PLANT REQUIREMENTS FOR MANUFACTURE OF MOLASSES

TECHNICAL AIDS BRANCH

INTERNATIONAL COOPERATION ADMINISTRATION

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FOREWORD

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For further information and assistance, contact should be made with the local Productivity Center, Industrial Institute, Servicio, or United States Operations Mission.

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MOLASSES

INTRODUCTION

Molasses is a viscous sweet liquid or syrup generally produced as a by-product in the manufacture of sugar. Since molasses is a mixture, rather than a chemical compound, an exact composition cannot be given. A typical blackstrap molasses might contain 52 percent sugars, 26 percent water, and crude protein and ash would make up the remainder. Among the factors responsible for the highly variable composition are the following:

- Basic plant raw material
- Soil and fertilizer
- Climate
- Insect, weed and disease control
- Cultural methods
- Harvesting procedures
- Storage before processing
- Change during the various steps of storage, transportation and marketing.

The following figures on molasses composition are based on laboratory analysis of a typical cane feed-grade molasses. They are presented for the purpose of illustration only. Any other sample, due to the factors mentioned above, might vary greatly from this.

Carbohydrates	60.19%
Crude protein	4.81
Ash (mineral matter)	12.44
Water	22.56
	100.00%

Molasses is an important source of the water soluble vitamins such as pyridoxine, biotin and those for which quantities are shown in the following typical analysis:

Vitamin	Milligrams Per Pound
Thiamin	0.4
Riboflavin	1.0
Niacin	21.3
Pantothenic acid	19.5
Choline	290.0

Molasses may be classified, by source, into the following principal categories:

1. Blackstrap Molasses - The liquid or syrup remaining after all possible sugar is crystallized from the juice of sugar cane during the sugar mill operation.

2. High Test Molasses - A heavier grade of molasses produced in a sugar mill when the available supply of cane exceeds the quota permissible to be processed into sugar.

3. Beet Molasses - The liquid or syrup remaining after all the possible sugar is crystallized from the juice of sugar beets during the sugar mill operation.

4. Hydrol (also called hydrol molasses and corn-sugar molasses) - a by-product of the corn sugar industry.

5. Refiners' Molasses - The liquid remaining when raw sugar is refined into a higher quality product.

6. Citrus Molasses - A liquid produced from the skins and pulp of citrus fruits. It is a by-product of the frozen fruit juice and canning industries.

7. Miscellaneous - This category includes all other molasses, such as any that might be made as a by-product of the palm sugar industry.

Although important commercially, blackstrap and beet molasses are not considered in this report, since they are never produced except as a by-product in cane and beet sugar mills. The next paragraph describes a new type of molasses, high test, which under certain conditions is produced as a by-product of a sugar cane mill. It is this type of molasses which is the subject of this report.

High Test Molasses

For many years all cane molasses was considered as blackstrap molasses. Developments in recent years have changed this custom, and the term "blackstrap" in modern usage is limited to the syrup remaining after all possible sugar has been crystallized from the juice of the cane during the

sugar mill operation. Blackstrap is an unavoidable by-product of a sugar mill and is sometimes dumped into rivers when it cannot be sold profitably. The aim of the sugar mill is to produce as much sugar as economically feasible and as little lower priced products, such as molasses and bagasse, as possible. The success of the process in meeting this goal may be judged by the fact that the value of the sugar produced is roughly 25 times that of the molasses.

The industry has adopted a new term, "high test," to designate a heavier grade of molasses produced in a sugar mill when the sugar production quotas allowed by the International Sugar Conference have been reached and there still remains a quantity of excess cane. By a modification of the processing steps in the sugar mill, no sugar is produced as crystalline sugar and there is a corresponding increase in molasses yield.

Normally, high test is produced following the close of the regular season, and its production has fluctuated widely. High test is normally produced only when there is excess cane and when there is a mill which was erected for use as a sugar mill. An investor contemplating the erection of a facility for the production of molasses alone is cautioned to give the most careful consideration to the profit and loss projection at the end of this report as well as to the other comments pointing out the possible risks in such an enterprise.

USES AND CHARACTERISTICS OF MOLASSES

Usage of molasses may be classified into human food, animal food and industrial categories:

Human Food

As a human food, molasses is used as a table syrup and in the preparation of baked beans, brown bread, and many candies, pastries and confections. Although use as human food should not be ignored, consumption is relatively constant and the expansion potential is smaller than that of the other two classifications.

Animal Feed

Although molasses is known to have been used as an additive for animal feed mixtures in the sugar beet areas of Europe in 1800, it was much later before it became important in animal feed and is still not used to the maximum extent. In 1895, United States Government stations in Louisiana were experimenting with mixtures of molasses, cotton seed meal and hulls. By 1903, commercial feeds containing molasses were beginning to be marketed. Use of molasses for feed use in the United States reached 75 million gallons per year in 1940 and was up to 300 million gallons per year in 1952.

Molasses contains from 48 to 55 percent sugar and is an excellent source of carbohydrate, although it is a poor source of protein. On the basis of carbohydrate content, molasses has 70 to 75 percent of the energy value of an equivalent weight of corn. Expressed in the customary units for a commodity, six and a half gallons of molasses provide the carbohydrate equivalent of one bushel of corn.

As a source of energy in cattle feed, molasses was more economical than corn in the United States from 1945 to the fall of 1950. A feeder or feed mixer may pay up to 15.4 percent of the price of a bushel of corn for a gallon of molasses and still obtain the same energy value for each dollar of raw material cost. As an example, if corn sells for $1.20 per bushel, 15.4 percent of $1.20 is $0.1848, the maximum amount to pay for molasses per gallon.

In addition to its value as a source of carbohydrate, molasses adds palatability to animal feeds, acts as a binder and dust settler and stimulates appetite and water consumption. Molasses is an excellent solvent for urea $CO(NH_2)_2$, and recent research has shown the need for a readily available source of carbohydrate with urea for use in animal feeds.

