DEVELOPMENT DOCUMENT

for

INTERIM FINAL EFFLUENT LIMITATIONS GUIDELINES

and

PROPOSED NEW SOURCE PERFORMANCE STANDARDS

for the

RAW CANE SUGAR PROCESSING SEGMENT OF THE SUGAR PROCESSING POINT SOURCE CATEGORY

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ABSTRACT

This document presents the findings of an extensive study of the raw cane sugar processing segment of the sugar processing category for the purpose of establishing effluent limitations and guidelines, Federal standards of performance, and pretreatment standards for the industry for the purpose of implementing Sections 301, 304(b) and (c), 306(b), and 307(b) and (c) of the Federal Water Pollution Control Act, as amended (33 U.S.C. 1251, 1311 and 1314(b) and (c), 1316(b) and 1317(c); 86 Stat. 816 et seq.).

Effluent limitations and guidelines contained herein are based on the degree of effluent reduction attainable through the application of the best practicable control technology currently available (BPCTCA) and the degree of effluent reduction attainable through the application of the best available technology economically achievable (BATEA) which must be achieved by existing point sources by July 1, 1977, and July 1, 1983, respectively. The standards of performance for new sources (NSPS) contained herein as based on the degree of effluent reduction which is achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives.

The development of data and recommendations presented in the document relate to the raw cane sugar processing segment of the sugar processing category. This segment is further divided into five subcategories based on differing harvesting methods, harvesting conditions, and manufacturing processes, and differences in the availability and cost of control and treatment technologies. Separate effluent limitations are developed for each subcategory on the basis of the level of raw waste loading as well as on the degree of treatment achievable by suggested model systems. These systems include both biological and physical-chemical treatment.

Supportive data and rationale for development of the recommended effluent limitations and guidelines and standards of performance are contained in this document.

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SECTION I

CONCLUSIONS

For the purpose of establishing effluent limitations and guidelines, this study has indicated that the raw cane sugar processing segment of the sugar processing category is best characterized by the following five subcategories:

Subcategory I - This subcategory includes those cane sugar factories which process sugarcane into a raw sugar product and are located within the State of Louisiana.

Subcategory II - This subcategory includes those cane sugar factories which process sugarcane into a raw sugar product and are located within the States of Florida and Texas.

Subcategory III - This subcategory includes those cane sugar factories which process sugarcane into a raw sugar product and are located on the Hilo-Hamakua Coast of the Island of Hawaii in the State of Hawaii.

Subcategory IV - This subcategory includes those cane sugar factories not included in Subcategory III, which process sugarcane into a raw sugar product and are located in the State of Hawaii.

Subcategory V - This subcategory includes those cane sugar factories which process sugarcane into a raw sugar product and are located on the Island of Puerto Rico.

The main criteria for subcategorization include differences in waste water characteristics due to differing harvesting methods, harvesting conditions, and manufacturing processes, and differences in the availability and cost of control and treatment technologies. Factors such as age and size of facilities, climatic variations, and waste treatability support the aforementioned subcategorization.

Process waste water pollutants of significance for the industry segment include organics and solids. These pollutants can be adequately controlled by limiting the discharge of BOD_5 and suspended solids.

It is concluded that Subcategories I and V can be represented by a model cane sugar factory processing 2,730 metric tons (3,000 tons) of field (gross) cane per day, that Subcategory II can be represented by a model factory processing 7,300 metric tons (8,000 tons) of field (gross) cane per day, Subcategory III by a model factory processing 3,340 metric tons (3,675 tons) of net cane per day or 6,680 metric tons (7,350 tons) of field cane per day, and Subcategory IV by a model factory processing 3,000 metric tons (3,300 tons) of net cane per day.

It was determined that the best practicable control technology currently available for Subcategory I is identified as the use of in-plant controls to the extent typified by general operating practice (such as the use of entrainment prevention devices to reduce the degree of entrainment of sucrose into barometric condenser cooling water and the elimination of the discharge of filter cake and boiler ash), the use of settling ponds to remove solids from cane wash water, and the use of a biological treatment system to treat the effluent from the settling ponds and all other waste streams except barometric condenser cooling water and excess condensate.

The best available technology economically achievable for Subcategory I is identified as the equivalent of the recycle of barometric condenser cooling water and cane wash water with biological treatment of the blowdown and miscellaneous wastes.

The standards of performance for new sources are identified as being equivalent to the best available technology economically achievable.

The best practicable control technology currently available and the best available technology economically achievable for Subcategories II and IV are identified as the containment of all waste waters to eliminate a discharge of waste water pollutants to navigable waters, except when rainfall events cause an overflow of process waste water from a facility designed, constructed, and operated to contain all process generated waste waters. Those factories included in Subcategories II and IV are currently achieving this level of technology and no additional costs are associated.

The best practicable control technology currently available for Subcategory III is identified as the use of in-plant controls and clarification of the entire waste stream (except barometric condenser cooling water and excess condensate) with polymer addition.

The best available technology economically achievable for Subcategory III is identified as the addition of a barometric condenser cooling water recirculation system, the blowdown used as make-up to the cane wash system. The entire clarified stream would then be treated in a biological treatment system.

The standards of performance for new sources are identified as being equivalent to the best available technology economically achievable.

That portion of the industry segment comprising Subcategory V is in a state of flux between the hand-harvesting of sugar cane and an increased reliance on mechanical harvesting techniques, with limited data available on which to base raw waste loadings. It has been concluded that the application of those treatment techniques currently employed by Louisiana factories is a quite reasonable approach to establishing effluent limitations and guidelines for Subcategory V. Raw waste loadings typical of Subcategory I operations were assumed because the available current data relating to Puerto Rican factories indicate raw waste loadings in the lower range of those associated with Subcategory I factories. It is therefore concluded that the technologies identified for Subcategory I can be directly applied to Subcategory V operations.

The capital and total yearly costs (August-1971 dollars) to the raw cane sugar processing segment of the sugar processing category to achieve the best practicable control technology currently available effluent limitations are estimated to range from between $9.52 and $10.41 million, and $2.98 and $4.06 million, respectively. These costs are based on an estimation of those control and treatment techniques which will be applied at each of the seventy-six individual cane sugar factories to achieve the effluent limitations. These costs do not include expenses already incurred as a result of pollution abatement facilities already existent at the individual factories.

The additional capital and total yearly costs (August-1971 dollars) to the raw cane sugar processing segment of the sugar processing category to achieve the best available technology effluent limitations are estimated to range from between $6.05 and $7.53 million, and $1.02 and $1.33 million, respectively. This estimate does not include those costs associated with attainment of best practicable control technology currently available and is based on an estimation of those control and treatment techniques which must be applied at each individual factory in order that the best available technology economically achievable effluent limitations be attained. This cost estimate does not include those expenses already incurred as a result of pollution abatement facilities already existent at the individual factories.

SECTION II

RECOMMENDATIONS

It is recommended that the effluent limitations to be applied as the best practicable control technology currently available (BPCTCA) which must be achieved by existing point sources by July 1, 1977, the best available technology economically achievable (BATEA) which must be achieved by existing point sources by July 1, 1983, and the standards of performance for new sources (NSPS) be as follows:

	BPCTCA		BATEA		NSPS	
	BOD5	TSS	BOD5	TSS	BOD5	TSS
Subcategory I (Subpart D)						
30-Day Average	0.63	0.47	0.050	0.080	0.050	0.080
Daily Average	1.14	1.41	0.10	0.24	0.10	0.24
Subcategory II (Subpart E)	0	0	0	0	0	0
Subcategory III (Subpart F)						
30-Day Average	-	2.1	The greater of: 0.11 or $0.76(1-x)+0.0060$	The greater of: 0.13 or $1.01(1-x)+0.0080$	The greater of: 0.11 or $0.76(1-x)+0.0060$	The greater of: 0.13 or $1.01(1-x)+0.0080$
Daily Average	-	4.2	The greater of: 0.22 or $1.52(1-x)+0.012$	The greater of: 0.39 or $3.03(1-x)+0.024$	The greater of. 0.22 or $1.52(1-x)+0.012$	The greater of: 0.39 or $3.03(1-x)+0.024$
Subcategory IV (Subpart G)	0	0	0	0	0	0
Subcategory V (Subpart H)						
30-Day Average	0.63	0.47	0.050	0.080	0.050	0.080
Daily Average	1.14	1.41	0.10	0.24	0.10	0.24

The above recommended values are expressed in terms of kilograms of pollutant per metric ton of field cane, except for Subcategory III which are expressed in terms of kilograms of pollutant per metric ton of net cane.

