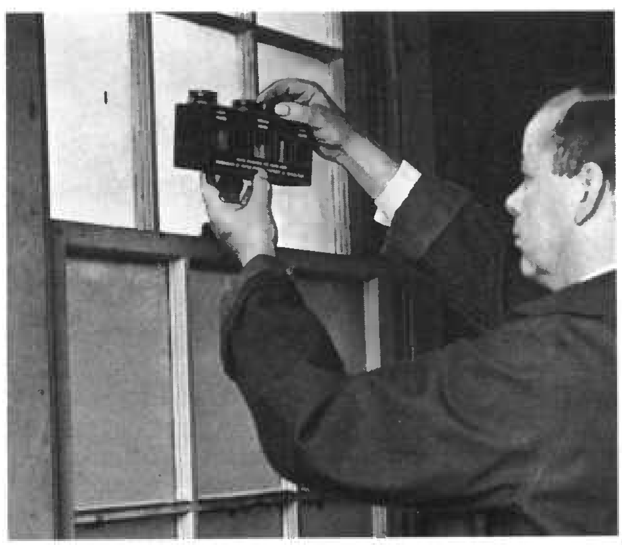

Figure 61.—Exhibit of packaged sirup in labeled bottles and lithographed cans.

Figure 62.—For large operations, it is desirable to carry out the making of maple confections in a separate room; this may be part of the evaporator house.

Figure 63.—Gas, whether supplied from tanks or from mains, is an ideal form 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 making maple cream.

Figure 64.—A trough with flowing cold water for cooling the thickened sirup quickly.

Figure 65.—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.

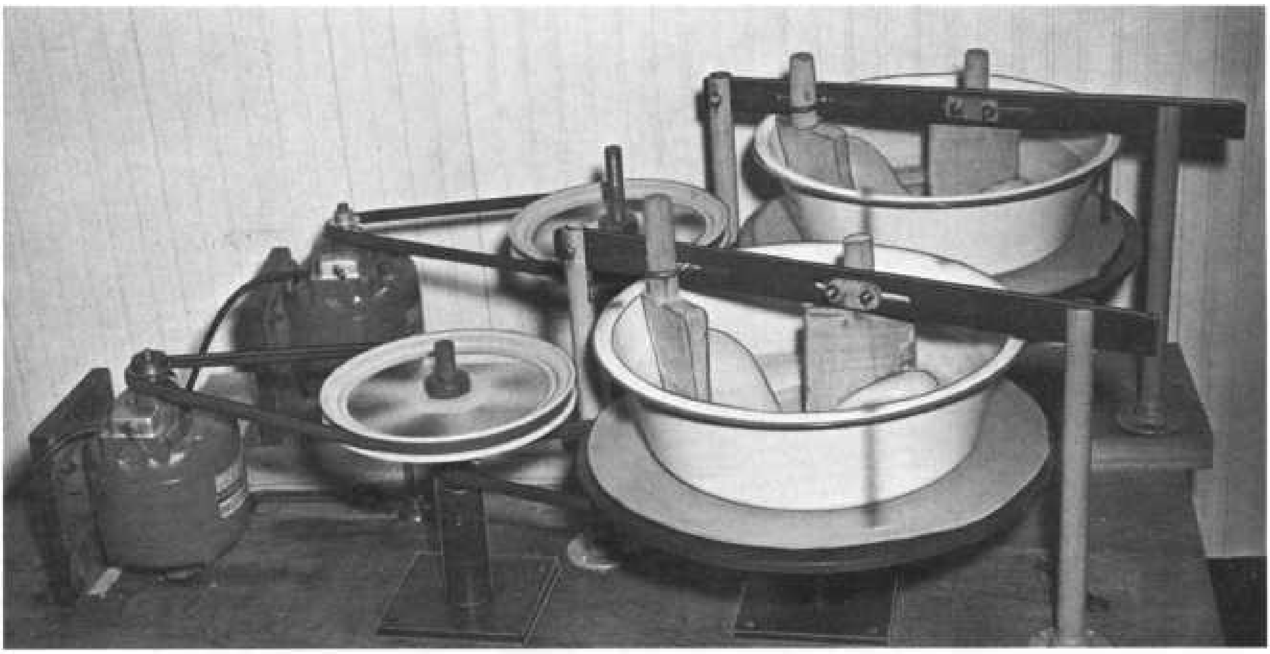

Figure 66.—Homemade cream beaters in which the stirrers are held stationary and the pan is ratated at approximately 70 r. p. m.