Molasses has been found to be more effective than many other substances in stimulating the digestibility of low-grade roughage by rumen bacteria and is more effective with low-grade roughage or feed than high-grade. The following table shows suggested molasses feeding per head:

	Pounds Per Day		Pounds Per Day
Beef cattle	5	Hogs	1.5
Dairy cattle	3	Sheep	1.0
Horses, mules	4	Poultry	.01

Based on these amounts and the farm animal population, the potential consumption of molasses for feed purposes can be closely estimated for any given area. As an example, in the United States in 1953, if all farm animals had been fed the above stated molasses quota, 16,335,000,000 gallons of molasses would have been required, whereas the actual consumption was only 300,000,000 gallons. More recent investigations show an additional potential use in the feeding of poultry, one study showing that by the maximum use of molasses in poultry feed, the cost of eggs could be lowered approximately seven cents per dozen.

Industrial Uses

The industrial uses of molasses are numerous, although some uses do not account for an important portion of the consumption. It should be remembered that for many of these uses molasses is only one of many possible materials. The following is a representative list of typical uses or users:

Foundries	Leather tanning
Yeast production	Lamp black
Citric acid	Shoe polish
Vinegar	Health foods
Insecticides	Lactic acid
Graphite paste	Itaconic acid
Printing rollers	Kojic acid
Flavoring	Ethyl alcohol
Acetone	Other alcohols
Butanone	Rum
Biological products	Pharmaceutical products
Licorice	

Some conception of the relative importance of the various uses may be obtained from this tabulation of uses during 1955 in the United States:

Industry	Million Gallons
Animal feeds	428
Ethyl alcohol	70
Yeast, vinegar and citric acid	65
Butyl alcohol and acetone	35
Edible and miscellaneous	12
Spirits and rum	3
	613
Exported	10
Total marketed	623

The relative amounts consumed will vary greatly from country to country and period to period. During war periods, larger quantities of molasses were used in alcohol production, due to greater demands for alcohol coupled with the limitations put on the use of petroleum products for alcohol manufacturing.

By 1955, 78 percent of the alcohol produced in the United States was from petroleum and only 16 percent from molasses, the remainder coming from other materials. On the other hand, in parts of the

world where alcohol is an important fuel, a large portion of it may still be made from molasses. A typical yield is 62 gallons of power alcohol from one ton of molasses.

Another important development which may have considerable influence on molasses consumption in many areas is the increasing use of yeast as human and animal food and for flavoring, as distinct from its use in fermentation or bread raising. Yeast made from molasses is being used to improve the flavor of soups and to increase the food value of many foods.

RAW MATERIALS

The basic raw material, of course, is sugar cane. If cane is not cultivated in the area under consideration, a careful study of soil, climate and water supply (rainfall or irrigation) should be made to determine the adaptability of the area to cane culture. If this study indicates the area is favorable, further studies will be required to determine the varieties of cane best suited.

Any group sponsoring a mill development will find it necessary to take steps to insure an adequate cane supply. This may involve owning and operating cane lands, inducing farmers to change to cane raising, sponsoring training programs, securing government aids, etc. Also, an adequate supply of harvesting labor must be available during an extended cutting season. The location of cane fields must afford good transportation to the mill, or the mill owners must be prepared to arrange for construction of roads, railroads, flumes, etc.

In considering the area of cane fields required to produce a crop of the desired size for the capacity of the mill contemplated, the area in any one year must be multiplied by a factor based on the anticipated crop rotation system in order to produce a figure representing the total area to be used for cane raising at various times. This total area must meet the requirements for soil, climate, adaptability to cultivation and transportation.

Other raw materials needed are water, lime, sulphur and either yeast or sulphuric acid. Lime is often produced locally and the yeast or acid may be purchased or produced at the mill.

CANE AND CANE GROWING

Sugar cane, botannically known as Saccharum Officinarum, is a solid, jointed perennial grass. Varieties differ greatly in color and appearance. The cane stalks are one-half to three inches in diameter and usually 10 to 20 feet high, although some have been known to reach 42 feet. Sugar cane is now grown in all tropical and semi-tropical countries. Its origin is believed to be either India or China, and its use in the manufacture of sugar antedates history. White sugar was shipped from India to Europe in 500 A.D. By the 8th century, sugar cane was extensively cultivated in the Nile Delta. It was introduced into Santa Domingo soon after the discovery of the New World.

Cane does well in areas with an average temperature of 80°F. and at least 60 inches of rainfall or the equivalent in irrigation. Rich soil, careful fertilization and cultural practices are essential to secure substantial yields. The sugar content is greatly influenced by such factors as the distribution and amount of rainfall, fertilization, flowering, etc. Practices which produce the largest stalk yield per acre may decrease the yield of sugars per acre.

Cane produces seeds under favorable conditions, but since its propagation from these is very difficult, they are only used in the creation of new varieties and botannical experimentation. The manner of planting varies considerably in different areas, but all systems are based on the ability of pieces of cane to grow when buried in the soil. When cane is plentiful, whole cane may be buried. At other times, pieces one to three feet long containing several joints are used. Some planters prefer pieces from the upper part of the stalk, although collecting these interfers with the regular harvesting routine. Planting may be done by hand or machine. Rows are spaced four to six feet apart and the stalks covered two to four inches deep. From four to six tons of cane are required to plant one acre. Cane for planting is preserved through the winter by wind-rowing or matting in the fields.

Considerable cultivation and careful control of insects, diseases and weeds are required to secure a good crop. Elaborate irrigation systems are employed in some areas, and soil moisture is carefully controlled by accurate measurements in order to produce the highest sugar yield. Well managed plantations follow a scientific plan of crop rotation best adapted to their soil and climate.

The growing season is 8 months in Louisiana, 12 to 18 months in Cuba and other tropical countries, and may extend to 30 months in a few areas. In Louisiana, the harvest period is from October to January and in the tropics from January to mid-summer. In some areas, of which Hawaii is one, the fields are set afire and the leaves burned off prior to cutting. Recently military flame throwers have been introduced for this purpose.

After many failures, harvesting machines have been developed which cut off the cane, strip the leaves and pile the stalks for loading. Hand cutting is still used in most areas and becomes mandatory when cane has been damaged by hurricanes. For hand cutting, a strong knife with a blade 5 by 18 inches and a hook at the back is used. The cane is cut at or near the ground, the leaves removed with the hook, the top severed at the last matured joint and the stalks piled in rows.

