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ANT REQUIREMENTS FOR MANUFACTURE OF REFINED SUGAR

SMALL INDUSTRY SERIES

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FOREWORD

The purpose of this report is to present basic information for establishing and operating a plant to refine sugar from sugar cane in a country with a tropical or semi-tropical climate. The information includes general manufacturing methods, plant layout, and costs of materials, equipment, and labor based on the assumptions contained in this report.

The plant described is considered to be the economic minimum in size which utilizes suitable equipment and methods. Products are to be simple and varieties limited in order that costs may be kept to a minimum.

As an essential preliminary, potential plant operators must determine whether or not there is a market for the products of this plant. Naturally, they must be willing to assume the risks inherent in any business. The profits shown in the profit and loss statement are illustrative and depend upon market conditions, good management, and local factors.

For further information and assistance, readers should contact their local Productivity Center, Industrial Institute, Servicio, or United States Operations Mission.

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PLANT REQUIREMENTS FOR MANUFACTURE OF REFINED SUGAR

INTRODUCTION:

The ancients longed for a land "flowing with milk and honey." Probably the "honey flowing reeds" of these ancients were sugar cane. Sugar was known in India in 600 B.C., and was introduced into Europe by the Arabs. Christopher Columbus is said to have introduced the plant into Cuba. Sugar, a pure carbohydrate, is a quickly assimilated, energy-giving food which is greatly in demand throughout the entire world.

According to Goode's World Atlas, the entire production of cane sugar amounts to 18,375,340 short tons which originate as follows:

Latin America

Cuba	16.0%	Hawaii	5.0%
Brazil	6.2	Australia	4.4
Puerto Rico	4.8	U.S.A.	2.2
Dominican Republic	2.6		
Argentina	2.4	All other places	7.6
Peru	2.4		
Other	7.5		

Asia

India and Pakistan	19.3%
Indonesia	6.5
Formosa	6.5
Philippine Islands	5.4

There are numerous natural sources of sugar. The principal ones are:

Sugar Cane - (Bot. Saccharum Officiarum) grows in tropical or semi-tropical climates and is a perennial lasting from 2 to 40 years.

Sugar Beet - This is a large white beet root from which sugar is extracted; the process was initially developed in Germany about two hundred years ago.

Sugar Grape - This is a small grape that is dried in the sun. When dry, the grapes are called raisins or sultanas.

Sugar Maple - This is the Canadian maple tree, and sugar is made from its sap.

Saccharose (sucrose) is the general name of any crystalline sugar having the formula $C_{12}H_{22}O_{11}$.

This report contemplates that the plant will be located near the sugar cane producing area. That is so that harvested cane may be brought quickly and directly to the mill. Production of cane varies with many conditions such as soil, temperature, water, and climate; and yield amounts to from 40 to 75 tons per acre. The plant herein described requires an input of some 600 to 800 tons of cane per day for its economical operation and the harvesting campaign usually lasts about five months. It is therefore assumed that it will draw its raw materials from an area of not less than 2,000 acres under cultivation.

The output of this plant will amount to approximately 60 tons of refined sugar per day. It is assumed that this quantity will be removed promptly from the plant to a suitable warehouse and distribution center.

The plant described in this report performs the complete processing of sugar from cane through packaged, refined sugar. However, it is usual to perform the processing at two locations. The raw sugar is produced near the cane growing areas by mills usually called "centrals." The raw sugar from several centrals is then shipped, often long distances and usually overseas, to great refineries at the seaports of more densely populated areas where the consumption is high.

GENERAL ASSUMPTIONS:

In order to make realistic estimates, certain assumptions must be made. These are:

1. The costs of building, equipment, and material necessary are based on United States prices.

2. Labor costs used are the average labor costs for the industry and skill described, based on recently published figures of the United States Bureau of Labor Statistics.

3. All other costs, statistics, and figures are based on current United States prices.

4. Adequate water is available at the plant site; power is generated as required.

5. Adequate transportation facilities are available at the plant site.

6. The plant operates on a continuous basis for the duration of the harvesting campaign which is estimated as five months.

7. The following items cannot be estimated realistically:

   a. Distribution methods and selling costs.
   b. In-freight and out-freight.
   c. Land value.
   d. Taxes, insurance, and interest.

   Therefore, they are not included in the calculations except for general estimates in the working papers in the appendices.

8. Machinery is set up to perform only one function in the process, so no setup time is required and none is allowed in the unit cost calculations.