It is further recommended that for Subcategories I and IV, discharge of factory waste waters to navigable waters be allowed during the occurence of rainfall events which cause an overflow of process waste waters from a facility designed, constructed, and operated to contain all process generated waste waters.

It is recommended that for all cases for which a discharge of waste waters is allowed, the pH of the waste waters be required to be maintained in the range of 6.0 to 9.0.

The above recommendations represent, for existing installations, the degrees of effluent reduction attainable through the application of the best practicable control technology currently available and the best available technology economically achievable to be achieved by existing point sources by July 1, 1977, and July 1, 1983, respectively. For new sources the above recommendations reflect a standard of performance providing for the control of pollutant discharge which reflects the greatest degree of effluent reduction achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives.

The effluent limitations and guidelines and control, pretreatment, and treatment technologies pertaining to the non-process or non-contact waste waters generated by the raw cane sugar processing segment of the sugar processing category will be addressed by effluent guidelines documents and regulations promulgated separately at a future date.

SECTION III

INTRODUCTION

PURPOSE AND AUTHORITY

Section 301(b) of the Act requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best practicable control technology currently available as defined by the Administrator pursuant to Section 304(b) of the Act. Section 301(b) also requires the achievement by not later than July 1, 1983, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best available technology economically achievable which will result in reasonable further progress towards the national goal of eliminating the discharge of all pollutants, and which reflect the greatest degree of effluent reduction which the Administrator determines to be achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including where practicable a standard permitting no discharge of pollutants.

Section 304(b) of the Act requires the Administrator to publish regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best control measures and practices achievable including treatment techniques, process and procedure innovations, operation methods, and other alternatives. The regulations set forth effluent limitations and guidelines pursuant to Section 304 (b) of the Act for the raw cane sugar processing segment of the sugar processing point source category.

Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306(b) (1) (A) of the Act, to propose regulations establishing Federal standards of perfcrmances for new sources within such categories. The Administrator published, in the Federal Register of January 16, 1973 (38 F.R. 1624), a list of 27 source categories. Publication of the list constituted announcement of the Administrator's intention of establishing, under Section 306, standards of performance applicable to new sources within the sugar processing point source which was included within the list published January 16, 1973. The raw cane sugar processing industry, which this document addresses, is a segment of the sugar processing point source category, as are the beet sugar and cane sugar refining industries which have been previously studied.

Section 307(c) of the Act requires the Administrator to promulgate pretreatment standards for new sources at the same time that standards of performance for new sources are promulgated pursuant to Section 306. Section 307(b) of the Act requires the establishment of pretreatment standards for pollutants introduced into publicly owned treatment works. The regulations set forth pretreatment standards for new sources and for existing sources pursuant to Sections 307(b) and (c) of the Act for the raw cane sugar processing segment of the sugar processing point source category.

The guidelines in this document identify (in terms of the chemical, physical, and biological characteristics of pollutants) the level of pollutant reductions attainable through the application of the best practicable control technology currently available and the best available technology economically achievable. The guidelines also specify factors which must be considered in identifying the technology levels and in determining the control measures and practices which are to be applicable within given industrial categories or classes.

In addition to technical factors, the Act requires that a number of other factors be considered, such as the costs or cost-benefit and the non-water quality environmental impacts (including energy requirements) resulting from the application of such technologies.

SUMMARY OF METHODS USED FOR DEVELOPMENT OF THE EFFLUENT LIMITATIONS AND GUIDELINES AND STANDARDS OF PERFORMANCE

The effluent limitations and standards of performance set forth in this document were developed in the following manner:

1. An exhaustive review of available literature was conducted. This included searches at the University of Florida and Louisiana State University libraries, the Florida Sugar Cane League library, and the in-house libraries of Environmental Science and Engineering, Inc., F.C. Schaffer & Associates, and Sunn, Low, Tom & Hara, Inc. A list of references is contained in Section XIII of this document.

2. Applications to the U.S. Army Corps of Engineers or the Puerto Rico Environmental Quality Board for permits to discharge under the Refuse Act Permit Program (RAPP) were obtained for 30 factories. These applications provided data on the characteristics of influent and effluent waters, water usages, waste water treatment, control practices, daily production, and raw materials usage.

3. Information was obtained from questionnaires previously submitted by the Florida Sugar Cane League to 8 factories.

4. Information was obtained from questionnaires previously submitted by the American Sugar Cane League to 41 factories.

5. Detailed and general information was provided by the Hawaiian Sugar Planters' Association with regard to all Hawaiian cane sugar operations.

6. On-site inspections were conducted at 59 factories and information on process diagrams and related water usage, water management practices, and control and treatment practices was obtained. Sampling programs were conducted by the contractor at ten factories to verify the accumulated data.

7. Information from sampling programs supervised by the Environmental Protection Agency at fifteen factories was obtained.

8. Effluent data was obtained from a sampling program conducted by the Department of Engineering of the University of Puerto Rico.

9. Information was obtained from personal and telephone interviews; meetings with regional EPA personnel, industry personnel, and consultants; state permit applications; and internal data supplied by industry.

Table 1 presents a summary of the types and sources of information gathered.

The reviews, analyses, and evaluations were coordinated and applied to the following:

1. An identification of distinguishing features that could potentially provide a basis for subcategorization of the raw cane sugar processing segment. These features include the nature of raw materials utilized, plant size and age, the nature of processes, and others as discussed in Section IV.
2. A determination of the water usage and waste water characteristics for each subcategory, as discussed in Section V, including the volume of water used, the sources of pollution from the raw sugar factory, and the type and quantity of constituents in the waste water.
3. An identification of those waste water constituents, as discussed in Section VI, which are characteristic of the industry and were determined to be pollutants subject to effluent limitations guidelines and standards of performance.
4. An identification of the control and treatment technologies presently employed or capable of being employed by the cane sugar factory segment, as discussed in Section VII,

TABLE 1
SOURCES OF INFORMATION

Factory No.	Visited?	Sampled?	Data Sources	Factory No.	Visited?	Sampled?	Data Sources
1	yes	no	1,2,6,7	43	no	no	6
2	no	no	none	44	yes	no	1,2,4,6,7
3	no	no	6	45	yes	no	4,6,7
4	no	no	none	46	yes	no	1,5,6,7
5	yes	no	1,6,7	47	yes	no	1,2,4,6
6	no	no	6	48	yes	no	2,6,7
7	yes	no	1,2,6,7	49	yes	no	1,2,6,7
8	yes	no	2,6,7	50	yes	no	2,6,7
9	no	no	6	51	yes	yes	2,3,6,7
10	yes	yes	3,4,6,7	52	yes	no	1,6,7
11	yes	no	1,6,7	53	yes	yes	1,2,3,6,7
12	yes	no	6,7	54	yes	no	7
13	no	no	6	55	yes	no	1,6,7
14	no	no	6	56	no	no	1,5,6
15	no	no	6	57	yes	no	1,2,7
16	yes	yes	1,3,4,6,7	58	yes	no	1,2,5,6,7
17	yes	no	1,6,7	59	yes	no	1,5,6,7
18	no	no	1,6	60	no	no	1,5,6
19	yes	no	6,7	61	yes	no	1,5,6,7
20	yes	no	1,6,7	62	yes	no	1,5,6,7
21	no	no	6	63	yes	no	1,2,6,7
22	yes	yes	3,4,6,7	64	yes	yes	1,3,6,7
23	yes	no	6,7	65	no	no	none
24	yes	no	1,6,7	66	yes	no	2,4,5,7
25	no	no	6	67	yes	no	2,4,5,7
26	yes	no	1,6,7	68	yes	no	2,7
27	no	no	6	69	yes	yes	2,3,4,5,7
28	yes	no	2,6,7	70	yes	no	2,4,5,7
29	no	no	6	71	yes	no	2,4,7
30	yes	no	6	72	yes	yes	3,4,5,7
31	no	no	6	73	no	no	4
32	yes	no	1,4,6,7	74	yes	no	4,7
33	yes	no	1,6,7	75	yes	no	4,7
34	yes	no	1,6,7	76	yes	no	4,5
35	yes	no	6,7	77	no	no	4
36	yes	no	6,7	78	yes	no	4,5,7
37	yes	no	6	79	no	no	4
38	no	no	6	80	yes	yes	2,3,4,7
39	yes	no	6,7	81	no	no	4
40	no	no	6	82	yes	yes	2,3,4,5,7
41	no	no	6	83	yes	no	4,7
42	yes	no	1,2,6,7	84	yes	no	7
				85	yes	no	7