On small plantations, cane is loaded by hand on carts or cars, but on the larger modern plantations tractors and other equipment are used to push the stalks into piles and to pick up the piles and dump them into cars or carts. In some cases the cane is carefully laid side by side on chains or ropes and tied into easily handled compact bundles for transportation and unloading at the mill.

In some areas, the cane is stacked upright in special railroad cars. In suitable terrain, it is sometimes floated to the mill on diverted streams. Although yields vary greatly, 30 to 40 tons of cane per acre are common. This volume per acre would fill three or four special cane railroad cars.

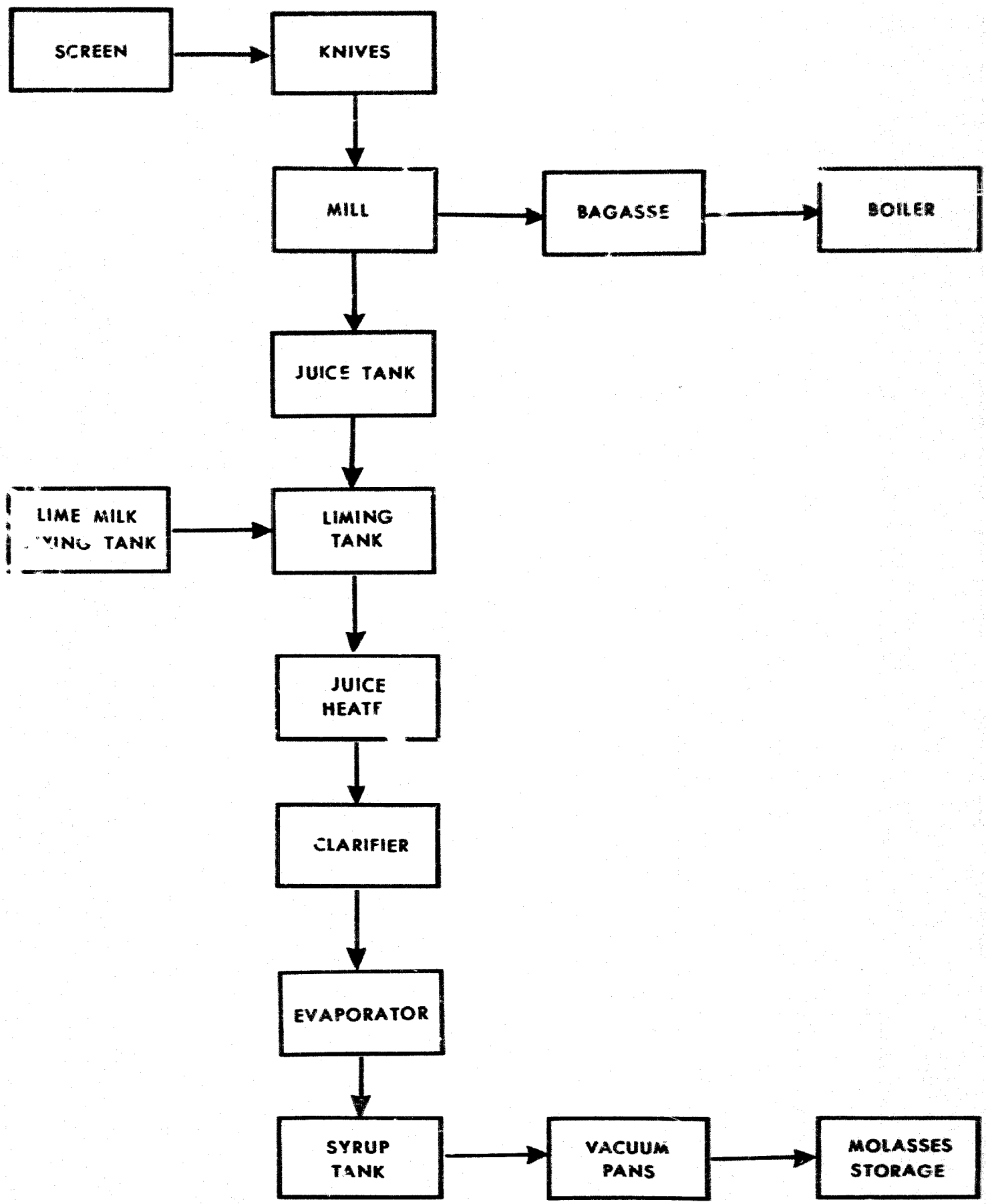
Cane cut near the surface of the ground leaves a stubble or ratoon which sprouts in the spring. In the United States, this produces a second or third crop; in the tropics five to ten crops are produced from one planting. The general practice where cane and labor are abundant is to plant annually or biannually.

PROCESSING

Following is a suggested process for the production of high test molasses. A flow chart is included. The exact method used will vary from mill to mill, since the regular equipment of a sugar mill is utilized as far as possible. As previously stated, normally high test production is not commenced until the raw sugar production is completed and is limited by quotas or other factors, although in a large mill with sufficient facilities, it is possible to produce raw sugar and high test molasses simultaneously.

The efficiency of the mill depends on proper basic design and correct operation under the guidance of a skilled sugar technologist, who will direct the operation as indicated by laboratory tests.

SIMPLIFIED FLOW SHEET FOR PRODUCTION OF MOLASSES



Extraction of Juice

There are two methods of obtaining the sugar bearing juice,(1) milling, in which the plant material is crushed and the juice squeezed or pressed out, and (2) diffusion, in which the cells of the material are damaged as little as possible and juice is secured by successive diffusion through the cell walls. Since milling is more applicable to cane, only this method is considered in this report.

Cane Mill

Because chemical changes occur in the cane following cutting, every effort is made to process the cane as cut, and very little is stored at the mill ahead of processing. In the larger modern mill, the incoming cane is handled by machinery. Derricks are used to unload the chained bundles, and overhead cranes or tilting platforms are used to dump trucks or carts.

