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SUGAR-CANE SIRUP MANUFACTURE

Compiled by

H. S. PAINE and C. F. WALTON, Jr.
Carbohydrate Laboratory, Bureau of Chemistry

CONTENTS

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Compiled by H. S. Paine and C. F. Walton, Jr., *Carbohydrate Laboratory, Bureau of Chemistry*[1]

CONTENTS

INTRODUCTION

In the States bordering the Gulf of Mexico sugar cane is an important crop. Except in Louisiana, which has been a sugar-producing State since colonial days, the production of sugar cane is so scattering, however, that it has not been generally profitable for cane growers to engage in sugar manufacture. Sirup, rather than sugar and molasses, is the principal product made from sugar cane in Florida, Georgia, Alabama, Mississippi, and Texas.[2] Table 1 shows the production of sugar-cane sirup since 1899 by States.

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[1] Recognition is given to the various contributors under the chapter headings.

[2] Under favorable conditions Louisiana produces 250,000 to 300,000 tons of cane sugar yearly, Texas produces 2,000 to 3,000 tons of sugar yearly, and recently Florida has entered into sugar production.

Note.—The purpose of this bulletin is to describe the manufacture of sugar-cane sirup in a comprehensive manner and in this way to assemble existing knowledge of the subject in one publication. It is largely a compilation of data from various sources, some of which have been published in technical bulletins and journals. Much new material, such as cost data, descriptions of model plants and apparatus, supplemented by sketches, and a comparison of the different methods of manufacture, is included.

TABLE 1.—*Sugar-cane sirup production by States* [1]

State	1899	1909	1919	1920	1921	1922	1923	1924
	Gallons	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*
Georgia	3, 226, 367	5, 533, 520	10, 640, 000	9, 697, 000	7, 335, 000	7, 040, 000	5, 103, 000	3, 800, 000
Louisiana	1, 552, 641	4, 125, 083	3, 672, 000	4, 640, 000	6, 454, 000	6, 490, 000	6, 718, 000	6, 684, 000
Alabama	2, 672, 438	3, 078, 531	8, 480, 000	7, 665, 000	8, 760, 000	11, 937, 000	9, 920, 000	3, 816, 000
Mississippi	1, 413, 219	2, 920, 519	6, 675, 000	7, 358, 000	7, 582, 000	7, 040, 000	5, 565, 000	610, 000
Florida	1, 687, 452	2, 533, 096	4, 590, 000	6, 110, 000	6, 300, 000	4, 800, 000	4, 255, 000	5, 200, 000
Texas	888, 637	2, 246, 774	2, 421, 000	2, 215, 000	3, 192, 000	2, 485, 000	2, 118, 000	1, 091, 000
South Carolina	805, 064	881, 558	1, 369, 000	858, 000	1, 107, 000	1, 288, 000	1, 100, 000	962, 000
Arkansas	44, 819	286, 637	336, 000	437, 000	437, 000	531, 000	594, 000	135, 000
North Carolina	1, 957	21, 677	(2)	(2)	(2)	(2)	(2)	(2)
Arizona	438	1, 040	(2)	(2)	(2)	(2)	(2)	(2)
New Mexico	(2)	5, 038	(2)	(2)	(2)	(2)	(2)	(2)
Oklahoma	(2)	56	(2)	(2)	(2)	(2)	(2)	(2)
Total	12, 293, 032	21, 633, 529	38, 183, 000	38, 980, 000	41, 167, 000	41, 611, 000	35, 373, 000	22, 298, 000

[1] The figures for 1899 and 1909 are from the Bureau of the Census, U. S. Department of Commerce; those for all other years are from the Bureau of Agricultural Economics, U. S. Department of Agriculture. The latter figures are more comprehensive in that they include reports from the small sirup makers.

[2] Figures not available.

Experience has shown that when production in any section increases so rapidly that the supply materially exceeds the demand, the results of this overproduction are clearly reflected in the statistics for this particular section for the following year. The decrease in production for 1923 and 1924 is doubtless attributable largely to the unfavorable growing seasons and ravages of the mosaic disease. For Louisiana, however, although this State likewise suffered a severe reduction in cane production, sirup production held up, for the reason that with relatively high prices prevailing for sirup many manufacturers found it more profitable to make sirup than sugar.

Progress in the sirup industry has been greatly retarded, because new markets have not been established to make possible the profitable disposal of surplus sirup. Lack of uniformity in quality has been largely responsible for this condition. Except through the agency of the largest packers and distributors, who could handle comparatively little of the sirup as a rule, the industry has been unable to assemble enough sirup of uniform quality for carload shipments. Large-scale shipments of "farm-made sirup in buckets" have occasionally been made, it is true; but the sirup thus handled has represented a miscellaneous collection from small-scale producers and has varied greatly in quality. Dealers to whom such shipments have been made have frequently been so greatly disappointed in the sirup that they have been unwilling to receive another shipment. Until a product of uniform and acceptable quality can be obtained, the production is likely to remain fairly close to the established level, increasing only slowly and depending primarily on the growth of the local market.

Table 2 shows the magnitude of the cane-sirup industry as compared with the volume of business in other sirups (including certain grades of cane molasses) in the United States.

The total production of corn sirup is greatly in excess of that given in the table; the estimate includes only that which is used for table sirup. Estimates are not available for the quantity of refiners' sirup consumed as such or in mixture as table sirup, nor for the quantity of food molasses imported from the West Indies. The total annual consumption of sirups and edible molasses, however, is estimated to be well over 1 gallon per capita.

TABLE 2.—*Sirup production in the United States in 1919*

Sirup	Quantity produced
	Gallons
Cane sirup [1]	38, 183, 000
Sorgo sirup [1]	39, 413, 000
Corn sirup [2]	81, 800, 000
Maple sirup [1]	3, 885, 000
Maple sugar as sirup [1]	684, 000
Cane molasses (consumed as food) [1]	6, 706, 000
Total	170, 671, 000

[1] Reported by Bureau of Agricultural Economics, U. S. Department of Agriculture.
[2] Estimated by W. L. Owen (Facts About Sugar (1922), vol. 14, p. 309).

INFLUENCE OF CULTURAL CONDITIONS ON QUALITY AND YIELD OF SIRUP

By P. A. YODER, *Office of Sugar Plant Investigations, Bureau of Plant Industry, U. S. Department of Agriculture* [3]

CLIMATE

The climatic limit for growing sugar cane for sirup is reached at a latitude so far north that the cane either remains immature, imparting an obnoxious green taste to the sirup, or gives a prohibitively small yield because of the short season.

SOIL

Regions that are climatically adapted to sugar-cane growing for sugar manufacture do not have uniformly good sugar-cane soil. The available areas of satisfactorily drained, sandy-clay loam soils, well adapted to sugar-cane growing, are not, as a rule, in compactly arranged tracts large enough to supply a sugar factory with cane. Nevertheless, sirup making has flourished under such conditions, for it can be conducted on a small scale, the supply of cane being economically produced on selected plots of the best land or on small areas that have received special treatment.

Although there are occasional years during which the rainfall is so abundant and so well distributed that a good crop of cane can be grown on typical sandy land by applying fertilizer liberally, there are too many years in which a drought practically ruins the crop. If sandy soil has mixed with it an abundance of humus-forming manures, it may be possible, while this manure lasts, to grow good crops of cane. Likewise a relatively sandy area frequently grows one or more good crops after the land is first cleared of the native forest growth, while the humus and plant food from the native vegetation last; when this is weathered and leached away, however, the soil is as unproductive as other sandy soils.

Clay soils usually contain a relatively large proportion of plant-food constituents, especially potash, which become gradually available to the plant through the weathering of the soil. Moreover, clay has a high capacity for retaining moisture and the plant-food constituents applied in fertilizers. Pure clay, or stiff clay, however, has distinct disadvantages. After rains it is slow to dry out sufficiently for cultivation to proceed. In droughts it is likely to bake so hard that

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[3] Taken mainly from a series of articles by P. A. Yoder, entitled "Sugar Cane Culture for Sirup," published in Facts about Sugar, (1922) vol. 15, pp. 12, 34, 114, 158, 176, 222, 260, 302, 322, 337, 380, 402, 462, 518.

it can not be cultivated, and without cultivation it is not porous enough to give the aeration needed for normal plant growth. Heavy or stiff clay lands may be greatly improved by heavy applications of humus-forming material, such as barnyard manure or green crops plowed under. So treated they may return big crops of cane. The quality of sirup made therefrom, however, is likely to be poor.

A sandy-clay loam, a mean between sandy soil and heavy clay soil, is best for sugar cane. The sand makes the soil porous enough for aeration and drainage, easy to cultivate, and warm early in the spring. The clay supplies mineral plant-food constituents and enables the soil to retain them and moisture.

Rich dark loam soils are among the best for big yields of cane, but they are not suitable for cane to be grown for fancy sirup. The very rich dark alluvial soils of the Mississippi River delta and the rich black bayhead soils and pond borders, as well as soils enriched by cowpenning or by heavy applications of barnyard manure, give big yields of cane. The sirup made with ordinary farm outfits from such cane, however, tends to be dark, with a rank flavor, and to contain suspended matter and sediment which has not been removed by skimming. To make a salable sirup from such cane, it is necessary to subject the juice to a special process of decolorizing and clarification, which is usually convenient and economical only in large factories.

The extent to which appreciation of fine quality in sirup is reflected in market prices governs the selection of soil. Sometimes the wholesale prices for a fancy product are not enough higher than those for ordinary sirup to compensate for the lower yields on lighter soils. Rich dark loam soils will then be sought. Sirup from cane grown on such soils, however, is often not suitable for table use. Sirup makers who cater to a fancy trade and grow cane on medium sandy-clay loam soil, with only moderate applications of fertilizers, can usually get a sufficiently higher price for their sirup to compensate for the ower yields.

FERTILIZATION

The sugar-cane area is usually a relatively small portion of the sirup-producing farm, in most cases a mere "patch." Land where soil conditions are best suited for cane can therefore be chosen. Thoughtful farmers select the area a year or two in advance, and before planting it in sugar cane give it a special preparation. Corn and legumes are good crops with which to precede the sugar cane, light applications of commercial fertilizer being necessary with the corn. On the sandy-loam soils prevailing in most of the cane-growing sections, the velvet bean is the favorite leguminous crop. Cowpeas may also be used to advantage, especially on the heavier soils. The vines of the leguminous crop and the old cornstalks are turned under in the fall to supply more humus. If crops which repay heavy application of fertilizer are grown on the farm, it is good practice to plant the cane in a field that has been previously thus cropped, so that the cane may utilize the residual fertilizer. Thus, if the soil and the location with reference to shipping points are suited for watermelons or cantaloupes, old watermelon or cantaloupe ground may be taken for the cane field.

Sweet potatoes respond well to heavy fertilization, especially to applications of barnyard manure. Although sugar cane also responds well to this treatment, sirup from cane which has received heavy and direct applications is inferior—dark red in color and poor in flavor. If, however, the heavy application of barnyard manure is made to the crop preceding the sugar cane, the quality of the sirup is not seriously affected, and the yield of cane is greatly increased. Farmers who have much barnyard manure available and grow sweet potatoes may well plan the rotation so that sweet potatoes precede the sugar cane, the barnyard manure being applied to the sweet potatoes. What has been said concerning the application of barnyard manure is true also of cowpenning the land.

It is not unusual for farmers to think of cane growing on the richer sandy-clay loam lands as a means of building up their land for the crops that are to follow it, rather than to think of growing other crops to build up the land for cane. Heavy applications of commercial fertilizer are accepted as an unavoidable expense connected with cane growing, calculated, however, to give increased returns from the other crops grown during the next year or two. When the land is more nearly exhausted, cotton, for which a very rich soil is not desirable, is often planted. When the land has become too greatly exhausted for cotton, cane may be planted again. If barnyard manure is available and heavy applications of it have not been made to the crop preceding the sugar cane, moderate quantities only should be applied to the cane.

Not many sugar-cane-producing farms where sirup is made have enough barnyard manure to maintain fertility, so commercial fertilizers must be used. Practically all soils in the sirup sections of the Southern States require applications of nitrogen and phosphoric acid. Although it has had but little effect when applied in Louisiana, potash is now generally used in fertilizer mixtures in the eastern Gulf States. With the increasing demand for it as a stock food and the decreasing supply because of the boll weevil, cottonseed meal, which has been the favorite nitrogenous fertilizer (ammoniate), is giving way to tankage, dried blood, fish scraps, etc., for a slowly available ammoniate, and to the more concentrated ammoniates, sulphate of ammonia, and nitrate of soda. The phosphoric acid fertilizer almost universally used is the acid phosphate, with about 16 per cent of available phosphoric acid. Sulphate of potash is the best form of potash.

VARIETIES OF CANE

Only the earliest maturing of the sugar-cane varieties known are adapted to the Southern States, where the growing season is limited to 8 to 10 months. A large yield of stalks is, of course, one of the most important qualities sought. A high percentage yield of juice in the stalks (a low fiber content) is desired. A juice having a high percentage of solids—that is, a juice of high spindle (saccharometer) test—yields more sirup than one low in total solids.

For sirup making, it is desirable that a portion of the sugars present be in the form of invert sugar, which consists of the two sugars dextrose and levulose. Then the sirup can be boiled with no granulation (crystallization of sugar) to a higher density than would be possible otherwise. Stalks of light color (green and yellow) almost always yield a sirup of lighter, more attractive color than darker stalks.

The coloring matter of cane juice is derived from the soluble pigments in the rind of the cane, the substances in the juice which form dark products with iron, and dark substances produced by decomposition of the sugars by heat. As the pigments of the cane constitute one of the principal sources of color in sirup, the use of a light-colored cane evidently is desirable for sirup manufacture.[4]

Because of the recent introduction and wide dissemination of mosaic disease in all of the Southern States, it is likely that the varieties will be radically changed during the next two or three years. None of the varieties now commonly grown is immune to this disease and most of them are severely injured by it. The gradually diminishing yields of cane during the past few years have been attributed in a large measure to the steady and rapid spread of mosaic. Investigations by the Office of Sugar Plant Investigations, Bureau of Plant Industry, have brought to light a number of varieties that produce well, even under the present conditions of disease saturation. These varieties belong to two distinct groups, the Chunnee-Cheribon hybrids and the Chinese. Other groups under investigation have given great promise, but only these two are available in any quantity. Although they differ in many details, all of these varieties greatly outyield the varieties now grown, owing to their immunity to or tolerance of disease. Much less seed cane is required to produce a stand, and profitable stubble crops are produced over a longer period. The labor requirements for planting and cultivating are smaller, but the harvesting cost is somewhat greater. All the canes are harder than the old varieties and higher in fiber content. In Louisiana it is freely predicted that by 1927 the new varieties will have completely replaced those now in use, and it is likely that a similar revolution will take place in the sirup sections. This may necessitate minor modifications in the methods of manufacturing sugar and sirup.

VARIETIES SUSCEPTIBLE TO MOSAIC DISEASE

The Louisiana Purple (also called "Red Cane"), which is by far the most extensively grown variety in the sirup-producing sections, owes its popularity primarily to the fact that it matures early and yields a sirup of excellent quality. Because of its early maturity, the percentage of cane sugar (sucrose) in solution in the juice is relatively high and that of the invert sugar relatively low. Consequently sugar tends to crystallize from sirup which is boiled thick. The flavor of sirup from the Louisiana Purple cane is milder than that from many other varieties. The sirup has a tendency to be dark red, partly because of the coloring matter in the cane rind.

The Ribbon cane (also called "Red Ribbon" or "Louisiana Striped") is almost as popular as the Louisiana Purple throughout the cane-sirup sections, and it is more extensively planted in central and southern Florida. The stalk is striped, wine-red or purple streaks alternating with green or yellow. Because of the lighter color of the rind, the sirup from this variety is a shade lighter than that from the Louisiana Purple. In all other respects the ribbon cane differs very little from the Louisiana Purple cane.

The Crystalina (known also as "White" or "White Transparent") is closely related to the Louisiana Purple, having almost identical growing habits, disease resistance, and sirup-making qualities, except that it makes a sirup decidedly lighter in color. The stalk is light green or yellow, tending toward pink. Because of the light color of the sirup made from it, it deserves a more extensive trial.

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[4] "The juice from purple canes may be 50 per cent darker than that from green canes." F. W. Zerban, Industrial and Engineering Chemistry, (1920) vol. 12, no. 8, p. 744.

The Home Green (commonly called "Green" in Georgia and Florida, and apparently identical with the Otaheite of Cuba and the Bourbon of the British West Indies) is grown extensively for sirup in central and southern Florida; it is used but little for field planting farther north. Because of the softness of the stalk, however, it is very popular as a chewing or eating cane. For this purpose most of the cane growers in the sirup belt and many who make no sirup plant a few short rows of it in fields or gardens. It has yellowish-green or russet-green stalks and makes a beautiful bright sirup of fine flavor. Its yield is low and it is one of the most susceptible of the varieties in use to red rot, mosaic, and other cane diseases. It ratoons so poorly that it is not practicable to take more than one crop from a planting. The leaves fall from the stalk about as readily as those from the Home Purple; the stalks are equally susceptible to lodging in a storm, or slightly more so. Poor soil conditions and drought affect it greatly. Unless the soil is very rich or heavily fertilized, planting this variety for commercial sirup production is hardly worth while. The leaf sheaths of the Home Green cane have an abundance of stiff prickles that cause much discomfort in handling the cane before it is stripped. Being a soft cane, it is very easily milled and yields a high percentage of juice.

The Green Ribbon (commonly called "Simpson" in Florida) is also extensively grown in central and southern Florida as a sirup cane and elsewhere as a chewing or eating cane. It is practically identical with the Home Green in all its characteristics, except that the stalks are striped with green and yellow. Sirup made from this variety is light colored, mild flavored, and of excellent quality. Unfortunately, it can not be especially recommended as a sirup-making cane because of its low yielding and poor ratooning qualities and its lack of resistance to disease.

The D–74 has been a popular variety in the sugar and sirup-making sections of Louisiana. Sirup from this variety has a strong tendency to crystallize, if concentrated to a density as high as the market likes it. Being a lighter-colored cane, the D–74 produces a somewhat lighter-colored sirup than the Home Purple. Its susceptibility to disease is about the same as that of Home Purple. The yield per acre is slightly higher, and its stalks are erect, not readily lodging in storms. The D–74 resists ordinary winds, which prostrate many varieties, but in violent storms some of the stalks are snapped at the top joints. However, the less visible damage to Louisiana Purple and Ribbon at the ground line is greater than the top damage to D–74. In nearly all sections of Louisiana it has given heavier yields than the Red or Ribbon canes; it is estimated to be 20 per cent superior in tonnage. In addition, its juice contains a higher percentage of sugar than most of the other varieties, and its yield of sirup is correspondingly greater. Cane varieties with such rich juice need not be avoided for fear of crystallization of the sirup, as this difficulty can be readily overcome (p. 61).

The Cavangerie from Cuba (commonly called Cuban Red in Florida) has become popular in central and southern Florida as a sirup cane. It has a very large deep wine-red stalk, with narrow, obscure brownish-black streaks. Because of the low percentage of cane sugar and the high percentage of invert sugar in the juice, the sirup from it can be evaporated to high density without granulating. The quality of the sirup, however, is somewhat inferior.

TOLERANT OR RESISTANT VARIETIES

The varieties of the Chinese group (Cayana–10 and Uba) have several advantages from the cultural standpoint. They germinate well, and less plant cane is required per acre than for the large-stalk varieties, such as Louisiana Purple. These slender, hardy varieties ratoon exceptionally well, as a result of which the chances for three or four stubble crops are considered to be about as good as those for two successful stubble crops from the large-stalk varieties. They are exceptionally resistant to disease. The Cayana–10 and the Uba are apparently immune to the mosaic disease, and the other Chinese varieties are so tolerant of it that there is practically no loss from this disease, even in mosaic-infested districts. In yield of stalks these slender varieties surpass the large-stalk varieties. Their juice contains a relatively high proportion of invert sugar, yielding a sirup with less tendency to crystallize when boiled to high density. The rinds are green, and the sirup is lighter than that from a deep-colored cane, such as the Louisiana Purple. Because of their prolific growth, all these varieties are good forage crops.

The varieties of the Chinese type, on the other hand, have several disadvantages. The labor of stripping and topping them is about double that for harvesting the standard large varieties, computed on the ton of cane, the stalks being much smaller and the leaves adhering more closely to the stalks. The cane is so tough that it requires a stronger mill and more power to grind it. The yield of juice per ton of cane is smaller than that from the large, softer varieties. The flavor of the sirup differs somewhat from that obtained from Louisiana Purple or Ribbon cane, to which most cane-sirup users are accustomed.

The stalks and leaves of the old, small Japanese cane, long grown in this country, are still more slender than those of the other Chinese varieties, and the stalks are more fibrous. The yield of juice per ton of cane is therefore lower. The juice has a lower solids content and the "purity" is less. The flavor of the sirup from this variety differs from that obtained from the Louisiana Purple and Ribbon canes to a greater extent than does that of sirup from the other Chinese varieties.

A group of varieties that has aroused great interest in Louisiana on account of their tolerance to mosaic disease and resistance to frost, the Chunnee-Cheribon hybrids, may be of value for sirup production. These varieties, 36, 213, and 234 P. O. J., are notable also for high sucrose content and purity of juice. Their juice would therefore need to be mixed with the juice of Cayana or another variety having a fairly large proportion of invert sugar in order to produce a sirup that would not crystallize. The Chunnee-Cheribon hybrids are not immune to mosaic. They become infected readily but are not severely injured by the disease. This means, of course, that they act as carriers of the disease, and remain a potential source of danger to corn, sorghum, millet, and other crops that are susceptible to mosaic. On this account they do not offer a complete solution of the mosaic problem, as does Cayana–10 of the Chinese group, which is completely immune.

Some varieties of cane are less fibrous than the Louisiana Purple and the Ribbon and yield a higher percentage of juice; others are more fibrous and yield less juice. Thus the Home Green (Otaheite or Bourbon) yields about 5 per cent more juice (with a small power mill), the Cayana–10 and Uba yield 2 to 4 per cent less juice, and the small Japanese 5 to 7 per cent less. As a rule, the juice of the small Japanese cane is about 1° Brix less dense. If the Louisiana Purple cane yields 20 gallons of sirup per ton of cane, the Cayana–10 and the Uba may be expected to yield about 19 gallons per ton and the small Japanese about 17 gallons. The higher tonnage per acre from the slender hardy varieties of the Chinese group, however, usually more than offsets the decrease in extraction, so that the yield of sirup per acre is actually greater, especially from the Cayana–10 and Uba varieties.

CONSIDERATIONS GOVERNING SIZE OF SIRUP PLANT

By C. F. Walton, Jr., *Bureau of Chemistry, U. S. Department of Agriculture*

After a survey of agricultural and marketing conditions has been made to estimate the probable success of a proposed sirup plant, the scale of operation demands consideration.

COST OF TRANSPORTING CANE

The acreage of suitable land available within economical hauling distance is important. The transportation of cane to a mill may so increase the price of manufacture as to make it impossible to compete with producers more advantageously placed. Sugar cane is such a heavy crop that the haul to the mill plays an important part in determining profits.

Past experience will show the approximate charge which is considered reasonable for transporting cane to the mill. In most instances, even with very good roads, a radius of 5 miles has been accepted as the maximum hauling distance for delivering cane by wagon or truck to a mill. A haul shorter than this over poorer roads has usually proved to be fully as expensive.

The problem of delivering cane to the mill by railroad has received much attention in Louisiana. A sugarhouse in that State requires as many as 2,000 acres of sugar cane for profitable operation, and many of the sirup factories there are much larger than those in other States. As a result of the extensive shipment by railroad, freight rates for sugar cane are lower in Louisiana than in other States. Cane can not economically be brought to the mill from a distance much greater than 50 miles, and the average distance for the haul is closer to 25 miles. The rates between points in Louisiana on sugar cane in carload lots from June 25, 1918, to May 12, 1924, per ton of 2,000 pounds, were as follows: 1 to 25 miles, $0.60; 25 to 35 miles, $0.70; 35 to 50 miles, $0.80; 50 to 100 miles, $0.90; 100 to 150 miles, $1.30; and 150 to 200 miles, $1.60. The average distances over which cane was transported in Louisiana by three railroad systems from 1916 to 1920, inclusive, are given in Table 3. The New Orleans Joint Traffic Bureau, to which acknowledgment is made for these data, believes that the figures for 1921 to 1924, inclusive, do not differ substantially from those given in Table 3.

Assuming that approximately 20 gallons of sirup is obtained from a ton of cane, the portion of expense for manufacturing sirup which is chargeable to transportation of cane to the mill may readily be calculated. For example, if the distance is 35 to 50 miles, the transportation cost by railroad is $0.80 per ton of cane. In addition there is the charge for loading the cane on the cars, which varies from

$0.12 to $0.25 per ton. The total delivery charge for a distance of 35 to 50 miles, therefore, is $0.92 to $1.05 per ton of cane. Estimating this cost at $1 per ton, the charge against a gallon of sirup is $0.05.

TABLE 3.—*Average hauls of sugar cane in Louisiana, 1916–1920*

Year	Railroad No. 1	Railroad No. 2	Railroad No. 3
	Miles	*Miles*	*Miles*
1916	26.6	32.1	45.8
1917	28.3	34.4	39.8
1918	19.6	29.5	43.7
1919	24.4	30.7	37.4
1920	22.0	33.7	48.5

How does the cost of transporting cane to the mill compare with the freight cost for shipping finished sirup in barrels to a central canning plant? Freight rates on sirup vary somewhat in different States. According to the 1923 operation report of a cooperative sirup canning plant in Texas, the freight rate per hundred pounds for sirup in barrels was roughly $0.50 for 100 miles and $0.25 for 50 miles, or $0.06 per gallon for 100 miles and $0.03 per gallon for 50 miles. At these rates, sirup may be shipped nearly twice as far to a central canning plant as an equivalent quantity of sugar cane can be shipped to a mill. A refining-in-transit freight rate is assumed in both cases.