PRODUCT SPECIFICATIONS:

The plant described in this report produces 99.9% pure sucrose or crystalline cane sugar. It is packaged in wooden barrels containing approximately 400 pounds for the industrial user, and in paper bags or cardboard containers of 1, 2, 5, or 10 pounds capacity for the consumer.

As by-products of the production of sugar, molasses (blackstrap) may be sold to the fermentation industries, and bagasse or megasse (wood fibre) may be used as fuel or sold for the manufacture of insulating or wall board.

PRODUCTION PROCESS:

Cane sugar is produced from a plant which is a member of the grass family, Graminacae. The cultivation of sugar cane requires tropical or semi-tropical temperatures and a great deal of rain. This limits its successful growth to those regions within, or adjacent to, the isotherms of 68° F.

There are many varieties of sugar cane. Each is grown in the region which is most favorable because of climatic and soil conditions, or resistance to the diseases of cane prevalent in that area. It grows from 5 feet in height to a height of 25 to 30 feet, but commonly ranges from 10 feet to 15 feet. The stems are from 1 to 3 inches in diameter.

Sugar cane is propagated from cuttings from the stalk rather than from seed. Sections of the stalk, each containing two or three buds which are located at a node or joint, are planted in the ground with a shallow covering of earth. Growth arises from the bud as several shoots known collectively as a stool.

A decreasing yield results from subsequent cuttings so it is not feasible to harvest cane for many years from one planting. The first crop after planting is known as plant cane; subsequent crops from the same planting are known as ratoons.

Harvesting is usually started just before the crop is fully matured in order that the entire crop may be disposed of before it has passed the optimum state of maturity. The stalks are cut off just above, at, or a little below the ground. The tops, because of their lower yield, are chopped off, and the leaves stripped. Burning the leaves off may be advantageous when there is objectionable weed growth, but cane from burned fields is subject to spoilage during wet weather because the action of microorganisms is favored. The sooner cane is hauled to the mill, the higher the yield of sucrose will be.

There are several variations to the process of making sugar. Following is a general outline of the process.

Crushing. When the cane reaches the mill (see figure 1), it is subjected to a process of slicing, shredding, or chipping, which reduces the cane to pieces of small size. This operation is not primarily to obtain juice, but to facilitate extraction in the crushing process which follows. Crushers consist of three grooved or toothed rolls through which the shredded cane is passed.

There are generally three or more sets of these three-roller mills employed in pressing out (extracting) the juice from the cane. By the time the cane has gone through the shredder and the first mill about 60% of the juice has been extracted. The succeeding mills express additional quantities of juice -- water or dilute juice usually being added to facilitate the removal of as much as possible at the final regrinding and milling. The woody fibre left as a result is known as bagasse or megasse.

Purification of the juice. The purpose of purification, also called clarification or defication, is to remove the largest possible amount of impurities from the juice at the start. Clarification is effected by the use of sulfur dioxide (SO_2), lime and heat. For a picture of a clarifier, see figure 2. The amount of SO_2 and lime used, the way in which they are added, and the temperature to which the juice is heated are variable factors depending upon the region and conditions. The more common way of adding lime is that of mixing a definite amount in the form of milk of lime ($Ca(OH)_2$) with a weighted quantity of the cold juice. The exact amount of lime to be used, until recently, was determined by various methods employing different indicators and titrating. It is now common to adjust the juice to the desired hydrogen ion concentration by means of pH determining apparatus. Best results are obtained when the pH of the cold juice is brought up to 8 or 8.5. Some of the factors which must be considered in regulating the pH of the juice are: inversion of sucrose, destruction of sucrose, destruction of

glucose, clearness of the juice, increase in purity, and the volume of the settling.

The temperature is generally raised to boiling after liming. A flocculent precipitate containing calcium phosphates and other insoluble salts carries down finely divided material in the juice, including coagulated albumen, fat, gum, and wax. The juice is then permitted to settle and the clear liquid decanted. The mud, slops, or sludge which remains is pressed in a filter (see figure 3), and the juice extracted by the filters is mixed with the purified juice. The combined clarified juice is evaporated in multiple-effect vacuum evaporators to a syrup containing about 35 to 45 per cent of water.

Crystallization. The concentrated juice, or syrup, is further evaporated in vacuum pans until it is saturated with sugar (see figure 4). When the syrup becomes saturated, crystals of sugar separate out. As water evaporates, more syrup is added to the pan and sugar is deposited on the crystals already formed. The mass of syrup and sugar crystals finally obtained is designated by the sugar manufacturers as massecuite, magma, or melada.