The cane has a hard outer coat surrounding a mass of softer tissue interspersed with fiber (the fibro-vascular bundles). There is a thick layer of wax on the outside of the stalk. The goal of the milling process is to separate the sugar bearing juices from the non-sugar material as completely and efficiently as possible.

Prior to the actual start of mill processing, the newly arrived cane, or cane from temporary storage, is passed over grates or screens to remove trash, and in some cases it is passed over magnetic metal separators. The cleaned cane is then passed through cutters containing several sets of revolving knives which cut it into small pieces, breaking the fibers and rupturing the cells. Some knives have serrated edges to tear as well as cut the cane.

Between cutting or shredding and the actual juice extraction, many mills employ crushers, an extra set of rolls through which the cane passes. The crushers break up the cane, produce a more even blanket, reduce the strain on the mill, improve extraction, and increase mill capacity.

The modern mill contains three heavy rollers mounted horizontally. One of the rollers is mounted above and between the lower two so that the blanket of cane passes between the upper roller and each lower roller.

Power is usually applied to the upper roller and transmitted to the lower ones by gears, with the upper and lower rollers rotating in opposite directions. Rollers vary in length from 18 to 72 inches and in diameter from 12 to 32 inches. The surface of the rollers is grooved to provide channels for the juice. The upper roll is free to move vertically, or in some models at a slight inclination to the perpendicular, and is subjected to considerable hydraulic pressure.

Although juice may be extracted with one such three-roller unit or even a two-roller unit, the usual modern practice is to use at least two three-roller units in a series. Some plants employ as many as five sets. As the cane passes through each set of rollers in succession, the rollers are closer together and the pressure greater. The grinding capacity of such mills often varies from 200 to 1,400 tons per day and may be even greater in the newest mills. A large mill may have more than one such train, and total capacity may exceed 150 tons per hour. In good practice, the extraction is 70 to 80 percent of the cane weight, and 90 to 95 percent of the sugar in the cane is recovered.

Maceration

Increased extraction may be secured by maceration, that is, spraying the blanket of cane with hot or cold water or juice. The normal procedure is to use diluted juice from the third operation to spray between the first and second operations and water between the second and third. The quantity of water used will vary from 5 to 15 percent of the cane weight and may run as high as 20 percent. The determining factors in deciding how much water to use are the cost of fuel and the capacity of the evaporating equipment.

The value of maceration may be seen from the following example. It has been estimated that maceration increases the sugar extraction by four to six pounds per ton of cane. A factory with a grinding capacity of 500 tons per day, operating for 90 days, would process 45,000 tons of cane. If maceration increased the yield by five pounds (the average of the four to six pound figure) per ton, the total increase would be 225,000 pounds of sugar. If $0.055 per pound is taken as the value of the sugar, the 225,000 pounds are worth $12,375. If a ratio of 10 percent water were used, each ton (2,000 pounds) of cane would require 200 pounds of water, or approximately 25 gallons.

Since one pound of coal is capable of evaporating one gallon of water, the 25 gallons would require 25 pounds of coal. If the cost of the coal is $8 per ton, the 25 pounds would cost $0.10. The five extra pounds of sugar per ton of cane are worth $0.275 at $0.055 per pound.

Subtracting the $0.10 cost of the coal from the $0.275 increment leaves $0.175 as the net value added per ton of cane. The increase in value of the 45,000 tons of cane would be $7,875 per season. A similar calculation may be made for other mill capacities, sugar prices and fuel costs.

It should be noted that this rough estimate makes no provision for the added cost of the spraying and pumping equipment for maceration or for the greater evaporator or boiler capacity required.

Composition of Juice

The juice from the last operation, untreated except for straining to remove large particles, is gray-green or brown in color and is full of air bubbles. Not only does the color vary, but the composition of the juice will vary greatly from region to region, season to season, etc. The juice normally contains 0.2 to 1.0 percent suspended matter which is too finely divided to remove by straining methods. This consists of soil, trash, cane flake and a small amount of cane wax.

The juice has an acid reaction with the pH ranging from 4.5 to 5.4. From 12 to 14 percent of the weight of the juice is due to dissolved solids with 10 to 12 percent of the total weight being due to sucrose. The purity, expressed as the ratio of sucrose weight to total solid weight, will range from 80 to 86 percent. There also will be small and variable quantities of glucose, dextrose, levulose, fructose, organic acids, ash, nitrogen compounds, pectin, gums, albumen and coloring matters. There will be a difference in sucrose content of 2 to 3 percent from the beginning to the end of the grinding season.

Bagasse - A Residue

The wet fibrous material coming from the last operation after all possible juice has been extracted is known as final bagasse. This final bagasse may contain 1 to 4 percent sucrose, 40 to 50 percent water, 50 percent fiber and 2 percent ash. In certain areas of the United States, bagasse supplies two-thirds of the fuel requirements of a sugar mill and, due to the higher fiber content in the tropics, about all of a tropical mill's fuel requirements.

The fuel value of final bagasse is often stated to be 2,700 to 3,000 B.t.u., or 8,300 B.t.u. on a dry ash free basis. For purposes of rough calculations, 6 tons of wet or 3 tons of water-free bagasse may be taken as equivalent to 1 ton of bituminous coal.

Large mills burn bagasse in special stoker-fed bagasse-burning boilers, producing steam for driving the tandem turbines, evaporator operation, etc. Some of the largest of these plants produce over 100,000 pounds per hour of high-pressure high-temperature steam. The ash may be used for fertilizer.

If the size of the mill or other economic factors make the utilization of bagasse as fuel undesirable, there are a number of other uses, which, under some conditions, may be possible as a means of increasing mill income. Bagasse is used in some areas for the manufacture of wallboard and more recently in the manufacture of several types of paper and paper products. It is also mixed with molasses for use as cattle feed and in some areas is used as an agricultural mulch or litter.