ACREAGE AVAILABLE

The acreage required for the economical operation of sirup plants of various capacities may be readily calculated. Eighteen to twenty-two acres of cane within economical hauling distance by wagon or truck will supply a small farm outfit, using gasoline engine, furnace, and 15-foot evaporator, for the length of time that operation is ordinarily possible each season. Such an evaporator (p. 13) produces daily about 200 gallons of sirup, requiring approximately 10 tons of cane. Estimating the yield of cane at 20 tons per acre, 1 acre would supply such an outfit for about two days. The length of the grinding season, therefore, would be 35 to 45 days, about as long as is practicable in most places before killing frosts come.

For a small steam plant, grinding 50 tons of cane per 24 hours and producing about 1,000 gallons of sirup daily, approximately 100 acres of cane should be within economical hauling distance. For larger steam plants, producing 2,000 gallons and 4,000 gallons of sirup per 24 hours, approximately 200 acres and 400 acres of cane are required.

QUALITY OF SIRUP TO BE PRODUCED

Cultural conditions play an important part in determining the quality of sirup (p. 3). Farmers who have land suitable for growing cane of good quality and who prefer to cultivate a variety known to yield sirup of the finest quality can obtain a very good product with a reasonable degree of skill and average equipment. Small farm evaporators produce excellent sirup. Farmers who wish to market their sirup either by selling to their own customers in cans under special labels or by selling in barrels to a canning plant will find that small evaporators are best for a limited acreage.

Growers who desire to use heavy black or bottom land, or to cultivate a variety of cane that yields greater tonnage per acre and is more resistant to cane pests and diseases than those which produce sirup of the best quality, may find it best to sell their cane to a large steam plant. The larger steam plants may use methods of clarification which largely neutralize the tendency of poor-quality cane to yield a poor-quality sirup. Chemical clarification or the use of a refining carbon makes possible the manufacture on a large scale of a sirup of very uniform quality, almost regardless of the quality of the cane. Such sirup, however, may lack the typical juice flavor of sirup made by the simple boiling and skimming method.

Larger plants operated by steam also obtain a higher extraction of the juice, and consequently they can make more sirup per ton of cane. Without corrective measures, however, higher extraction yields a sirup of poor quality. In the larger plants this tendency may be corrected by making suitable separation of juice from the mills (p. 39). With poor-quality cane and under certain market conditions, small cane farmers may find it advisable to sell their cane to larger mills.

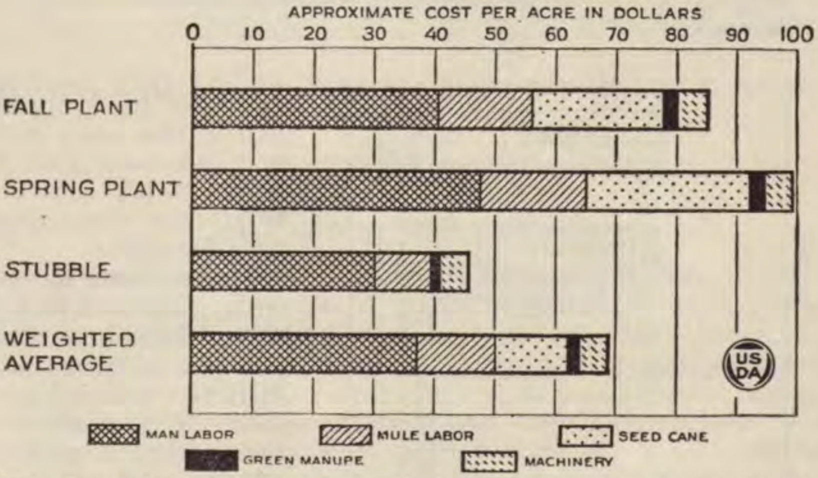

FIG. 1.—Cost, exclusive of interest and rent of land, of producing an acre of sugar cane not fertilized, in Louisiana in 1922

COST OF PRODUCING CANE

Exclusive of interest or rent of land, the 1922 cost of producing an acre of sugar cane in Louisiana, when using no fertilizer, is shown in Figure 1. As an average for all cane on a plantation, for the purpose of this chart, one-fourth is considered fall planted, one-fourth spring planted, and one-half stubble cane.

The average cost, exclusive of rent of land, interest charges, and overhead supervision, for growing and harvesting for the factory an acre of sugar cane on plantations in Louisiana for 1922 is itemized in Table 4.

In Table 4 also the cane is assumed to be one-fourth fall planted, one-fourth spring planted, and one-half stubble. Man labor is estimated at $1.25 a day and mule labor at $0.80 a day. At the usual rates of planting, about 4 tons of seed cane per acre is required for fall planting and 5 tons of seed cane per acre for spring planting.

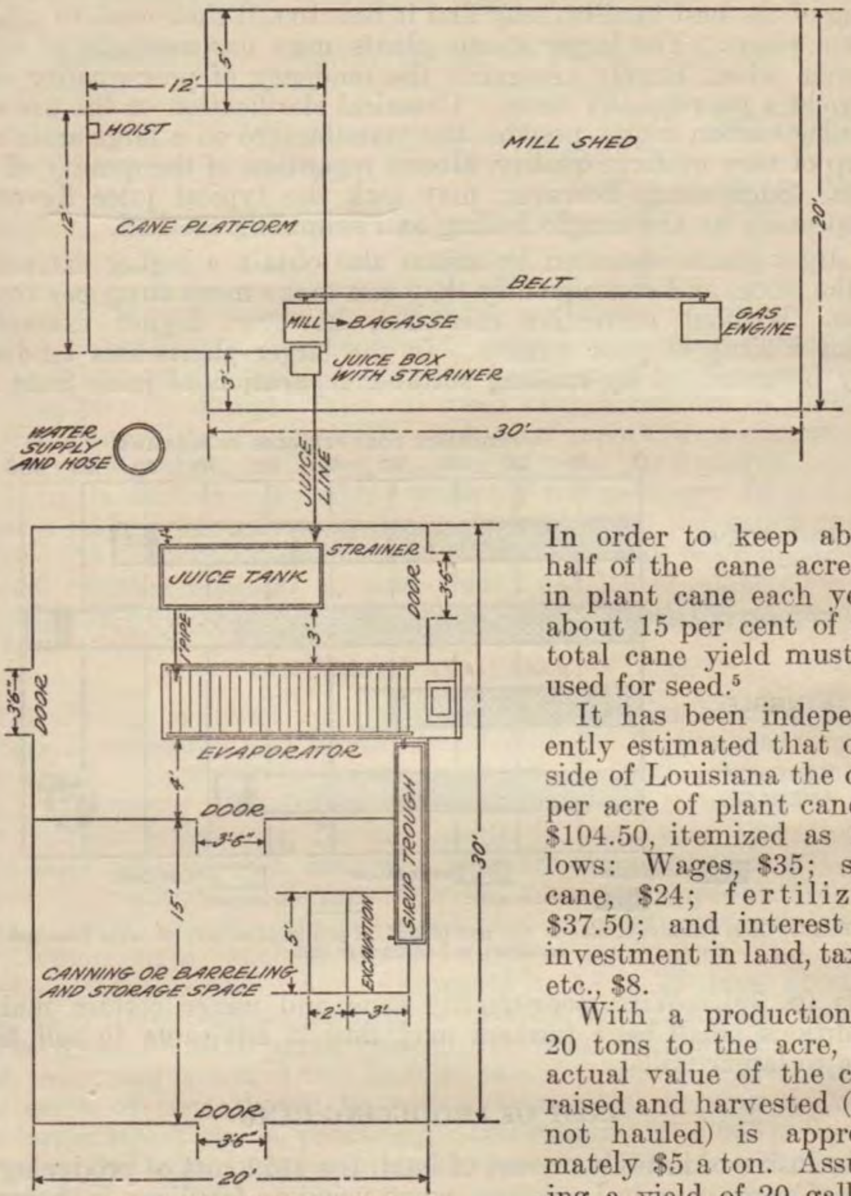

FIG. 2.—Plan of cane-sirup plant

In order to keep about half of the cane acreage in plant cane each year, about 15 per cent of the total cane yield must be used for seed.[5]

It has been independently estimated that outside of Louisiana the cost per acre of plant cane is $104.50, itemized as follows: Wages, $35; seed cane, $24; fertilizer, $37.50; and interest on investment in land, taxes, etc., $8.

With a production of 20 tons to the acre, the actual value of the cane raised and harvested (but not hauled) is approximately $5 a ton. Assuming a yield of 20 gallons of sirup per ton of cane, the actual cost of raising cane is $0.25 per gallon of sirup.

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[5] These cost-of-production data are based on experience with the older, large-stalk cane varieties, rather than on results obtained with the slender-stalk, disease-resistant varieties (p. 8). When more complete information on tonnage production of the newer varieties per acre, number of good stubble crops possible, requirements for seed cane, and cost of harvesting is available, all cost calculations may easily be altered accordingly. The figures cited are given only as an example; they will vary with the kind of cane produced and with the favorable or unfavorable nature of the growing season.

TABLE 4.[1]—*Average cost, excluding land rent, of growing and harvesting for the factory 1 acre of sugar cane on individual plantations in Louisiana, 1922* [2]

Item	Fall plant	Spring plant	Stubble	Weighted average [3]
Man labor [4]	$39.46	$46.54	$29.20	$36.10
Contract labor	1.00	1.00	1.00	1.00
Mule labor [4]	15.66	17.82	9.26	13.00
Seed cane	21.60	27.00	----------	12.15
Green manure (peas)	2.43	2.43	1.42	1.92
Machinery	4.96	4.96	4.96	4.96
Total—unfertilized	85.11	99.75	45.84	69.13
Fertilizer	4.34	4.34	6.17	5.26
Man labor for fertilizing	.56	.56	.56	.56
Mule labor for fertilizing	.44	.44	.44	.44
Total—fertilized	90.45	105.09	53.01	75.39
Average yield (tons)	17	17	12	14.5
Cost per ton	$5.32	$6.18	$4.42	$5.08

[1] U. S. Department of Agriculture Yearbook, 1923, p. 175.
[2] Exclusive of overhead supervision and interest on investment in land.
[3] Assuming one-fourth in fall plant, one-fourth in spring plant, and one-half in stubble.
[4] Man labor at $1.25 per day and mule labor at $0.80 per day. Value of perquisites not included.

EQUIPMENT AND COSTS FOR MAKING SIRUP ON A SMALL SCALE

By M. A. McCALIP and C. F. WALTON, Jr., *Bureau of Chemistry, U. S. Department of Agriculture*

MILL AND EVAPORATOR

The small size of individual acreages of cane and the fact that the tonnage produced in a given locality is not always so centrally placed as to permit efficient operation of a large custom plant, frequently render it necessary for farmers to make sirup on a comparatively small scale. The capacity of mill, engine, and evaporator should be so chosen as to permit economical and steady operation. The sirup-making season usually lasts only five or six weeks, during which period a horse-driven mill, with a kettle or small evaporator, can handle a season's output ranging from 1,500 to 2,500 gallons of sirup. A power mill, with a larger evaporator steadily operated, is adequate for a 10,000-gallon output. Table 5 may be of assistance in selecting mills, engines, and evaporators of appropriate capacity.

TABLE 5.—*Equipment for small-scale sirup making*

Rated capacity of mill	Power	Evaporator
Tons of cane per 12-hour day	*Horsepower*	*Feet*
3 to 5	[1]1	[2]7.5
6 to 8	[1]2	[3]10.5
9 to 11	5 to 8	12
12 to 15	10	15
16 to 20	15	[4]12

[1] Horse or mule operated. [2] Or a 60-gallon kettle. [3] Or a 100-gallon kettle. [4] Two 12-foot evaporators.

LAYOUT

Figure 2 shows a convenient arrangement for a power mill with an 8-horsepower engine and a 12-foot evaporator. The side elevation of mill shed and sectional side elevation of pan (evaporator) house for the same arrangement are shown in Figures 3 and 4. Placing the mill shed some distance from the evaporator diminishes the noise nuisance from the gasoline engine. Elevating the base of the mill 4 or 5 feet above the top of the evaporator makes it possible to bring the juice from the mill to the evaporator by gravity and makes prompt removal of the bagasse unnecessary. The covered cane platform, 12 feet square and 4 feet high, made of heavy material, provides space for cane supply and feeding, and affords shelter during bad weather for the man who feeds the mill.

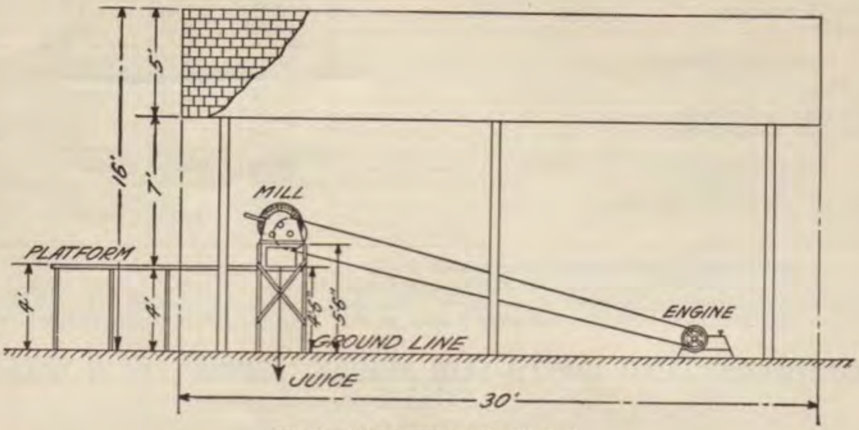

FIG. 3.—Side elevation of mill shed

Walling up the house or shed for the evaporator (fig. 4) causes vapors from the pan to rise and escape through the ventilator, thus interfering as little as possible with the work of the sirup maker. A partition in the pan house keeps the escaping vapors from coming in contact with the cans in the canning room. Such a partition is desirable, because vapors from the evaporator cause the cans to rust very quickly. The storage room should also be as dry as possible for sanitary reasons.

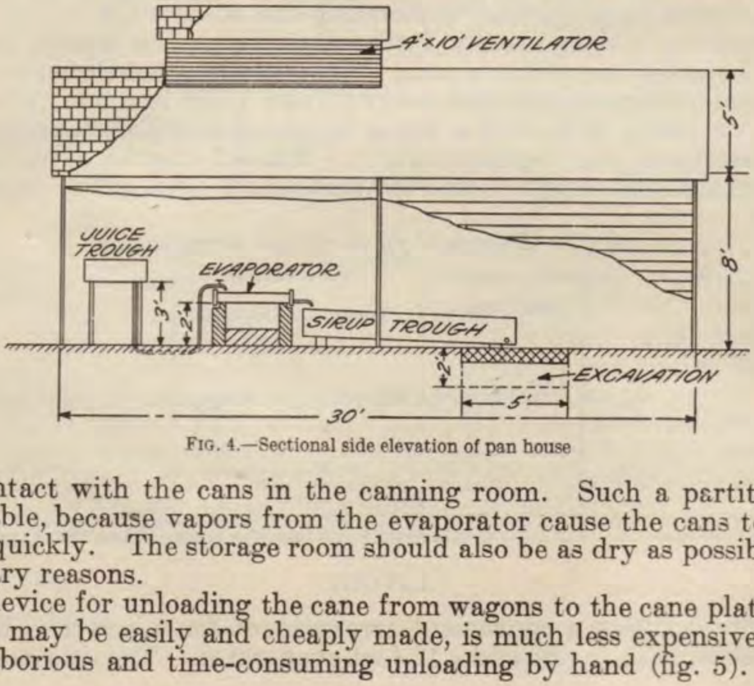

FIG. 4.—Sectional side elevation of pan house

A device for unloading the cane from wagons to the cane platform, which may be easily and cheaply made, is much less expensive than the laborious and time-consuming unloading by hand (fig. 5).

The juice flows from the mill through a coarse 4-mesh screen into a small juice box, one with a capacity of 4 cubic feet being large enough (fig. 2). A 1¼-inch pipe connection leads the juice from this box to the juice tank, which is in the pan house near the evaporator. This arrangement reduces the contamination of the juice by mill trash and gives better opportunity for straining the juice through a sack or screen. A juice tank large enough to hold a 2-hour juice supply permits continuous operation of the evaporator, in case it should become necessary to stop the mill. Crushed cane leaves and particles of soil, bagasse, etc., may be removed from juice entering the evaporator supply tank by straining the juice through a coarse sack, suspended in the juice tank, or through a 16-mesh screen, placed vertically in the tank, dividing it in two.

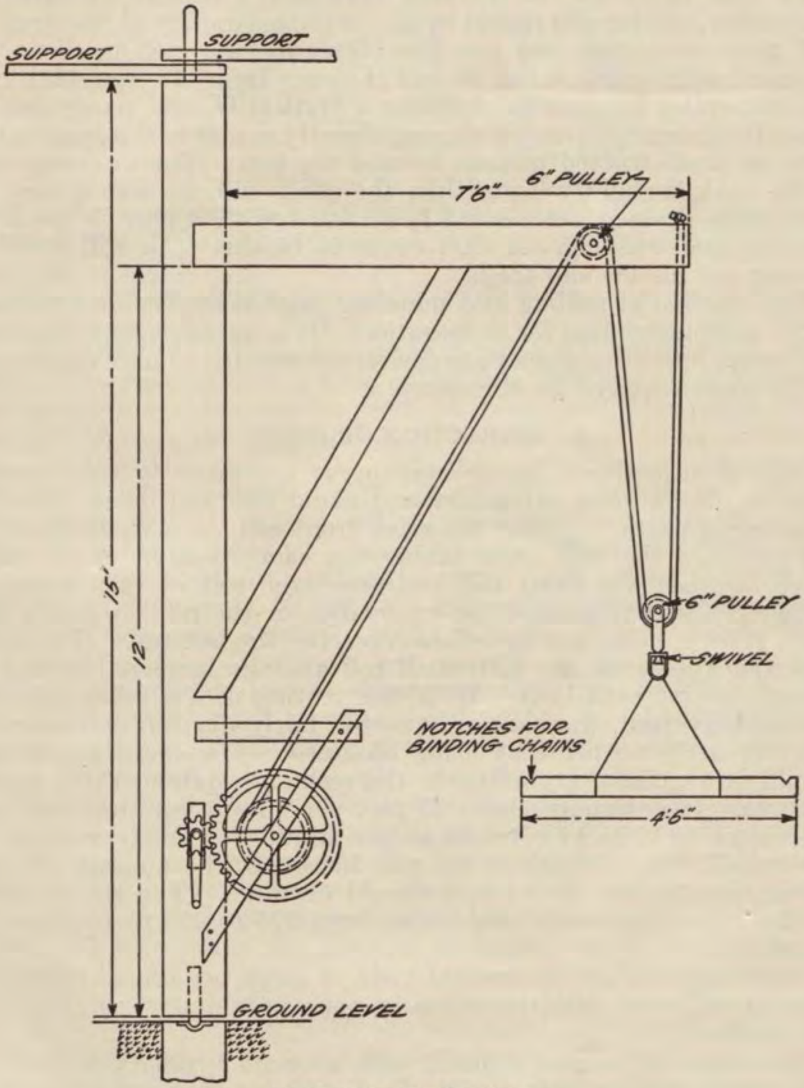

FIG. 5.—Cane unloading device

If the juice tank is partitioned into three compartments, one compartment full of juice can settle for about half an hour before being drawn into the evaporator. While the juice is settling in this compartment the evaporator is being supplied with a previously settled lot and juice from the mill is running into the third compartment. Care in removing as much as possible of the impurities which will settle out of the cold juice before running it into the evaporator, will be well repaid by the improved quality of the sirup.

A pipe connection not less than three-fourths inch in diameter, equipped with a gate valve, to lead the juice from the juice tank into the evaporator by gravity, forming a vertical U, and partly buried under the ground, instead of passing directly across to the evaporator, gives an unobstructed passage around the pan. The discharge end of the tank is slightly lower than the other end, so that it may be completely drained. A second hole, fitted with a plug, is used for draining and washing. A thin cover to fit this tank will assist in keeping out insects and trash.

This method of milling and handling juice is applicable regardless of the equipment used for evaporation. It is inconvenient, however, and comparatively expensive to shelter a horse-driven mill, on account of the space required for the sweep.

EXTRACTION OF JUICE

Careful adjustment before starting is necessary in small power mills to obtain good extraction and avoid loss and delay from the breaking of parts. Setting the small front roll too close to the large roll prevents the mill from taking the cane readily. A clearance space between the front roll and the large roll of approximately three-eighths inch permits the cane to enter the mill promptly and keeps it from being cut up before it reaches the last roll. The clearance space between the last small roll and the large roll should be about one-sixteenth inch. With this setting of a 3-roller mill and full-capacity feed, the cane is squeezed fairly dry, an extraction of approximately 60 per cent being obtained. The speed of the mill should be regulated according to the recommendation of the manufacturer. It is usually about 27 feet per minute for the large roll, equivalent to 10 to 12 revolutions per minute for the average small-power mill. As the size of the mill increases, the number of revolutions per minute of the mill should decrease. The engine speed for the types commonly used varies from 375 to 425 revolutions per minute.

Table 6 shows the theoretical yield of sirup per ton of cane from juice at different densities when various percentages of extraction are obtained.

In seasons of normal rainfall, with efficient 3-roller power-driven mills, sirup makers may expect about a 60 per cent extraction from the Louisiana Purple and Ribbon varieties of cane—that is, out of every 100 pounds of cane stalks about 60 pounds of juice. Although the percentage of total solids is not identical with the number of degrees indicated on the Brix hydrometer scale, the solids content of the juice may conveniently be expressed in terms of this scale. This is usually 14° to 16° Brix—that is, the juice has approximately 14 to 16 per cent of dissolved solids, the remaining 84 to 86 per cent being water. When the apparent solids content of such juice is expressed in terms of the scale of the Baumé hydrometer, it is

TABLE 6.—*Theoretical yield of sirup per ton of cane as influenced by apparent solids content of juice*

Apparent solids content of juice		Yield of sirup per ton of cane		
		60 per cent extraction	70 per cent extraction	80 per cent extraction
° *Brix*	° *Baumé*	*Gallons*	*Gallons*	*Gallons*
13.5	7.6	20.55	23.98	27.41
14.0	7.9	21.32	24.86	28.42
14.5	8.2	22.08	25.76	29.44
15.0	8.5	22.84	26.65	30.45
15.5	8.8	23.60	27.54	31.47
16.0	9.0	24.36	28.42	32.49
16.5	9.3	25.13	29.31	33.50
17.0	9.6	25.88	30.20	34.50

said to have a "density" of 7.9° to 9.0° Baumé. The degrees of the Baumé scale[6] do not correspond even approximately to the percentage of solids.

Assuming an average extraction of 60 per cent of juice from the cane and an average Brix reading for this juice of 15° (1.06133 specific gravity), if this juice is evaporated without the loss of any of the dissolved solids to a sirup of 70° Brix (1.35088 specific gravity), 100 pounds of cane should yield 60 pounds of juice, and the 60 pounds of juice should yield $\frac{15}{70} \times 60$ pounds, or 12.86 pounds, of sirup. A gallon of sirup at 70° Brix (1.35088 specific gravity) weighs 11.25 pounds; hence the 12.86 pounds of sirup is equivalent to 1.14 gallons, which represents the theoretical yield in gallons of sirup from 100 pounds of cane. Theoretically, therefore, a ton of cane yields 22.8 gallons of sirup. The actual yield of sirup per ton of cane, with 60 per cent extraction and with juice testing 15° Brix, however, is only 19 to 20 gallons. In practice not all the dissolved solids in the juice are retained in the sirup, and some juice is unavoidably lost by skimming, decanting, or filtering. This loss is especially great in small farm outfits, in which clarification is accomplished by skimming alone. The yield of sirup therefore is 12 to 18 per cent below the calculated theoretical yield.

With smaller mills driven by horsepower or by gasoline or kerosene engines the extraction is frequently as low as 50 per cent instead of 60 per cent, as assumed for the larger 3-roller mills. Moreover, early in the harvesting season, when the cane may be less mature, the juice may test less than 15° Brix, sometimes even less than 14° Brix. In such cases the yield of sirup will be proportionately reduced.

With a good 3-roller mill and crusher, the extraction may be 65 to 70 per cent; and, with the still more powerful 6 and 9 roller mills, it may reach 75 to 80 per cent, with a proportionate increase in the sirup yield. If the extraction is much above 65 per cent, however, objectionable nonsugar substances are expressed from the

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[6] Several different Baumé scales are in common use by sirup manufacturers and buyers. Moreover, some Baumé spindles are graduated by the manufacturers at one temperature and others at another temperature. Much confusion therefore exists in the industry, for the manufacturer does not ordinarily know which scale the buyer may be using, nor does he know what the most approved scale may be. For the purpose of avoiding misunderstandings and disputes as to sirup density, and for the reason that the Brix scale indicates the approximate percentage of solids, it is strongly recommended that the Brix scale be universally adopted in the sirup industry. Owing to the present popularity of the Baumé scale, however, an immediate and definite understanding between instrument makers and sirup manufacturers and buyers would seem advisable.

cane in sufficient quantity to impart to the sirup a dark color and inferior flavor. This tendency may be counteracted in large-scale manufacture by clarification with chemicals, but at the sacrifice of much of the natural cane flavor.

COST OF MAKING SIRUP

Table 7 gives the itemized costs of materials, equipment, and labor required to install a sirup-making outfit suitable for grinding 10 tons of cane per 10-hour day and making approximately 200 gallons of sirup daily. These costs vary somewhat from year to year and also for different localities.

TABLE 7.—*Cost of constructing a small sirup plant*

Lumber and building supplies	$100. 00
Brick, lime, sand, etc., for furnace	56. 00
Grates for furnace	30. 00
Labor for building sheds and furnace	72. 00
Galvanized-iron roofing	93. 00
Total cost of building and furnace	351. 00
Mill and accessories	500. 00
15-foot copper evaporator	54. 00
Engine and freight	300. 00
Total cost of equipment	854. 00
Total investment	1, 205. 00
Interest at 6 per cent and depreciation at 10 per cent for one year	192. 80

Table 8 gives the itemized cost of operating this small plant.