Centrifuging. The massecuite is placed in centrifugals (see figure 5) with perforated metal baskets which have a lining of wire cloth and perforated bronze sheets. Crystals of sugar remain in the basket while the liquor, or molasses, is thrown out through the perforations by centrifugal force. The crystals of sugar are brown and some syrup still adheres. This sugar, known as raw sugar, may be further prepared for consumption by refining. The molasses still contains crystallizable sucrose and is therefore mixed with syrup and returned to the vacuum pans. The new massecuite is centrifuged and molasses again returned to the vacuum pan to be treated as before. After the centrifugal treatment has been repeated three times, the higher quality A and B sugars are ready to be bagged and the C sugars, of lower grade, are returned to the vacuum pans as seed for more A and B sugars. Molasses of such low sucrose concentration that removal of sucrose is uneconomical is called blackstrap and is largely used in the fermentation industries.

To produce a higher quality white sugar, a further refining process may dissolve the crystals in hot water, passing the liquid through an activated carbon filter. The water is then evaporated in a vacuum and the sugar passed through a centrifugal which throws off most of the remaining molasses.

The crystalline sugar is washed to remove the remaining film of molasses, and passed through a revolving agitator (see figure 6) where it is dried in a heated air current and emerges as white crystals of granulated sugar. These are sifted through wire mesh screens from which they pass to the automatic packaging machinery (see figure 7).

The process for making sugar can be shown graphically as in figure 8.

PLANT LAYOUT:

Approximately 25,000 square feet of floor space are required. Figure 9 indicates possible space allocations.

BUILDINGS AND EQUIPMENT:

The following equipment roughly outlines the most important items of a 600 to 800 metric ton sugar factory:

1. Rotary cane hoists, electrically driven, 60' beams, capacity 10 tons, all steel construction.

2. Cane feeder table, all steel construction, driven by 5 HP motor.

3. One (1) auxiliary cane carrier, about 6' wide x 80' long, all steel construction, with roller chains and steel slats driven by a 25 HP electric motor.

4. One (1) main cane carrier, 42" wide x 100' long, all steel construction, with steel chain, sprockets, shafts, and the like, and driven by one 25 HP electric motor.

5. One (1) rotary cane leveler mounted on shaft and driven by one (1) 15 HP motor.

6. Two (2) sets of cane knives mounted on rotating shafts; each driven by one (1) 100 HP electric motor.

7. One (1) magnetic separator.

8. Five (5) heavy duty, 3-roll cane mills, 25" x 42". Each mill driven by one (1) 150 HP motor, complete with all accessories. (The mills would be driven by individual electric motors and all auxiliary equipment of the factory such as pumps, conveyors, and the like would also be motor driven.) The factory would be completely electrified.

9. Complete set of tanks, pumps, conveyors, air compressors, and so on.

10. Two (2) 600 square foot horizontal juice heaters.

11. One (1) clarifier, approximately 20' diameter.

12. One (1) multiple-effect evaporator of approximately 10,000 square feet heating surface, complete with condenser and accessories.

13. Three (3) vacuum pans about 8' diameter, complete with all accessories and condensers.

14. Four (4) electrically driven centrifugals with frame and accessories.

15. One (1) complete refinery using vegetable carbon as a refining medium and of a capacity to refine the complete output of the factory which should amount to approximately 60 - 70 metric tons of sugar per day.

16. One (1) complete station for bagging and packing the granulated finished sugar.

17. Power plant containing two (2) 750 KW turbo-generators; one (1) 250 KW diesel generator, with all necessary switchgear and wiring in the entire factory.

18. Three (3) 500 HP water tube boilers with furnaces and accessories.

19. All necessary buildings of steel construction with approximately 25,000 square feet of floor space and with corrugated siding and roofing, ventilating sash, windows, steel doors, and the like.

It is estimated that a factory of this size would cost about $2,750,000 delivered along side ship at a United States port.

The expense for transporting, assembling, and erecting such a plant would in all probability cost up to $100,000, making an estimated total erected plant cost of $2,850,000.

The automotive and tractor equipment required will amount to approximately another $50,000, making a total plant cost of $2,900,000.

One week's inventory of cane would be about $25,000.

The investment for necessary operating supplies, including chemicals, containers, repair parts, and office supplies, will amount to about $75,000.

Another $250,000 would be required as a cash revolving fund to meet operating expenses.

Another $200,000 would be required to finance accounts receivable amounting to an assumed 30 days' sales.

These figures do not include any investment to finance plantations which some concerns operate to raise their own sugar cane.

LABOR:

The manpower requirements, of course, would vary with organization and practices for any particular area. However, a total of 125 people per day on a three-shift basis would be needed to operate the factory for a campaign which generally lasts about five months.