KEY TO SOURCES OF DATA

1. Corps of Engineers Applications/Puerto Rico Environmental Quality Board Applications
2. Prior Analysis Provided by Factory
3. ES&E Sampling
4. Prior Waste Water Studies
5. EPA (FWPCA) Supervised Studies
6. Questionnaires
7. Interview of Plant Personnel

including the effluent level attainable and associated treatment efficiency related to each technology.

5. An evaluation of the cost associated with the application of each control and treatment technology, as discussed in Section VIII.

DESCRIPTION OF THE INDUSTRY

The raw cane sugar manufacturing segment of the cane sugar processing industry is defined as that listed in Standard Industrial Classification (SIC) Code 2061 Cane Sugar, Except Refining Only (1). The cane sugar industry is also comprised of establishments defined by SIC Code 2062 or those engaged in the processing of raw sugar into refined sugar. The cane sugar refining segment of the sugar processing industry has been the subject of a separate study (43 and 44).

BACKGROUND OF THE RAW CANE SUGAR PROCESSING SEGMENT

In the United States and Puerto Rico, the geographical distribution of raw cane sugar factories corresponds to the cane growing areas since rapid spoilage of cut cane precludes long distance transportation. Cane is grown and processed into raw sugar in four states of the United States (Florida, Louisiana, Texas, and Hawaii) and in the Commonwealth of Puerto Rico.

Authorities generally agree that sugarcane originated in New Guinea and was transported to Southern Asia in ancient times. The earliest recorded production of sugarcane was in Southeast Asia three thousand years ago. Sugarcane was introduced into Europe in the eleventh century, and by the thirteenth century the crystallization of sugar from cane juice was being practiced throughout the Eastern Hemisphere.

The origin of sugarcane in the Western World was with the second voyage of Columbus in 1493. With the "Age of Discovery", every newly discovered area suitable for cane growth was supplied with sugarcane for planting. Sugar from the Americas allowed for sugar to be in large supply in Europe and it ceased to be a luxury item dispensed only in apothecaries. By the year 1600, raw sugar production was the largest industry in the world.

Sugarcane was introduced into Louisiana by the French in 1751 and the first Louisiana mill was constructed in 1758. The Spanish began cane sugar production in Puerto Rico and Florida as well as in other Spanish territories during their early exploratory periods, and Cook brought the plant to Hawaii in 1778.

The production of sugarcane grew steadily in Louisiana from the beginning until well into the twentieth century, but has experienced a leveling off during the last few decades as lands suitable for cane growing were exhausted. The trend since 1948 has been a consolidation of Louisiana factories from 59 factories to 38 in 1974 (not including an experimental mill at Louisiana State University and a small installation at Angola State Penitentiary). These factories, as indicated in Figures 1 and 2, are located in the wet, south-central flatlands along the Mississippi River and the Bayous Teche and Lafourche. The grinding season in Louisiana, usually extending from late October to early January, currently produces about 600,000 metric tons (700,000 tons) of raw sugar. A listing of Louisiana factories is contained in Table 2.

Raw cane sugar processing has been a part of Puerto Rico's history and heritage for the several centuries since the introduction of sugarcane to that island. By 1940 there were 40 sugar factories operating in Puerto Rico. However, during the last decade the Puerto Rican industry has experienced a steady decline. The once dynamic sugar industry now supports only 11 factories located around the periphery of the island, as shown in Figure 3 and listed in Table 3. The current annual production of raw sugar is about 270,000 metric tons (300,000 tons) as opposed to 1,300,000 metric tons (1,400,000 tons) in the record year of 1951. The reasons for the decline reportedly originate in the political philosophy of Puerto Rico (2), but in any event the high cost of production, labor problems, low sugar yields, and other problems have reduced the industry to a point where the Puerto Rico sugar industry is in a state of decline.

In Florida, after the initial start, the industry collapsed not to be reborn for two centuries. Prior to 1960 there was one major sugar operation in Florida. But with the relaxation of domestic quotas in the mid-nineteen sixties, accompanied by an influx of Cuban sugar growers and technologists, the Florida industry began a decade of rapid growth. Currently, eight factories, generally representing the largest and most modern in the industry, are located along the southern shore of Lake Okeechobee, as shown in Figure 4. A listing of Florida factories is shown in Table 4. These factories, normally operating from November to March, produce about 600,000 metric tons (700,000 tons) of raw sugar per year.

In Hawaii, the sugar industry has long played a dominant role in the economic and cultural development of the islands. After the exhaustion of the sandalwood forests and the decline of the whaling industry, sugarcane production began its upswing in the latter 1870's. At the same time importation of workers for the plantations from China, Japan, the Phillipines, Portugal, and other areas began the shaping of the present ethnic distribution of Hawaii.