Clarification

The purpose of clarification is to remove, as far as possible, the impurities present in the cane juice. By the use of chemicals or heat treatment, soluble impurities become insoluble, or solids, and are then removed by settling and filtration. The principal chemicals used are lime, sulfur and phosphoric acid. The sulfur is applied in the form of sulfur dioxide which breaches, disinfects, and coagulates some of the albumen and prepares the juice for taking more lime, which causes a heavier precipitation and results in a more thorough mechanical cleansing. Sulfur is not much used in the tropics due to the purity of the juice, but it is extensively employed in southern areas of the United States (where high-grade sulfur is mined) and in other areas where the juice contains large quantities of impurities.

Lime is always used and is the most important chemical in the sugar industry. In processing the juice for high test molasses, only about one-fifth as much lime is used as in other types of molasses. Lime neutralizes acids, acts upon the gums, albuminous substances, coloring matters, and, if applied in excess, upon the glucose.

The majority of the lime compounds thus formed are insoluble, but some are soluble. The insoluble compounds are removed by settling or filtration. The soluble lime compounds are removed by the addition of phosphoric acid to form the insoluble tri-calcium phosphate, or in some cases sodium carbonate is added to form calcium carbonate which is nearly insoluble.

Phosphoric acid is also used to correct any excess akalinity resulting from excessive liming. Sodium carbonate is very essential in correcting the acidity of sour juices. If any considerable quantity of lime salts is left in solution in the juice, it will precipitate or deposit on the coils of the pans, reducing their efficiency in heat exchange and mechanically restricting the flow of juice.

Concentration

After the juice has been clarified, it is piped to the multiple effect evaporators, and the process of heating and transferring from vessel to vessel is continued until the juice has become a syrup or melada of about 55 degrees Brix. The pH is below 6, which is less than the pH value of the melada in raw sugar production.

Inversion

In the early days of high test production, the melada was run into inverting tanks, the crystallizers often being used, and from one to two gallons of sulfuric acid added to each 100 gallons of syrup. This mixture was kept at a temperature of 195-200 F. until the inversion progressed far enough to give a polarization test of near zero. In this process, each molecule of cane sugar (sucrose) in the melada is hydrolyzed into one molecule of d-glucose and one of d-fructose. D-fructose is also known as levulose and the mixture of the d-glucose and d-fructose as invert sugar.

In actual practice, all the sucrose is not inverted. Sufficient milk of lime was then added to return the pH to the 6 range. The inverted syrup was then run into the single effects, that is, the regular vacuum pans where steam heat was used to evaporate excess water until a concentration of about 85 degrees Brix was reached.

Although heating in the presence of acid is an effective means of producing inversion, it was found that this process destroyed from 3 to 5 percent of the sugars present. The deep red color of the syrup was also objectionable for many uses. The difficulties caused by the acid inversion process have been eliminated by substituting enzymes for acid. Not only are lower temperatures required in the process, but neutralization of acid with lime is not necessary.

Strains of yeast rich in invertase have been developed by microbiologists. While it is possible to grow and develop a suitable strain

of yeast in last mill juice and concentrate this to a cream of yeast in a yeast separator, the intermittent nature of the high test operation and the greater economies possible by the use of purchased dry yeast have caused virtual abandonment of the production of yeast at the mill.

Approximately one-half pound of dry yeast is required for each 1,000 gallons of 55-degree Brix syrup from the evaporators. The inversion is performed in the regular crystallizers, or inverting tanks may be used. Steam is used to maintain a temperature of 140 F. The modern dry yeasts work much faster than the mill developed ones formerly used and the process takes only 6 to 8 hours. The rate of inversion is readily controlled by regulating the amount of yeast added. The extent of inversion is determined by direct polarization or by the water purity method in which case the goal is an apparent purity of about 15.

This enzyme method inverts about two-thirds of the sucrose in the syrup. This partially inverted syrup is drawn into vacuum pans and concentrated to 85 degrees Brix.

Storage

It is very important to avoid storage of high test molasses at high temperatures. If stored at 60°C. (140°F.), losses may run as high as 5 percent of all sugar present. The optimum temperature is 40°C. (104°F.) and the maximum 43°C. (109°F.). Some plants use artificial cooling, but this is not necessary if the concentrated syrup is placed in small tank cars to allow some cooling before delivery to the large storage tank.

Concentrated syrup, such as 85° Brix high test, keeps fairly well under proper conditions. A loss of one percent of the sugar in one year is considered normal.

The method of producing high test described above yields a product which is clear, light brown and of relatively standard composition. The concentration, or Brix, which is entirely under the control of the operator of the last evaporator, will be 80 to 85°, as measured by the refractometer or the double dilution method. The amount and composition of the sugar present is controlled by the inversion process. Two-thirds invert or reducing sugars and one-third sucrose is the usual goal.

A typical high test would consist of 52 percent reducing sugars calculated as invert sugar and 26 percent sucrose. There will be very little ash due to the small amount of lime added in clarification, the total mineral content being about two percent. The balance of the solids, about 6 percent, is undetermined non-sugar. About 14 percent is water. Since the composition is so largely carbohydrate, the Brix, as determined by the double dilution method, by the refractometer, or as true solids (100 minus moisture) will be in close agreement. The Brix of this typical high test would be about 84-85° by the first two methods and 86° by the true solids method. In contrast, the Brix for blackstrap is very much higher than the true solids.

UTILIZATION OF BY-PRODUCTS

Due to world-wide economic conditions, quotas, tariffs, etc., profit margins in the sugar and molasses industry have not been high, making recovery of all possible value from the raw material imperative. The uses of filter cake as fertilizer and animal food and the use of bagasse as fuel or raw material for wallboard or paper products have been mentioned previously in this report.

The investor contemplating making a substantial investment in a molasses production enterprise must give consideration to utilizing all by-products but must avoid being over-influenced by future potentials not available to his plant at the present time. For example, although several mills for manufacturing paper products from bagasse are successful after many failures, most cane mills are not located within shipping distance of such paper plants and may never be. Similarly, there may be no local market for other by-products.

ECONOMICS

Methods used in determining the price paid for cane vary considerably. Cane may be bought by the acre or ton for a fixed price or for a price determined by a formula based on raw sugar and molasses prices. A few mills base the price on the sugar content, but this, although a very fair method, is not extensively used due to local customs and the difficulties of making the required analysis.