TABLE 8.—*Operating cost of small sirup plant*

1 sirup boiler, per day	$2. 00	
1 fireman, per day	1. 50	
1 feeder, per day	1. 50	
1 boy for bagasse, per day	1. 00	
Total labor, per day		$6. 00
Wood, at $2.50 per cord	$5. 00	
Oil	. 75	
Gasoline (12 gallons, at $0.25)	3. 00	
		8. 75
Total operating cost per day		14. 75
Operating cost for 45 days (14.75×45)		663. 75
Interest at 6 per cent and depreciation at 10 per cent for one year		192. 80
Total cost for season's operations		856. 55

Assuming that 10 tons of cane are ground per day and 19.4 gallons of sirup per ton of cane are obtained, using a 15° Brix juice, with a 60 per cent extraction and an actual yield 85 per cent of the theoretical, the output of sirup in this small plant would be 194×45, or 8,730 gallons during the 45-day season.

The manufacturing cost, exclusive of cost of the cane, is $\frac{\$856.55}{8,730}$, or $0.098 per gallon. The cost of cane per gallon of sirup, with cane valued at $6 per ton ($5 value in the field plus $1 for hauling to mill), assuming a yield of 19.4 gallons of sirup per ton of cane, is $\frac{\$6.00}{19.4}$, or

\$0.309 per gallon.[7] The total cost for making sirup is \$0.407 per gallon. With sirup at \$0.50 a gallon, the net profit is \$0.093 per gallon. Therefore the profit per 45-day season is \$0.093×8,730, or \$811.89.

The foregoing cost data apply to small sirup plants using a 3-roller mill, with a rated capacity of 12 to 15 tons of cane per 12 hours and an extraction rarely exceeding 60 per cent. A 3-roller mill with a crusher will give an extraction of approximately 67 per cent, with a proportionate increase in the quantity of sirup per ton of cane. A 3-roller mill and crusher (5-roller mill) would cost about \$1,400, and the engine required would cost more than one for the smaller mill. The increased interest and depreciation on capital invested would increase slightly the operating cost per gallon of sirup made; the increased extraction would give a higher yield of sirup to more than offset the higher overhead expense. Table 9 shows the cost of making sirup with the more expensive mill.

TABLE 9.—*Cost of producing sirup with 5-roller mill*

Building and furnace	\$351. 00
Mill	1, 400. 00
15-foot evaporator	54. 00
Engine and freight	400. 00
Total investment	2, 205. 00
Cost of operating for 45 days (same as for 3-roller mill)	663. 75
Interest at 6 per cent and depreciation at 10 per cent for one year	352. 80
Total operating cost	1, 016. 55

Assuming that 10 tons of cane are ground per day and 21.7 gallons of sirup per ton of cane are obtained, using a 15° Brix juice and 67 per cent extraction, with an actual yield 85 per cent of the theoretical, the output of sirup during a 45-day season would be 217×45, or 9,765 gallons. The manufacturing cost, exclusive of the cost of the cane, is $\frac{\$1,016.55}{9,765}$, or \$0.104 per gallon. The cost of cane per gallon of sirup, with cane valued at \$6 per ton (\$5 value in the field plus \$1 for hauling to mill), assuming a yield of 21.7 gallons of sirup per ton of cane, is $\frac{\$6.00}{21.7}$, or \$0.276 per gallon.[8] The total cost for making sirup is \$0.38 per gallon. With sirup at 50 cents a gallon, the net profit would be \$0.12 per gallon. The profit for a 45-day season would be \$0.12×9,765, or \$1,171.80.

The increased net profit is \$1,171.80 − \$811.89, or \$359.91. This will pay the difference between the prices of the two mills (and engines) in $\frac{\$1,000.00}{359.91}$, or 2.8 years.

The foregoing calculations show the extra profit obtained from the increase in yield of sirup resulting from an increase of 7 per cent in extraction. It has been assumed that the 3-roller and 5-roller mills give extractions of 60 per cent and 67 per cent. The data in Table 6 were used in calculating the yields resulting from the two percentages of extraction. With 15° Brix juice and 60 per cent extraction, the theoretical yield of sirup per ton of cane is 22.84 gallons.

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[7] See footnote 5, page 12.

[8] Ibid.

The actual yield, or 85 per cent of the theoretical (p. 18), is therefore 19.41 gallons. With 15° Brix juice and 67 per cent extraction, the theoretical yield (Table 6) is 25.5 gallons of sirup per ton of cane; the actual yield is 0.85×25.5, or 21.67 gallons. The increase in gallons of sirup per ton of cane resulting from 7 per cent increase in extraction is $21.67 - 19.41$, or 2.26 gallons.

The 5-roller mill is usually of heavier construction than the small 3-roller mill, so that it gives less trouble from breakage. The crusher prepares the cane for the mill, thereby making it possible for a thicker and more even blanket of cane to pass through the mill. The tendency is to underfeed rather than to overfeed small 3-roller mills, owing to the fear of "choking" the engine or breaking a shaft of the mill. This decreases the extraction because of insufficient pressure on the cane.

In the foregoing calculations the small cost of evaporating the extra juice obtained by higher extraction has not been considered. It has also been assumed that the quality of sirup resulting from 67 per cent juice extraction is so nearly equal to that of sirup obtained from 60 per cent extraction that the two lots of sirup have the same market value. Under certain conditions, for example with poor quality cane, this may not be strictly true. In most cases, however, it is believed that the small-scale boiling and skimming method will yield sirup of satisfactory quality, without recourse to chemical clarification, provided the extraction does not greatly exceed 65 per cent.

COMPARISON OF METHODS OF MANUFACTURE

Although the quality of sirup depends to a large extent upon the variety of cane and the type of soil on which the cane is grown, it may also be greatly influenced by the equipment and process used in manufacture and by the skill of the sirup maker.[9]

In making sirup from sugar-cane juice, 1 gallon of sirup is obtained from 6 to 7 gallons of juice, 5 to 6 gallons of water being evaporated. Cane juice, however, contains many substances besides sugar and water. As first obtained at the mill, the juice contains some suspended soil, which has adhered to the cane, particles of finely ground cane stalk or fiber in suspension, and certain dissolved substances. Among the dissolved nonsugar substances, commonly classed as impurities because they represent material other than sugar but which are just as much a part of the juice as is the dissolved cane sugar itself, are organic and inorganic salts, proteins, pigments, gums, and cane wax. These so-called impurities affect the quality of the sirup, but not all of them are objectionable. Although it is never necessary or feasible to remove all of them, some must be eliminated to get a sirup of satisfactory flavor, color, and clarity. In practice, therefore, the manufacture of sirup consists in the evaporation of excess water and the removal of certain impurities by clarification.

The methods of clarification used by sirup makers differ somewhat, depending on whether the operation is on a large or a small scale and

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[9] The methods of manufacture herein described apply primarily to the large-stalk, disease-susceptible varieties of cane, which are at present most extensively cultivated. From the experience thus far available in making sirup from the slender-stalk, disease-resistant varieties, it is believed that the methods of manufacture in the future will need to be altered but little, if at all.

also on whether or not chemicals are used as clarifying agents. The use of chemicals as clarifying agents is practiced, for the most part, only by the larger manufacturers, who use steam for evaporation and may even be able to filter the juice or sirup at any stage. When sirup is made on a comparatively small scale, as is the most general practice through the sugar-cane belt, suitable regulation of temperature and careful skimming are the requirements for producing good-quality sirup.

BOILING AND SKIMMING METHOD

By M. A. McCalip and C. F. Walton, Jr., *Bureau of Chemistry, U. S. Department of Agriculture*

When heat is applied to cane juice, certain proteins and other nonsugar substances become coagulated. Some of this coagulated material rises to the surface of the juice and some sinks to the bottom. By the most approved practice, this material is removed as quickly as possible by skimming when it appears at the surface of the juice, after being coagulated by heat. Success in making sirup depends first of all on the thoroughness with which the juice is skimmed before it begins to boil rapidly. The agitation of the juice due to active boiling breaks the coagulated material into smaller particles, which are more difficult to remove by skimming than the original mass. This breaking up of coagulated material is commonly referred to by sirup makers as "boiling in" the impurities. Additional nonsugar substances separate as boiling continues and the juice becomes denser, making it advisable to continue the skimming until the juice has been evaporated to the density of finished sirup, even when skimming has been most carefully done at the beginning of evaporation.

KETTLES

Of the many types of equipment used for concentrating juice to sirup, kettles are probably the oldest. Less skill is required to make sirup with kettles than with any other means of evaporation, and a product of good quality results when they are properly operated.

The advantages in using kettles for small-scale sirup making are: (1) The density of the finished sirup may be readily controlled; (2) the method is easy to operate; (3) a long period of time is available for skimming, thus making it possible to obtain a clean sirup; (4) long-continued boiling causes increased inversion, giving a sirup with a diminished tendency to crystallize. The disadvantages are: (1) A long period is required for evaporation, frequently 3½ hours to a batch; (2) a dark product is obtained as a result of the prolonged slow boiling; and (3) it is feasible only on a very small scale.

EVAPORATORS

Most of the sugar-cane sirup made by farmers operating on a comparatively small scale is made on open galvanized-iron or copper evaporators. A galvanized-iron evaporator is cheaper than one of copper and, while new, will produce sirup of as good quality as can be made in the copper evaporator. A galvanized-iron evaporator also will last a reasonable length of time. Cane juice, however, is always slightly acid and consequently gradually corrodes galvanized iron. When the zinc surface of the galvanized iron becomes corroded and pitted, the juice is boiled in contact with the exposed iron, which reacts with certain constituents of the juice to produce a dark sirup. Although a copper evaporator costs nearly twice as much as one of galvanized iron, the extra expense is more than counterbalanced by the advantages gained. Copper lasts much longer than galvanized iron; it can be easily cleaned without injury by the use of acid; it conducts heat better than does galvanized iron; and the use of a copper evaporator results in a lighter-colored sirup. The first cost of a good evaporator is only a small item in the total cost of making sirup, so that the use of copper is in no sense of the word an extravagance.

The advantages of evaporators are: (1) Rapid evaporation, which is essential in making light-colored sirup, is obtained; (2) the sirup is concentrated in a thin layer, thus increasing the rate of boiling and foaming and affording better opportunity for thorough skimming; (3) heat is applied to the bottom of the evaporator, thus imparting an upward motion to the coagulated material, whereby skimming is facilitated. The disadvantages are: (1) More attention is required to maintain a properly regulated flow of juice; (2) there is increased danger of scorching the sirup and altering its color and flavor; (3) more careful attention to firing is necessary; (4) it is difficult to obtain uniform sirup density.

In continuous evaporation, a steady stream of juice flows by gravity into the lower end of the pan and then flows slowly to the opposite end, at which point it reaches the density of finished sirup. The juice end of the pan is sufficiently lower than the finishing end to maintain a juice layer 2 to 2½ inches deep, which should give a layer three-fourths to 1½ inches deep (preferably only three-fourths inch) in the finishing end of the evaporator. In most common practice the juice enters the front end of the pan and during evaporation moves toward the back or chimney end. In some instances, however, the juice enters at the chimney end and is drawn off at the front end as sirup. As water is evaporated and sirup drawn off, the juice, with continuous skimming, flows toward the finishing end of the evaporator, while cold juice from the supply tank is run in to maintain the desired level in the juice end of the pan. The heat applied to the juice from the bottom of the pan increases from the juice end to that part of the evaporator where there is danger of scorching the sirup. Beyond this point the heat applied gradually decreases, until only a small amount is required under the last compartment, from which the sirup is drawn off. The hottest portion of the pan, and consequently the place where the juice boils most vigorously, is where concentration to sirup is a little more than half completed. This scheme of operating a continuous evaporator makes it easier to regulate the boiling. The scum is carried back to the juice end of the pan with the foam and may be readily removed by skimming.

FURNACES

The furnace for a furnace-heated continuous evaporator must be properly constructed and the fire must be carefully controlled. In direct-fire evaporation, success depends to a great extent upon the construction and operation of the furnace. The capacity of a plant equipped with a mill and evaporator of the best type may be reduced as much as 50 per cent by an improperly constructed fire box and ash pit. The distribution of heat over the bottom of the pan is controlled by filling in the furnace between the end of the grates and the chimney. Although all furnaces look very much alike on the outside, they differ greatly in the size of fire box, ash pit, chimney, and filling.

Figure 6 shows a furnace suitable for a 12-foot evaporator. The dimensions for width, height, distance of grates below pan, and thickness of wall apply also to furnaces for evaporators of other lengths. For longer furnaces the length of the fire box should be increased to 4 or 4½ feet. The chimney of the furnace should be as high as the furnace is long. A well-constructed fire box is about 2½ inches longer than the wood used. The highest point in the filling of the furnace, where the flames are brought closest to the pan, should be approximately 1½ feet beyond the middle of the evaporator toward the sirup end.

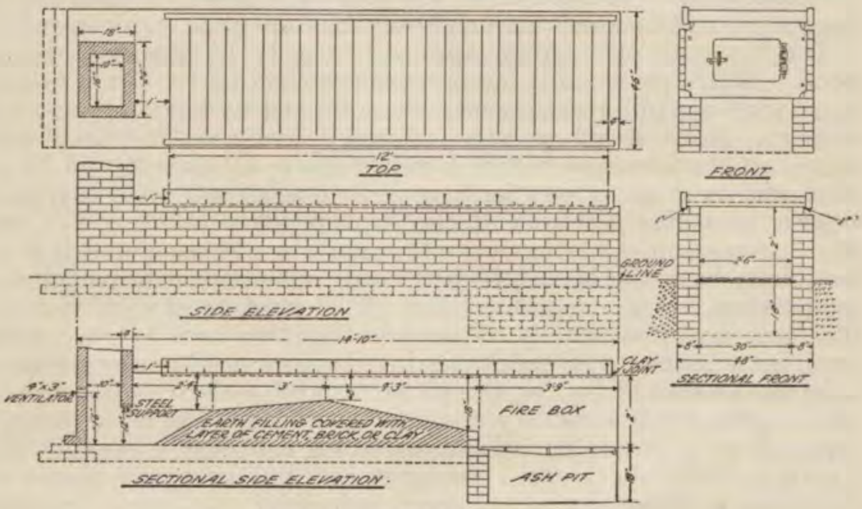

FIG. 6.—Furnace and 12-foot evaporator

Some furnace fronts manufactured with grates attached give too small a fire box. Moreover, the continual opening and closing of the door, in the case of heavy fronts, frequently tears the end brick from the furnace. Sirup makers often install a grate in the proper position, using for the front a large piece of sheet metal, hung from a joist of the pan shed. This inexpensive arrangement works very satisfactorily, affording a larger door for firing and rapidity in opening and closing.

Beginning at the bottom of the ash pit, a 2-thickness transverse brick wall built up to the bottom of the grates furnishes a support for their back end. The wall is then reduced to one thickness of brick and is extended about 6 inches above the grates. This keeps the filling of the furnace in place and prevents it from falling back into the fire box. The filling is banked up against this wall and gradually slopes up to the highest point, which is about 1½ feet beyond the center of the pan. Beyond this point the filling slopes gradually downward to the last compartment of the pan, where it drops off suddenly. If dirt is used for this filling, it should be covered with a layer of brick cement or hard clay to keep the contour of the filling from being changed by a strong draft.

Three by 4-inch dampers in the chimney regulate the draft. Enough air to give good combustion of fuel should be admitted. With proper draft the flames should extend slightly beyond the arch of the chimney.

The pan is set on a single line of bricks, which are laid lengthwise on a 2-thickness brick wall, flush with the inside surface of the wall. A good joint between the furnace and evaporator is conveniently made with clay or mortar. With the width of furnace given in Figure 6, about an inch of the width of the pan on each side projects over the outside of this line of brick, which protects the sides of the pan from the fire. The front of the pan should be within 6 inches of the front of the furnace. A space of 1 foot between the front of the chimney and the back of the pan is convenient in skimming and drawing off the sirup. A small crack left here admits air to the chimney end of the furnace, the draft thus created preventing too close contact of the flame with the sirup end of the pan. The front, or juice end, of the pan should be about an inch lower than the back, or sirup end.

The foregoing description applies primarily to furnaces burning wood. Whenever wood is more expensive than oil (p. 57), a furnace of somewhat similar design may be equipped to burn oil very efficiently. Since steam is not ordinarily available for small-scale sirup manufacture, however, it is impossible to atomize the oil by use of steam, as is customary in large-scale operations. Nor is it practicable to utilize the heat of the furnace for preheating the fuel. For these reasons a mechanical oil burner must be used, and it is not feasible to burn oils of such high viscosity as to require heating before atomization. Fuel oils lighter than 18° Baumé, or of such viscosity that they will flow readily without heating, are usually required in small installations. All mechanical oil burners need power for atomizing the fuel and injecting the proper quantity of air. The oil may be pumped, but it is usually under gravity feed. The air pressure is supplied by a power-driven blower or an air compressor. If electricity is available, a small motor is an ideal source of power for operating a blower or compressor; otherwise, the power required may be obtained by a belt connection to a small gasoline engine (one-half horsepower) or to the shaft of the mill. Manufacturers will supply information on equipment for burning fuel oil on a small scale. The fuel requirement for a 12-foot evaporator (p. 23) is estimated to be approximately 15 gallons of oil (on 12° Baumé basis, p. 56) per hour, assuming a production of 16 to 17 gallons of sirup per hour.

OPERATION

The evaporator must be thoroughly clean when operation is started. If sediment from the previous operation has been deposited on the bottom and sides, a copper evaporator may be cleaned by allowing a hot dilute solution of hydrochloric (muriatic) acid to stand in it for a short period. This partially dissolves the sediment, so that it can be removed by slight scrubbing while running water through the pan. Galvanized iron is badly corroded by contact with acid. Evaporators may be cleaned also by boiling water in them and scrubbing, but this is time consuming. The evaporator should be cleaned every two or three days, depending largely upon the quantity of deposit adhering to it. When two evaporators are in use, it is convenient to clean one every day and use the other for evaporating the first supply of juice in the morning.

When operating during the day only, the evaporator must be cooled and held partly full of juice or water overnight. This can be satisfactorily accomplished by flooding the pan with juice while the furnace is hot (taking care, of course, that the pan does not boil dry at any time) and skimming the juice with care before leaving it overnight. Even with the most careful skimming, however, a deposit will be found on the bottom of the pan the next morning, and if the juice is undisturbed when the furnace is fired, the heat will cause this deposit to stick to the bottom of the evaporator, producing a sirup of darker color and poorer flavor. This difficulty can be largely overcome by scraping the bottom of the pan and stirring the juice before firing the furnace, thereby returning the deposit to suspension. When the sediment is thus loosened from the bottom and sides of the pan, part of it can be removed by skimming and the rest can be run out with the first few gallons of sirup made. The removal of this sediment gives a cleaner and brighter sirup. Too much care can not be taken in keeping the pan clean; dirty pans are responsible for much low-grade sirup.

When starting with water or juice in the pan, careful regulation of the evaporator is necessary for the continuous flow of juice and sirup. Starting with the pan full of juice is probably the more difficult procedure, because the juice is at practically the same density over the entire length of the pan. As evaporation continues, however, and more juice is run into the pan, the sirup can be forced to the proper end of the evaporator. Dipping juice or sirup of low density to parts of the pan where the sirup is becoming too dense is bad practice, but is sometimes unavoidable at the start. As soon as sirup is being finished in the back compartment of the evaporator and there is a continuous decrease in density toward the front end, it is time to permit a continuous flow of juice. The rates at which juice is run into the evaporator and sirup is run out are now controlled by the sirup maker. Most of his time is occupied in keeping the flow well regulated. His station is at the sirup end of the pan, where he can constantly watch the density of the sirup during the final stage of concentration and correct any irregularities. The sirup maker should caution the fireman when he needs the fire tended; a steady fire is necessary to regulate the evaporator.

When starting the operation after water has been left in the pan overnight, juice is run into the front or lower end as usual. The water is partly evaporated, partly displaced, and partly mixed with the thickening juice. Consequently some sirup will be mixed with the last of the water that is displaced or forced out; this can be caught and returned to the evaporator. The juice seldom boils in the first compartment, which is the coolest part of the evaporator, unless for some reason the inflow of cold juice is temporarily stopped; this juice has a smooth, cool surface, over which the scum forms a blanket and is occasionally removed with a perforated skimmer. When the furnace is properly constructed the boiling of the juice increases in vigor toward the back end of the pan as far as the section under which the fire is the hottest. This causes the scum to run, counter to the flow of juice, to the cooler or front portion of the evaporator. The juice is boiled over the sides to the skimming trough and flows back to the front of the pan. A portion of the skimmings remains in the trough and the remainder flows to the front of the pan, where it is removed.

By the time the juice reaches the hottest part of the pan, which is about 1½ feet beyond the middle, it has been evaporated to semisirup and is fairly well cleaned. As the sirup becomes more concentrated, more flocculated material separates. This should be carefully removed by skimming. Although not absolutely necessary, the skimming troughs, divided into two parts, should, for convenience, extend the full length of the pan. Such troughs are inexpensive and easily constructed. For efficient skimming, a hot fire must be maintained to "roll" the foam. The fireman can easily remove skimmings from the cool end of the pan, in this way greatly assisting the sirup maker. Firing at the proper time, however, should be his main consideration.

Scorching thick sirup is a difficulty sometimes experienced in open-pan evaporation; such sirup acquires a red color and a burnt flavor. Scorching is accompanied by a white puff of vapor, and can always be detected by careful observation. Experienced sirup makers detect it by odor almost instantly. Scorching is caused by local overheating at portions of the pan where the sirup has reached high density. Sometimes poor furnace construction is the cause of this; sometimes the sirup has become too concentrated. Sediment adhering to the bottom of the pan may readily result in a scorching area. Such scorching may be stopped by thoroughly scraping the surface over which it occurs with a piece of metal (galvanized iron or copper) fastened to a handle. In case the sirup is of too high density at the point where the scorching occurred, sirup of lower density should be forced in from the next compartment.

In operating a continuous evaporator, the flow of juice should be kept as nearly constant as possible without dipping from one compartment to another. Such dipping detracts from the clarity of the sirup, owing doubtless to the mixing of juice and sirup at different stages of clarification. This mixing of high and low density sirup usually causes a persistent cloudiness in the finished product. It is a good plan to divide the skimming trough into two sections by means of a transverse partition, to avoid mixing the clarified sirup with the juice. Even if no injurious effect on clarity or color should result, it is useless to again subject well-skimmed semisirup from the finishing end to the skimming process. It is little trouble to divide the trough into two sections and to make suitable holes, through which the overflow may return to the pan.

One of the difficulties most commonly experienced in using a continuous evaporator is that of concentrating the sirup to uniform density. Many operators are able by experience to judge accurately the density of sirup while it is still boiling. They do this by dipping the skimmer into the boiling sirup, holding it up, and noting how the cooling sirup "flakes off." No amount of experience, however, can entirely take the place of accurate knowledge, and the uncertainties of guessing the density by the "flaking-off" method can be easily eliminated by the use of a thermometer. A good thermometer is more useful in the operation of an evaporator than is the hydrometer, often recommended for the purpose. In using the hydrometer it is necessary to draw off a cylinder of sirup from the evaporator and then float the hydrometer in it. This procedure is troublesome when using an evaporator, because the sirup is in such a shallow layer that it is not easily dipped out. The hydrometer, although very useful when sirup is made in a deep evaporator by the batch or noncontinuous process, is considered less valuable than a thermometer for use with the ordinary continuous evaporator.

The thermometer most suitable for the purpose is one protected by a substantial copper case and graduated from approximately 50° to 250° F. The bulb of such a thermometer should be very close to the bottom of the protecting copper case but not quite touching it. This design is necessary in order that the thermometer bulb may be entirely covered by the shallow layer of boiling sirup (three-fourths inch deep). Thermometers with long stems and magnified wide-mercury columns that may be easily read at a reasonable distance are very convenient. Such thermometers may be kept continuously in the sirup, and serve accurately to indicate the point of final evaporation, when the sirup should be allowed to run out of the evaporator. Even though the thermometer be used only to check the sirup maker's guess as to the proper density, it will prove very useful. Sirup which tests 38.5° to 39° Baumé (70.8° to 71.8° Brix) at atmospheric temperature, using a hydrometer, boils at 224° F. (106.7° C.), sea level, at the time when it should be allowed to flow from the evaporator. In testing a sirup for its density in this manner it is well to determine the accuracy of the thermometer by placing it in boiling water and noting the boiling point. Using an accurate thermometer, water should boil at 212° F. (100° C.) at sea level, 211° F. (99.4° C.) at an altitude of 500 feet, and at 210° F. (98.9° C.) at an altitude of 1,000 feet. For every 500 feet above sea level, roughly speaking, the boiling point is lowered 1° F., so that when using an accurate thermometer at a point 500 feet above sea level finished sirup would boil at 223° F. (106.1° C.), and at 1,000 feet above sea level it would boil at 222° F. (105.5° C.). The sirup is finished at a temperature 12° to 13° F. higher than the boiling point of water.

From the evaporator the finished sirup flows into a sirup trough or tank in the room partitioned off for canning or barreling the sirup (fig. 2). Complete directions for canning are given on pages 58 to 60.

Some sirup makers, when marketing in bulk, barrel the sirup hot as it comes from the evaporator. This is considered bad practice, because sirup at high temperature often causes the barrels to leak, and hot sirup in barrels cools so slowly that the color and flavor are frequently impaired. Moreover, sirup that contains an excessive quantity of suspended material should remain in the tank overnight, and sometimes even longer, until this material has settled to the bottom. Clear sirup may then be drawn off from the top and barreled and the layer of sediment, if it contains much sirup, may be returned to the juice for skimming in order to avoid loss of sirup.

Some sirup makers experience more difficulty than others from having an excessive amount of sediment in their sirup, this depending as much on the type of soil on which the cane was grown, the variety of cane, and extraction obtained as upon the skill of the operator. Sedimentation is in general the most feasible procedure for removing this material from sirup, before either barreling or canning. Sirup that has settled overnight, however, should be reheated for canning to the proper canning temperature (p. 59).

Filtration of sirup when boiling hot, using cloth strainers, through which the sirup will pass within a reasonable time, does not remove much of the sediment. Moreover, when it has cooled to atmospheric temperature, the sirup at final density can not be filtered efficiently by any known means. In deciding whether or not to allow the finished sirup to sediment, it should be remembered that sedimentation is most effective at high temperatures. Provided deterioration in color and flavor does not result from the prolonged retention of heat, wooden troughs or insulated tanks may be used to keep the sirup hot and thus facilitate sedimentation. If the color darkens appreciably when the sirup is kept hot, however, it is considered better practice to cool it sufficiently to prevent this deterioration in quality before running it to the settling tanks, and then permit it to sediment for a longer period.