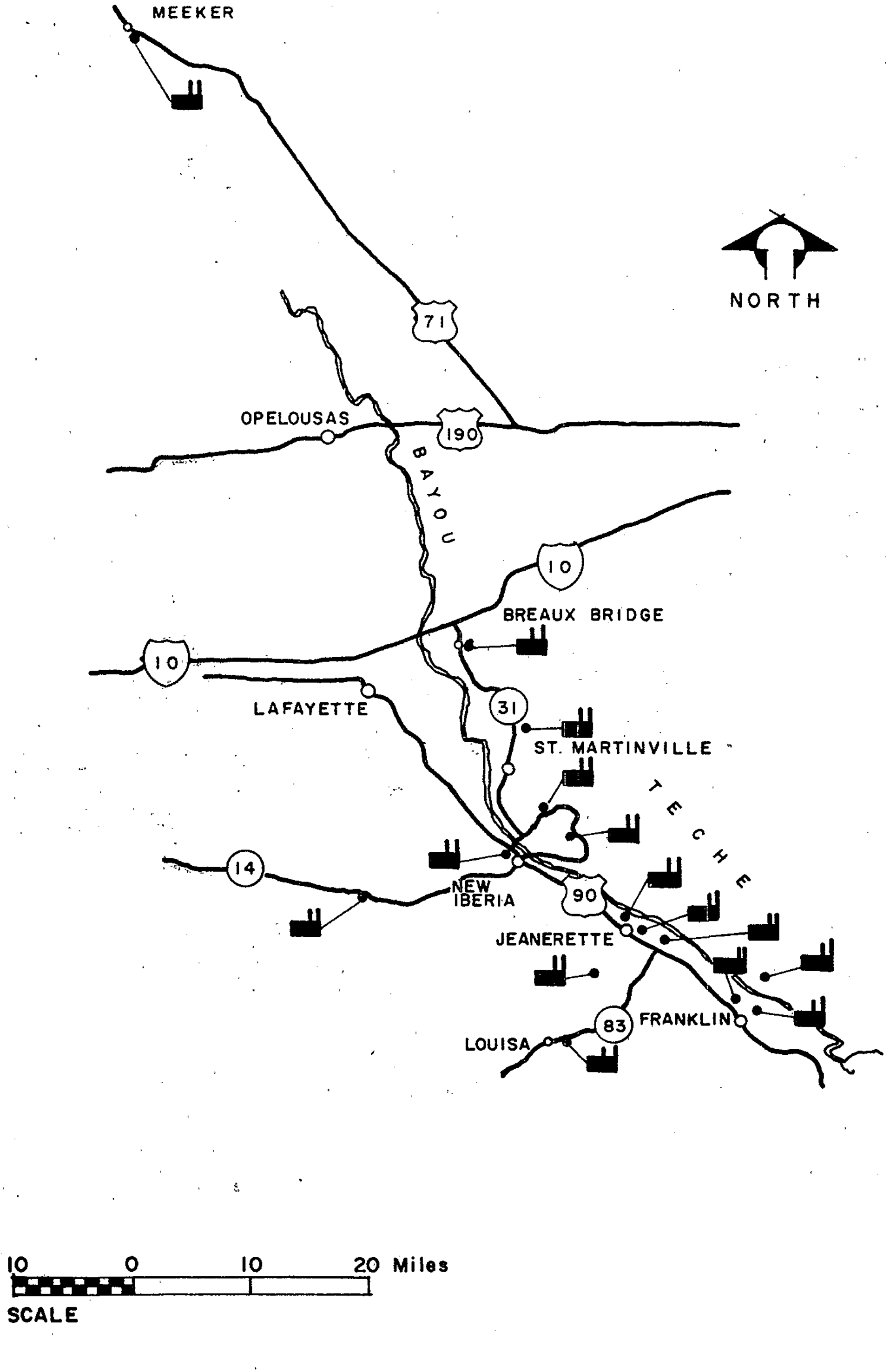

FIGURE I LOUISIANA SUGAR FACTORIES (BAYOU TECHE) OPERATING 1973

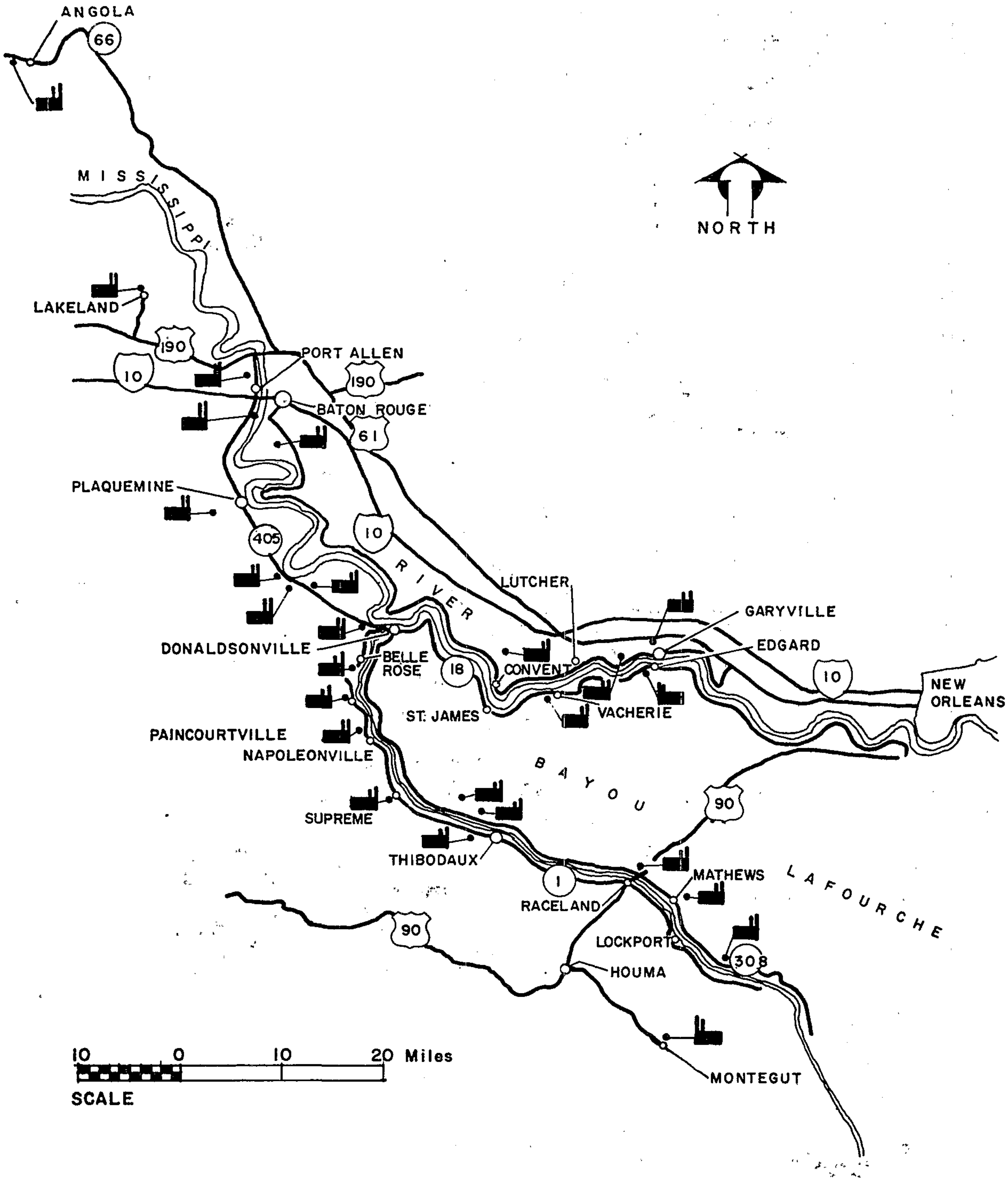

FIGURE 2 LOUISIANA SUGAR FACTORIES (MISSISSIPPI RIVER VALLEY) OPERATING 1973

TABLE 2

LOUISIANA SUGAR FACTORIES OPERATING 1972-1973

Factory Name	Location	Normal Grind (Metric Tons/Day)
Alma	Lakeland	1,820
Angola	Angola State Prison	780
Armant	Vacherie	2,730
Audubon	Baton Rouge	330*
Billeaud	Broussard	2,270
Breaux Bridge	Breaux Bridge	1,800
Cajun	New Iberia	5,000
Caldwell	Thibodaux	3,730
Catherine	Bayou Goula	1,490
Cedar Grove	White Castle	2,000
Cinclare	Brusly	2,820
Columbia	Edgard	1,640
Columbia	Franklin	1,680
Cora-Texas	White Castle	2,730
Delgado-Albania	Jeanerette	1,600
Duhe & Bourgeois	Jeanerette	1,270
Enterprise	Jeanerette	3,680
Evan Hall	McCall	4,550
Georgia	Mathews	2,180
Glenwood	Napoleonville	3,820
Greenwood	Thibodaux	2,730
Helvetia	Convent	2,270
Iberia	New Iberia	3,630
Leighton	Thibodaux	5,000
Louisa	Louisa	1,900
Lula	Belle Rose	3,360
Meeker	Meeker	2,100
Myrtle Grove	Plaquemine	2,270
Oaklawn	Franklin	4,360
Poplar Grove	Port Allen	1,800
Raceland	Raceland	4,550
St. James	St. James	3,500
St. John	St. Martinville	2,800
St. Mary	Jeanerette	3,180
San Francisco	Reserve	1,450
Smithfield	Port Allen	1,850
Southdown	Houma	2,800
Sterling	Franklin	4,550
Supreme	Supreme	3,270
Terrebonne	Montegut	2,360
Valentine	Lockport	2,730
Vida	Loreauville	1,100
Westfield	Paincourtville	3,360