The modern trend in many areas is toward formation of large processing plants, growers associations, etc. For example, the published 1955-56 report of one major company indicates that it crushed 852,190 short tons

of cane in a 38-1/2 week campaign and that the hourly rate of crushing was 156.89 tons. This huge quantity of cane came from both company and non-company land.

Some Factors Influencing Crop Yields, Plant Yields and Profits

As with any crop, the yield of cane depends on many factors, some under the control of the grower, some subject to mill control and others not influenced by man. In the case of sugar cane, the situation is complicated by the fact that the desired product is sugars (in the form of raw sugar or molasses) rather than mere tonnage of cane.

Factors which increase cane yield may reduce the yield of sugar. Particular varieties and suitability to the soil and climate, of course, are important. If the ratoon system is followed, the age of the plant is an important factor. The length of the growing season has a very direct relationship to sugar content of cane. Cultural practices, including soil preparation, crop rotation, cultivation, fertilizing, insect and weed control and harvesting methods influence yields of both cane and sugar.

Allowing the cane to tassel or bloom, while creating a beautiful effect, lowers the sugar yield. In some cases this is carefully controlled by constant checks on soil moisture using special test blocks throughout the plantations. Prevention of tasseling is said to increase sugar yields as much as two tons per acre.

Some idea of the varied results obtained in different areas is indicated by the fact that, although the typical yield often quoted is five tons of sugar per acre, the Bantu area of South Africa recently produced a yield of only one ton of sugar per acre, while yields up to 14 tons have been reached in Hawaii. On the company land of the major company referred to on page 15, the 1955-56 yield was 5.97 tons sucrose per acre. All these figures represent the sum of the efforts of both grower and mill.

Rainfall is probably the most important single element influencing crop yields. In 1947, the rainfall on the unirrigated island of Barbados was 30.97 inches and the 1948 crop was 78,226 tons of sugar. With 77.15 inches rainfall in 1950, the 1951 crop was 187,643 tons. A recent forecast by the United States Department of Agriculture was that, due to too little rainfall in 1956, no cane would be cut for high test molasses production on the entire island of Cuba which is one of the largest sugar producing areas. Recent technical literature contains references to cloud seeding as a means of increasing rainfall over plantation areas.

In addition to the effect of all the factors influencing sugar content considered under crop yields, the yield of sugar obtained by the mill from one ton of cane is influenced by the efficiency of the mill and the economic advantage to be gained by incurring additional expense to increase yields. The paragraphs on mill processes indicate the advantage to be gained by such steps as maceration.

The modern mill must be not only properly designed but properly operated if it is to attain maximum efficiency. Some of the newer mills are supplied with elaborate electronic devices to control the many delicate processes with a high degree of precision. Constant laboratory tests are made to determine the efficiency of the processing and to regulate temperatures, roll pressures, feeding rates, evaporator pressures, and quantities of water and chemicals used.

A primitive type mill does not have many of the features described in this report, does not produce a quality product and its yield will be low. A plant whose main aim is sugar production will require more elaborate equipment and interconnection of processing apparatus than would one with the efficient production of molasses as the sole purpose.

There are other factors besides efficiency of plant operation in producing the maximum amount of sugars for the least cost and maximum profit. The utilization of by-products has been mentioned elsewhere in this report. Further, for example, shortage of cane due to low rainfall, shortage of labor for cutting, or restrictions on processing could make it impossible for a mill to operate at an efficient rate or to produce a product of sufficient value to show a profit.

Since sugar and molasses are shipped extensively, over-production in one area may drive down prices elsewhere. For many years and in many countries, sugar and molasses have been the subject of an unusual number of laws, some designed to encourage production or export, others to restrict production or import, and many for fiscal or political purposes.

The unstable price of sugar and molasses has been mentioned in other sections of this report. Also, it must be realized that, for practical purposes, no profit is realized until the sugars are sold, and in many areas there is a large carry-over from preceding years. Lack of transportation for the liquid molasses could also be a problem in many areas.

Some Factors for Consideration

The problems faced by an investor in embarking on a molasses production enterprise will vary greatly in different parts of the world. It is unlikely that a plant for molasses production alone would be practical in an area where cane is now grown and sugar produced, as the excess capacity of the existing mills could probably handle a reasonable quantity of high test molasses production at a lower cost than could a new and separate plant. Also, the cane production from the best land might be controlled by existing mills.

Therefore, it must be assumed, for the purpose of this report, that the production of high test molasses is being considered for an area which at present is not raising sugar cane but in which sugar cane might be expected to be adaptable, or for an area now raising some sugar cane but only processing it into relatively crude sugar for local consumption.

MARKETING

It is not enough to make a product efficiently. It must be sold and sold at a profit. While the list of uses of molasses contained in this report may appear to be quite extensive, the reader must avoid the impression that any individual molasses plant could anticipate having all these users as potential customers. Some of the uses account for relatively small quantities of molasses and some are confined to certain geographical areas.

As mentioned previously, molasses was formerly used extensively for ethyl alcohol production in the United States but this use has largely been superseded by petroleum products. It will be recalled that over two--thirds of the molasses used in the United States in 1955 was used as cattle feed and that much of this use is dependent on the price relationship of corn and molasses so that a decline in the price of corn could seriously affect the demand for molasses or its price or both.

There is little molasses sold directly by producer to consumer. Most of it passes through the medium of brokers and large molasses dealers. A small mill in an area not now producing or consuming molasses might find some difficulty in getting the molasses into regular trade channels, which, for the most part, are set up to handle large quantities.

In considering the sale of molasses in a given area for animal feeding, thought must be given to local customs which are often difficult to change. The small amount used for dairy cattle as compared to beef cattle is also a factor. This could be quite important in sections where there are religious prohibitions against meat eating or where meat is not an important part of the diet.

An additional factor which might influence the use of high test molasses for animal feeding could develop from the emphasis currently being placed on vitamin and mineral values in molasses. Published analyses are usually of samples of blackstrap molasses. In the blackstrap process, most of the non-sugars in the cane juice are concentrated into a few gallons of blackstrap for each ton of cane.