Figure 67.—During the creaming aperatian, the butterlike mass at first has a shiny surface. When the surface becames dull, creaming is complete.

Figure 68.—The finished or remelted cream is sufficiently fluid ta be paured into containers. Use wide-mouth jars to make filling and emptying easier.

Figure 69.—The thick supersaturated sirup is stirred to form sugar crystals and to cause them to grow sufficiently large to be palpable but not large enough to be gritty.

Figure 70.—The partially 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.

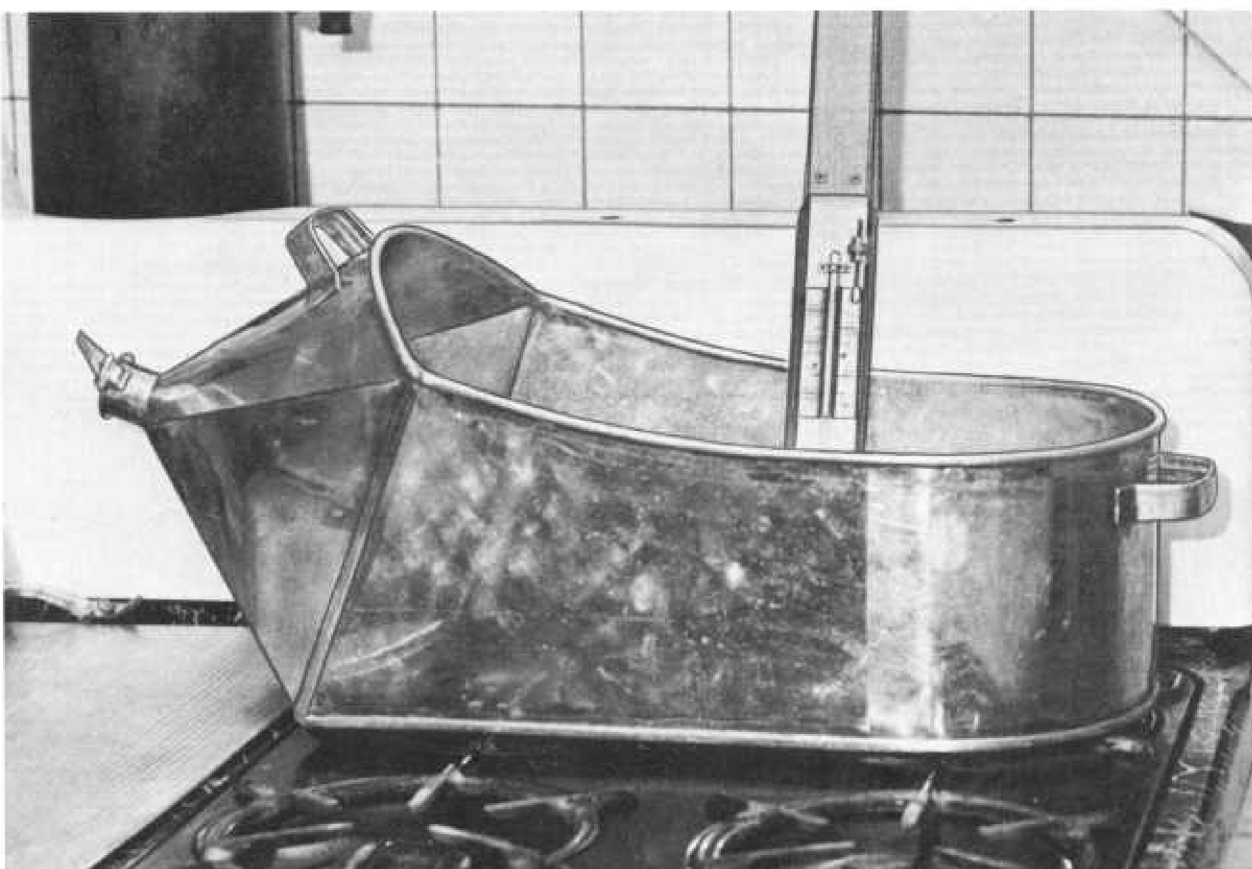

Figure 71.—A special candy cooking kettle has one end shaped like a funnel and is provided with a spout and shutoff. After the cooked sirup has cooled but while it is still fluid, the kettle is mounted in an upended position and the sirup is run out through the shutoff.