*24 Hour Capacity

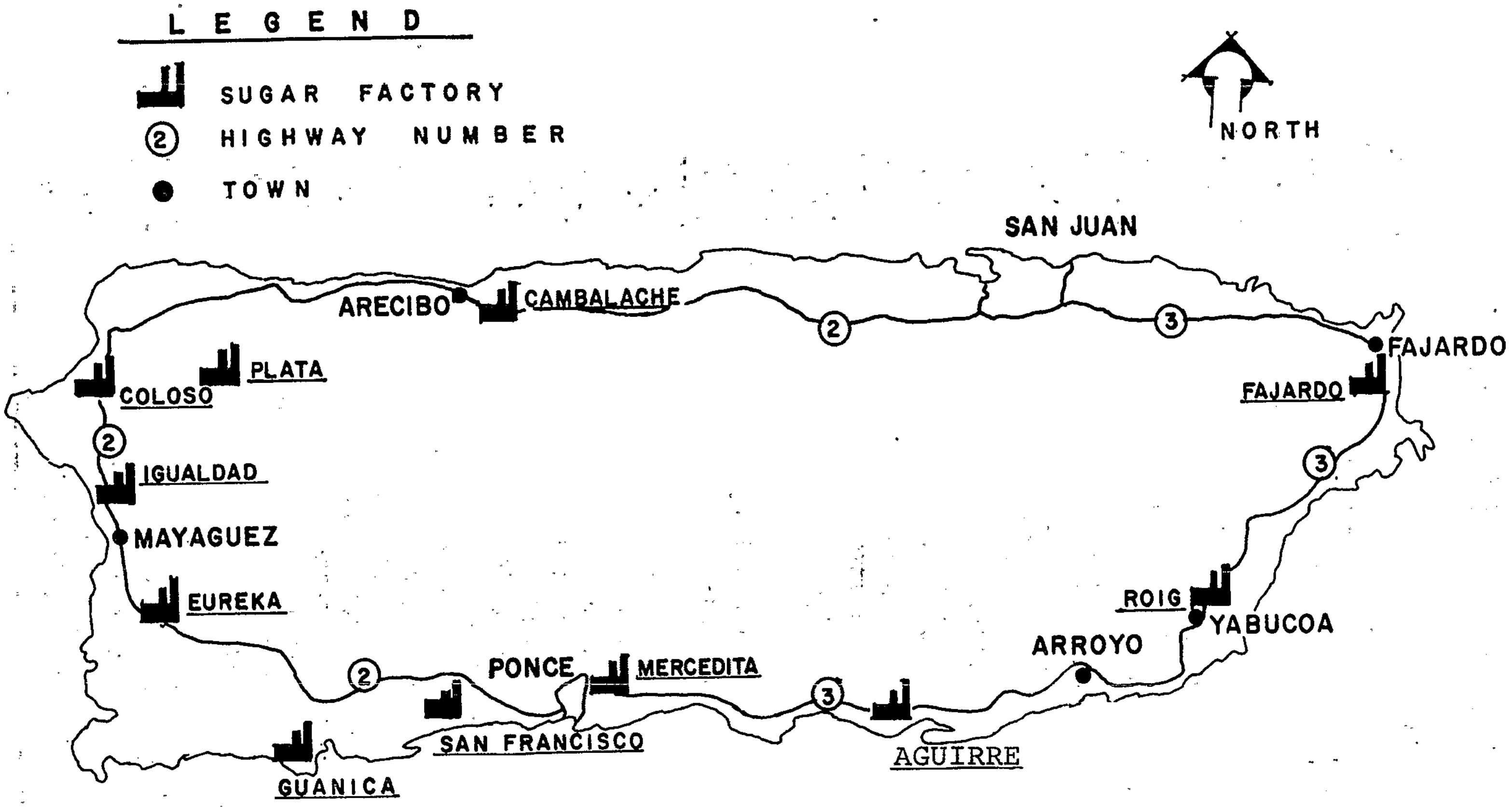

FIGURE 3

OPERATING SUGAR FACTORIES IN PUERTO RICO (1974)

0 2 4 6 8 10 12 14 16

APPROXIMATE SCALE
IN MILES

TABLE 3

PUERTO RICO FACTORIES OPERATING 1974

Factory Name	Location	Capacity (Metric Tons/Day)
Central Aguirre	Aguirre	4,550
Central Cambalache	Arecibo	4,090
Central Coloso	Coloso	4,550
Central Eureka	Hormigueros	3,090
Central Fajardo	Fajardo	2,730
Central Guancia	Ensenada	5,910
Central Igualdad	Mayaguez	2,910
Central Mercedita	Mercedita	3,820
Central Roig	Yabucoa	3,180
Central Plata	San Sebastian	4,090
Central San Francisco	Yauco	730

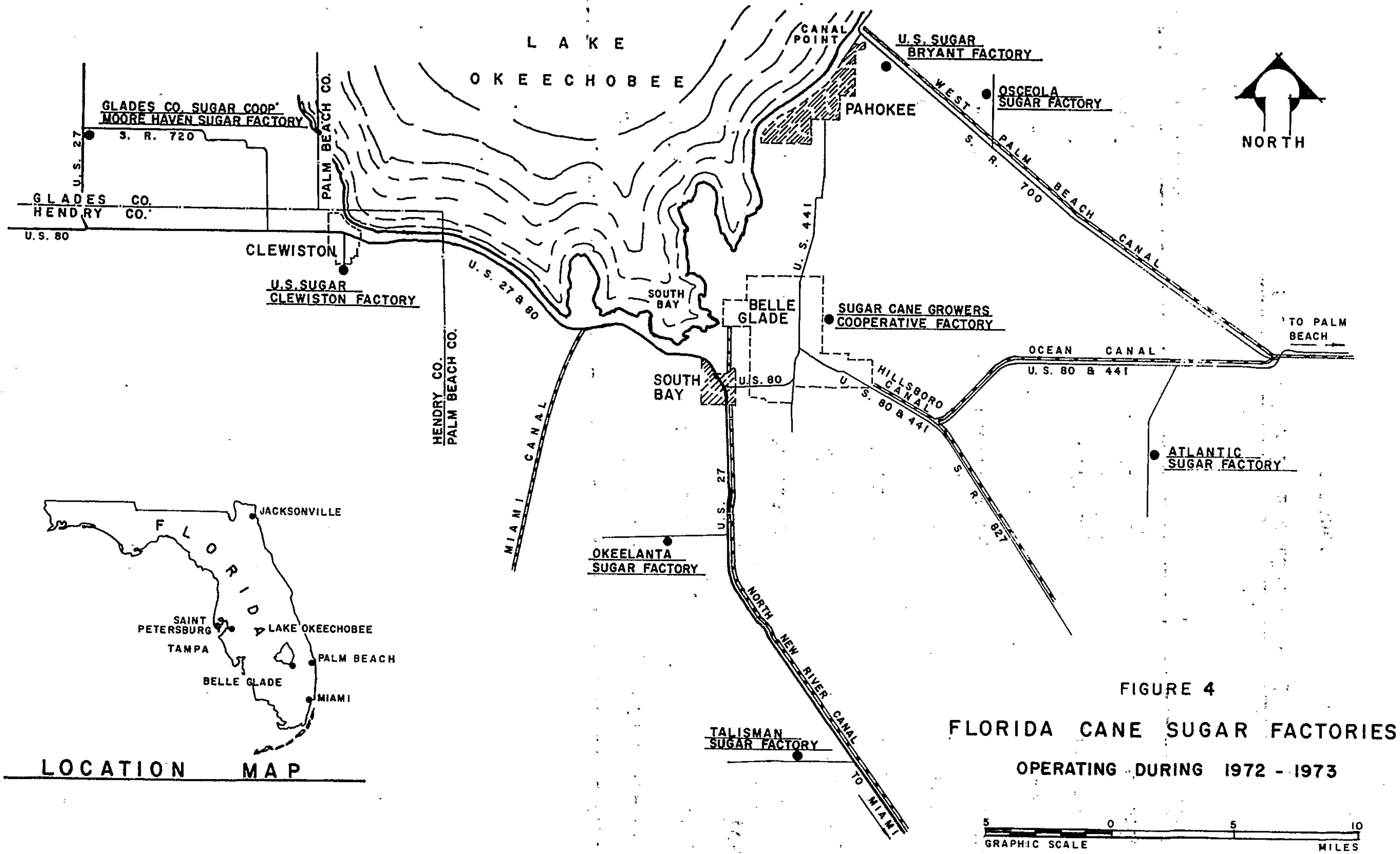

FIGURE 4

FLORIDA CANE SUGAR FACTORIES

OPERATING DURING 1972 - 1973

TABLE 4

FLORIDA SUGAR FACTORIES OPERATING 1974

Factory Name	Location	Normal Grind (Metric Tons/Day)
Atlanta Sugar Association	Belle Glade	5,200
Glades County Sugar Growers Coop.	Moore Haven	4,100
Gulf Western Food Okeelanta Sugar Div.	South Bay	11,000
Osceola Farms	Pahokee	5,400
Sugar Cane Growers Coop. of Florida	Belle Glade	9,100
Talisman Sugar Corporation	Belle Glade	7,730
U.S. Sugar Corporation	Bryant	10,000
U.S. Sugar Corporation	Clewiston	10,000