The importance of cleanliness in making sirup can not be too strongly stressed. As one object of clarification and evaporation is the removal of suspended material and the sterilization of the sirup by heat, it is obviously unreasonable to permit dirt of any kind, which is likely to cause fermentation, to contaminate the sirup after it has been made. In addition to keeping the evaporator and tanks free from sediment and scale, it is well to dispose of the skimmings in such a way that they do not become sour, thus creating an unsanitary condition around the mill. The sirup plant should be supplied with plenty of water, so that all the equipment may be washed as often as necessary. All equipment that has stood idle for several days should be thoroughly washed with strong limewater, which neutralizes acids and to a certain extent prevents fermentation. If lime is used, however, all equipment should be carefully washed again before resuming operations, as the addition of lime to juice or sirup produces a dark color.

CLARIFICATION BY SULPHUR DIOXIDE AND LIME

By C. E. Coates and W. G. Taggart, *Louisiana State University and Louisiana Sugar Experiment Station*

The process of clarifying cane juice by the use of sulphur dioxide and lime is practiced in many factories where sirup making is conducted on a large scale. This method has long been in use in most of the larger Louisiana sirup factories, and is therefore commonly called the Louisiana process of clarification. As the sulphur dioxide bleaches some of the pigments in the juice, sirup made by this process has a lighter color than that ordinarily produced by the boiling and skimming method. The use of sulphur dioxide and lime also gives the juice a more complete clarification than is obtained by simply boiling and skimming.

A preliminary removal of suspended material from the juice as it leaves the mill (p. 15) is the first step in this process. In the larger factories the separation of suspended matter, such as particles of bagasse and adhering soil, is usually accomplished by straining the juice, as it leaves the mill, through fine-mesh bronze or copper sieves or through cloth. In order to prevent loss of juice, the material removed from the juice by straining should be returned to the bagasse at some point on the carrier before it reaches the last mill. Straining the juice is of great importance, not only on account of the danger of clogging pipe lines and pumps by the suspended material, but also because the presence of sediment in the juice tends to impart undesirable properties to the sirup.

Although it is the general custom to run the strained juice to the sulphuring apparatus without further treatment, the small particles that pass through the screen are sometimes removed by filtration or sedimentation. At this stage of the process sedimentation of the juice is inexpensive and is always considered good practice.

SULPHURING

The juice is next treated with sulphur fumes (sulphur dioxide). As the absorption of sulphur dioxide increases the acidity of the juice, the best means of determining when sulphuring has gone far enough is to test the juice for its degree of acidity. This simple chemical test can be easily learned and requires but little apparatus and skill. Those who are unfamiliar with the chemical principles involved but who wish to use the method can best learn how it is done by consulting a chemist or by visiting a sirup or sugar factory where it is practiced. Juice is usually subjected to the action of sulphur dioxide until its acidity is such that 10 cubic centimeters of the juice will require 3.5 to 4 cubic centimeters of tenth-normal alkali for neutralization, using phenolphthalein as an indicator. This chemical test is considered an accurate means of control for obtaining the degree of sulphuring required for the manufacture of a uniform product.

In many Louisiana sirup factories men have become so skillful from long experience that they can regulate the sulphuring and the subsequent addition of lime to insure a sirup of fully as good quality as that made in plants where the entire process is under chemical control. The control of clarification, however, may not be left to an unskilled man, who knows neither from experience nor by chemical test how to regulate the clarification. In the clarification of cane juice chemicals must be used in exactly the right proportion; otherwise the sirup produced is almost always inferior. Types of apparatus used in sulphuring are described on page 49.

LIMING

Milk of lime screened free from lumps and of approximately 15° Baumé density (26° to 27° Brix) is added to the cold sulphured juice, with thorough mixing, until 10 cubic centimeters of the juice, to which has been added a few drops of phenolphthalein, requires the addition of 1 to 1.5 cubic centimeters of tenth-normal alkali to produce a permanent slightly pink color. The quantity of milk of lime required to effect a good clarification varies with the character of the juice and degree of sulphuring, and must be determined by trial. As a rule it is best to add as little lime as may be required to give a greenish-yellow juice, from which the precipitate sediments readily (10 to 15 minutes) after the limed juice has been heated to boiling. Enough lime to make the juice alkaline must never be added; the juice must always remain acid, for alkaline juice yields a very dark sirup. Moreover, the addition of too much lime makes the juice decidedly yellow or reddish-yellow, even if it remains slightly acid. Although such juice may be clear and bright, it will yield too dark a sirup. Inexperienced operators often use an excess of lime in an effort to obtain a brilliantly clear juice, believing that this is required for the production of a clear sirup of good color. A milky turbidity in the sedimented juice is not objectionable; in fact, juice properly clarified by the sulphur-lime process nearly always is slightly turbid, and this appearance serves as a guide to the quantity of lime required for effective clarification.

Liming is best accomplished in several clarifiers (at least three). While the first contains sedimenting juice the second is being emptied and the third is being filled.

The clarifier is filled with juice to within a few inches of the top, and milk of lime is added, usually from 0.4 to 0.8 pound (on the dry basis) to 100 gallons of juice. It is a common practice to make a large quantity of lime into a paste and later dilute small batches to 15° Baumé before adding it to the juice. After the addition of lime the juice is rapidly and thoroughly agitated.

The limed juice is heated just to boiling in the clarifier and allowed to stand for a minute or two, after which the blanket of scum which has collected on the surface is brushed into the scum gutter at the side of the clarifier. The juice is heated again until it just begins to boil; after the scum is again brushed off, it is allowed to sediment for 40 to 50 minutes. At the end of this time most of the juice, which should be bright and clear and almost free from suspended material, is drawn off through a cock placed slightly above the bottom of the tank. Sometimes it is then run through bag filters or into settling tanks, but more frequently this additional treatment is unnecessary.

The scums and sediment are best filtered by means of a filter press. In the absence of a filter press, they are transferred to a tall settling tank of small diameter, provided with a steam coil. When this tank is nearly full, the liquor containing the suspended material from the clarifiers is heated and this material is allowed to subside; the clear juice is then drawn off and one volume of water is added to each volume of scums and sediment. This mixture is heated, and the scums and sediment are allowed to subside, in order to remove as much sugar as possible from the waste, the washing being repeated at least twice before the final sediment is run into the waste ditch.

EVAPORATION OF JUICE TO SIRUP

The clarified juice is evaporated to the desired density, either in an open pan or in multiple effects under vacuum. In either case evaporation is accomplished in two stages. The juice is first evaporated to a semisirup having a density of 20° to 25° Baumé (35.8° to 45° Brix). By the time this density is reached additional nonsugar solids will have separated from solution; unless removed, they will make the finished sirup unduly turbid. The semisirup, therefore, should be "brushed" or skimmed in a "brush pan."

After being skimmed this low-density sirup is run into settling tanks and allowed to remain until sedimentation is complete (5 to 6 hours). Sodium phosphate is sometimes added to the hot sirup in the proportion of 1 to 100,000 before the sirup is transferred to the settling tanks. Sodium phosphate in this proportion promotes sedimentation and does not affect the flavor of the sirup. The sedimented sirup is finally evaporated until it tests 33.5° to 34° Baumé (61° to 62° Brix) while at the boiling temperature. If a filter press is not available, the sediment and "brushings" from the low-density sirup should be added to the raw juice or combined with the sediment from the clarifiers and washed with water to prevent loss of sirup.

It is advantageous to allow the final sirup to undergo sedimentation. If time and tank space do not permit this, however, the sirup is now ready for canning or barreling. Sirup that is to be stored for a while and sedimented in tanks should be quickly cooled to 120° to 140° F. (p. 28), for sirup may deteriorate in color and hence in value when stored in bulk at too high a temperature. Sirup makers, however, should never substitute the sedimentation of final sirup for the sedimentation of low-density semisirup. Suspended material in semisirup sediments much more rapidly than that in final sirup; in fact, some of the suspended material that can be removed from the low-density sirup by sedimentation will not settle out from the final sirup within a reasonable length of time.

If the juice is evaporated in multiple-effect evaporators, the same density should be reached in the first stage of the procedure as in the case of juice evaporated in open pans, and the semisirup likewise should be subjected to brushing and settling. Sirup concentrated in vacuum is deficient in typical aroma and flavor and should be finished in an open pan; open evaporation imparts a distinctive flavor. If the sirup is to be concentrated to final density under vacuum, this should be accomplished in a pan at low vacuum. The process of evaporation should be conducted as rapidly as possible, regardless of the type of pan used. Sirup heated for a long time, especially in an open pan, is very likely to be dark. Rapid evaporation in an open pan may be obtained by keeping the layer of juice relatively thin. Speed in a multiple-effect evaporator is obtained by keeping the apparatus in good order and the heating surface free from scale. In both cases a plentiful supply of steam should be available.

CONTROLLING THE DENSITY

The density to which sirup is evaporated in this process may be controlled by the use of a Baumé or a Brix hydrometer. A small sample of sirup from the boiling mass is caught in an upright tin or copper cylinder and the spindle is floated in it. Sirup testing 35° to 35.5° Baumé (63.9° to 64.9° Brix) at 185° F. will, when cooled to ordinary atmospheric temperature, test 38.5° to 39° Baumé (70.8° to 71.8° Brix), which is the density ordinarily preferred by the market. The same sirup will test 34° to 34.5° Baumé (62° to 63° Brix) at 200° to 210° F. (immediately after removal from the evaporator). The Brix hydrometer is similar to the Baumé hydrometer in appearance and use (p. 16), but the scale is so designed that the readings represent the approximate percentage of dissolved solids in the juice or sirup. Table 10 shows the manner in which variation in temperature affects the Baumé and Brix readings of a given sirup. Thus, if a sirup tests 34.7° Baumé (63.3° Brix) at 210° F., it will test 39.5° Baumé (72.8° Brix) at 72° F.

Table 10.—*Observed densities of sirup at different temperatures*

Hydrometer reading		Temperature		Hydrometer reading		Temperature	
° Baumé	*° Brix*	*° C.*	*° F.*	*° Baumé*	*° Brix*	*° C.*	*° F.*
34.7	63.3	98.9	210	37.7	69.2	49.0	120
35.5	64.5	85.0	185	38.3	70.4	41.0	106
36.1	66.0	80.0	176	38.9	71.5	35.0	95
36.6	67.0	70.0	158	39.1	72.0	29.0	84
37.1	68.0	60.0	140	39.5	72.8	22.2	72
37.4	68.5	55.0	131				

The Baumé or Brix reading for any given sample of juice or sirup varies with the temperature at which the reading is made. Most of the Baumé hydrometers used in the sirup industry are graduated at the standard temperature of 17.5° C. (63.5° F.), although some hydrometers graduated at 20° C. (68° F.) are in use. To use the hydrometer accurately, therefore, it is necessary either to cool the sirup to the standard temperature or to consult an appropriate table for the temperature correction. Since the sample is customarily cooled to atmospheric temperature instead of to standard temperature, and since the hydrometer readings at the atmospheric and standard temperatures do not usually differ greatly, the term "ordinary temperature" or "atmospheric temperature" is used in this bulletin to refer to readings corrected to the standard temperature of 17.5° C. (63.5° F.).

CLARIFICATION BY LIME ALONE

By C. F. WALTON, Jr., *Bureau of Chemistry, U. S. Department of Agriculture*

In addition to chemical clarification employing both sulphur dioxide and lime, use is sometimes made of lime and phosphoric acid as the clarifying agents, and at times lime alone is used. The lime-phosphoric acid method is not as popular with sirup manufacturers as the lime-sulphur process, but the application of lime as the sole clarifying agent is common enough to merit consideration with the other methods of clarification.

Manufacturers sometimes desire to make sirup of the so-called Georgia type in large-capacity plants. The simple boiling and skimming method, employing direct-fire, rapid, open evaporation in a shallow layer, all the way from juice to sirup, has been found to give the best-quality sirup of the so-called Georgia type (p. 69). The largest plants, however, are not as a rule ideally equipped to use this process, and consequently do not usually produce sirup of equally good quality. A decision to engage in the large-scale manufacture of such sirup, therefore, depends upon market conditions, or, more specifically, upon the demand for a somewhat lower grade sirup resembling the Georgia type.

As the larger factories ordinarily have no equipment for boiling and skimming the juice and evaporating rapidly in a shallow layer, they must use comparatively large and deep tanks, in which the juice is heated to boiling and the coagulated impurities are permitted to separate out. When no chemicals are used, however, the impurities settle to the bottom or come to the top so slowly that much valuable operating time is lost. As it is desirable to run the grinding part of the plant to capacity, the juice must be handled at a sufficiently rapid rate to "keep out of the way of the mill." Juice treated with lime settles more quickly and is more completely clarified than that which is simply heated to the boiling point. The lime-clarified juice may then be evaporated in open brush pans of the Louisiana type or in vacuum evaporators (p. 53).

When the juice is excessively acid the use of lime is an additional advantage, in that it partially neutralizes the acidity and gives the sirup a somewhat milder flavor. One disadvantage is that the sirup is usually darker than that made by the typical small-scale process, owing partly to the use of lime and partly to the large-scale method of evaporation. Another objection is that the flavor of the sirup is somewhat different from that of typical Georgia-type sirup.

In operating the lime process on a large scale, it is best to use the minimum quantity of lime which will enable the factory to use the settling tanks or clarifiers efficiently enough to "keep out of the way of the mill." The less lime that can be used the better the quality of the sirup will be. If the cane is of good quality and there is ample settling capacity, it is sometimes possible to keep the juice at its original acidity without the use of any lime. For best results, the juice should never be limed below an acidity corresponding to 0.8 cubic centimeter of tenth-normal sodium hydroxide solution per 10 cubic centimeters of juice, using phenolphthalein as the indicator (p. 29). The lime, preferably milk of lime (p. 30), is always added to the cold juice before heating. As lime is a chemical clarifying agent, its use in proper proportions must be under careful control. This is fully as important when lime alone is used as in the process employing both lime and sulphur dioxide.

EVAPORATION OF JUICE TO SIRUP

Heating sirup clarified by lime to a high temperature at some time during manufacture improves its quality. When vacuum evaporation alone is practiced, the sirup usually tends to have a darker color and a somewhat flat flavor. Good results have been obtained when sirup from the double or triple-effect evaporators at about 20° Baumé (35.8° Brix) has been heated rapidly in the open to the boiling temperature, brushed or skimmed, and allowed to settle, after which it has been evaporated to final density in a vacuum pan and discharged to the sirup storage tanks at a temperature of 140° F. or lower. Another method consists in settling the sirup discharged from the effects at about 20° Baumé and 140° F., finishing in a vacuum pan to a density a degree or two lower than that required, boiling for a few minutes in brush pans, and discharging through a cooling system (p.54) into the sirup storage tanks.

The equipment used for clarifying sirup by the sulphur dioxide and lime method (p. 42) may be used for clarifying it by lime. When more open evaporators are provided and when these open evaporators resemble the small units designed for rapid open evaporation in a shallow layer, however, sirup of a better quality may be expected. Open evaporation is more expensive than vacuum evaporation, a fact to be considered in connection with the market values of sirup produced by the two methods.

Figure 7 shows a satisfactory continuous open evaporator with steam coils. The skimmings collect readily in the front end (cold juice space), from which they are frequently removed. Cold juice flows continuously into this end of the evaporator and semisirup at 20° to 25° Baumé (35.8° to 45° Brix) is drawn off from the opposite end to an open finishing evaporator of the noncontinuous type. The steam supply and rapidity of boiling may be so regulated by adjusting the steam inlet and outlet valves that the foam will "float the skimmings along," partly over the edges of the evaporator into the skimming troughs, but mostly backward toward the cold surface. Evaporation is rapid and in a shallow layer. Such an evaporator may be used in making sirup of the Georgia type without lime and also for evaporating lime-clarified juice. The principle governing the design of this evaporator has been employed also in manufacturing steam evaporators of somewhat simpler construction.

Steam coils with swing-joint connections (fig. 8) may be swung up out of the evaporator whenever it is necessary to scrape them. This design is particularly good for galvanized-iron evaporators, because the frequent use of hydrochloric (muriatic) acid and caustic soda, the most common cleansing agents for coils in copper evaporators,

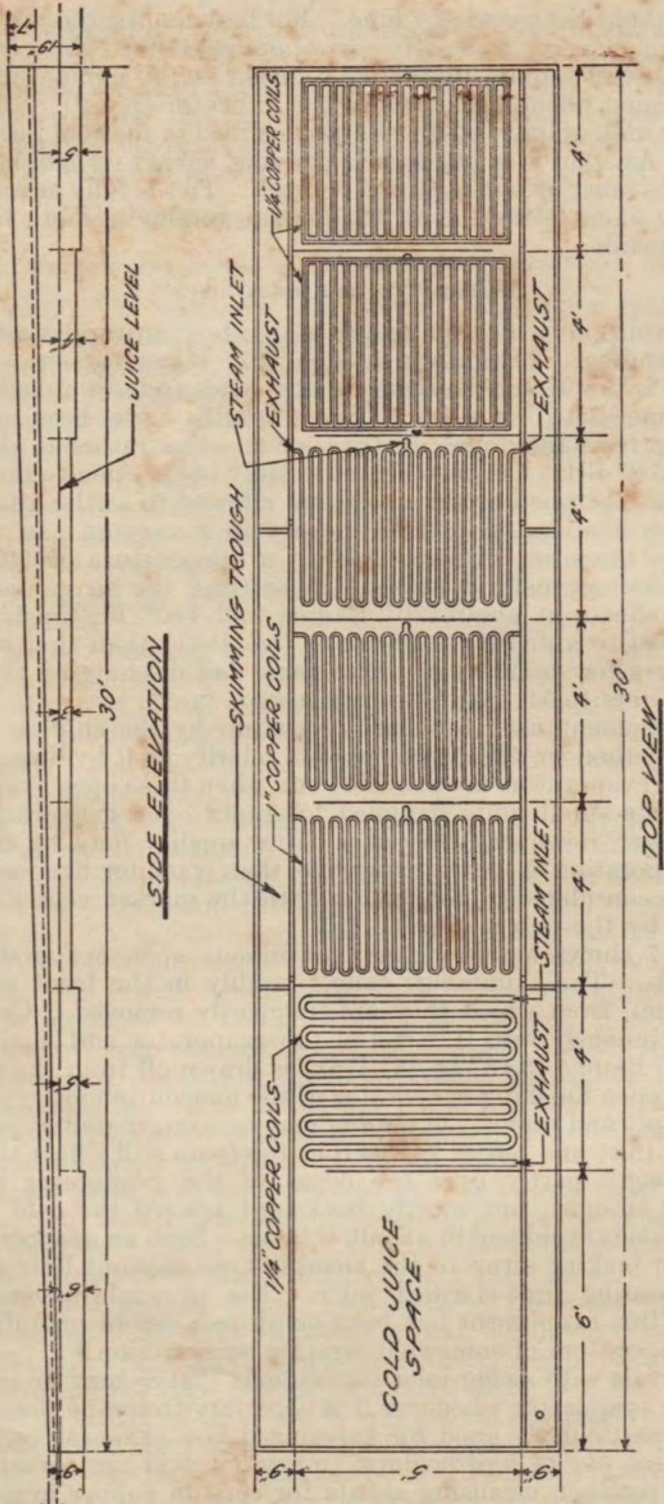

FIG. 7.—Continuous evaporator with steam coils

rapidly corrodes and destroys galvanized iron. The principal disadvantage of swing-joint connections is that they gradually work loose and cause leaks.

Oil burners under a long open evaporator are also practicable for large-scale sirup manufacture. Large plants have a plentiful supply of steam with which to atomize the fuel oil; small plants must atomize the oil by mechanical means (p. 24).

MECHANICAL CLARIFICATION [10]

By C. F. Walton, Jr., *Bureau of Chemistry, U. S. Department of Agriculture*

Both the small-scale manufacture of sirup, by the boiling and skimming method, and the large-scale manufacture, by the use of sulphur dioxide and lime, have disadvantages. The simple boiling and skimming method is comparatively slow and wasteful and, unless it is very carefully conducted, does not completely remove the suspended particles present in the juice. Sirup made by this process varies greatly in quality, not only because the sugar cane varies in character but also because the equipment used in manufacture and the skill of the sirup maker vary. The chemical process of clarification using sulphur dioxide and lime is open to the objection that many people dislike the flavor of the resulting sirup. Moreover, unless enough of the chemical reagents is added to the juice, the insoluble material separates slowly and incompletely, whereas an excess of lime makes the sirup dark and too much sulphur dioxide gives it a peculiar metallic flavor. Both the small-scale method and the chemical process of clarification, however, are widely used and have the advantages already enumerated.

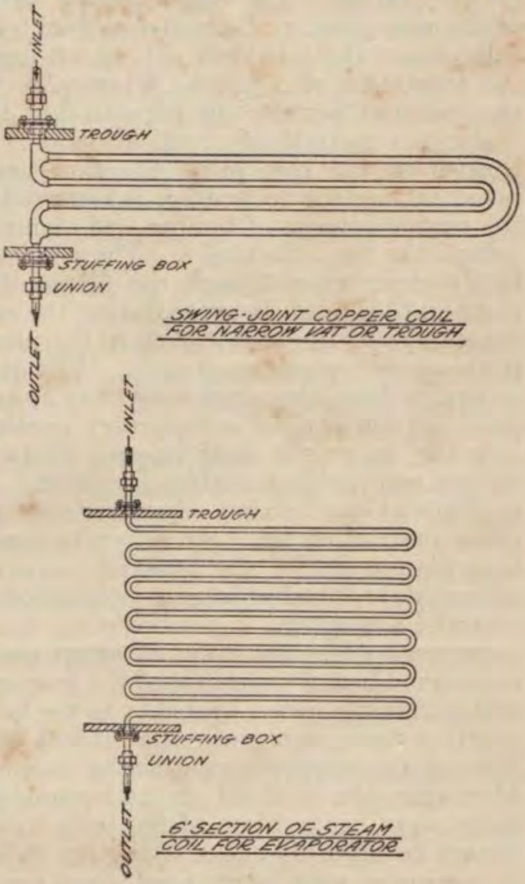

Fig. 8.—Steam coils with swing-joint connections

The so-called mechanical method of clarification is a comparatively recent development, which promises to have useful applications. Sugar-cane juice, when heated to boiling for the purpose of coagulating certain of its constituents, is usually very difficult to filter because the coagulated material, being gummy, quickly clogs the pores of

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[10] This section supersedes Department of Agriculture Bulletin 921, "Sugar-cane juice clarification for sirup manufacture," by J. K. Dale and C. S. Hudson, issued November 9, 1920.

the filter cloth. By intimately mixing with the juice a little suitable inert material, commonly termed a "filter aid," the juice can be rapidly and efficiently filtered without premature clogging of the cloth. Infusorial earth, also known as kieselguhr or diatomaceous earth, is an effective filter aid; paper pulp and wood flour have also been used as filter aids.

The addition of from 12 to 18 pounds of infusorial earth of a good grade to the juice from a ton of cane, followed by heating to boiling, makes it possible to filter the juice effectively through a plate and frame filter press. The resulting filtrate is clear and ready for evaporation to sirup, and no further skimming or other treatment ordinarily is required. The color of the resulting sirup depends upon the quality of cane from which the juice has been extracted and upon the care taken during evaporation to prevent local overheating and caramelization. The characteristic flavor of the sirup will be that of the cane juice, as the material used for clarification does not chemically affect the juice but acts as an inert filter aid, making possible the formation of a porous filter cake, which retains the suspended particles but permits the juice to flow through freely.

By this method of clarification only the material originally suspended in the raw juice, together with that coagulated or separated by heating to boiling, is removed; that is, the material which the simple process of boiling and skimming seeks to remove but accomplishes less effectively. The resulting sirup is not always absolutely clear, even though the filtrate from the filter press may be clear and brilliant, because during the concentration of juice to sirup substances which were soluble in the juice gradually become insoluble in the more concentrated sirup. The quantity of this material which separates from the sirup may vary from a mere trace, provided the juice is from cane of satisfactory quality, to a larger proportion, in case the cane used is of inferior quality. It is not ordinarily considered very objectionable, however. As in the case of the other methods of clarification, whenever sediment appears in the sirup after every precaution has been taken to thoroughly clarify the juice, the best plan is to let the finished sirup remain in settling tanks for several days, until as large a proportion as possible of the suspended material has settled to the bottom.

In some cases the color of sirup made by this process has been considered better than that of the average cane sirup made by boiling and skimming, owing probably to the fact that no particles of bagasse or other trash remain in the filtered juice to adhere to the coils or sides of the evaporators, thereby darkening the color by scorching. Moreover, the removal of the suspended particles makes possible a more rapid evaporation of the juice to sirup and permits the man in charge to give his entire attention to evaporation, except for such skimming as may be required when the sirup reaches higher density. It is an advantage also that juice clarified in this way is in suitable condition to be evaporated at once under diminished pressure in vacuum evaporators.

This mechanical method of clarification is not practicable for sirup makers who operate on a comparatively small scale, using the boiling and skimming method and producing usually not more than 200 gallons of sirup daily, for the reason that it requires a filter press and steam supply. In the larger sirup factories, where steam is used to operate the mill and for evaporation, the application of the process would call for very little additional equipment.

Little alteration of equipment for infusorial-earth clarification would be required in those Louisiana sirup factories which are provided with filter presses. The cost of manufacture would be practically the same as that by the sulphur-lime process, as the total fuel, labor, and overhead costs would be very nearly identical. The cost of the clarifying materials would be somewhat greater in the infusorial-earth method, but this is partly offset by the smaller quantity of sirup lost during manufacture. Another advantage of the infusorial-earth method is the elimination of juice-settling tanks, skimming tanks, bag filters, and similar equipment.

The principal loss of sirup or sugar, after the juice has been extracted from the cane, in well-managed Louisiana sirup or sugarhouses using the sulphur-lime process and equipped with filter presses, is in the filter-press mud. Approximately 36 pounds of filter-press cake, with an average sugar content of 6 per cent, is produced per ton of cane, a loss of 2.16 pounds of sugar, or 0.27 gallon of sirup. Calculated on a basis of $0.50 per gallon for sirup, this represents a loss of $0.135 per ton of cane. In sirup factories where the sulphur-lime clarification process is practiced without the use of filter presses the loss of sirup is estimated to be one-half to 1 gallon per ton of cane, or between $0.25 and $0.50 when sirup is valued at $0.50 per gallon.