To operate such a plant would require a permanent staff of:

	Estimated	Actual
Management - 5 @ $10,000 per year	$ 50,000	_____
Operating staff - 20 @ $4,000 per year (Most of whom are skilled workers)	80,000	_____
And for seasonal direct labor for the 150-day duration of the campaign:		
100 @ $1.25 per hour or $10.00 per day	150,000	_____
Total annual payroll	$280,000	_____

CAPITAL REQUIREMENTS

	Value Estimated	Value Actual
Land	No figures	_____
Buildings, equipment, and machinery	$2,900,000	_____
Raw material inventory	25,000	_____
Operating supplies	75,000	_____
Working capital	450,000	_____
Total capital requirements	$3,450,000	_____

PROFIT CALCULATION:

		Actual
Campaign - 5 months (operate continuously)	150 days	_____
Input		
Sugar cane, 600 metric tons per day (This represents the yield of upwards of 2,000 acres under cultivation)	90,000 tons	_____
Output		
Refined and packaged sugar, 60 metric tons per day	9,000 tons	_____
Which at a gross refinery price of $8.50 per 100 pounds or $187 per ton represents approximately	$1,681,000*	_____

*Customers would probably include jobbers, large grocery houses, and manufacturers using sugar such as candy and soft drink manufacturers.

Operating Expenses

	Value Estimated	Value Actual
Cane 90,000 tons @ $6.00/ton	$ 540,000	
Labor - 125 men	280,000	
Power	50,000	
Operating supplies	170,000	
Depreciation (7% of $2,900,000)	203,000	
Selling expenses (excluding freight)	80,000	
Operating profit (before taxes)	358,000	
Total	$1,681,000	

SUMMARY:

This report shows that a plant to produce refined sugar can be established for a total capital investment of $3,450,000. The fixed assets will total $2,900,000 and the working capital $450,000. The efficient operation of this plant should result in yearly profits of approximately $358,000 before taxes.

Production will require a permanent staff of about 25 workers including 5 management men and at least 15 skilled workers. During the 5-month manufacturing campaign, an additional 100 men would be required so that operations can run continuously.

The data in this report were drawn from a variety of sources. The equipment requirements and the processes conform generally with similar practices where they exist in the United States. The manpower requirements are those suggested by equipment manufacturers.

An experienced engineer analyzed the data obtained in the light of his knowledge and augmented it in areas where additional information was needed. The financial ratios of profits to sales, profit to working capital, return on investment, and the like are based on realistic United States practices.

APPENDIX I - WORKING PAPERS - FIRST YEAR'S OPERATIONS

ASSETS	Pre-operations Period		1st Quarter's Operations		Trial Balance		2nd Quarter's Operations		Trial Balance		3rd & 4th Quarters' Operations		Trial Balance		Manufacturing		Profit and Loss		Balance Sheet End of Year	
	Debit	Credit	Debit	Credit	Debit	Credit	Debit	Credit	Debit	Credit	Debit	Credit	Debit	Credit	Debit	Credit	Debit	Credit	Debit	Credit
Current Assets																				
Cash	400,000		180,000	415,000	167,000		293,000	246,000	214,000		585,000	166,000	633,000						633,000	
Accounts Receivable			182,000		142,000		182,000	142,000	142,000		142,000	142,000	142,000						142,000	
Inventories-beg. of year																				
Raw Materials	25,000				25,000			25,000			25,000		25,000		25,000				25,000	
Work-in-Process																				
Finished Goods																				
Supplies	75,000				75,000			25,000	50,000		25,000		75,000		75,000				75,000	
Fixed Assets																				
Machinery and Building	2,900,000				2,900,000				2,900,000				2,900,000						2,900,000	
Reserve for Depreciation												203,000		203,000						203,000
Land																				
Net Worth																				
Capital Account		3,450,000				3,450,000				3,450,000				3,450,000						3,450,000
Surplus																				142,000
OPERATING ACCOUNTS																				
Income																				
Sales				292,000		292,000		293,000		585,000		585,000		1,170,000				1,170,000		
Expenses																				
Purchases																				
Raw Materials			226,000		226,000		152,000		378,000				378,000		378,000					
Supplies			55,000		55,000		40,000		95,000		24,000		119,000		119,000					
Wages			98,000		98,000		74,000		172,000		52,000		224,000		224,000					
Light, Heat, and Power			18,000		18,000		14,000		32,000		8,000		40,000		40,000					
Selling and Other Expense			16,000		16,000		16,000		32,000		32,000		64,000				64,000			
Depreciation											203,000		203,000		203,000					
Inventories-end of year																				
Raw Materials																25,000				
Work-in-Process																				
Finished Goods																				
Supplies																75,000				
Cost of Goods Manufactured																964,000	964,000			
Surplus																	142,000			
	$3,450,000	$3,450,000	$705,000	$705,000	$3,742,000	$3,742,000	$731,000	$731,000	$4,035,000	$4,035,000	$1,096,000	$1,096,000	$4,823,000	$4,823,000	$1,064,000	$1,064,000	$1,170,000	$1,170,000	$3,795,000	$3,795,000