In the high test process, the same quantity of non-sugars (including the vitamins and minerals) is spread over approximately six times as much high test. On the other hand, the small quantities of non-sugar solids present in the high test molasses is an advantage for some industrial uses, as their presence interferes with some processes.

As mentioned above, molasses from the less important sources is usually consumed locally by stock feeders. This would also very likely be the use made of the production from small cane or beet mills, particularly those in areas lacking a well organized molasses trade due to limited production or great distances from markets. Molasses for export is shipped from the mill to deep water terminals by railroad tank car or tank truck. These terminals have large metal or concrete storage tanks. At a few terminals, due to shallow water, barges must be used to shuttle the molasses to ocean going vessels. Ocean transport is by means of conventional tankers with capacities of 500,000 to 3,000,000 gallons.

Transportation in the country of destination may be by railroad tank cars of 6,000 to 10,000 gallon capacity, tank trucks of 3,000 to 4,000 gallon capacity, by inland barge or a combination of these. Smaller quantities are shipped in barrels, which in modern practice are steel drums of 55-gallon capacity, or even in 5-gallon cans. In some areas, distribution to farmers and feed mixers is made by tank truck to points up to 300 miles distance with the molasses being heated to facilitate handling.

In the areas of the world which are large users of molasses and in which commercial and economic development is well advanced, a highly organized molasses trade exists. In the United States, for example, there are large molasses terminals at several ports on the Atlantic, Pacific and Gulf coasts with barge lines extending long distances up some rivers.

Molasses is traded on the commodity market in the State of Louisiana in units of five tank cars.

Prices

The wholesale price of molasses has fluctuated over a wide range in the last decade. Many of these fluctuations are related to changing factors in the use of molasses in the feeding and fermenting industries.

The average wholesale price per gallon in New York was 31 cents in 1948, dropped to 16 cents in the first part of 1949 and by December 1949 was down to 8 cents. Low prices continued until the Korean war, which caused an advance to 37.5 cents in January 1951. By October 1952, the price was down to 11.5 cents. Prices in New Orleans, Louisiana are usually about one-half cent per gallon lower than New York prices. Much of the decline in price after 1945 is attributed to the increasing use of petroleum as a raw material in alcohol production, and the high price in January 1951 was largely due to heavy demands for molasses for fermentation into alcohol.

Since in many areas the cattle feeding use of molasses accounts for over two-thirds of the total consumption, the use of molasses for this purpose has considerable influence in determining the market price. Assuming no change in the relative acceptability of molasses for animal feeding, the quantities consumed will depend on the varying needs of the feeding industry. Prices are related to meat and dairy prices as well as to the prices of other feeds, as discussed under feeding uses.

In addition to feeding and alcohol, the only use, in the United States at least, which accounts for as much as 10 percent of the molasses consumption is fermentation into such products as yeast, vinegar and citric acid. Since all these may be produced by the fermentation of many other materials, molasses is in price competition with a wide variety of products in this field too.

CAUTION TO PROSPECTIVE INVESTORS

Throughout this report, emphasis is placed upon four basic facts:

1. Molasses as an industry is (a) a by-product of sugar mills, (b) an adjunct to animal feed producing or mixer mills, and (c) one source of basic raw material in the production of ethyl alcohol.

2. In all instances, molasses, regardless of its source or origin, is considered as a part of the sugar, feed mill or ethyl alcohol industries.

3. Industrial molasses encompasses (a) blackstrap molasses (the liquids remaining after removal of as much sugar as possible from the cane), (b) beet molasses (similar by-product of beet sugar), (c) hydrol (corn), (d) citrus molasses, and (e) molasses from other crops.

4. Industrial or commercial molasses is never produced to meet a demand for the molasses alone. It is very definitely a by-product of other production.

With the foregoing in mind and the fact that marketability of molasses fluctuates in most erratic variables, prospective investors are cautioned that embarking upon such an enterprise is highly speculative. Therefore, advice and guidance of a reputable firm of consulting management engineers should be sought before considering investment in as complex an industry as molasses processing.

In view of the foregoing, the construction and installation of a completely new facility for the processing and manufacturing of molasses is not considered economically feasible unless both price and demand for the product assume a radical change in world economics.

Obviously, economies undoubtedly could be achieved by those embarking upon such an enterprise if they resorted to the use of re-built machinery and careful planning and design.

This report, therefore, is prepared on just such a basis, and the following cost factors and estimates are based upon used equipment and facilities, with raw materials and labor factors at applicable current rates in the United States.

RAW MATERIAL REQUIREMENT

The juice content of sugar cane covers a wide range of percentages. This report is based on a cane variety from which 75 percent of the cane weight is extracted as juice. One ton of cane will produce 230 pounds of sucrose. The chemical equation for the inversion is:

$$C_{12}H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6 + C_6H_{12}O_6$$

Sucrose + water → d-glucose + d-fructose

Or, in units of atomic weight, 230 pounds sucrose combined with 18 pounds water produces 121 pounds d-glucose and 121 pounds d-fructose, or a total of 242 pounds of invert sugar, which is roughly increased by one-third when calculated as molasses, giving 322 pounds of molasses. At 12 pounds to the gallon, this would be 27 gallons of molasses.

To produce a capacity of 10,800 gallons of molasses per day would require 400 tons of sugar cane.

400 tons × 120 days = 48,000 tons per year

48,000 tons @ $6.15 = $295,200 per year.

BUILDING REQUIREMENTS

In tropical or temperate zones, the building costs would be nominal. A very simple type of construction would be adequate and would provide the necessary protection from the elements. Buildings of one-story design with steel framework and corrugated sheet metal sides and roof would be conservative in cost. The buildings are estimated to be economical and would cost approximately $25,000.