In infusorial-earth filtration, 40 to 45 pounds of filter-press cake per ton of cane may be expected. Considering the ease and rapidity with which this cake can be washed, there is no reason why the sugar content should not be readily reduced to less than 1 per cent. If washed to a sugar content of 1 per cent, the loss would amount to approximately 0.45 pound of sugar, or about 0.06 gallon of sirup per ton of cane. On the basis of $0.50 per gallon for sirup, this would be a loss of only $0.03 per ton. The difference in losses, $0.135 – $0.03, or $0.105 per ton of cane, or $0.25 – $0.03, or $0.22 per ton of cane if no filter presses are used, would largely compensate for the greater cost of infusorial earth as compared with the cost of sulphur and lime.

The materials required for clarification with sulphur dioxide and lime cost approximately $0.035 per ton of cane—$0.0075 for lime (1 pound per ton of cane at $0.0075 per pound) and $0.0275 for sulphur (1 pound per ton of cane at $0.0275 per pound).

The infusorial earth needed (12 pounds per ton of cane at $0.025 per pound) costs $0.30. When the cane is of good quality less infusorial earth is required than when the cane is immature or has deteriorated after cutting. Factory tests have shown that from 12 to 18 pounds of infusorial earth of good quality per ton of cane ground are required to give a satisfactory rate of filtration.

In addition to the accessory tanks, pumps, and piping, filters either of the plate and frame or of the leaf type are needed for mechanical clarification. The filter press area should be ample, so that no interruption in operation need occur. In order that poor-quality juice may be promptly filtered, the filter area installed should be somewhat in excess of that which would ordinarily be needed. Approximately 8 square feet of filter area per ton of cane per 24 hours has been found sufficient to handle a slow-filtering juice, whereas 4 square feet per ton of cane per 24 hours has proved ample for free-filtering juice.

It is preferable to install at least two filters, so that the filtration may be continuous, one remaining in use while the second is being dressed. On this basis a plant grinding 150 tons of cane per 24-hour day would install two 600-square-foot filters.

This method of clarification requires a somewhat greater outlay of capital and slightly greater operating expense than is necessary when the simple process of skimming and concentrating in open evaporators is employed. Its advantages are as follows: (1) A product of greater clarity is ordinarily obtained; (2) the capacity of the evaporators can be increased, for it is not necessary to retard the evaporation as is at present the case in order to permit proper skimming; (3) the yield of sirup can be somewhat increased, owing to the fact that all the scums and dregs are obtained in a firm compact mass, instead of in a thin "mush" containing a large proportion of juice; (4) the quality of the resulting sirup is more uniform and depends less upon the skill of the individual sirup maker and the care taken in skimming; (5) the sirup has a color which compares favorably with that of the leading brands of sulphur-lime cane sirup on the market. The flavor is considered milder and, by many consumers, more agreeable, lacking the somewhat tart and metallic flavor of the ordinary sulphur-lime sirup.

TREATMENT WITH DECOLORIZING CARBONS

By C. F. WALTON, Jr., *Bureau of Chemistry, U. S. Department of Agriculture*

During the last few years much interest has been manifested in the use of vegetable carbons of high decolorizing efficiency in the manufacture of sugar and sirup. Manufacturers who are producing a poor-grade sirup because they have been grinding cane of unsatisfactory quality can by carbon filtration remove excessive color and unusually strong or objectionable flavors, which may be so pronounced as to make the sirup marketable only as a second-grade product. Sirup made in this way is lighter in color and milder in flavor. The typical cane-juice flavor is somewhat lessened, for decolorizing carbons diminish the intensity of practically all flavors. The net result of treatment with decolorizing carbon, however, is to improve the flavor of lower-grade sirups.

The carbon may be added to the juice following defecation or after filtration with infusorial earth, or it may be added to the semisirup at that stage of the process when the sirup would ordinarily be permitted to undergo sedimentation. Two or three times the necessary quantity of carbon may be used during the first filtration, in which case the same lot may be used over again two or three times before it is exhausted; or the minimum quantity may be used and discarded after the first filtration. In the largest sirup plants, however, it is feasible to install apparatus for "revivifying" the carbon, either by chemical treatment or by reburning, or both, after which its activity is practically the same as it was in the beginning.

The quantity of carbon required for cane sirup has been found experimentally to vary from about 1 to 3 per cent, based on the weight of solids contained in the juice or sirup to be filtered. The requirement varies with the quality of the sirup and the degree of decolorization desired. Basing calculations on a price of $0.15 per pound for vegetable decolorizing carbon of suitable quality, and assuming that the carbon is used for only one filtration, without subsequent "revivification," the additional cost for carbon is estimated to be $0.012 to $0.037 per gallon of final sirup. This estimate does not include labor, interest, and depreciation of equipment.

A canning plant receives sirup of varying quality. By installing carbon-filtration equipment, all poor-quality sirup could be converted into a better-grade sirup and mixed with that of higher grade. Thus it would be possible to market one standard grade alone.

Certain markets of the North and West prefer a very mild, light-colored sirup to the darker sirup of pronounced cane flavor, which is preferred in the South. Vegetable carbon offers possibilities for extending the market for cane sirup.

When a higher extraction of juice from the cane is desired, the use of either carbon or chemical clarifying agents in a large plant makes possible the manufacture of sirup of satisfactory quality. Ordinarily, when a higher percentage extraction of juice is obtained, the juice is correspondingly more difficult to clarify properly and a poor-quality sirup results (p. 17). As higher extraction means greater efficiency of operation and more gallons of sirup per ton of cane, the possibility of separating the juice from the mills and treating that from the last mill (representing the highest extraction) with carbon deserves serious consideration, especially in the larger plants. The sirup made from high-extraction juice treated with carbon could be mixed with that obtained in the usual manner from low-extraction juice so as to produce a single standard grade of acceptable quality.

The equipment required for a factory using vegetable carbon in connection with the process of clarification varies with the size of the plant and the decision of the manager as to whether or not the carbon will be "revivified." On the whole, it closely resembles the equipment required for filtering juice or sirup with infusorial earth. If the mechanical process of clarification is also being practiced, the same filtration equipment, if of sufficient capacity, may be employed for the carbon filtration.

EQUIPMENT AND COSTS FOR MAKING SIRUP ON A LARGE SCALE

By L. J. Lassalle and J. J. Munson, *Louisiana State University*

Cane from which sirup is to be made is usually delivered to the factory in carts, wagons, or railroad cars. The cane is transferred to hoppers, from which it is fed onto a carrier to the mills. The cane is crushed and most of the juice is expressed, leaving the fiber relatively dry. In small plants this fiber, known as bagasse, is discarded. In the larger plants the bagasse is carried from the mills on bagasse carriers to the boiler furnaces, where it is used as fuel, in some cases generating the greater part of the steam required to operate the plant.

The juice that is expressed at the mills first passes to a juice strainer, where the small particles of bagasse are partially removed. It then goes to the raw juice tank, from which it is pumped to the sulphur tower or sulphur box, where it is treated with sulphur dioxide gas. Next it may pass to a sulphured juice tank, from which it is pumped to the defecators, or it may be pumped directly from the seal tank of the sulphur tower to the defecator, where lime is added and the juice heated. The juice is then allowed to sediment, after which it is decanted and transferred to the evaporator supply tank.

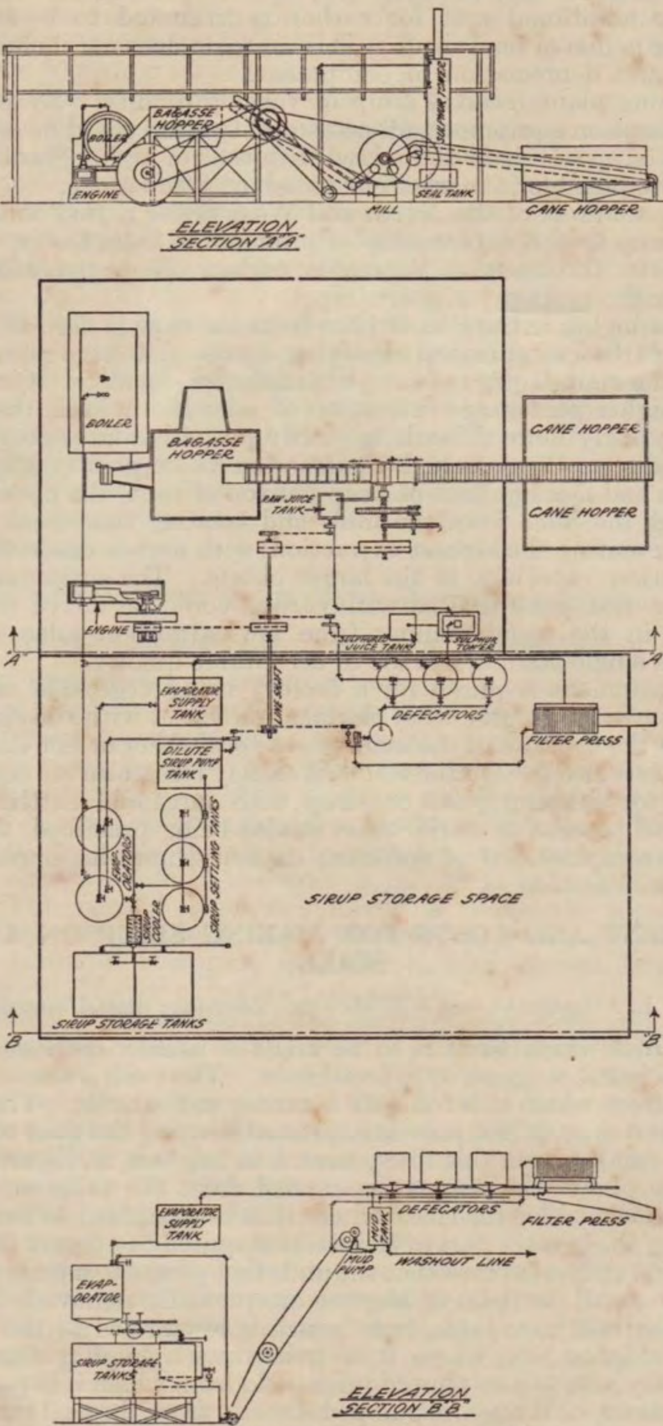

FIG. 9.—Diagram of a 50 to 100 ton sirup mill

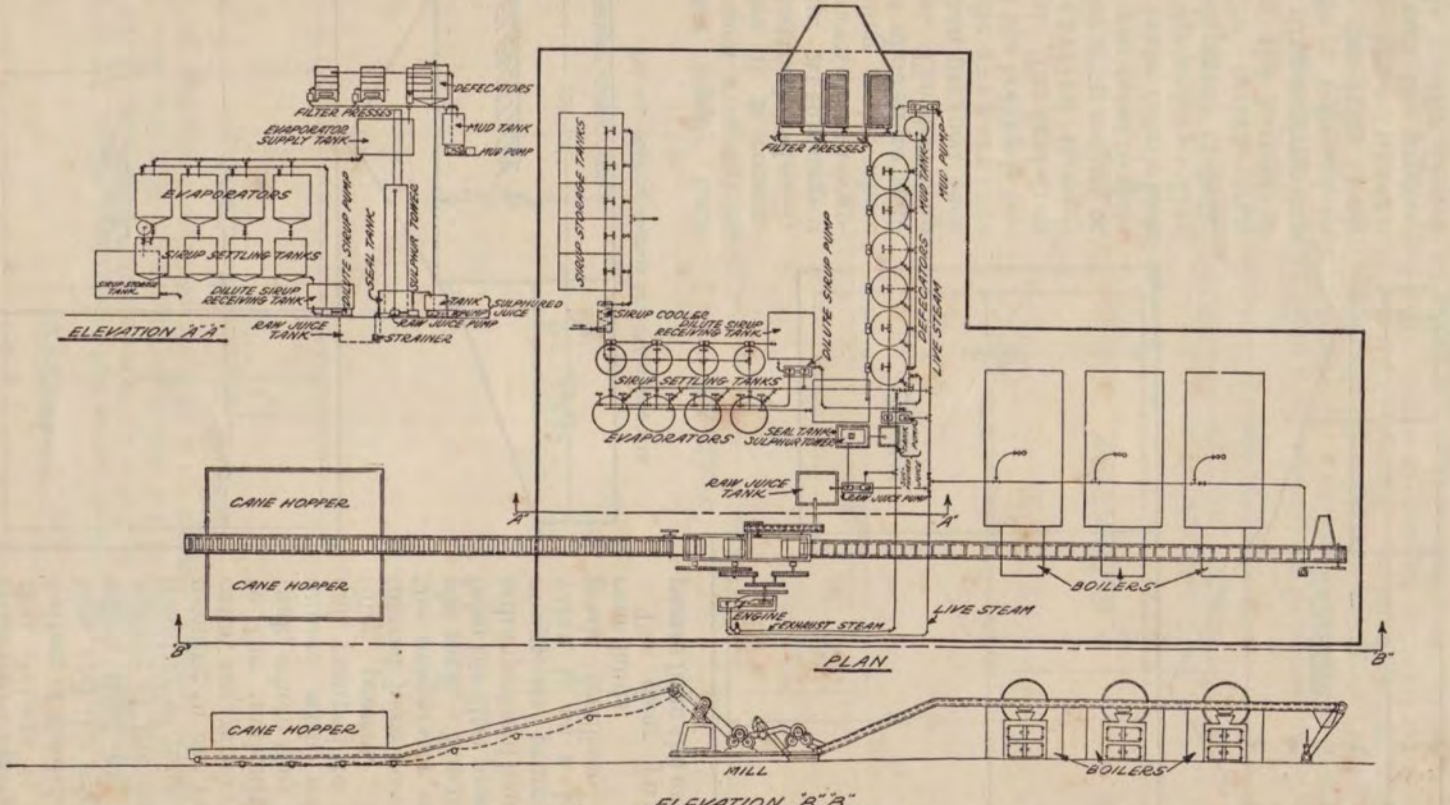

FIG. 10.—Diagram of a 150 to 300 ton sirup mill

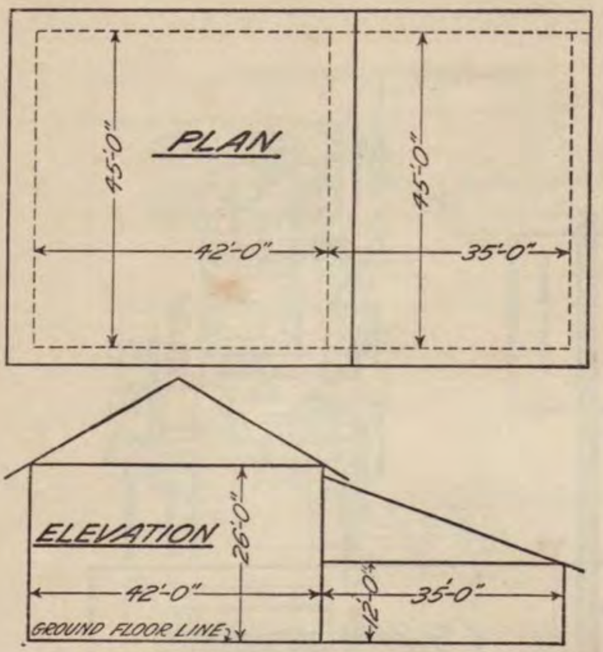

FIG. 11.—Building diagram for a 50-ton sirup mill

The "mud," or sedimented material, that collects at the bottom of the defecators, and the scums, which float on the surface of the small quantity of juice remaining in the defecator, are transferred to the mud-mixing tank, where they are diluted with water and pumped to the filter presses. The filtered juice goes to the evaporator supply tank. The mud from the filter presses is dumped and hauled away; its principal value is as a low-grade fertilizer for cane lands.

The clear juice passes from the evaporator supply tank to open evaporators, where it is concentrated to a low-density sirup. At this stage it is drawn off into sirup-settling tanks, where it is allowed to sediment. The clear sirup is then pumped back to the evaporators and the boiling is finished. The final sirup is carried through either sirup coolers or an open canal to storage tanks, from which it is drawn for packing or shipment in bulk.

The turbid sirup from the bottom of the sirup-sedimenting tanks is returned to the raw-juice tank and again passed through the process. It is usually diluted at the time the sedi-

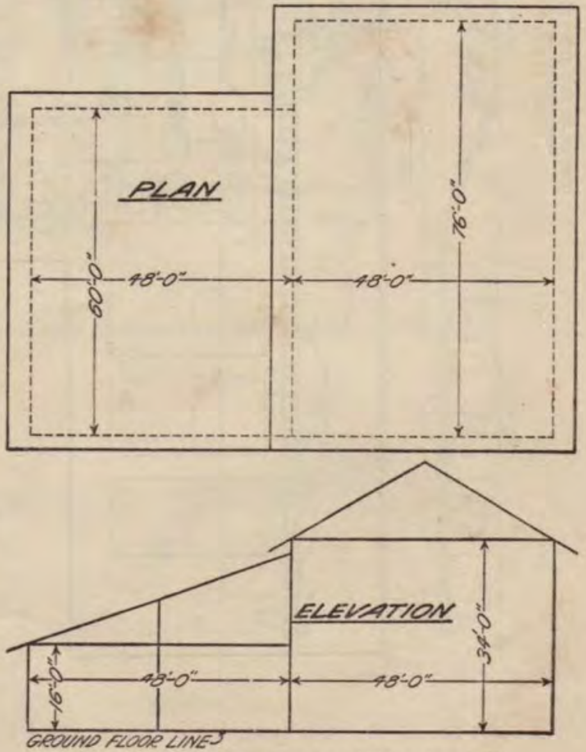

FIG. 12.—Building diagram for a 100-ton sirup mill

menting tanks are washed. The water used to wash the evaporators is also transferred to the raw-juice tank.

EQUIPMENT

In operating this process (more fully described on pp. 28 to 32), the equipment listed in Table 11 is required. This table shows all the equipment required for plants having a 50, 100, 200, and 300 ton daily capacity, based on a 24-hour per day operating period.

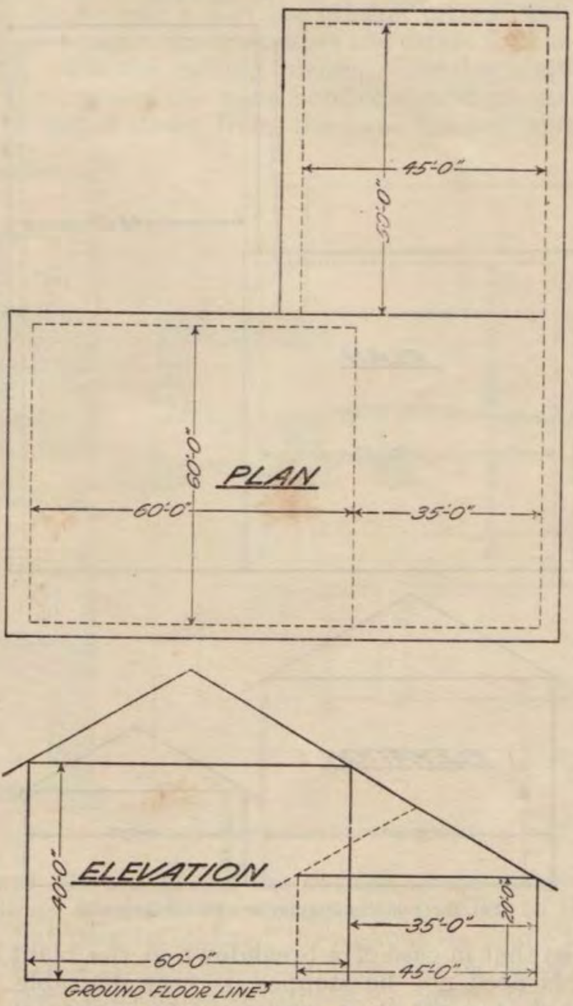

FIG. 13.—Building diagram for a 200-ton sirup mill

An arrangement of equipment for a plant of each of the four sizes is shown in Figures 9 and 10. The building diagrams (figs. 11, 12, 13, and 14) are given as a guide for the preparation of detailed plans by prospective builders. Figure 15 shows the boiler setting and furnace for burning bagasse or wood. The following discussions of each station in the plant, as listed in Table 11, will serve to explain various details of construction and operation.

CANE HANDLING FROM CARTS AND CARS

In the 50-ton plant, and in the 100-ton plant if desired, the hopper is placed so low that the cane can be dumped directly into it from the carts and wagons. In the 200-ton and 300-ton plants, and in the 100-ton plant when desired, the cane is unloaded from carts and cars into hoppers by means of steam-operated derricks. This method, although more expensive than direct unloading into hoppers placed low enough to receive the cane, makes it possible to store cane more efficiently when an interruption in the supply occurs. Some way of storing cane so that in case of a breakdown in the plant the hauling from the fields need not be stopped is very desirable. When the mill is operated at night it is convenient to haul most of the cane in the daytime; this is impossible without some means for handling stored cane. The advantages probably justify the expenditure for a derrick for even a 100-ton plant. A small jib crane, which is less expensive than a derrick, is suitable for handling the cane for the 100-ton plant.

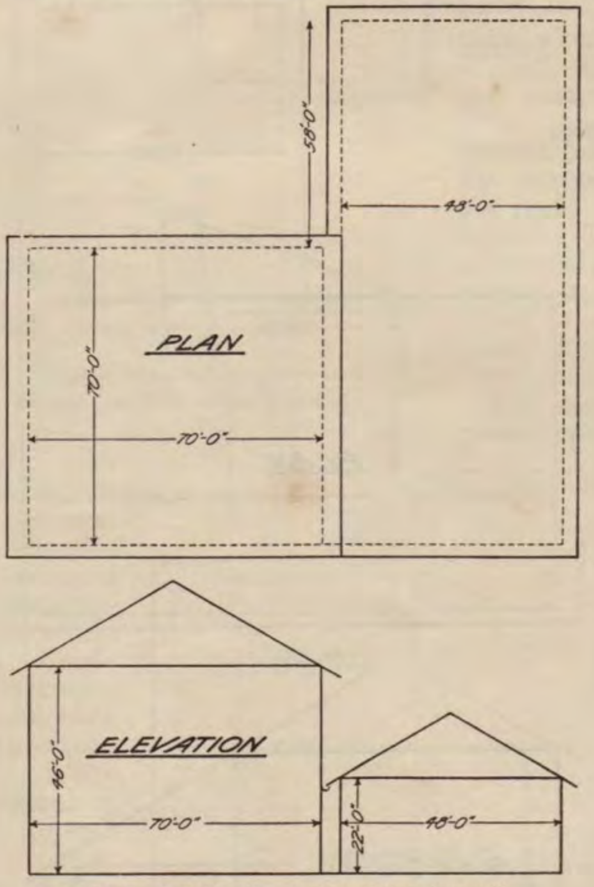

FIG. 14.—Building diagram for a 300-ton sirup mill

CANE CARRIERS

The most common carrier is a wooden trough of suitable width and depth and long enough to extend horizontally the full length of the cane hopper. It extends beyond the cane hopper, at an incline of not more than 22°, up to the top of the cane chute that leads down to the crusher or first mill. This trough contains a wooden apron, made of wooden slats, fastened to two strands of chain. These two strands of chain are passed over sprocket wheels, carried on a head and tail shaft, and over runners fastened to the sides of the wooden trough, designed to hold the apron in place when it is loaded with cane.

The carrier may be driven by a small separate engine, or it may be run from the bottom roll of the crusher or first mill by means of a chain and sprockets. In most cases the drives for the cane carriers are furnished with the milling plants. The horizontal portion of the carrier that passes the cane hopper should be so low that the cane may be raked down from the cane hopper upon the apron.

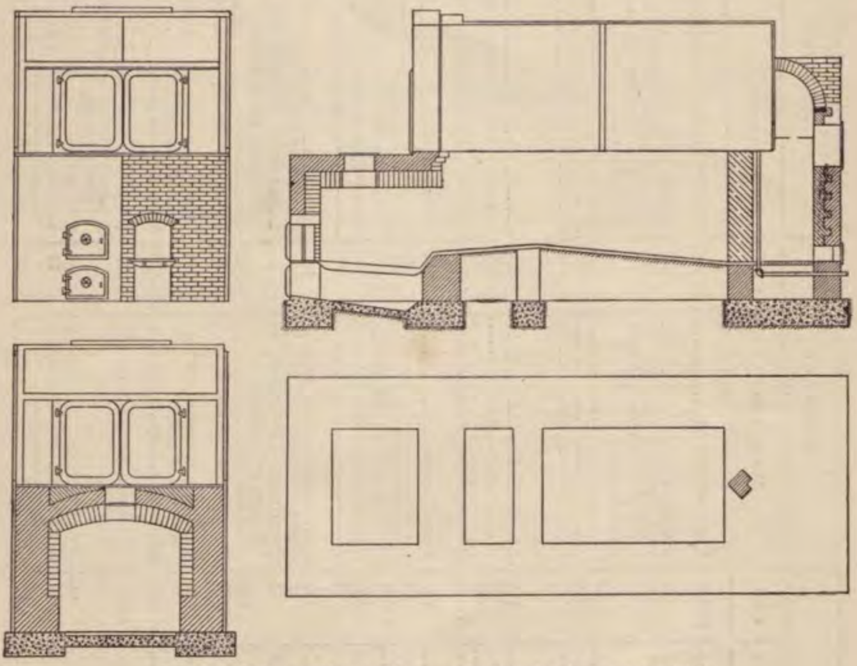

FIG. 15.—Boiler setting and furnace for burning bagasse or wood

In the 50 and 100 ton plants the portion of the carrier adjacent to the cane hopper need not be horizontal or parallel to the bottom of the hopper, but may be inclined throughout its whole length. This simplifies the construction and eliminates the tendency of the apron to rise from the chain runners when the tension on the chain becomes great and there is no cane on the horizontal portion of the carrier to hold it down. In the 50 and 100 ton plants the cane carrier may be made rather short, say from 15 to 25 feet; in the larger plants it is better to have it longer and moderately inclined (not over 22°) to make certain that the cane does not slip on the apron. The width of the cane carriers should be the same as the length of the mill rolls, and the depth should be two-thirds of the width.