APPENDIX II - WORKING PAPERS - SECOND YEAR'S OPERATIONS

ASSETS	Balance Sheet Beginning of 2nd Year		Second Year's Operations		Trial Balance		Manufacturing		Profit and Loss		Balance Sheet End of 2nd Year	
	Debit	Credit	Debit	Credit	Debit	Credit	Debit	Credit	Debit	Credit	Debit	Credit
Current Assets												
Cash	653,000		1,623,000	1,120,000	1,156,000						1,156,000	
Accounts Receivable	142,000		200,000	142,000	200,000						200,000	
Inventories-beg. of year												
Raw Materials	25,000				25,000		25,000				25,000	
Work-in-Process												
Finished Goods												
Supplies	75,000				75,000		75,000				75,000	
Fixed Assets												
Machinery and Building	2,900,000				2,900,000						2,900,000	
Reserve for Depreciation		203,000		203,000		406,000						406,000
Land												
Net Worth												
Capital Account		3,450,000				3,450,000						3,450,000
Surplus		142,000				142,000						500,000
OPERATING ACCOUNTS												
Income												
Sales				1,681,000		1,681,000				1,681,000		
Expenses												
Purchases												
Raw Materials			540,000		540,000		540,000					
Supplies			170,000		170,000		170,000					
Wages			280,000		280,000		280,000					
Light, Heat, and Power			50,000		50,000		50,000					
Selling Expense			80,000		80,000				80,000			
Depreciation			203,000		203,000		203,000					
Inventories-end of year												
Raw Materials								25,000				
Work-in-Process												
Finished Goods												
Supplies								75,000				
Cost of Goods Manufactured								1,243,000	1,243,000			
Surplus									358,000			
	$3,795,000	$3,795,000	$3,146,000	$3,146,000	$5,679,000	$5,679,000	$1,343,000	$1,343,000	$1,681,000	$1,681,000	$4,356,000	$4,356,000

APPENDIX III - BIBLIOGRAPHY:

Name	Author	Publisher
The Manufacture of Sugar from the Cane and Beet	Heriot, T. H. P.	1920, Longman Green Co., London
Principles of Sugar Technology	Honig, P.	1953, Elsevier Publishing Co., New York
The Story of Sugar	Strong, L. A. G.	1954, Geo. Weidenfield and Nicolson, London
Sugar - Where Does It Come From?	Fawcett, R.	1952, Gawthorn Ltd., London
Technology for Sugar Refinery Workers	Lyle, O.	1941, Chapman Hall, London

APPENDIX IV -- ILLUSTRATIONS:

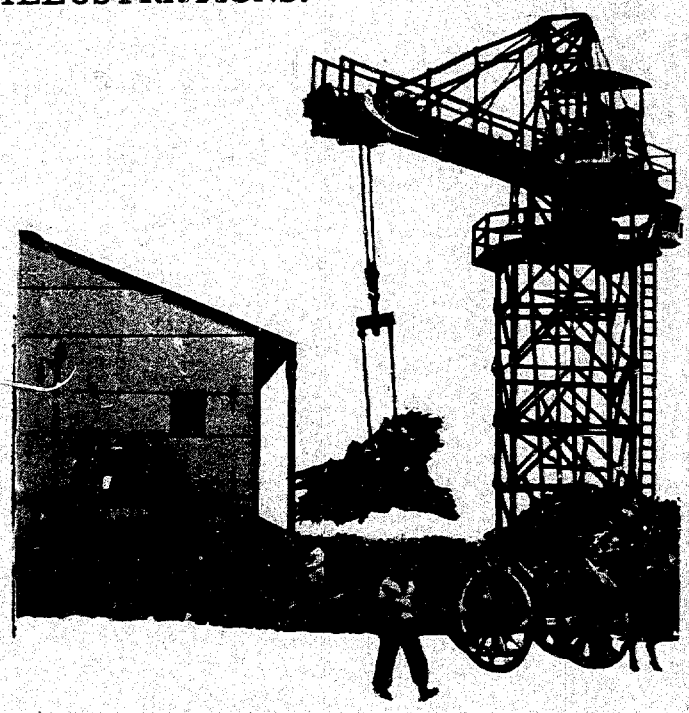

Figure 1 - Tower crane for handling sugar cane

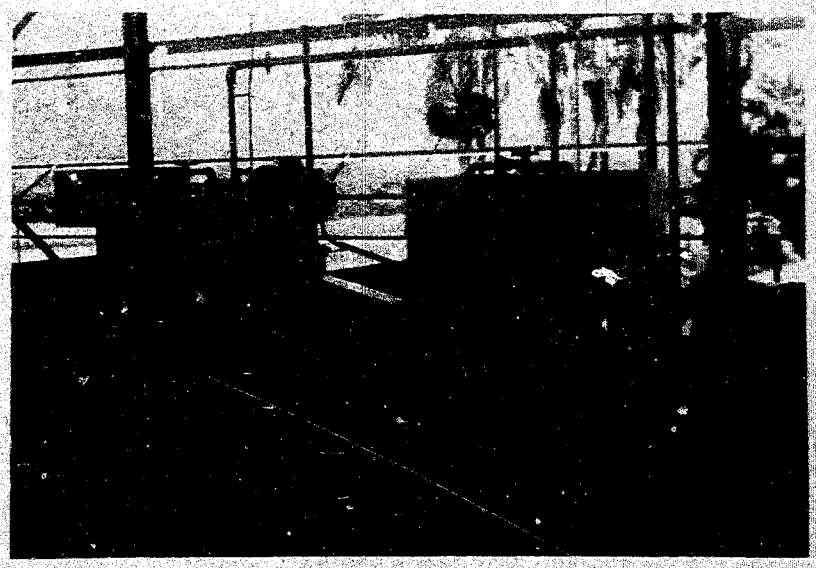

Figure 2 - A clarifier

Figure 3 - A filter

Figure 4 - A vacuum pan

Figure 5 - A battery of four centrifugal machines

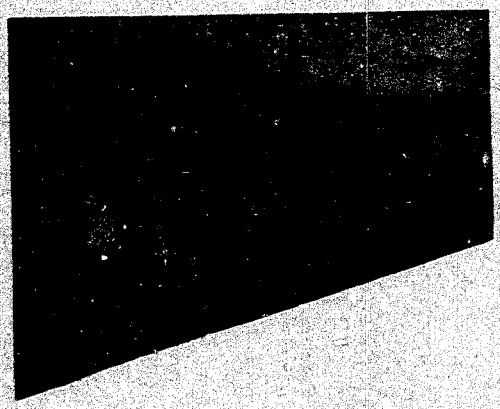

Figure 6 - A dryer consisting of a revolving agitator

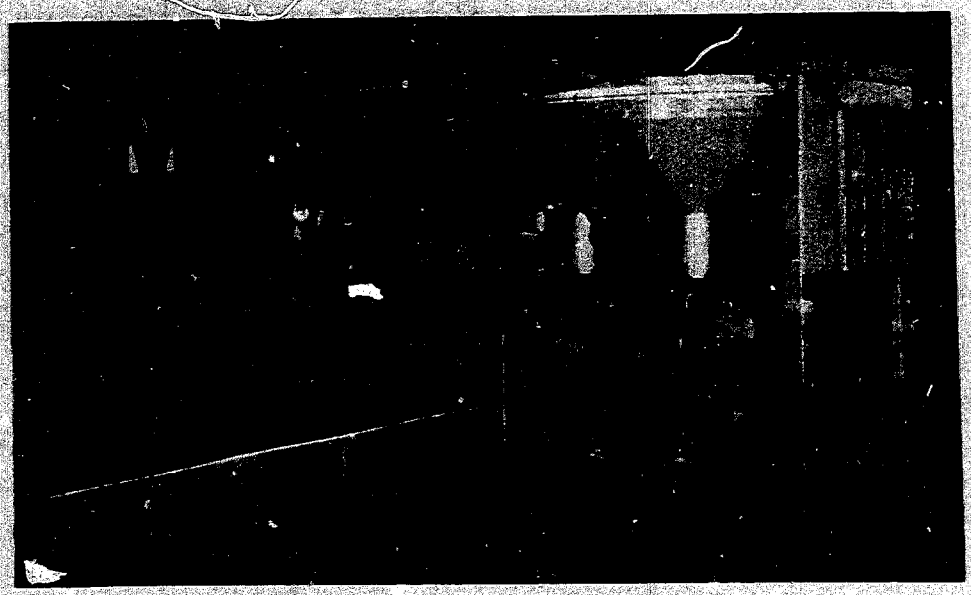

Figure 7 - An automatic packaging station