As shown in Figure 5 and listed in Table 5, four of the Hawaiian Islands support 20 cane sugar factories. The Hawaiian factories, normally shutting down for only a month to two months or longer in early winter, produce about 1,200,000 metric tons (1,300,000 tons) of raw sugar per year. The Hawaiian sugar companies market their sugar as a cooperative unit. They also combine efforts to support the Hawaiian Sugar Planters' Association (HSPA) and its experimental station which serves as the research institute for the industry. With no competition between the individual companies, information and technology are freely exchanged and the result is an industry that has remained viable under the severe economic constraints of remoteness from the marketing area, high labor costs, limited area for expansion, and in some areas extremely adverse climatological and topographical conditions.

While sugarcane had been grown to a limited extent in southeastern Texas, there was no significant industry in that state. During 1973, however, a new factory was constructed near the mouth of the Rio Grande River at Harlingen, Texas. This factory is designed to produce over 90,000 metric tons (100,000 tons) of raw sugar per year.

PROCESS DESCRIPTION

The manufacturing of raw sugar may be broadly defined as extraction of juice from sugarcane, purification of the juice, crystallization of the sucrose in the juice, and separation of the crystals from the juice. The following is a discussion of the production of raw sugar, beginning with a discussion of sugarcane production and continuing through a discussion of product handling.

Sugarcane Production

Sugarcane is a giant perennial grass with a commercial value derived from the large amount of sucrose in the juice of the mature plant. The exact concentration of sucrose in the juice depends on the variety of cane grown as well as agricultural factors in general. Sugarcane ordinarily averages about 15 percent by weight of fiber and 85 percent by weight of juice. The juice typically is composed of 80 percent water, 12 percent sucrose, and five percent invert sugars and impurities.

The important sugars in cane juice are the simple monosaccharides and disaccharides composed of five or six carbon chains. Of these, sucrose, glucose, and fructose are the most important. Glucose and fructose are six carbon monosaccharide isomers; sucrose is the product of the condensation of these two simple sugars and can be represented as in Figure 6. Since essentially pure sucrose is the ultimate product of sugar manufacturing, the inversion or hydrolyzation of sucrose into glucose and fructose represents lost production and is of primary concern throughout the cane sugar manufacturing process.

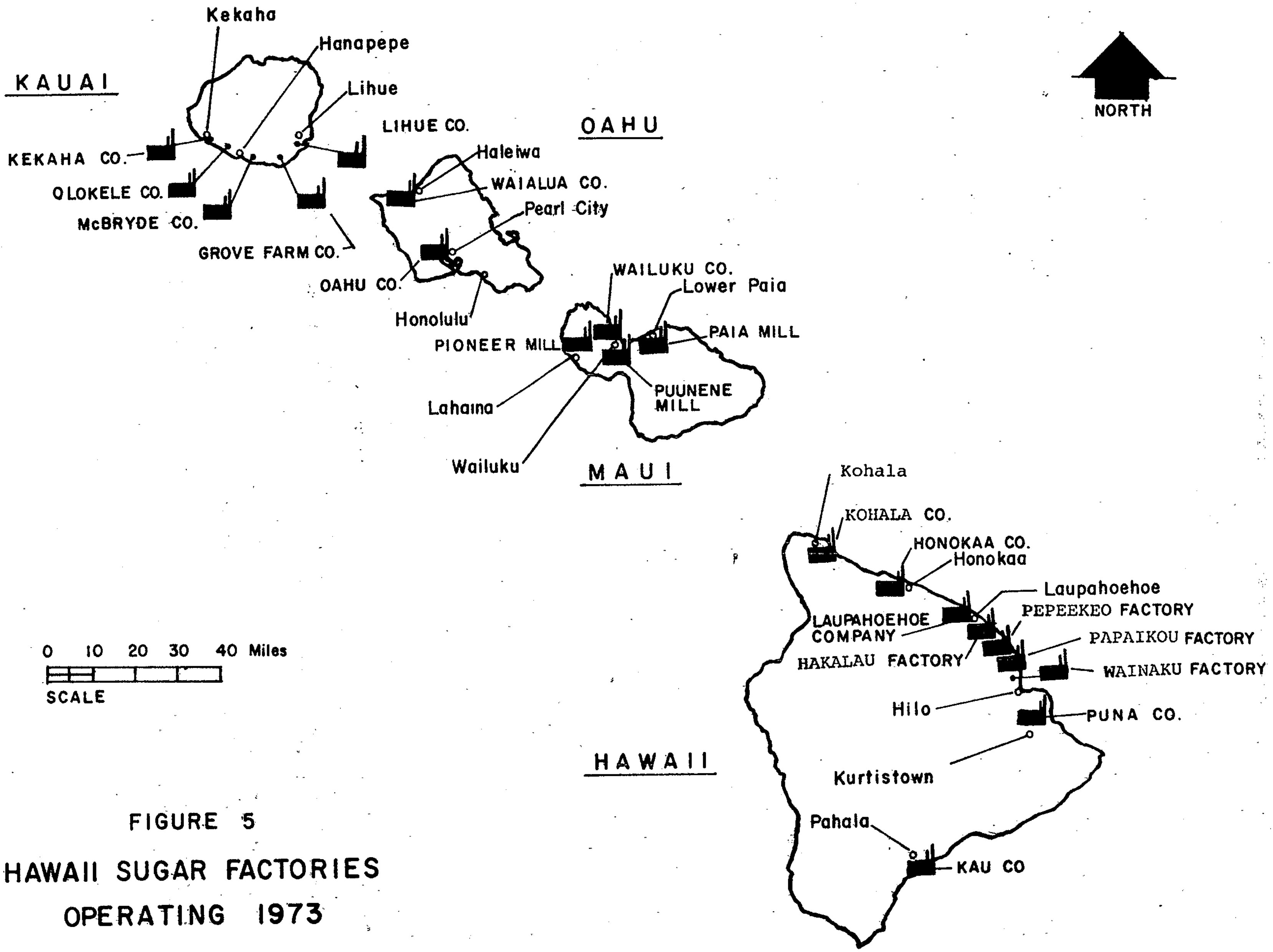

FIGURE 5

HAWAII SUGAR FACTORIES
OPERATING 1973

TABLE 5

HAWAIIAN SUGAR FACTORIES OPERATING 1973

Location	Company/Factory	Normal Grind (Metric tons of Net Cane/Day)
Island of Hawaii	Kohala Sugar Co.[1]	2,400
	Honokaa Sugar Co.[2]	2,200
	Laupahoehoe Sugar Co.[3]	2,700
	Hilo Coast Processing Co.	
	Hakalau Factory[4]	1,200
	Pepeekeo Factory[5]	1,500
	Papaikou Factory	1,400
	Wainaku Factory[4]	1,400
	Puna Sugar Co.	2,400
	Ka'u Sugar Co.	2,600
Island of Kauai	Kekaha Sugar Co.	2,500
	Olokele Sugar Co.	2,100
	McBryde Sugar Co.[6]	2,200
	Grove Farm Co.[6]	2,000
	Lihue Plantation Co.	3,600
Island of Maui	Hawaiian Commercial Sugar Co.	
	Paia Factory	3,600
	Puunene	5,900
	Wailuku Sugar Co.	1,700
	Pioneer Mill Co.	2,300
Island of Oahu	Oahu Sugar Co.	3,600
	Waialua Sugar Co.	3,600

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[1] Kohala Sugar Company is to be closed by December, 1975.