Perforated water pipes arranged across the carrier wash the cane thoroughly, freeing it from mud, dirt, or other adhering matter while it is being carried from the hopper to the mills.

TABLE 11.—*Equipment for sirup mills* [1]

Equipment	50-ton mill		100-ton mill		200-ton mill		300-ton mill	
	Description	Cost	Description	Cost	Description	Cost	Description	Cost
Building (wood with metal roof).	Figures 9 and 11	$2,550	Figures 9 and 12	$5,350	Figures 10 and 13	$8,000	Figures 10 and 14	$12,000
Sulphur tower	Figure 16	120	Figure 16	155	Figure 16	155	Figure 16	155
Boiler	100-horsepower, locomotive type.	[2] 1,560	100-horsepower H. R. T. (2, one burning oil and one bagasse).	[2] 5,200	135-horsepower H. R. T. (3, one burning oil and two bagasse).	[2] 9,900	200-horsepower H. R. T. (3, one burning oil and two bagasse).	[2] 12,000
Smokestack		80		150		180		220
Oil-burning installation		300		400		500		700
Feed-water pump, piping, and receiver for condensate.		75		150		250		350
Piping		169		228		2,346		3,760
Labor		100		100		650		950
Cane hopper		42		63		94		125
Cane handling (from carts or cars).	By hand		200-ton steam-operated derrick.	1,500	400-ton steam-operated derrick.	4,000	600-ton steam-operated derrick.	5,000
Cane carrier	20-inch apron	137	24-inch apron	174	30-inch apron	387	42-inch apron	463
Bagasse carrier	do	99	do	149	do	364	do	429
Milling plant	14 by 20 inch 3-roller mill	1,568	16 by 24 inch crusher 16 by 24 inch 3-roller mill	1,350 1,650	20 by 30 inch crusher 20 by 30 inch 3-roller mills (2)	3,339 10,050	22 by 42 inch crusher 22 by 42 inch 3-roller mills (2)	4,185 12,555
Engine	20-horsepower slide valve	450	40-horsepower slide valve	700	80-horsepower slide valve	2,500	120-horsepower, Corliss	3,000
Foundation and installation of mills.		95		200		1,650		3,250
Line shafting		143		200				
Raw-juice tank	4 by 5 by 3 feet	69	5 by 6 by 4 feet	96	6 by 8 by 5 feet	169	8 by 8 by 6 feet	230
Raw-juice pump	Centrifugal, belt-driven, 10 gallons per minute.	16	Centrifugal, belt-driven, 20 gallons per minute.	16	Direct-acting steam pump, 40 gallons per minute.	160	Direct-acting steam pump, 80 gallons per minute.	260
Defecator	250-gallon (3)	900	400-gallon (4)	1,600	500-gallon (6)	3,000	750-gallon (6)	4,000
Filter press (plate and frame).	70 square feet	433	70 square feet (2)	866	100 square feet (3)	1,619	150 square feet (3)	1,935
Filter press pump	Triplex, belt-driven, 10 gallons per minute.	160	Triplex, belt-driven, 10 gallons per minute.	160	Direct-acting steam pump, 20 gallons per minute.	100	Direct-acting steam pump, 20 gallons per minute.	100
Mud-mixing tank, with stirrer.	100-gallon	125	100-gallon	125	200-gallon	200	200-gallon	200
Evaporator (open)	100 square feet heating surface (2).	1,400	100 square feet heating surface (4).	2,500	200 square feet heating surface (4), or 100 square feet heating surface (8).	4,500	200 square feet heating surface (6), or 100 square feet heating surface (12).	6,000
Evaporator supply tank	600-gallon	81	1,000-gallon	120	1,400-gallon	158	2,000-gallon	210
Dilute-sirup pump	Centrifugal, belt-driven, 20 gallons per minute.	22	Centrifugal, belt-driven, 40 gallons per minute.	31	Direct-acting steam pump, 80 gallons per minute.	264	Direct-acting steam pump, 120 gallons per minute.	292
Dilute-sirup pump tank	600-gallon	81	1,000-gallon	120	1,400-gallon	158	2,000-gallon	210

Sirup settling tank (cylindrical).	250-gallon (3)	144	500-gallon (3)	202	800-gallon (4) or 550-gallon (6)	408	800-gallon (6) or 600-gallon (8)	612
Sirup storage tank	1,500-gallon (2)	225	2,000-gallon (3)	414	2,000-gallon (5)	660	3,000-gallon (5)	900
Sirup cooler	Figure 17	20	Figure 17	65	Figure 17	100	Figure 17	140
Incidentals (estimated)		100		200		500		650
Total cost		11, 264		24, 234		56, 361		74, 881

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[1] When more than one piece of equipment is to be installed the number of pieces is given in parenthesis.

[2] Includes cost of setting.

MILLING PLANT

Some plants, especially the small ones, have only one 3-roller mill. Others have a 2-roller crusher and a 3-roller mill. Another installation consists of one 2-roller crusher and two 3-roller mills. Sometimes (in sugar factories) as many as seven mills are used with one crusher. In some sugar factories two crushers are used with as many as six 3-roller mills.

The object of using several milling units is to increase the extraction of sugar from the cane and at the same time produce bagasse sufficiently dry to be burned efficiently. Higher extraction can be obtained with a crusher and one or two 3-roller mills than with one 3-roller mill. When only one 3-roller mill is used the extraction is low and the resulting bagasse, which usually contains too high a percentage of moisture to be burned efficiently, is discarded. When a crusher and two mills are used the crusher prepares the cane by partly crushing it before it reaches the first mill, thereby making it possible for the first mill to express more juice. Upon leaving the first mill the bagasse may be partly saturated with water before entering the second mill. The purpose of this process (maceration) is to dilute the juice remaining in the partially ground cane, thereby facilitating its extraction by the second mill.

The process of maceration may be extended and water may be applied to the bagasse before it enters the third mill (when a third mill is used), a still greater proportion of the juice being thus extracted. Sometimes, in order to reduce the fuel consumption required to evaporate this added water, dilute juice, perhaps from the last mill, is pumped back and used for maceration on some of the preceding mills. Adequate equipment is necessary for high extraction.

The importance of high extraction in large-scale operation is indicated by the fact that 1 per cent increase in extraction, when grinding ordinary Louisiana cane, yields one-third gallon more of sirup per ton of cane. When grinding 200 tons of cane per day for a 60-day season the additional sirup thus obtained would amount to 4,000 gallons, which, at $0.50 per gallon, would be worth $2,000. High extraction also makes it possible to utilize the bagasse as fuel. In obtaining the highest extraction, however, it is necessary to use water for maceration, and evaporation of this water requires increased fuel consumption. The cost of evaporating this water would have to be subtracted from the $2,000 to determine the net gain.

Owing to their acidity, juice and sirup dissolve iron, which darkens the sirup. For this reason juice and sirup should be exposed to iron surfaces as little as possible. The clarifying tanks and settling tanks may be made of sheet iron if they are kept well coated with a special heat-resisting paint. It is impossible to make a high-grade sirup if these precautions against contamination are not observed. The surface of the mill rollers is the only iron material with which the juice should be allowed to come in contact. Clarified juice should be evaporated to sirup in copper vessels. Copper evaporators of the Louisiana type are best, but satisfactory evaporators have been made of heavy cypress lined with copper sheeting and provided with copper heating coils.

All pipe lines, especially in factories using the sulphur-lime process, are best made of copper. As copper is expensive, placing the apparatus as close together as is convenient effects an economy. The zinc surface of galvanized-iron piping gradually dissolves, exposing the juice and sirup to iron surfaces. If copper is considered too expensive, plain iron pipe may be coated on the inside with a heat and acid resistant paint by closing one end, filling the pipe with paint, pouring it out, and allowing the pipe to dry. Two coats of paint are usually sufficient.

The plans listed in Table 11 were selected after a careful consideration of all governing factors. It is more economical and convenient to drive the mills in the smaller plants by belts; in the larger mills direct gearing to the engine is almost always used. An ordinary slide-valve engine is sufficient for the small plants. Corliss engines are used extensively for driving the larger units. The sizes of engines required for plants of varying size are shown in Table 11.

RAW-JUICE TANK

A small, plain, galvanized-iron, painted sheet-iron, or copper tank of rectangular cross section (the raw-juice tank) is placed near the mill to receive the juice from the juice strainer. The sizes required are shown in Table 11. The juice is generally carried to this tank through a canal by gravity.

RAW-JUICE PUMP

The pump used to pump the juice from the raw-juice tank to the sulphur tower may be of the centrifugal, direct-acting, or power type. The centrifugal type is less expensive and lends itself to an easy method for driving. The direct-acting type is often more convenient in larger plants.

SULPHUR TOWER

Among the methods of sulphuring juice are the following: (1) Blowing sulphur dioxide directly into the juice through perforated pipes placed near the bottom of a suitable tank; (2) conducting the raw juice into a sulphur box, from which it is pumped to the defecators or heaters, the pump being allowed at the same time to draw in sulphur dioxide through the sulphur box; (3) using a sulphur tower (fig. 16). The principal objection to the first method is that the perforated coils soon become stopped up with sulphur and the sulphur dioxide has a detrimental action on the blower. The second method gives better results than the first, but practically all of the mixing of the sulphur dioxide with the juice takes place in the pump, soon destroying the linings, valves, etc. Moreover, this method is unsatisfactory for controlling the degree of sulphuring. The third method, generally considered the best, provides a means for controlling the degree of sulphuring and conducts the objectionable excess fumes to the outside of the building.

The sulphur tower, used when the sulphur-lime method of clarification is employed, is made as follows: 2 by 12 inch planks of good lumber, preferably cypress, placed as shown in Figure 16, are screwed or nailed to 3 by 4 inch crosspieces, to form the sides, and bolted together with long bolts. The top is made of 2 by 12 inch lumber, and a small wooden fume pipe, made of 1 by 6 inch lumber, is placed over a square opening left in the top, having the same cross section area as the pipe. The tower is generally of rectangular rather than square cross section, because this shape facilitates the arrangement of the baffles which are placed inside. These baffles may be made of 1 by 12 inch lumber and should be placed inside the tower as indicated in Figure 16. They are held in place by nailing 1 by 3 inch pieces to the sides of the tower on the inside.

One-half or three-quarter inch perforations in the baffles make the juice fall in cascades, thus bringing it in thorough contact with the sulphur dioxide. The tower is left open at the bottom, and the two narrow sides are cut back for about a foot. This open end is placed in a seal tank, which is provided with a juice outlet in the form of an overflow and also has a drain at the bottom. A draft is produced through the tower by placing a three-sixteenths inch steam nozzle, connected to a one-half inch pipe, in the position indicated in Figure 16. The sulphur dioxide is thus drawn in from an ordinary sulphur stove, after the seal tank has been filled with juice, and then passes upward around the baffles, all fumes which are not absorbed being conducted out of the building through the fume pipe. The juice is pumped into the top of the tower through the pipe (*B*) and flows downward through the current of sulphur dioxide gas. It leaves the tower through the pipe (*D*), which is connected to the seal tank.

A better control of the sulphuring is effected by connecting an additional pump, by which the juice from the seal tank may be recirculated through the tower. A centrifugal pump is best for this purpose, as it may be regulated by throttling the juice on the discharge side. Juice which has not been sufficiently sulphured may thus be returned to the sulphur tower and the degree of sulphuring closely controlled. The juice outlet from the seal tank leads to the sulphured juice tank, where the juice may be limed, if desired, before it is pumped to the defecators.

DEFECATORS

The juice is defecated in tanks of circular or rectangular cross section, equipped with copper coils at the bottom, with two or more valves on the sides for decanting or drawing off the clear juice, and with a valve in the bottom for drawing off the mud and washing out. Where juice heaters are used, as in sugar factories grinding large quantities of cane, the defecators receive the juice at a relatively high temperature. Steam is used in the copper coils in this case merely to heat the juice through a short temperature range to the boiling point before it is allowed to sediment. When the juice heater is not used, the juice is pumped from the sulphured-juice tank directly to the defecators. It may be limed in the sulphured-juice tank or in the defecators. In either case all of the heating is accomplished by the use of steam in the coils of the defecators.

MUD-MIXING TANK

The mud remaining in the bottom of the defecators, together with the small quantity of scums that collect on the surface of the juice, is transferred to a vertical tank of circular cross section, equipped with a stirring element, driven by means of a bevel gear and usually a chain or belt. The mud is diluted with water and thoroughly mixed

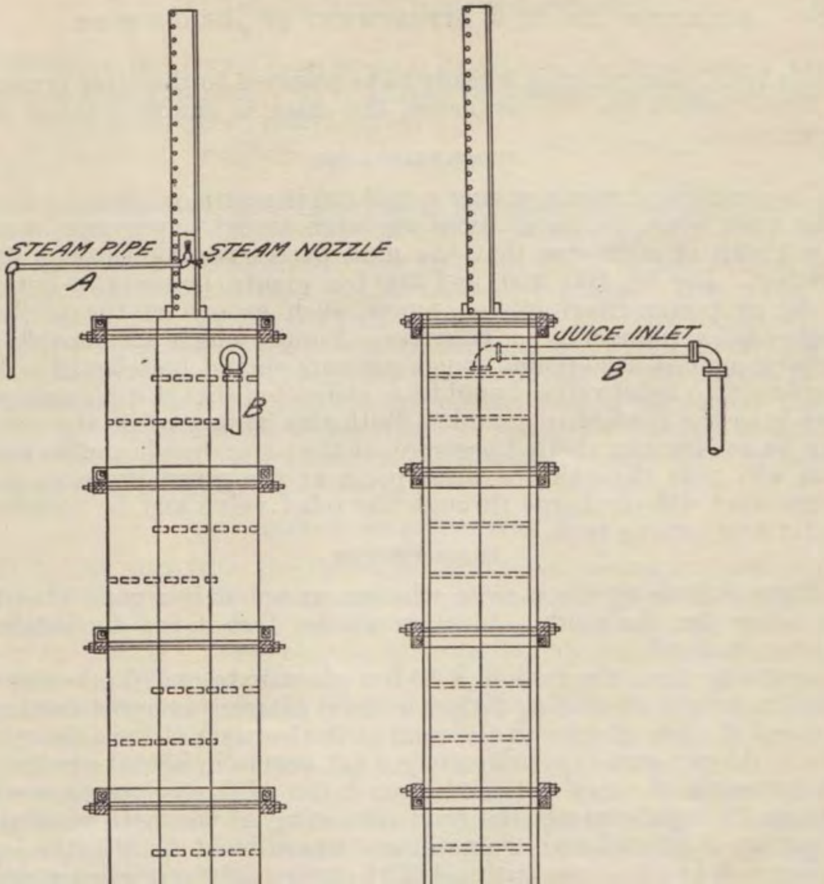

FIG. 16.—Sulphur tower

Size of plant	Width of tower	Breadth of tower	Height of tower	Diameter of pipe				
				A	B	C	D	E
Tons	*Inches*	*Inches*	*Feet*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
50	12	24	20	½	1¼	2½	1½	1½
100	18	30	20	½	1½	3	2	2
200	24	36	20	½	2	4	2½	2½
300	24	36	20	½	2½	5	3	2½

in this tank, after which it is ready to be pumped to the filter presses. If filter presses are not available, the mud is simply washed by decantation.

FILTER PRESS PUMP

The centrifugal pump, giving a uniform pressure, is ideal for filter press work when the installations are large enough to warrant the use of a pump of such size that the mud passes readily through the impeller. For 50, 100, 200, and 300 ton plants, however, a direct-acting or power-driven piston pump, such as one of the triplex, single-acting, plunger type, is better. Pumps which are capable of working against a 60-pound gauge pressure should be selected. An overflow with relief valve should be so connected that it will discharge back into the mud-mixing tank. With this arrangement the valve may be set for any desired pressure; if the pump handles more mud than will pass through the filter press at the given pressure, the excess mud will discharge through the relief valve and be returned to the mud-mixing tank.

FILTER PRESSES

There is some question as to whether or not it is a good plan to use filters for the muds. In other words, does it pay to install a filtering station?

Assuming that the mill in a 50-ton plant extracts 70 per cent of juice on weight of cane and that without filtering or resedimenting the mud the loss of juice in the mud at the bottoms of the defecators will be 15 per cent (approximately what occurs in actual practice), the quantity of sirup obtained from 1 ton of Louisiana cane will average 20.5 gallons. If the mud remaining at the bottom of the defecators is diluted and again allowed to sediment (p. 30), the loss of juice will be 10 per cent instead of 15 per cent of the original weight of juice. This saving, which increases the yield of sirup from 20.5 to 21.7 gallons per ton of cane, represents a gain in yield of sirup of 5.8 per cent. The value of this increased yield, when extended over a grinding season of 60 days, with sirup selling at $0.50 per gallon, will amount to $1,800. When filter presses are used, the quantity of mud remaining from defecation is not much more than 30 pounds per ton of cane. Under these conditions the increase in yield of sirup over the resedimenting process is 8.7 per cent, which, with sirup at $0.50 per gallon, amounts to a saving over the resedimenting method of $2,850. The saving from the use of filter presses over the method of discarding the mud at the bottoms of the defecators without any resedimentation whatever will be the sum of $1,800 and $2,850, or $4,650.

The extra cost during a 60-day season of a filter press installation in a 50-ton plant is $275, itemized as follows: Man on night watch, at $1.50 per day, $90; man on day watch, at $1.50 per day, $90; fixed charges on press, $70; increased cost due to space occupied, $10; cost of filter cloth per season, $15. The fixed charges consist of depreciation (8 per cent), upkeep (2 per cent), interest on the original investment over entire period (3 per cent), and taxes and insurance (3 per cent). The cost of the press is shown in Table 11. These figures prove the economy effected by the use of filters.

The plate and frame filter press is in general the most satisfactory type for mud filtration. It is simple to operate and less expensive than some of the more complicated types.

EVAPORATORS

Evaporators used in the larger sirup factories are practically always of the open type. Most of them are made entirely of copper, but some have iron bodies and copper coils (p. 22). In the very small plants galvanized-iron pipe is often used for the coils. Regardless of their cost, copper evaporators and copper coils are recommended.

Open evaporators of the Louisiana type generally contain 50 to 100 square feet of heating surface, with a maximum of 200 square feet. The fact that these evaporators are constructed in very small units of heating surface makes it necessary to employ a number of units. This is not objectionable, however, as it makes possible greater flexibility in the operation of the plant.

EVAPORATOR SUPPLY TANK

The clear juice from the defecators and filter presses is piped to an evaporator supply tank large enough to hold the juice that collects during the intervals between the intermittent demands for juice by the evaporators. Trash may be kept out by covering all but a small portion of the top of this tank with a metal or wooden cover and placing a fine-mesh screen over the part not covered. The juice enters through this screen, which catches any trash that might fall into the juice while it is passing from the defecators and filters to the evaporator supply tank. A connection in the bottom, which drains either to a sewer or back into the raw-juice tank, makes it possible to wash the tank. The evaporator supply tank is placed low enough to permit all juice to flow into it by gravity but high enough to permit juice also to flow to the evaporators by gravity.

SIRUP-SEDIMENTING TANKS FOR DILUTE SIRUP

The dilute sirup resulting from the initial stages of boiling in the evaporators is sedimented in tanks arranged in the same manner as defecators, but with no steam coils. They should be large enough to readily hold the sirup drawn off from one evaporator at the end of the first boiling stage. The bottom of each sedimenting tank should have a connection leading to the sewer and to the raw-juice tank so that it may be washed out. Dirt and trash are kept out by a removable fine-mesh screen.

PUMP TANK FOR DILUTE SIRUP

The sirup-sedimenting tanks are arranged to discharge by decantation into a trough leading down to the pump tank for dilute sirup. This tank collects the sirup after sedimentation, so that it may be pumped back to the evaporators for final concentration. It should be placed low enough to permit the sirup to flow into it by gravity from the sedimenting tanks. A connection at the bottom makes it possible to wash it out into the sewer or into the raw-juice tank.

DILUTE-SIRUP PUMP

A centrifugal, direct-acting, or power-driven pump is necessary for pumping the dilute sirup from the dilute-sirup pump tank back to the evaporators. The centrifugal type, which is easily driven from the line shaft by means of a belt, is recommended for smaller plants. The direct-acting type will no doubt be more convenient for larger plants.

SIRUP STORAGE TANKS

Sirup storage tanks of the sizes designated in Table 11 should be provided for storing a reasonable quantity of the finished product. They may be of circular, rectangular, or square cross section, and are arranged in several units, so that inferior lots of sirup may be kept apart. The storage tanks are placed high enough to permit the sirup to flow to the canning or barreling department by gravity. Washout connections in the bottom of each tank lead to the sewer and to the raw-juice tank. All storage tanks should be well covered.

SIRUP COOLER

Sirup should not be placed in storage tanks while hot, but should be cooled somewhat during its passage from the evaporators to the sirup storage tanks. This may be accomplished by providing an open canal, 60 to 80 feet long, through which the sirup is conducted slowly and in a shallow layer to the storage tanks, or use may be made of a sirup cooler (fig. 17), made by placing a copper coil in a piece of large pipe. The end covers of the cooler are made by drilling blind flanges to permit passage of the ends of the coil, connections being made by lock nuts and washers. The water inlet is at the bottom of the pipe, and the outlet is at the top. The sirup is cooled as it passes through the coil thus surrounded by running water. The cooler required for the 50 and 100 ton plants is made of 18 turns of 1½-inch copper coil placed in a 12-inch pipe. For the 200 and 300 ton plants 22 turns of 2-inch copper coil placed in a 14-inch pipe are needed. Although the open-canal method of cooling is most generally used at present, the temperature can be controlled better by using the cooler.

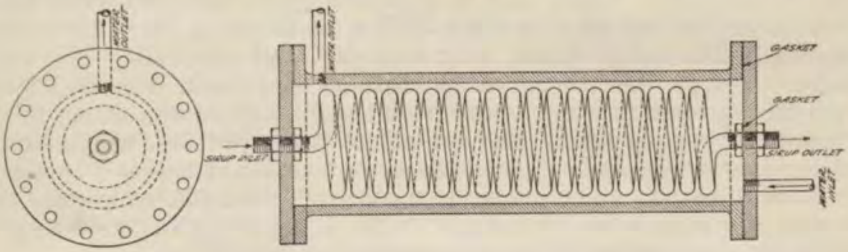

FIG. 17.—Sirup cooler

COST OF BUILDINGS

The costs in Table 11 are for wooden buildings; steel buildings cost approximately three times as much, but the depreciation and insurance charges on them are less. On the whole, wooden buildings are satisfactory for a sirup factory, principally because no very heavy machinery is staged and supported by the building proper, all of the heavy equipment being on the ground floor or on low platforms. The framework of the building may therefore be of lighter construction.

COST OF MAKING SIRUP

One of the first questions asked by anyone who contemplates going into the sirup-making business is, "How much will it cost per gallon to make sirup?" This question should be followed by, "How much will a gallon of sirup bring on the market?" and "What is the probability of selling the output year after year?" The first question can be answered more definitely in advance than the last two.

The costs of the plants complete (Table 11) are used to calculate the cost of making sirup shown in Table 14. This gives the cost per gallon of making sirup, based on cane selling at $5 per ton delivered at the mill and on the assumption that the yield of sirup per ton of cane is somewhat lower than may reasonably be expected. The cost is divided into four parts—cost of cane, fixed charges, labor, and fuel and supplies.

COST OF CANE[11]

Table 14 shows that the cost for cane per gallon of sirup varies from $0.244 for a 50-ton plant to $0.218 for a 300-ton plant. In the calculations following Table 8 (p. 18) the yield of sirup from a 3-roller mill is given as 19.4 gallons per ton of cane, whereas for a 50-ton plant (Table 14) a yield of 20.5 gallons per ton of cane from a 3-roller mill is assumed. This difference is due to the fact that an extraction of 60 per cent is assumed for the small plant (Table 8) and an extraction of 70 per cent for the larger and more heavily constructed mill recommended for the 50-ton plant (p. 44). Table 15 shows the cost per gallon of sirup for variations in price of cane which may reasonably be expected.

FIXED CHARGES

Fixed charges are calculated on the basis of 8 per cent yearly depreciation, 2 per cent yearly upkeep, 6 per cent interest on investment, and 3 per cent for taxes and insurance. As the plant depreciates in value from the original cost to nothing in 12½ years, the average investment over the entire period is one-half of the original cost. Interest therefore is calculated at 3 per cent instead of 6 per cent on the first cost of the plant. Consequently the fixed charge per year for plants of each type is equivalent to 16 per cent of the original cost.

LABOR

Labor costs vary greatly in different sections of the country. The figures in Table 12 apply to rural districts, where the cost of labor is usually relatively low during the sirup-making season. Estimates of the cost of this item in any locality or for any future period, when the prevailing daily rates of pay differ from those given in Table 12, may be made by substituting other daily rates and recalculating the labor costs per gallon of sirup.

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[11] See footnote 5, p. 12.

FUEL AND SUPPLIES

The outlay for fuel and supplies is determined principally by the cost of fuel, which is calculated in terms of oil at 5 cents per gallon (Table 13). As the price of fuel changes, the cost of fuel and supplies may, without any appreciable error, be obtained by making a change proportional to change in cost of fuel. Table 16 will serve as a guide in determining whether oil, coal, or wood is the most economical fuel. This tabulation has been prepared on the assumption that red or black oak, weighing 3,250 pounds per cord, is the wood used, that the oil has a density corresponding to 12° Baumé and a calorific value of 18,500 British thermal units per pound, and that coal has a calorific value of 12,000 British thermal units per pound. Oil can be burned more efficiently than coal, and coal can be burned more efficiently than wood. It is therefore calculated in this table that one cord of wood is equivalent to 1,300 pounds of coal, and one pound of oil to 1.6 pounds of coal. It is also calculated that it will cost 75 cents per cord to handle the wood, 75 cents per ton to handle the coal, and nothing to handle the oil.