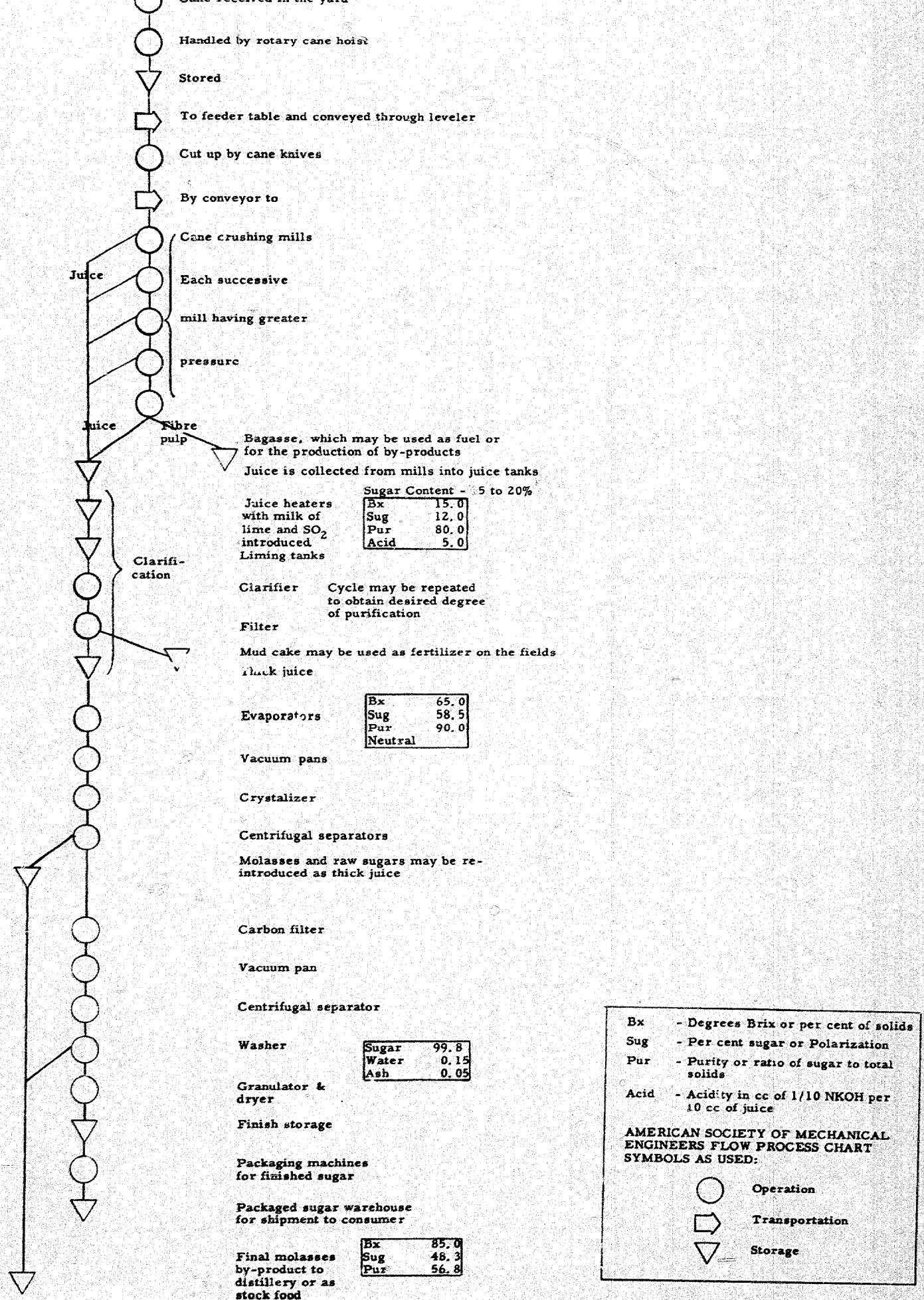

Figure 8 - Diagram showing a way to extract and refine sugar

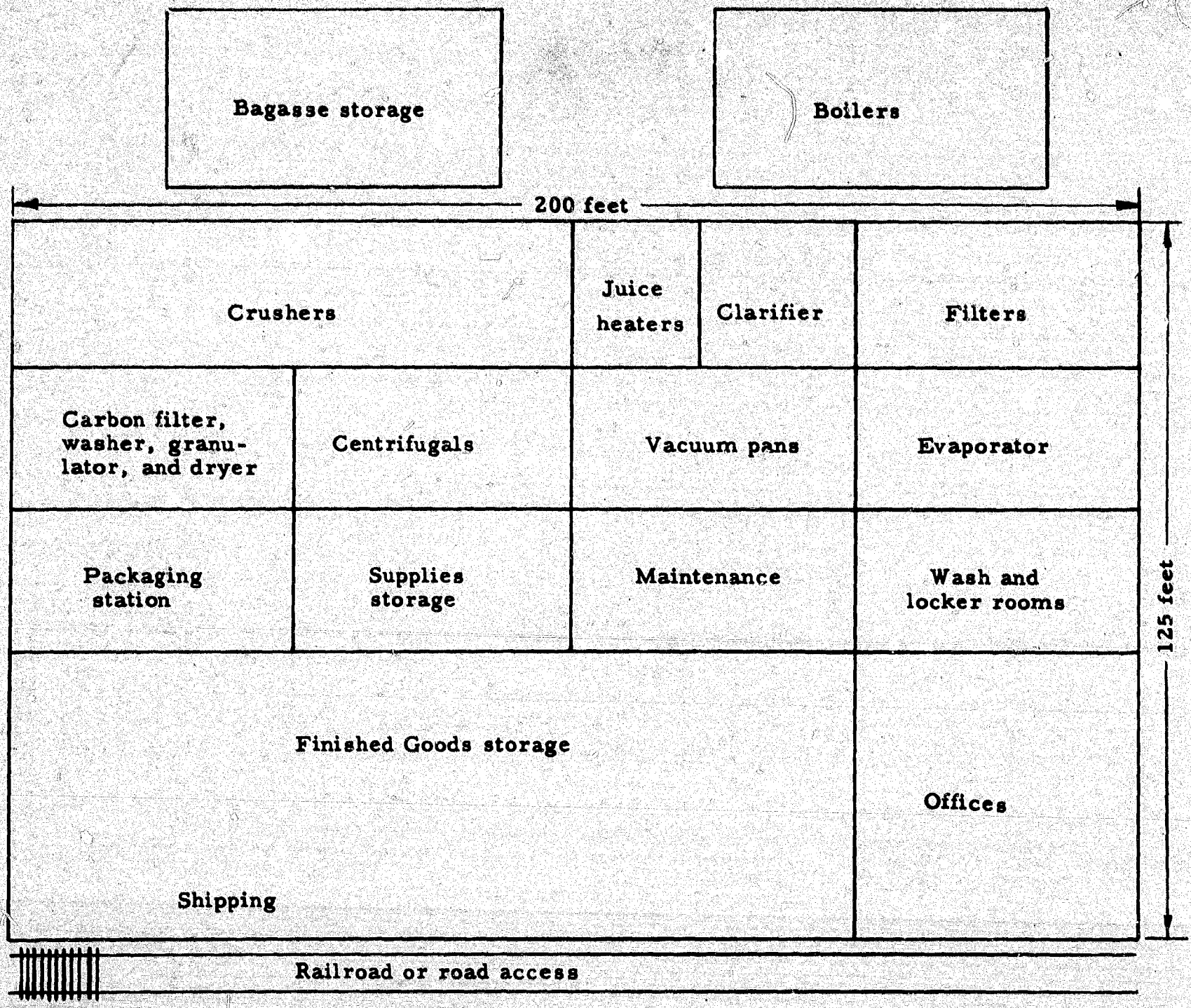

Figure 9 - Preliminary plant layout

[illegible]ANT REQUIREMENTS REPORTS AVAILABLE

A[illegible]VE WHEELS
AN[illegible]AL FEED PELLETS
ASBESTOS - CEMENT SIDING
BRASS FOUNDRY
BUCKETS, PAILS AND PANS
BUILDING BRICKS
BUILDING HARDWARE
CERAMIC DINNERWARE
COARSE WRAPPING PAPER
CONCRETE BLOCKS & SLABS FOR WALLS
COTTON DRESSES
COTTONSEED OIL
FARM HAND TOOLS
FERTILIZER MIXING
FIBRE BOXES
FLAT GLASS
GLASS CONTAINERS
GRAY IRON JOBBING FOUNDRY
JOB MACHINE SHOP
KITCHEN EARTHENWARE
LEATHER TANNING
MEN'S HOSE
MEN'S UNDERWEAR
PAINT
PAINT AND VARNISH BRUSHES
PHOSPHATE PROCESSING
PLASTICS MOULDING
REFINED SUGAR
SANITARY WARE
SHELL BUTTONS
TERRY CLOTH
TWO-BURNER GAS PLATES
WALLBOARD

FOA-Federal Lithograph Co.
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