Figure 72.—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 turning worm in a metal trough. The turning worm beats the sirup, crystallizing it, and then drives the semi-liquid sirup to the drawoff cock which controls the flow of the sirup into the molds.

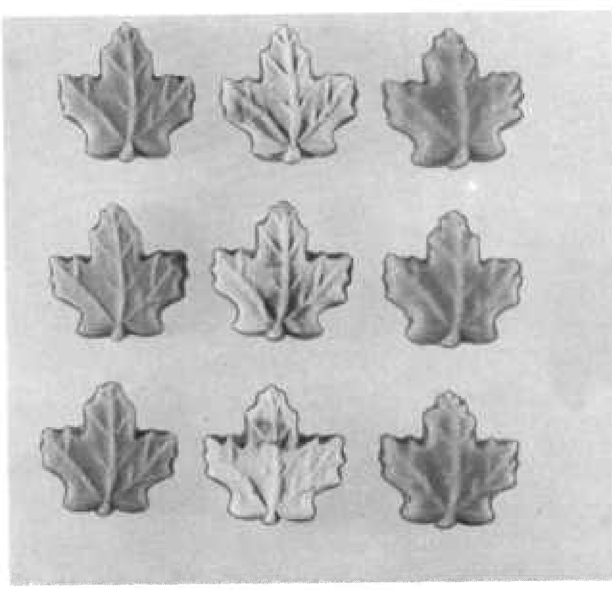

Figure 73.—Crystal-coated candies: *Left*, Freshly made uncoated candies. Center, uncoated candies that have been stored 3 months at room temperature; the white blotches that produce the unattractive appearance are caused by drying. *Right*, these candies, made at the same time as those in the center, were coated with sugar crystals which prevented loss of moisture, and they have kept the appearance of fresh candies.

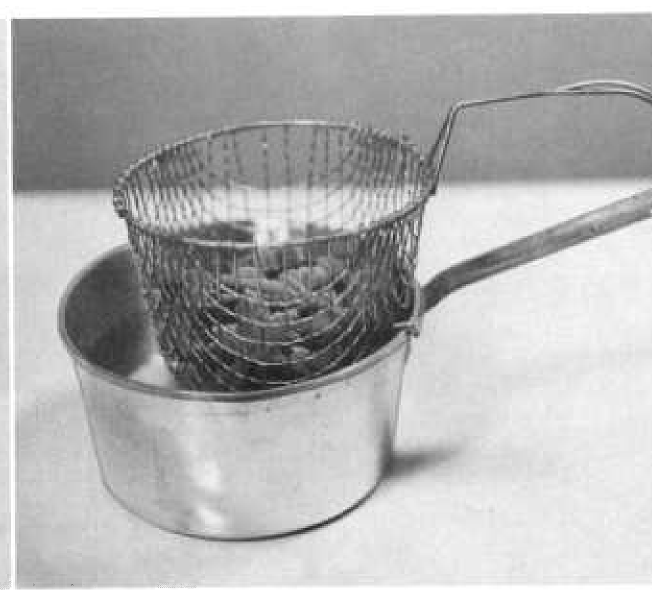

Figure 74.—A French fryer or blanching assembly provides a practical means for crystal coating maple candies. The candies are placed in the basket for crystallizing in the thick sirup and are left in the basket to drain. The drained sirup is caught in the sirup pan for reuse.

Figure 75.—The candies are placed in individual paper cups and then fitted into a special box, making a neat and attractive package.

Figure 76.—The candies are weighed before packaging to be sure their net weight will be at least as much as stated on the package.