TABLE 12.—*Labor costs for a 60-day sirup-making season (24-hour day)*

Labor	Cost of making sirup			
	50 tons	100 tons	200 tons	300 tons
Cane handling (to crusher):				
Day shift	[1] $120	[2] $240	[2] $240	[3] $360
Night shift	[1] 120	[2] 240	[2] 240	[3] 360
Boiler room:				
Day shift	[1] 120	[1] 120	[1] 120	[2] 240
Night shift	[1] 120	[1] 120	[1] 120	[2] 240
Engine room:				
Day shift	(4)	(4)	[5] 150	[1] 120
Night shift	(4)	(4)	[5] 150	[1] 120
Mills:				
Day shift	[6] 90	[7] 150	[8] 180	[8] 180
Night shift	[6] 90	[7] 150	[8] 180	[8] 180
Sulphur station and defecators:				
Day shift	[1] 120	[1] 120	[1] 120	[2] 240
Night shift	[1] 120	[1] 120	[1] 120	[2] 240
Filter press:				
Day shift	[6] 90	[6] 90	[6] 90	[8] 180
Night shift	[6] 90	[6] 90	[6] 90	[8] 180
Evaporators:				
Day shift	[9] 180	[9] 180	[10] 240	[11] 300
Night shift	[9] 180	[9] 180	[10] 240	[11] 300
Sirup settlers:				
Day shift	----------	----------	[6] 90	[6] 90
Night shift	----------	----------	[6] 90	[6] 90
Engineer in charge of factory	----------	----------	----------	[12] 540
Help required to put factory in operating condition each season	----------	[13] 120	[14] 180	[14] 180
Total	1,440	1,920	2,640	4,140

[1] One man at $2 a day.
[2] Two men at $2 a day.
[3] Three men at $2 a day.
[4] Work done by boiler-room force.
[5] One man at $2.50 a day.
[6] One man at $1.50 a day.
[7] One man at $1.50 a day and a boy at $1 a day.
[8] Two men at $1.50 a day.
[9] One man at $3 a day.
[10] One man at $4 a day.
[11] One man at $5 a day.
[12] One man at $6 a day for 90 days.
[13] Two men at $2 a day for 30 days.
[14] Three men at $2 a day for 30 days.

TABLE 13.—*Fuel and supply costs for a 60-day sirup-making season (24-hour day)*

Item	Cost of making sirup			
	50 tons	100 tons	200 tons	300 tons
Fuel (crude oil, estimated cost, 5 cents a gallon)	[1] $1,500	[2] $2,700	[3] $4,800	[4] $7,200
Lubricating oils, waste, packing, belting, and supplies	100	200	260	400
Sulphur, lime, and incidentals	20	40	80	120
Total	1,620	2,940	5,140	7,720

[1] 10 gallons of oil per ton of cane.
[2] 9 gallons of oil per ton of cane.
[3] 8 gallons of oil per ton of cane.
[4] 8 gallons of oil per ton of cane.

TABLE 14.—*Total cost of making sirup per season and per gallon*

Item	Cost of making sirup			
	[1] 50 tons	[2] 100 tons	[3] 200 tons	[4] 300 tons
Per season:				
Fixed charges	$1,802.00	$3,877.00	$9,018.00	$11,981.00
Labor	1,440.00	1,920.00	2,640.00	4,140.00
Fuel and supplies	1,620.00	2,940.00	5,140.00	7,720.00
Total	4,862.00	8,737.00	16,798.00	23,841.00
Per gallon of sirup:				
Manufacturing process	0.0795	0.0693	0.0636	0.0576
Cane [5]	.2439	.2380	.2274	.2175
Total	.3235	.3073	.2910	.2751

[1] Yields 61,500 gallons of sirup per season, or 20.5 gallons of sirup per ton of cane.
[2] Yields 126,000 gallons of sirup per season, or 21 gallons of sirup per ton of cane.
[3] Yields 264,000 gallons of sirup per season, or 22 gallons of sirup per ton of cane.
[4] Yields 414,000 gallons of sirup per season, or 23 gallons of sirup per ton of cane.
[5] Estimated at $5 per ton.

TABLE 15.—*Cost of sirup per gallon from cane at various prices*

Cost of cane per ton	Cost of sirup per gallon			
	50-ton plant	100-ton plant	200-ton plant	300-ton plant
$4.00	$0.195	$0.190	$0.182	$0.174
5.00	.244	.238	.227	.218
6.00	.293	.286	.272	.261
7.00	.342	.333	.317	.305

TABLE 16.—*Comparative costs for fuels*

Cost of oil per gallon	Cost per ton below which coal is a more economical fuel than oil	Cost per cord below which wood is a more economical fuel than oil	Cost of oil per gallon	Cost per ton below which coal is a more economical fuel than oil	Cost per cord below which wood is a more economical fuel than oil
$0.03	$3.87	$2.25	$0.07	$10.03	$6.25
.04	5.41	3.25	.08	11.56	7.25
.05	6.95	4.25	.09	13.11	8.25
.06	8.49	5.25			

CANNING SIRUP

OPERATION

By W. L. Owen, *Louisiana Sugar Experiment Station*

PRINCIPLES OF CANNING

Canning, as generally understood, is the act of filling cans with perishable goods and hermetically sealing them. In a broader sense the process includes also the preliminary preparation of the product, by heat or other means, to insure it against subsequent deterioration in the cans. In canning sirup the processing or conditioning of the sirup is implied, as well as the actual canning operation. The processing of cane sirup for canning is merely a partial sterilization to destroy the microorganisms which cause sirup to ferment. As the temperatures successfully used to preserve cane sirup do not kill microorganisms of all classes, the process is one of pasteurization rather than of sterilization.

Cane sirup may be preserved in cans with little chance of failure, if certain simple rules are observed. There are no great difficulties to be overcome, and there is no reason why, even with the simplest equipment, cane sirup can not be canned with minimum loss from spoilage. The three general conditions necessary are (1) to fill the cans with sirup at the proper temperature, (2) to obtain air-tight closure of the cans, and (3) to avoid long retention of heat by the sirup both before and after canning.

When the sirup has been concentrated to the desired density in an open pan, it should be cooled to the canning temperature as quickly as possible; otherwise, it will deteriorate in color and flavor. Owing to the tendency of cane sirup to retain heat for long periods, it is necessary, when handling large quantities in bulk while hot, to provide means for hastening cooling. It is most economical, of course, to fill the cans with the sirup as rapidly as it cools to the proper temperature after being concentrated to final density in the evaporator. In this way the sirup does not need to be heated twice; a saving of fuel is effected; and the sirup does not suffer in flavor and color by being reheated.

Sometimes sirup from a small open evaporator may be run into the sirup trough as rapidly as it is finished and canning may proceed at the same time. Again, depending on the size of the tank and the rate at which sirup is being made, two troughs or tanks may be better than one. Sirup may then be removed from one of these for canning, while hot sirup direct from the evaporator is being run into the second. Some sirup makers can the sirup directly as it comes from the evaporator, but this is not considered the best practice. The sirup should be cooled to at least 180° F. for gallon cans before canning is begun. When the temperature of the sirup in the tank has dropped to the safe minimum, 170° F. (p. 59), canning from that tank should be discontinued, and hot sirup from the evaporator should be run in to raise the temperature.

The process of concentrating the sirup in large batches in an evaporator sometimes proceeds much faster than the canning. In such cases means should be provided for cooling the sirup after concentration and for reheating or processing it in small batches at the rate required for canning. Special coolers may be provided whenever it is necessary to cool the sirup (p. 54). If the sirup is to be reprocessed, rather than canned directly, it should flow from the coolers into a storage tank. Sirup need not be cooled to atmospheric temperature before being discharged from the coolers into the storage tanks; reduction in temperature to 120° F. is sufficient.

The capacity of the coolers depends upon the capacity of the evaporators and the canning facilities. If the sirup is reheated for canning, the processing pans should be large enough to furnish hot sirup at the rate required for canning. The sirup, after being heated to the required temperature, should flow from the processing pan to the filling tank or directly to the filling machine. In small sirup houses, this equipment usually consists of a small tank and hand-operated valve for filling the cans; in larger canning plants, special machinery is employed (p. 61).

CANNING TEMPERATURES

The temperature to which cane sirup must be heated to prevent fermentation varies with the time during which an elevated temperature is maintained. When a required minimum temperature is exceeded, a lower temperature is as effective as a higher temperature, provided the lower one is applied for a sufficiently longer time. For this reason the temperature required for the preservation of sirup varies with the volume in the cans. As a larger volume takes a longer time to cool, the temperature required for preservation of sirup in large cans is lower than that essential in smaller cans. The canning temperatures shown in Table 17 are generally effective for cane sirup packed in cans of various sizes.

"Effective temperature" means the temperature of the sirup in the can at the time it is closed; the processing temperature is usually about 10° higher. Although there is no objection to canning sirup at a temperature a few degrees higher than the temperatures given in Table 17, the cans should not be closed when the temperature of the sirup is lower than that recommended. Higher temperatures are not only unnecessary; they cause the sirup to darken and may produce "buckling" of the cans, owing to the production of too high a vacuum on cooling.

TABLE 17.—*Canning temperatures for cane sirup*

Size of can	Effective temperature
	° F.
No. 10	160
No. 5	165
No. 2½	177
No. 1½	177

COOLING SIRUP AFTER CANNING

If cans of hot cane sirup are stacked or placed in such a position that they cool very slowly, the sirup may undergo "stack burning." This has practically the same effect upon color and flavor as overheating. The sirup becomes red and acquires a sharp, burnt taste. Not infrequently "stack burning" causes the cans of sirup to swell or bulge at the ends, as if their contents had fermented. This trouble is easily avoided in a small sirup house, where the output is relatively small and the problem of storing the hot cans is not difficult, by simply taking care not to place the cases of hot cans in large stacks, where temperature and circulation of air are unfavorable for rapid cooling. Whenever it is necessary to pile them in large stacks, they should be "stripped;" that is, narrow strips of wood are placed across the stacks at intervals of every three or four rows of cases, thus permitting air to circulate through the stack to accelerate the cooling.

CANS AND CANNING EQUIPMENT

By C. F. WALTON, Jr., *Bureau of Chemistry, U. S. Department of Agriculture*

Friction-top cans are generally preferred for small-scale canning, because they can be readily closed by hand. Only one serious difficulty exists in connection with hand canning—that of always obtaining perfect closure of large and small friction-top cans. Ordinarily, if the sirup is consumed fairly soon after it has been canned, there is no serious trouble from fermentation. The canning operation, however, even if it has not been properly done, is likely to give sirup makers a sense of security. Unless the closure with friction tops is perfect, air is drawn into the can as a result of the partial vacuum caused by the cooling of the hot sirup. The sirup thus becomes infected with microorganisms present in the air. Although fermentation usually takes place more slowly in cans than in barrels, and in only comparatively few cans, in time the contents of such cans become unmarketable. A much higher percentage of perfect closures is obtained with the small friction-top than is possible with the large friction-top cans. These statements refer exclusively to closure of friction tops by hand. Mechanical devices for inserting the tops now on the market give satisfactory results; and, as certain market territories prefer them, the small friction-top cans are still used by some of the larger packers.

The sanitary can and the solder-top can are the most satisfactory types for larger canning plants, which have special machinery for filling and closing the cans. Soldering small friction-top cans by hand immediately after closing, while the sirup is still hot, gives a perfect closure, but is troublesome and seldom done. Soldering by means of a mechanical device can be done on a large scale, however, so that solder-top cans are sometimes preferred by the larger sirup canners.

The most popular can for large-scale operations is the sanitary can, used exclusively by many of the largest sirup packers for all sirups. As a mechanical closing machine is required to close this can, however, it is not suitable for use on a small scale.

In canning sirup on a scale corresponding to that recommended for a central canning plant (p. 66), a sirup-filling machine automatically fills the cans with a weighed quantity of sirup. The filled cans are carried on a belt conveyor to the closing machine, where they are automatically closed. A mechanical conveyor then carries them through a washing machine, consisting essentially of a box of rectangular cross section containing running water, where sirup adhering to the outside of the can is washed off. The cans pass directly from the washing machine to the top of a gravity roller conveyor, over which they roll for a short distance to the labeling machine. After being labeled, the cans are packed in cases and stacked in such a manner as will permit rapid cooling.

Sirup-filling machines, which may be adjusted for filling cans of all sizes, are recommended when canning is done on a large scale, as in a central canning plant. Using one of these machines or two suitable machines of different adjustments, the number of closing and labeling machines required will depend on the number of sizes of cans to be filled. If a plant desires to market all of the customary sizes (Nos. 10, 5, 2½, and 1½), it is best to install two closing machines and two labeling machines, in addition to the one or two filling machines. Ordinarily the equipment is so arranged that one of the closing machines and one of the labelers may be adjusted to handle the two larger sizes, while the second closing and labeling machines are adjusted to the two smaller sizes. The two sets of machines may be operated simultaneously or alternately. If the sirup is to be marketed exclusively in the two larger sizes or in the two smaller sizes, one filling machine, one closing machine, and one labeling machine are sufficient. The cost of this equipment varies somewhat from year to year. The 1925 cost is estimated at approximately $4,050, divided as follows: Sirup-filling machine, $1,500; closing machines rented, $50 per year; labelers, two sizes, $800 and $950; conveyors, motor, pulleys, belts, and other accessories, $750.

PREVENTION OF CRYSTALLIZATION BY THE INVERTASE PROCESS [12]

By H. S. Paine and C. F. Walton, Jr., *Bureau of Chemistry, U. S. Department of Agriculture*

"Sugaring," or crystallization of sugar from cane sirup, occurs frequently, increasing as the cane becomes more mature and the density of the sirup greater. On the other hand, sirup which is of sufficiently low density to be free from crystallization often shows an increased tendency to undergo fermentation unless it has been carefully canned to insure preservation.

The presence of invert sugar in sirup increases the solubility of total sugars and makes it possible to concentrate the sirup to higher density without crystallization. Cane sirup always contains some invert sugar in addition to cane sugar. The proportion of invert sugar to cane sugar, however, varies in different varieties of cane, some of which do not contain enough invert sugar to prevent crystallization.

The presence of acid, particularly at higher temperatures, causes conversion of cane sugar into invert sugar, thereby increasing the proportion of the invert sugar. As cane juice normally contains certain organic acids, its natural acidity increases the proportion of invert sugar at the expense of cane sugar during the concentration of the juice to sirup. The quantity of invert sugar produced in this manner, together with that originally present in the juice, however, is not usually sufficient to prevent crystallization in the cane varieties which normally contain relatively small proportions of invert sugar.

In operating the sulphur-lime process the degree of sulphuring is sometimes increased for the purpose of increasing conversion of cane sugar into invert sugar. Excessive sulphuring, however, injures the quality of the sirup. Other methods proposed, such as the

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[12] This section supersedes the mimeographed circular, "Manufacture of sugar-cane sirup by the invertase process," by C. S. Hudson and J. K. Dale.

addition of acids, prolonged heating during concentration of juice to sirup, or allowing the cane or juice to undergo slight fermentation, impair either the flavor or the color of the sirup, or both. Adding acid to sirup made from mature cane imparts the objectionable acid quality characteristic of sirup made from green cane. None of these methods of treatment can be recommended. Crystallization may be prevented by mixing the sirup with glucose, but this procedure can not be used for a product which is to be sold as pure cane sirup.

The invertase process is the most satisfactory method for increasing the proportion of invert sugar in cane sirup in order to prevent crystallization. It may be used during the process of concentrating the juice to sirup, or it may be applied to the finished sirup at a central receiving, canning, and marketing plant.

Cane juice is sweet because it contains in solution cane sugar, with some invert sugar. The proportion of cane sugar is usually much higher than the proportion of invert sugar, but equal weights of cane sugar and invert sugar have practically the same degree of sweetness. Invert sugar is not a simple sugar, but a mixture of two sugars, dextrose and fructose, in equal proportion. It is widely distributed in nature, and is the principal constituent of honey. The production of honey by bees is a good example of the effect produced when the invertase process is used in manufacturing cane sirup. The sweet substance that the bees collect from plants and flowers consists essentially of sucrose, which is the chemical term for cane or beet sugar. Bees convert this sugar into invert sugar. The use of invertase in cane-sirup manufacture accomplishes the same transformation; it converts part of the cane sugar into invert sugar, which is just as sweet and wholesome as cane sugar but sugars or crystallizes much less readily.

Invertase is chemically classified as an enzyme. As the cheapest and most available material from which to prepare it is yeast, the water extract of yeast, suitably prepared, is generally termed invertase. Invertase is a yellowish-brown liquid, with a rather peculiar but not disagreeable odor and taste. It is not a chemical, in the ordinary meaning of this term. Because of the extremely small proportion added to sirup, moreover, it can not be detected in the sirup by either odor or flavor.

USE OF INVERTASE DURING MANUFACTURE OF SIRUP

After skimming or clarifying the cane juice from the mill in the customary manner, evaporation is continued until the density of the sirup, when quickly tested while still very hot, corresponds to 20° Baumé (35.8° Brix), which is equivalent to approximately 24° Baumé (43.1° Brix) at ordinary temperature. Sirup at this stage is about two-thirds evaporated and is termed "semisirup." Upon reaching this density, the semisirup is collected in a tank large enough to hold the entire day's output. When a continuous evaporator is used, the flow of juice should be adjusted so that the required density is obtained when the semisirup has reached the finishing end of the evaporator. The juice, therefore, must flow into the evaporator faster than would be necessary in case it were evaporated to finished sirup in one operation.

The required quantity of invertase is now added to the semisirup. As invertase is destroyed at fairly high temperatures, the semisirup must be at a suitable temperature. The semisirup, therefore, should be allowed to cool to the proper temperature, which is 140° to 145° F. (60° to 63°C.). Semisirup which tests 20° Baumé (35.8° Brix) when practically at a boiling temperature, or approximately 24° Baumé (43.1° Brix) at ordinary temperature, will test about 23° Baumé (41.3 Brix) at 140° to 145° F. The quantity of invertase required depends on the volume of semisirup. As invertase is used in relatively small quantities, for accuracy of measurement the required quantity should be measured in terms of a small unit of volume, such as the cubic centimeter. The proportion required varies ordinarily from 40 to 60 cubic centimeters of the most concentrated invertase preparation now on the market for every 100 gallons of semisirup. Other commercial invertase preparations are used in different proportions. Small bottles, glass vials, or cylinders graduated in cubic centimeters, usually sold in drug stores, are recommended for measuring the invertase accurately.

The required volume of invertase is mixed with a little water (about a quart) and then added to the tank of semisirup. Because of the small proportion of invertase added, the sirup must be well stirred so as to thoroughly mix it with the invertase. Although about 50 cubic centimeters of the most active invertase preparation per 100 gallons of semisirup is usually required, it may be necessary to vary the quantity somewhat in certain cases, owing to differences in the proportion of cane sugar and invert sugar originally present in the juice and the proportion of cane sugar converted into invert sugar during evaporation. Unless a polariscope is available for testing the semisirup both before and after the invertase has done its work, the only way to determine for the first time whether too little or too much invertase has been added is to observe the color and flavor of the sirup and its tendency to crystallize after evaporation to final density. If the sirup does not differ appreciably in quality from sirup obtained from the same kind of cane when no invertase was used, and if no sugar separates from the sirup, it is safe to conclude that the proper quantity of invertase has been added. If, however, the color and flavor of the finished sirup differ appreciably from those of sirup of the same density made without invertase, slightly less invertase should be used thereafter. Conversely, if the finished sirup shows a tendency to deposit sugar, the proportion of invertase used for the next lot should be increased.

The tendency of sirup to crystallize may be easily and quickly tested by permitting a small sample (about a quart) to cool until it is lukewarm and then adding about a teaspoonful of powdered or fine granulated sugar and stirring occasionally over a period of two or three hours. If no sugar in excess of that which has been added appears in the sirup after it has stood for a day or two, the quantity of sugar which may be deposited later will be very small, at the most. The smallest proportion of invertase which will prevent crystallization should be used.

Since invertase does not act instantaneously, a certain period is required for it to convert the necessary quantity of cane sugar into invert sugar. It has been found convenient to allow approximately 12 hours (overnight) from the time the invertase is added to the semisirup until evaporation to final sirup is started. The invertase is added when quitting work at night, and final evaporation of the semisirup is begun when operation is resumed next morning.

If the expense of installing an extra evaporator does not seem to be warranted, a single evaporator may be used, discontinuing grinding while the semisirup is being evaporated to finished sirup. The only additional equipment required is a tank for receiving the semisirup. Each sirup maker can easily determine from past experience with continuous evaporators the best manner of operating the evaporator in order to concentrate semisirup to final sirup.

With an extra evaporator, preferably one of the noncontinuous type, it is possible simultaneously to evaporate juice to semisirup and to concentrate semisirup to final sirup. This increases the capacity of the plant, justifying the expense of the second evaporator. Since the concentration of juice is approximately two-thirds complete at 20° Baumé, or 35.8° Brix (measured at the boiling temperature), the capacity of the finishing evaporator, should one be installed, need be only about one-half that of the juice evaporator. Two tanks for treating the semisirup with invertase are also essential in order that grinding may continue without interruption.

A plant in which approximately 10 tons of cane per 10-hour day is to be ground needs two tanks holding about 500 gallons each. Ten tons of cane will yield about 1,500 gallons of juice, which will make approximately 450 gallons of semisirup of the required density. The installation of two tanks makes it possible to draw semisirup from one for concentration to final sirup in the second evaporator, while the first evaporator is evaporating mill juice to semisirup and discharging it into the second tank. Thus a continuous operation may be maintained, one tank being filled with semisirup and one tank emptied each day. One evaporator would be in constant use, concentrating juice to semisirup, while the semisirup made the previous day would be concentrated to final sirup in the other evaporator. The juice evaporator would be piped to discharge into either tank, and each tank would be piped to discharge into the semisirup evaporator. The use of invertase at 1925 prices would increase the cost of making sirup one-half to three-quarters of a cent per gallon of final sirup. One pound of the most active invertase preparation on the market is sufficient for 300 to 400 gallons of final sirup.

SIRUP TO BE CANNED

Although the standard commercial density is about 39° Baumé (71.8° Brix), measured at ordinary temperature, it is believed that the sirup density preferred by most consumers is about 35° Baumé (63.9° Brix), measured at a temperature close to boiling, or approximately 40° Baumé (73.7° Brix), when cooled to ordinary temperature. Sirup concentrated to higher density usually has somewhat poorer color and flavor. The use of invertase during manufacture prevents crystallization in canned sirup, even after the can is opened. The "apparent purity" (determined by use of a polariscope) should be approximately 50 to 55 for sirup evaporated to 40° Baumé, cold. Proper canning is depended upon to prevent fermentation in sirup at this density.

SIRUP TO BE BARRELED

Several considerations govern the producer's decision as to whether or not to use invertase in barreled sirup which has a tendency to crystallize. If the sirup has been contracted for in advance and the buyer does not object to crystallization or is not willing to pay enough to justify invertase treatment, the use of invertase is generally not advisable. Although the cost of invertase is small, sirup concentrated to a higher density than customary contains less water and is therefore worth correspondingly more per gallon. If the sirup producer does not care to pack his sirup in cans and market it himself, and if he has no satisfactory market for shipment in barrels at the time the sirup is made, it is sometimes desirable to barrel the sirup at a higher density than customary so that it will keep for a longer time without danger of fermentation—until such time, for instance, as it is anticipated that sirup will command a better price. The use of invertase in this manner offers an economical alternative to cold-storage warehousing.

Experiments have shown that at a density of 43° Baumé (79.8° Brix), measured at ordinary temperature, cane sirup does not readily ferment in warm weather. At this density the sirup contains 21 to 22 per cent of water; at ordinary density it contains 28 to 30 per cent of water. A sugar-cane sirup containing as little as 21 per cent of water, however, will usually crystallize to a pronounced degree. The use of invertase makes it possible to concentrate such a sirup to the density required to retard fermentation without the attendant danger of excessive crystallization. For sirup having a water content of 21 to 22 per cent the "apparent purity" should be about 45. The production of sirup of unusually high density, while not recommended as the best everyday practice, may prove advisable at times for holding sirup in bulk for a better market.

La Cuite, a product closely resembling sirup, is highly esteemed in Louisiana and would doubtless be in much more extensive demand if manufactured in such a way as to prevent excessive sugaring. As this product is made on a comparatively large scale in Louisiana, the customary process of clarification with sulphur dioxide and lime is employed. A sufficient quantity of invertase is added to the semisirup to reduce the apparent purity from approximately 70 to 30 in the 12-hour period. The sirup may then be evaporated to a density of 86 to 87 per cent solids, or a water content of 13 to 14 per cent, when it is known as La Cuite. The proper application of invertase prevents excessive sugaring, even in products of this extremely high density.

USE OF INVERTASE BY CANNING PLANTS

The variation in quality of farm-made sirup is a serious obstacle to the successful marketing of any surplus sirup remaining in the local market, unless the surplus sirup is barreled and sold to large packers and sirup distributors (p. 2).

The invertase method, with certain modifications, is useful at canning plants in case the sirup received undergoes crystallization when packed at the density preferred by the market. The equipment used in an ordinary sirup-canning plant may be used, and the cost of operation is but little greater. Figures 18 and 19 show the floor plan and sectional end view of such a canning plant, designed by the Bureau of Chemistry, which has been in successful operation.

The essential difference between this plant and the usual canning plant consists in the installation of three large mixing tanks instead of only one. In both cases space is required for storing barrels of sirup and for grading, for installing the canning machinery, processing pan (or evaporator) and cooling tanks, and for storing empty cans and canned and crated sirup ready for shipment.

Following its receipt in barrels, the sirup is first graded, such properties as color, flavor, density, occurrence or absence of fermentation, and presence or absence of an excessive quantity of dregs or sediment in the sirup being used to determine the grade. The best-quality sirup is separated from second-grade sirup in this way.