USED EQUIPMENT REQUIREMENTS

Truck scale	$ 1,100
Screen, bar type	450
Leveler	1,820
Knife set	2,600
Conveyor cane carrier	1,560
Cane mill	26,000
Juice tanks	1,228
Juice pumps with motors (5)	2,158
Juice storage tank with scale	1,456
Lime mixer tank with agitator	1,268
Lime milk pump with motor	273

Liming tanks	$ 1,031
Juice heater, 500 sq. ft.	8,450
Clarifier	5,200
Clear juice pump with motor	527
Evaporator, quadruple	32,500
Syrup rotary pumps with motors	465
Syrup tank	585
Vacuum pans, 8-ft.	10,400
Inverting tanks	3,120
Molasses pumps with motors	455
Storage tank with weighing unit	1,820
Molasses storage tank	780
Steam boiler, bagasse burning, complete	104,000
Boiler feed pump with motor	1,400
Motor generator unit with panel	2,100
Vacuum pump with motor	580
Steam turbine	10,300
General service water pump with motor	1,030
Condenser service water pump with motor	840
Piping, valves, etc.	8,400
Miscellaneous items	5,200
	$239,096

DIRECT LABOR

The mill would operate only four months per year, three shifts daily:

4 mos. × 30 days × 8 hrs. × 3 shifts = 2,880 hours

5 men per shift @ $1.25 per hour = $6.25 per hour

$6.25 per hour × 2,880 hrs. = $18,000 direct labor cost per year.

INDIRECT LABOR

	Per Year
Maintenance (1 man per shift) @ $1.60 per hour × 2,880 hrs.	$ 4,608
Supervision (1 man per shift) @ $2.25 per hour × 2,880 hrs.	6,480
General Manager	6,000
Stenographer and office (1 man, day shift) @ $1.80 × 960 hrs.	1,728
Power plant operator (1 man per shift) @ $2.00 × 2,880 hrs.	5,760
Total indirect labor per year	$24,576

SELLING AND GENERAL EXPENSE

Power, electric	$ 2,500
Selling expense	7,500
Total per year	$10,000

SALES REVENUE

Annual production: 10,800 gal. × 120 days = 1,296,000 gal.

Estimated selling price of molasses is $0.25 per gal.

1,296,000 gal. @ $0.25 = $324.000 sales revenue per year.

ESTIMATED WORKING CAPITAL

Inventory:	
Sugar cane, 500 tons @ $6.15	$ 3,075
Work-in-process, 1,000 tons @ $6.15	6,150
Finished goods, 21,600 gal. molasses @ $0.25	5,400
Total inventory	14,625
Direct labor (1 month)	4,500
Indirect labor (1 month)	6,144
Selling and general expense (1 month)	2,500
Total estimated working capital (1 month)	$27,760

ESTIMATED FIXED CAPITAL

Land	$ - -
Building	25,000
Equipment	239,096
Total estimated fixed capital	$264,096

ESTIMATED TOTAL CAPITAL

Working capital	$ 27,769
Fixed capital	264,096
Total	$291,865

PROFIT AND LOSS PROJECTION

The following is an estimated profit and loss statement for the period of four months continuous 24-hour daily operation. It is contemplated the mill would operate only four months per year.

Net sales		$324,000
Less cost of goods sold:		
Raw materials	$295,200	
Direct labor	18,000	
Indirect labor	24,576	337,776
Gross profit on sales		(13,776)
Depreciation:		
Building, 5%	1,250	
Equipment, 7%	16,737	
Total depreciation	17,987	
Selling and general expense	10,000	27,987
Net profit (before taxes, insurance and miscellaneous expense)		($41,763)*

* Loss.

Interpolation using local costs for labor, raw materials, selling and general expense and the local selling price of the finished product could conceivably offset portions of the indicated loss. It should be apparent, however, as previously mentioned, that the establishment of a plant for the production of molasses alone is a highly speculative venture.

ENGINEERING FIRMS AND EQUIPMENT MANUFACTURERS

The following is a representative list of engineering firms serving the sugar industry and companies producing major items of mill equipment. Some of these firms both design mills and sell equipment.

Western States Machinery Co., Hamilton, Ohio

Honolulu Iron Works, 165 Broadway, New York, New York (also Honolulu and Hilo, Hawaii, and Manila, Philippines)

Farrel-Birmingham Co., Ansonia, Connecticut

Fulton Iron Works Co., St. Louis, Missouri

Squier Corporation, Buffalo, New York

St. Mary Iron Works, Franklin, Louisiana

Dorr-Oliver, Stamford, Connecticut

Silver Engineering Works, Deven, Colorado

Allis Chalmers Manufacturing Co., Milwaukee, Wisconsin

Edwards Engineering Corporation, New Orleans, Louisiana

Wolf Management Engineering Company, 7 South Dearborn Street, Chicago 3, Illinois

Thomas Broadstreet and Sons, Huddersfield, England

Duncan Stewart and Co., Glasgow, Scotland

Maschinenfabrik Buckau R. Wolf, Greuenbroich-Neuss, Germany

Braunschweigische Maschinenbauanstalt, Braunschweig, Germany

Ciede Fives-Lille, 7 Rue Montalivet, Paris VIII, France

Societe Francais de Constructions Mecaniques Denam (Nord), 14 Rue Cambaceies (8), Paris, France

Gebr. Stork and Co., Hengelo, Netherlands

Abarca, Miramar-Santurce, Puerto Rico

GLOSSARY

Baume - An arbitrary scale of specific gravity measurements largely superseded in sugar technology by the Brix scale.

Brix - A system of measurement of the concentration of sugar in water solution. The degree Brix equals the percentage by weight of sugar.

Clarification - Any process which reduces the turbidity of a sugar solution, such as defecation.

Defecation - The process of forming in a solution an insoluble material in fluffy form to trap or envelope other insoluble substances in the solution.

Invert Sugar - The d-glucose and d-fructose produced by heating sucrose in the presence of acid or enzymes. The term inversion has reference to the different direction in which a beam of polarized light is rotated by regular sugar, that is, sucrose and invert sugar.

Mud - The insoluble substances removed from a sugar solution by defecation.

Reducing Sugars - Sugars which possess the property of reducing, in alkaline solutions, compounds of copper, silver and other readily reducible metals, to lower oxides which are precipitated, or even the free metal which is precipitated.

Sugar Solids - The sum of the sucrose and invert sugar percentages in a solution.

Sucrose - The regular sugar sold as cane or beet sugar. When pure, it is a white crystal, soluble in half its weight of water and more soluble in hot water.