[2] Honokaa Sugar Company which was to be expanded, will instead operate seven days a week starting in 1974.

[3] Laupahoehoe Sugar Company is to be expanded to a rated capacity of 4360 metric tons of net cane per day.

[4] Hakalau and Wainaku Factories (Hilo Coast Processing Company) are to be closed by the end of 1974.

[5] Pepeekeo Factory (Hilo Coast Processing Company) is to be expanded to 3340 metric tons of net cane per day.

[6] McBryde Sugar Company and Grove Farm Company have merged. The McBryde Mill is to be closed by the end of 1974. Cane will be processed at the Grove Farm Company (Koloa) Mill and at the Lihue Plantation Company Mill.

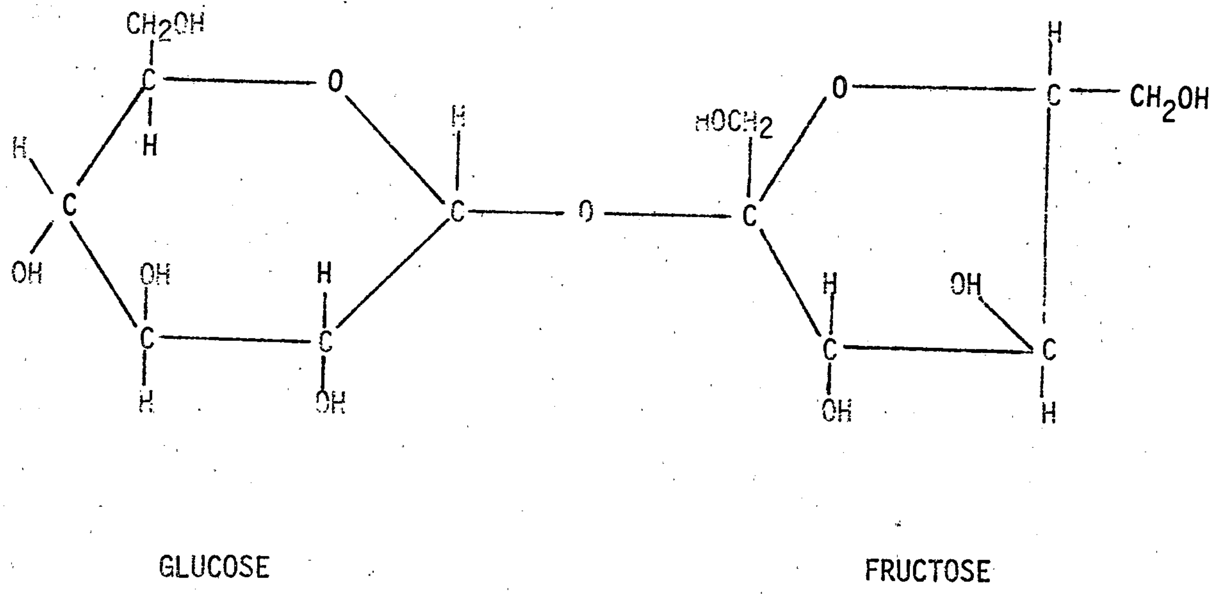


FIGURE 6

SUCROSE OR α-D-GLUCOPYRANOSYL--β-D-FRUCTOFURANOSIDE

Sugarcane is propagated by plant cuttings of the cane with a shallow soil covering. Each cut produces several shoots. Under favorable conditions of soil and climate, new plants, called "ratoons", will grow from the stubble after harvesting and a cane crop can perpetuate itself for a number of years. However, in order to maintain an acceptable quality level, only a few ratoon crops are normally allowed. An exception to this occurs at some Puerto Rican farms which have not had new plantings for a quarter of a century.

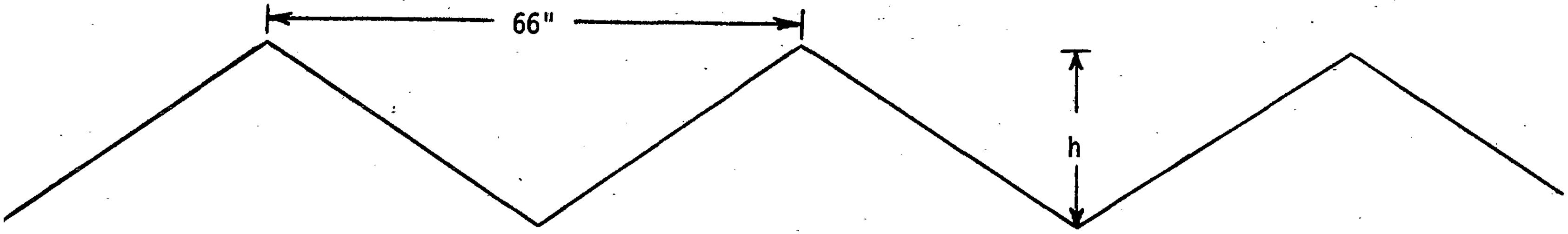
The length of time that cane is allowed to grow prior to harvesting varies from less than a year in Louisiana to two or more years in Hawaii.

In Puerto Rico and Louisiana the agricultural practices involved in producing a crop of sugarcane, other than in connection with agricultural runoff, are irrelevant to a study of waste water. However, at certain factories in Florida and Hawaii the disposal of process waste streams and the irrigation of the cane fields are interrelated.

Irrigation practice in Hawaii is primarily overland flow in ridge and furrow networks through the fields. The frequency and quantity of water applied is controlled to ultimately produce the highest sugar yields under natural local conditions. The first year of the approximate two year crop is the growth phase and the second, the ripening phase. Ample water as well as fertilizer is applied in the first year. Water application in the second year is controlled, and fertilizer application is stopped entirely. From about 90 days prior to harvesting, water application is stopped completely for the final ripening phase and drying of the fields.

Although ridge and furrow irrigation is still the primary method of irrigation, the current trend is toward overhead sprinkler irrigation. Also under development and regarded optimistically by the industry is drip or trickle irrigation in which water is applied at low rates through pipes in the field. The efficiency of water usage (about 80 to 90 percent) by this method is considerably higher than by the ridge and furrow technique (50 percent or less). The result is water conservation and the possibility of flat culture techniques which could ultimately affect harvesting techniques.

The ridge and furrow network is formed by plowing according to the cross-section and typical dimensions shown in Figure 7. The irrigation furrows are supplied from a flume or ditch at a rate which may be manually or automatically controlled. A given quantity of water is allowed to enter the furrows and as the water reaches the end, the water is turned off by the irrigator. The slopes of the furrows are usually set at about 1.5 percent so that water movement through the furrows is not excessively fast or slow. Spillways are



h is about 18 inches after plowing but weathers down to about 14 inches

FIGURE 7

CROSS SECTION AND TYPICAL DIMENSIONS OF IRRIGATION FURROWS sometimes provided at the middle or end of the furrows to allow excess water to spill over into the next furrow. However, if this continues until the bottom-most furrow is filled, overflow results. This excess is called tailwater.

Usually the irrigator manually opens and closes the gates at the head of each furrow. Several gates are worked at a time to split the total applied flow of 7,950 to 18,900 liters per minute (2,100 to 5,000 gpm) to several furrows. The time of application to each furrow is determined from experience, although when the cane is young, an irrigator can visually observe water movement to the end of the furrows. After the cane grows and forms a canopy over the fields, direct observation is not possible and timing becomes the main index. An error in judgment means either an overflow or under-irrigation.

In automatic furrow systems, the irrigation water is diverted to different sections of the fields through gates equipped with timers. The timers are set according to experience with the particular conditions in the fields. Mechanical failures of timers have occurred in the past, and vandalism has been a problem in some cases.