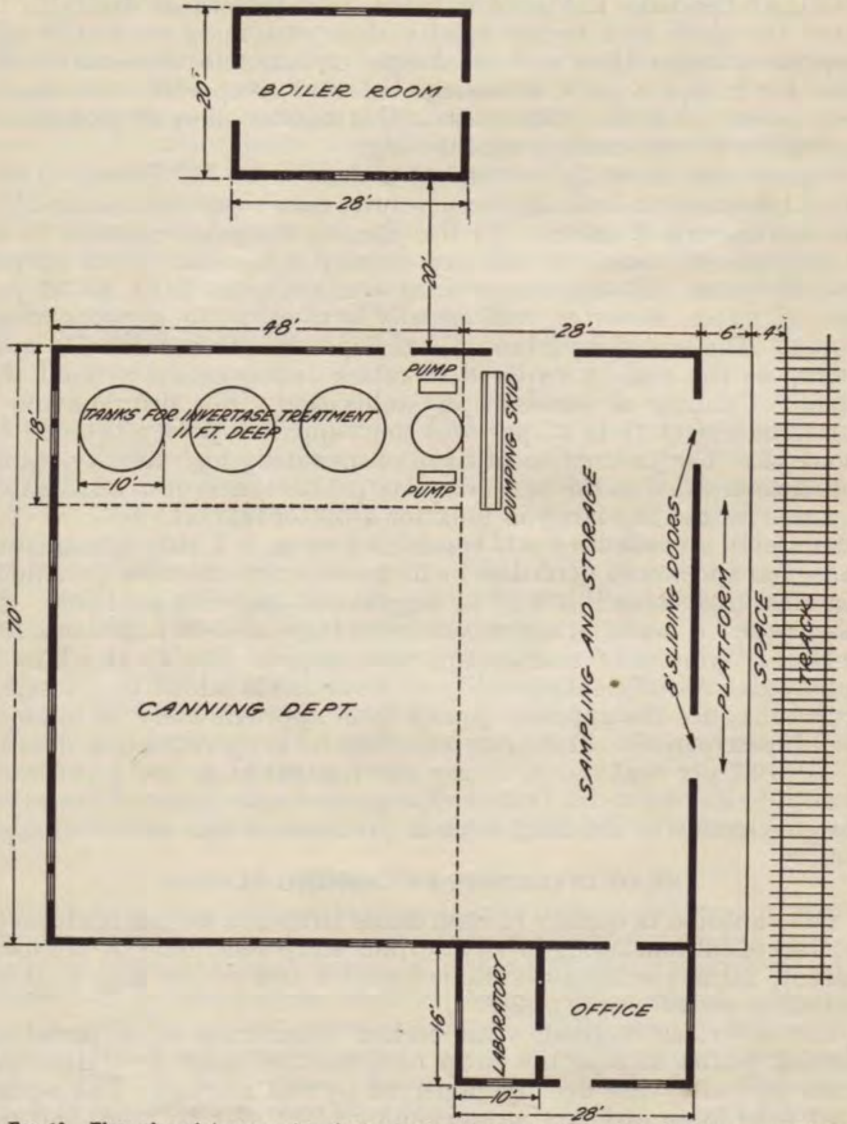

FIG. 18.—Floor plan of sirup-canning plant using invertase inversion. This plant has a capacity of 5,000 gallons per 10-hour day.

The second-grade sirup may be sold under a different label or it may be converted at the plant into a better product (p. 39).

The second step is to empty the sirup from the barrels, arranged on a dumping skid, so that it flows by gravity into a receiving tank below. From here it is pumped into one of the large mixing tanks, each of which is provided with a motor-driven stirrer and steam coils suitable for heating the sirup rapidly. When received, the sirup

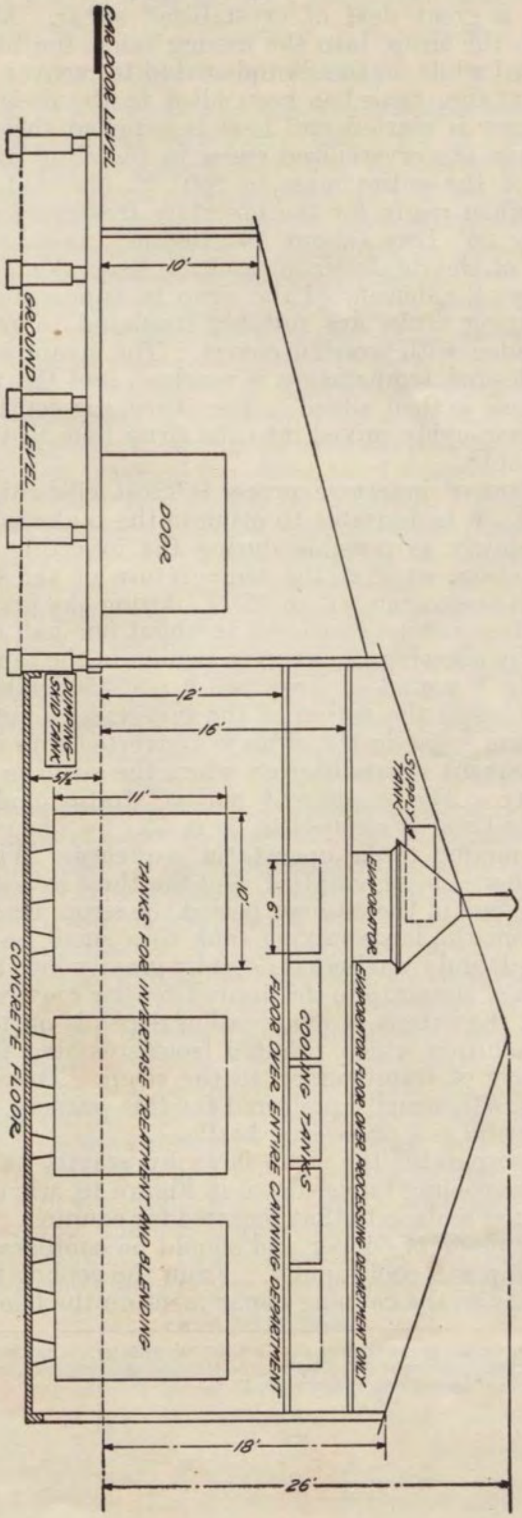

FIG. 19.—Sectional end elevation of sirup-canning plant using invertase inversion

may contain a great deal of crystallized sugar. Most of this is pumped, with the sirup, into the mixing tank; the barrels are thoroughly steamed while on the dumping skid to recover the rest.

When the mixing tank has been filled to the desired depth with sirup, the stirrer is started and heat is supplied through the steam coils to dissolve the crystallized sugar in the sirup and to raise the temperature of the entire mass to 140° F. (60° C.). The density of the sirup when ready for the invertase treatment corresponds to approximately 66° Brix (about 36° Baumé), measured at 140° F. The addition of the dilute sirup resulting from steaming the barrels usually reduces the density of the sirup to approximately 66° Brix. The large mixing tanks are suitably insulated to retain heat and are also provided with wooden covers. The steam is turned off as soon as the desired temperature is reached, and the required quantity of invertase is then added. The stirring is continued until the invertase is thoroughly mixed into the sirup (one to two hours for a 5,000-gallon tank).

As the action of invertase proceeds most efficiently at approximately 140° F., it is desirable to insulate the tanks so that the sirup will cool as slowly as possible during the inverting period. With suitable insulation, so that the temperature of the sirup does not decrease much more than 10° to 15° F. during the first 12 hours, the cost for invertase can be restricted to about one-half cent per gallon of final sirup by allowing the sirup to remain in the tank for 36 hours. Approximately 1 pound of invertase [13] per 350 gallons of sirup is required. Through the action of the invertase, a sufficient proportion of the cane sugar in the sirup is converted into invert sugar to prevent subsequent crystallization when the sirup is canned at the desired density. The "apparent purity" (ratio of direct polarization to degrees Brix) is reduced to 50 to 55.

The three mixing tanks operate in sequence. While one is full of sirup, another is being emptied, and the third is being cleaned and filled. At the end of the 36-hour period the sirup, ready for canning, is pumped from the large mixing tank to a small receiving tank at the rate desired, and from here it flows by gravity into the evaporator. Concentration of the sirup to the desired density requires only three or four minutes; the extent of evaporation depends on the quantity of dilute sugar solution which resulted from steaming the barrels and on the quantity of water added to the sirup. The Louisiana-type evaporator (p. 53), usually preferred for this purpose, serves both as an evaporator and as a processing kettle.

From the evaporator the sirup flows by gravity through a cooler or to one of the cooling tanks shown in Figure 19, where the temperature is permitted to drop to that required for canning. Cooling tanks are preferably made of copper and should be comparatively shallow, so that the sirup will cool rapidly. From the cooling tanks the sirup flows by gravity to the canning department on the floor below.

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[13] The most active invertase preparation of standardized strength on the market at the present time. An up-to-date list of manufacturers of invertase may be obtained upon request from the Bureau of Chemistry, U. S. Department of Agriculture, Washington, D. C.

COMPOSITION AND FOOD VALUE OF CANE SIRUP

By H. S. PAINE, *Bureau of Chemistry, U. S. Department of Agriculture*

COLOR AND FLAVOR

The merits of cane sirup as a food have doubtless been appreciated from the beginning of the sugar-cane industry. In those sections of the South where it is produced, this sirup is commonly preferred to all other sirups and forms an important part of the dietary. Commercial differentiation in the value of cane sirup depends almost exclusively upon color and flavor. Although the density or "body" of the product is also an important element of quality, this property is relatively constant in comparison with flavor and color.

The quality of flavor most desired in cane sirup is smoothness, with enough of the typical cane-juice flavor to give it the unmistakable taste of the cane. Although the production of much "caramel" flavor during evaporation of juice to sirup is to be avoided, a little may improve the general character of cane sirup by making sweetness more noticeable and masking less desirable flavors. Cane sirup possesses more flavor than may at first be apparent. While this can be measured only by tasting, a method based upon the detection of flavor at various dilutions with water shows that in the average sirup the flavor is from 25 to 60 per cent more persistent than sweetness. The formation of small quantities of caramel and partial neutralization of the acidity of the sirup tend to equalize the intensity of sweetness and flavor.

Although flavor has always been considered in judging the quality of sirup, color has been widely adopted as the most practical criterion of value. In those sections of the South where no chemical clarifying agents are used in manufacture, the lightest-color sirups usually have the mildest and most generally desired flavor. Moreover, for all practical purposes, sirup buyers and consumers know from experience what the ideal color of a cane sirup is, and, since comparison of flavor is much less definite, color is the criterion of value most readily applied.

Unfortunately, in attempting to employ color as a general index of commercial value a complication arises from the fact that a light color may be obtained by the use of chemical clarification. As it has not yet been found possible to manufacture sirup by chemical clarification in such a way as to obtain the same flavor as may be had when no chemicals are used, it is objectionable to place a premium on the color of sirup regardless of its flavor. For this reason and because many markets place a premium on flavor rather than on color alone, it is necessary to differentiate clearly between sirup that has been made by the so-called Georgia method (open boiling and skimming) and that made by the typical large-scale Louisiana method (using sulphur dioxide and lime for the clarification). It should not be inferred from these statements that the use of approved chemical clarifying agents gives an inferior product. This is a matter of individual preference, and in fact some consumers prefer a sirup manufactured in this way.

COMPOSITION

Variations in the composition of cane juice, which depend principally upon the variety of cane, type of soil, kind of fertilizer, and degree of maturity of the cane, are reflected in the composition of the sirup. There may be other variations in the composition of sirup, such as the transformation of a portion of the cane sugar into invert sugar during the process of evaporation of juice to sirup. In general, the greater the acidity of the cane juice and the longer the time required for evaporating to finished sirup, the greater the extent of the inversion of cane sugar. The removal of scums and dregs from the juice in the boiling and skimming process and the precipitation and removal of certain juice constituents in the sulphur-lime process also cause the composition of the sirup to differ from that of the juice. Aside from these factors and the removal of a large proportion of the water by evaporation, the sirup has essentially the same composition as the juice.

Although the composition of neither juice nor sirup can, in general, be represented by a single analysis, the analysis given in Table 18 is fairly typical of cane juice. A typical analysis of the mineral constituents originally present in the juice of Louisiana Purple cane is shown in Table 19.

TABLE 18.—*Composition of sugar-cane juice*

	Per cent
Water	83.00
Cane sugar (sucrose)	15.00
Invert sugar	.80
Ash	.45
Proteins	.05
Nucleins	.03
Proteoses	.01
Nitrogenous bases (guanine, etc.)	Trace.
Amides (asparagine, glutamine, etc.)	.05
Amino acids (aspartic, etc.)	0.12
Other organic acids (aconitic, etc.)	.10
Gums and pectins	.10
Fiber particles	.12
Fat and wax	.10
Earthy matter	.06
Chlorophyll, etc	.01
Total	100.00

TABLE 19.—*Composition of mineral constituents of sugar-cane juice*

	Per cent
Potash (K_2O)	49.63
Soda (Na_2O)	1.81
Lime (CaO)	3.00
Magnesia (MgO)	3.21
Iron oxide (Fe_2O_3)	.70
Alumina (Al_2O_3)	.40
Silica (SiO_2)	4.80
Phosphoric acid (P_2O_5)	5.80
Sulphuric acid (SO_3)	20.40
Carbonic acid (CO_2)	4.10
Chlorine (Cl)	5.80

Table 20 shows the average, maximum, and minimum percentages of several constituents of a large number of samples of cane sirup analyzed in the Bureau of Chemistry. The samples of sirup have been divided into those of the so-called Georgia type and those of the Louisiana type.

TABLE 20.—*Composition of sugar-cane sirup*

Type of sirup	Hydrometer reading		Total solids	Cane sugar	Invert sugar	Ash			Alkalinity of ash from 1 gram of sample	
						Total	Soluble	In-soluble	Soluble ash	In-soluble ash
	°Brix	*°Baumé*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*cc. of 0.1 N acid*	
Georgia:										
Maximum			75.92	61.61	46.50	1.63	1.26	0.53	0.7	1.4
Minimum			69.00	25.34	6.74	.64	.40	.17	.2	.4
Average			73.15	47.84	19.54	.98	.74	.24	.5	.6
Louisiana:										
Maximum	76.05	40.4	74.77	61.79	27.16	2.68	2.26	.85	2.40	1.76
Minimum	69.74	38.0	68.50	46.28	4.98	.85	.69	.17	.44	.48
Average	73.32	39.8	71.88	53.99	12.82	1.73	1.36	.37	1.29	.80
All samples:										
Maximum			77.36	61.79	46.50	2.68	2.26	.85	2.40	1.76
Minimum			68.50	25.34	4.98	.64	.40	.17	.20	.48
Average			72.06	51.08	16.01	1.53	1.20	.33	.92	.71

Table 21 shows the average general composition of the solids of the sirup samples listed in Table 20. The ratio of cane sugar to invert sugar is subject to variation in Georgia-type sirup, and the variation in the sulphur-lime sirups may be even greater, owing to the fact that by the use of sulphur dioxide and lime the acidity may be varied to a greater extent. The percentage of ash or mineral constituents in Louisiana-type sirup is usually higher than that in Georgia-type sirup.

TABLE 21.—*Average composition of solids in sugar-cane sirup*

Type of sirup	Cane sugar	Invert sugar	Ash			Organic nonsugar substances
			Total	Soluble	Insoluble	
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Georgia	65.40	26.71	1.33	1.01	0.32	6.56
Louisiana	75.11	17.84	2.41	1.90	.51	4.64
All samples	70.89	22.22	2.13	1.67	.46	4.76

The following standard for cane sirup has been adopted as a guide in the enforcement of the Federal food and drugs act and also in the enforcement of several State food laws: "Sugar-cane sirup is sirup made by the evaporation of the juice of the sugar cane or by the solution of sugar-cane concrete, and contains not more than thirty per cent (30%) of water and not more than two and five-tenths per cent (2.5%) of ash."

As the scale on which the Brix hydrometer is graduated is based upon pure cane sugar solutions and cane sirup contains solids other than cane sugar, the Brix reading of cane sirup does not coincide exactly with the percentage of solids in the sirup. According to the foregoing standard, cane sirup should contain not less than 70 per cent of solids, but the Brix reading corresponding thereto should, in general, be somewhat higher than 70, the exact value depending upon the proportion and composition of the nonsugar solids. As a rule, a Brix reading of 71° to 71.5°, corresponding to Baumé readings of 38.6° and 38.9°, all measured at standard temperature, indicates a percentage of solids not lower than 70 per cent and a percentage of water not higher than 30 per cent.

FOOD VALUE

Cane sirup owes its food value essentially to its sugar content. The proportion of solid constituents in the sirup other than cane sugar and invert sugar is indicated in Table 21. Some of the substances originally present in the juice are eliminated, either in whole or in part, by the clarification and evaporation from juice to sirup.

The salts (ash constituents) and organic nonsugars in cane sirup have some incidental food value.[14] As the dietary value of these nonsugar substances is somewhat indefinite, however, the food value is usually calculated in terms of energy units on the basis of total sugars. Taking as a basis of calculation a fuel value of 3.749 large

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[14] Recent studies in nutrition and dietetics indicate that sugar-cane sirup and molasses contain a noteworthy quantity of vitamines.

calories per gram for invert sugar and 3.955 large calories per gram for cane sugar, the energy value of 1 pound of cane sirup of the average composition for all samples indicated in Table 20 would be 1,188.6 large calories. One gallon of such sirup of 39° Baumé (71.8° Brix) measured at 63.5° F., weighing 11.35 pounds per gallon, has a food value of 13,491 large calories.

MARKETING CANE SIRUP

By H. S. Paine and C. F. Walton, Jr., *Bureau of Chemistry, U. S. Department of Agriculture*

SELLING IN BARRELS OR IN CANS

Producers who sell sirup in both cans and barrels may desire to calculate the net return per gallon of sirup. The extensively used No. 10, or "gallon," can does not contain a full gallon, but 15 to 20 per cent less of sirup by weight than a full gallon as measured in barrels. Knowing this, sirup makers sometimes assume that if they sell a "gallon" can of sirup for $0.50, as compared with sirup in barrels at $0.50 a gallon, the difference in quantity of sirup sold at the same price represents clear profit. The relative costs of the containers per gallon of sirup are not always sufficiently considered. For example, a barrel containing 52 full gallons of sirup, at $0.50 a gallon, would bring $26. Subtracting the cost of the barrel, $2.25, the amount received for the sirup would be $23.75. The same quantity of sirup (52 full gallons) will fill about 63 so-called gallon cans (9.25 pounds of sirup per can). This sirup, at $0.50 a can, would bring $31.50. Subtracting the cost of the cans ($0.10 each), which is $6.30, the amount received for the sirup would be $25.20.

Sirup packers, however, often buy sirup in barrels on a gross-weight basis, dividing the gross weight by 12 to determine the number of gallons. Thus, if the gross weight is 624 pounds, the packer would keep the barrel and pay for 52 gallons of sirup. At $0.50 per gallon, the price received for this sirup would be $26; subtracting the cost of the barrel ($2.25), the net return is $23.75. The barrel, however, contains less than 52 full gallons of sirup. Subtracting the weight of the barrel (58 pounds), the weight of sirup is 566 pounds (or 50 full gallons of sirup at 11.3 pounds per gallon), which would fill 61 gallons cans (9.25 pounds of sirup per can). This sirup at $0.50 a gallon would bring $30.50. Subtracting the cost of the cans at $0.10 each ($6.10), the net return is $24.40, or only slightly more than that received when selling the sirup in barrels.

Although cans cost more than barrels, there is somewhat more profit in selling sirup in cans than in barrels, assuming that the price obtained per "gallon" can is approximately the same as or greater than the price received per gallon in barrels. The small producer who sells his sirup in cans, however, should make a reasonable charge against the canned sirup for the value of his time, both in canning the sirup properly and in delivering it to his customers. Labels and cases also constitute important items of expense. As the relative return from selling in cans and in barrels may vary from year to year, small producers may need to change from one method to the other, according to market conditions, or to sell part of the output in cans and the rest in barrels.

Where production exceeds the demand of the local market, the shipment of surplus sirup in barrels to large-scale distributors and canners tends to limit the local supply of canned sirup, with consequent strengthening of local prices to the benefit of producers.

To obtain uniformity, grading and large-scale mixing of sirup of the same grade at a centrally located canning plant is the best plan. Each sirup maker's surplus over what can be sold by himself at a satisfactory price in cans in the local market may be packed in barrels and sold to the canning plant. Although "farm-made sirup in buckets," marketed locally, competes with the products of uniform quality offered by the larger manufacturers and packers, the function of the larger packer in the sirup industry is an important one. Only the larger packers or distributors or cooperative associations are in a position to handle the marketing problem involved in finding an outlet for the increased volume of sirup necessary to make increased production possible.

COOPERATIVE PLANTS

When surplus sirup is shipped in barrels to a centrally located distributing agency or directly to a canning plant, such an agency or plant may be operated privately or on a cooperative basis. A distributing agency for sirup is primarily a warehouse, the management of which receives and grades the sirup and distributes it to the canners in accordance with the principles of efficient and orderly marketing. Sometimes this is in the hands of one or two local business men, who have connections with the various sirup packers and whose function is primarily that of middlemen and brokers. Again, the distributing agency is a warehouse owned and operated by the sirup producers on a cooperative basis. When the sirup is shipped directly to a canning plant, this may likewise be owned privately or by the producers on a cooperative basis.

In 1925 there were few, if any, cooperative mills or canning plants in the cane-sirup industry. The cooperative principle, however, as applied to the distributing agency, or warehouse, has met with more favor and a considerable degree of success. From the producer's point of view, the cooperative warehouse, if successful in receiving the bulk of the sirup from a wide area, helps to maintain a fair price for the sirup and to distribute sales to packers in an orderly manner.

From the technical standpoint, a sirup factory, warehouse, or canning plant operated cooperatively does not differ essentially from one owned and operated privately. The difference is solely one of organization and management. Sponsors of a cooperative plant, whether for manufacturing, warehousing, or canning the sirup, should therefore carefully consider the factors which determine the success or failure of such enterprises. The question of greatest importance is whether or not the cane producers have a sufficient supply of cane or sirup to make the plant pay, and if so, whether they wish to truly cooperate. A strong organization and full cooperation under both favorable and temporarily adverse conditions are essential. A cooperative plant must receive the necessary volume of cane or of sirup; otherwise, it can not be operated efficiently and can not meet competition. It must receive its cane or sirup at a price consistent with what other concerns already established in business are able to pay competitively. As a result of shipping all surplus sirup out of a given community to a cooperative warehouse or canning plant, the local price for canned sirup may be increased, thereby furnishing an incentive to certain small producers to remain outside the cooperative association and sell their entire output locally. This situation has arisen several times. If there is a real surplus of sirup in the locality and a genuine need for a distributing organization, however, this situation is of little consequence.

Besides obtaining the cordial cooperation of a large percentage of all producers within the sirup area and their loyal support under all conditions, the cooperative plant needs good business management. Similar enterprises have frequently failed from lack of capable management, when all other conditions were favorable. A common fault in the initial stages of cooperative enterprises is the lack of comprehension of the competitive nature of the business and failure to provide the managerial ability demanded.

It is desirable that cooperative associations be incorporated in order that they may acquire a distinct legal status. More than two-thirds of the States have enacted special laws for the incorporation of cooperative associations. Some of these laws provide for organizations formed with capital stock; others provide for the nonstock form. Both forms usually provide that each member shall have only one vote, regardless of his financial interest in the organization, and that dividends shall be paid on the basis of patronage after a certain percentage of the net earnings has been set aside to create a reserve for contingencies and, in case of a capital-stock organization, to pay a reasonable rate of interest upon capital invested.

By-laws, in which definite working plans are outlined, should be adopted. The initial capital required to finance a cooperative organization will depend on the size of the plant, scale of operation, and plan of financing. By judicious use of a reasonable amount of working capital and the employment of bank credit, the expenses of operation can be met until returns from sirup sales are received. With the placing of cane sirup, on December 2, 1924, on the eligible list of commodities storable under the United States warehouse act,[15] the financing of the product while in storage has been simplified and made readily possible. Under this law the Secretary of Agriculture is authorized to license public warehousemen. The receipts which such licensed warehousemen must issue are uniform in their terms and are preferred by bankers generally as security for loans on stored agricultural products.

Although producers have been accustomed to sell their sirup for cash and receive payment in full at the time of sale, in a cooperative association a system of pooling the returns from all sales is desirable. Pooling means the averaging of returns for products sold during a given period, or for certain shipments, so that producers of sirup of the same quality and grade will receive the same price as soon as all of the sirup has been sold. In order to make pooling systems successful, uniform and effective grading must be strictly observed. This plan serves to a certain extent to equalize returns for sirup and to protect the individual members from possible loss resulting from

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[15] A copy of the United States warehouse act and the regulations for storing sugar-cane sirup thereunder, as well as additional detailed information, may be obtained from the Bureau of Agricultural Economics, U. S. Department of Agriculture, Washington, D. C.

an enforced sale when market conditions are unfavorable. Each producer commonly receives a partial payment for his sirup on delivery and a final payment after the plant has sold the sirup and averaged the returns.

Thoroughgoing instruction as to the merits and essential purpose of a cooperative association is necessary, so that the members may understand the methods of doing business and the benefits that result from a strong organization. Once this is accomplished and a management as capable as that in similar plants privately operated is obtained, there is every reason why a cooperative plant should be of great service to the community and profitable to its members as well.

Advertising is usually necessary in finding new outlets and in selling goods in competition with others in an established market. Good judgment, therefore, is required on the part of the management to place on the market only that quality of product which the public really wants. A product with selling merit will justify advertising and selling expense, whereas money spent in pushing an article without merit is largely wasted.

As the larger factories and canning plants can produce sirup of uniform grades and of modified color, flavor, and density, it is important to ascertain as definitely as possible the type of sirup generally preferred in prospective new markets. If, for example, it should be found that a product of lighter color and milder, less typical cane-juice flavor would sell to better advantage in certain sections of the North and West, where cane sirup is not very well known at present, it is possible from a technical standpoint to accomplish this by making use of the proper method of clarification in the larger plants, or by suitable treatment at the canning plant. Similarly, it is possible to give the trade a sirup of somewhat heavier "body" or density. The particular type of sirup desired in various sections where cane sirup is now little known is a question which must be studied in developing new markets; it can not be answered definitely at present.

It is important to consider what it costs for the factory or canning plant to produce sirup of modified characteristics in comparison with the cost of producing and canning sirup of the usual type. Expense is increased by each new step introduced into the manufacturing or canning operation. For example, filtration to improve clarity, or treatment with carbon to reduce color and objectionable flavor, causes an increase in expense, which must be carefully considered in relation to the probable market price obtainable for sirup of such a type. Likewise, if the trade prefers cane sirup of a density somewhat higher than that at which it is ordinarily marketed, it must be willing to pay correspondingly more for it.

The conclusion seems warranted that the growth and continued prosperity of the cane-sirup industry depend very largely upon the ability of this industry to find new markets for an increased production of sirup. Success in marketing requires first of all the production of sirup of uniform and satisfactory quality and of a type which appeals to consumers in the section where it is sold.

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