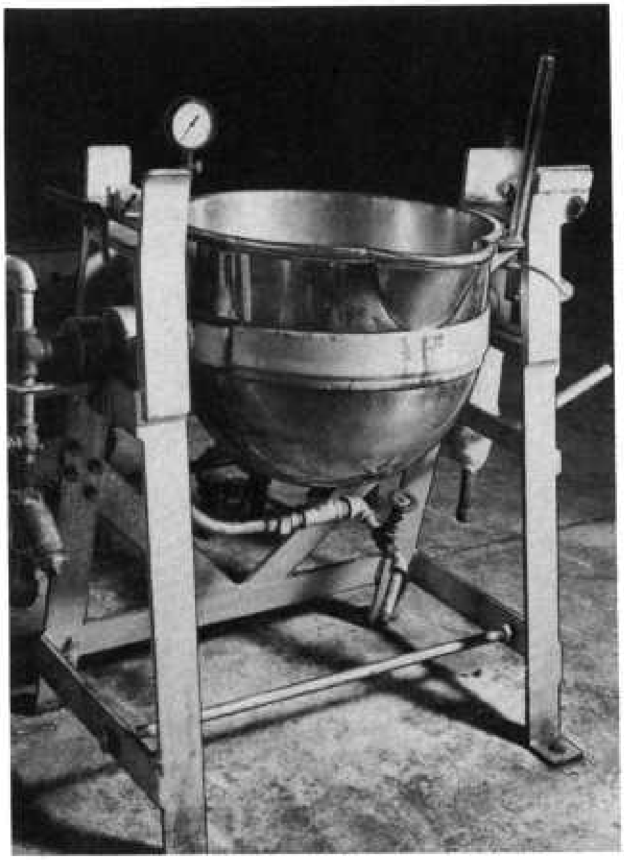

Figure 77.—A steam-jacketed kettle is an ideal cooker for the high-flavoring process. A kettle with a capacity of 10 gallons has a number of uses. It can be used as a finishing pan and as a candy kettle. To use the kettle efficiently, a supply of high-pressure steam is required. Provision must be made to discharge the condensed water; a water-logged kettle will not heat properly. The jacket should be connected to a cold water line to permit cooling of the sirup and for controlling the rate of boiling.

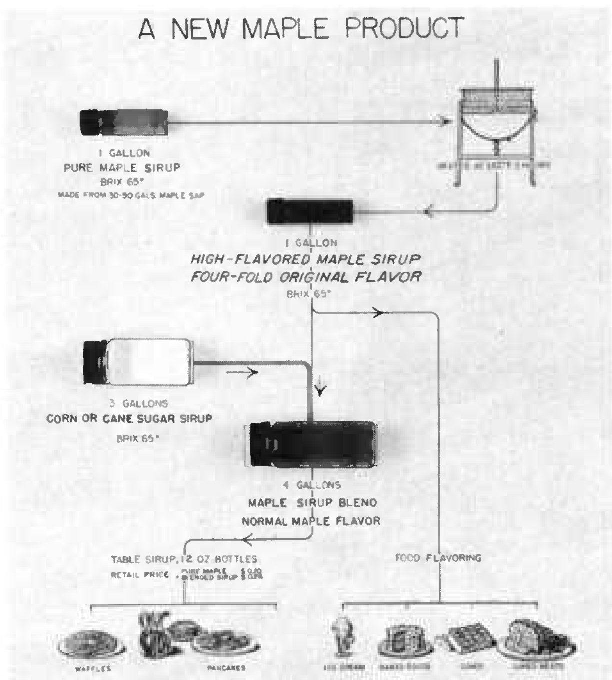

Figure 78.—A schematic drawing showing the high-flavoring process and its use in making blended sirup and as a food flavoring.

Figure 79.—Equipment required for testing maple sirup for invert sugar: One 16-quart pail, 1 long-handled spoon, 1 teaspoon, 5 glass tumblers (4-oz. size) 1 test-tube holder, paper, Clinitest tablets, color scale, 7 medicine droppers, 6 test tubes ½-inch in diameter and 3 or 4 inches long, 1 cupful of the sirup to be tested, 1 transparent measuring cup, 1 quart measure, 1 medicine glass, and 1 package of gummed labels.

U. S. GOVERNMENT PRINTING OFFICE: 1957 O - 446270

ACKNOWLEDGMENTS

The author wishes to acknowledge the technical assistance of M. C. Audsley, W. L. Porter, J. Naghski, T. S. Michener, A. J. Menna, and other personnel of the Engineering and Developments Section of the Eastern Utilization Research and Development Division; the suggestions and practical information obtained from F. E. Winch, Jr., Cornell University, and F. B. Trenk, University of Wisconsin; the research work of J. W. Marvin and his associates at the University of Vermont and of P. W. Robbins and his students at Michigan State University; and the facilities made available by the following maple-sirup producers, processors, and equipment manufacturers: Sipple and Sons, The Clark Estate, C. H. Hubbel, Robert Diamond, Schonagel Brothers, The Carey Maple Sugar Co., United Maple Products, American Maple Products, Geo. H. Soule Co., The Vermont Evaporator Co., and The Leader Evaporator Co.

NOTE: The Eastern Utilization Research and Development Division is located at Philadelphia 18, Pa.

Washington, D. C.

Issued January 1958

For sale by the Superintendent of Documents, U. S. Government Printing Office
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