In Florida it is common to maintain the surface water table in the cane fields with a network of canals that provide water to the fields during the dry season and remove excess water during the rainy season. The source of make up water for the canals, as well as the receiving water when the canals discharge, is usually one or more of the main drainage canals for the Everglades.

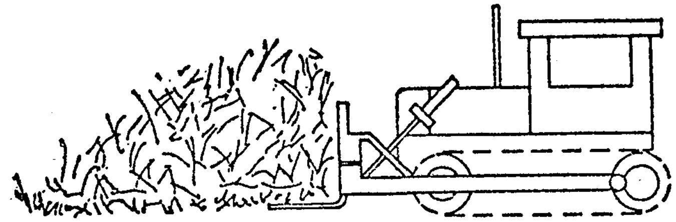
Cane Harvesting

The harvesting and subsequent loading of the cane onto transport vehicles can be performed either manually or mechanically, and the quantities of dirt and mud entering a factory can be appreciably influenced by the methods chosen. In general, harvesting techniques vary considerably among the geographical regions of the United States with the Hawaiian sugar industry being the most strikingly different.

Until the Second World War, hand labor was used extensively in Hawaii for cane harvesting. With the shortage of labor caused by the war and the high cost of labor in the post-war years, by 1950 the industry was almost totally mechanized. The current harvesting practice basically involves pushing the cane into windrows with bulldozers and then loading the piles onto trucks or buggies. Variations in harvesting techniques occur within the Hawaiian industry as illustrated in Figures 8 through 10.

On the characteristically rocky and hilly terrain of the Hawaiian fields, considerable pickup of soil, rock, and trash is inevitable. The gross cane received at the factory may often contain as much as 50

1. PUSH RAKE INTO WINDROWS



2. CRANE LOADS HAULER

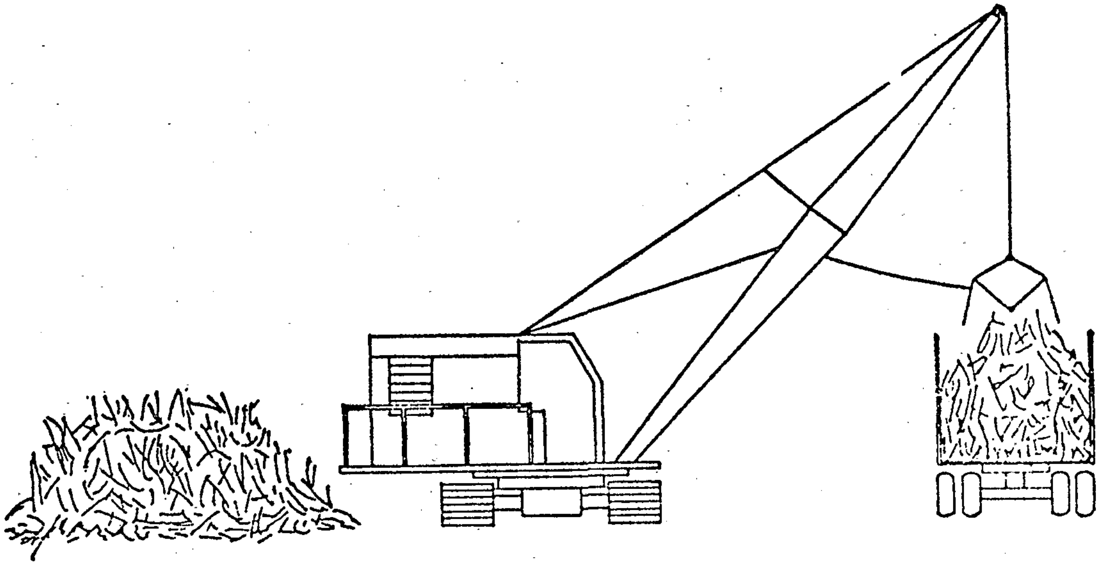


FIGURE 8

USUAL HARVESTING METHOD ON IRRIGATED PLANTATION

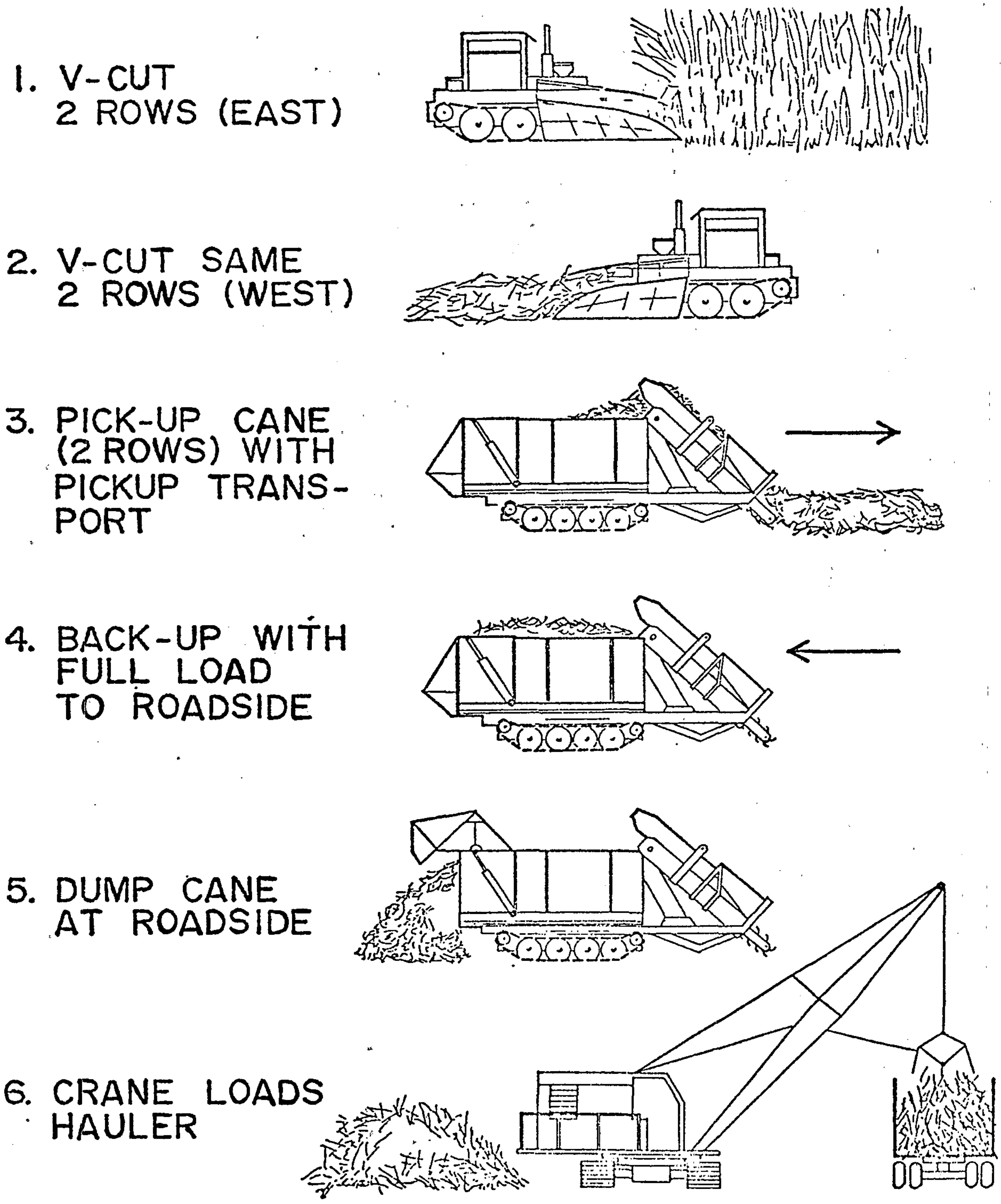


FIGURE 9

HARVESTING WITH PICKUP TRANSPORT ON NON-IRRIGATED PLANTATION

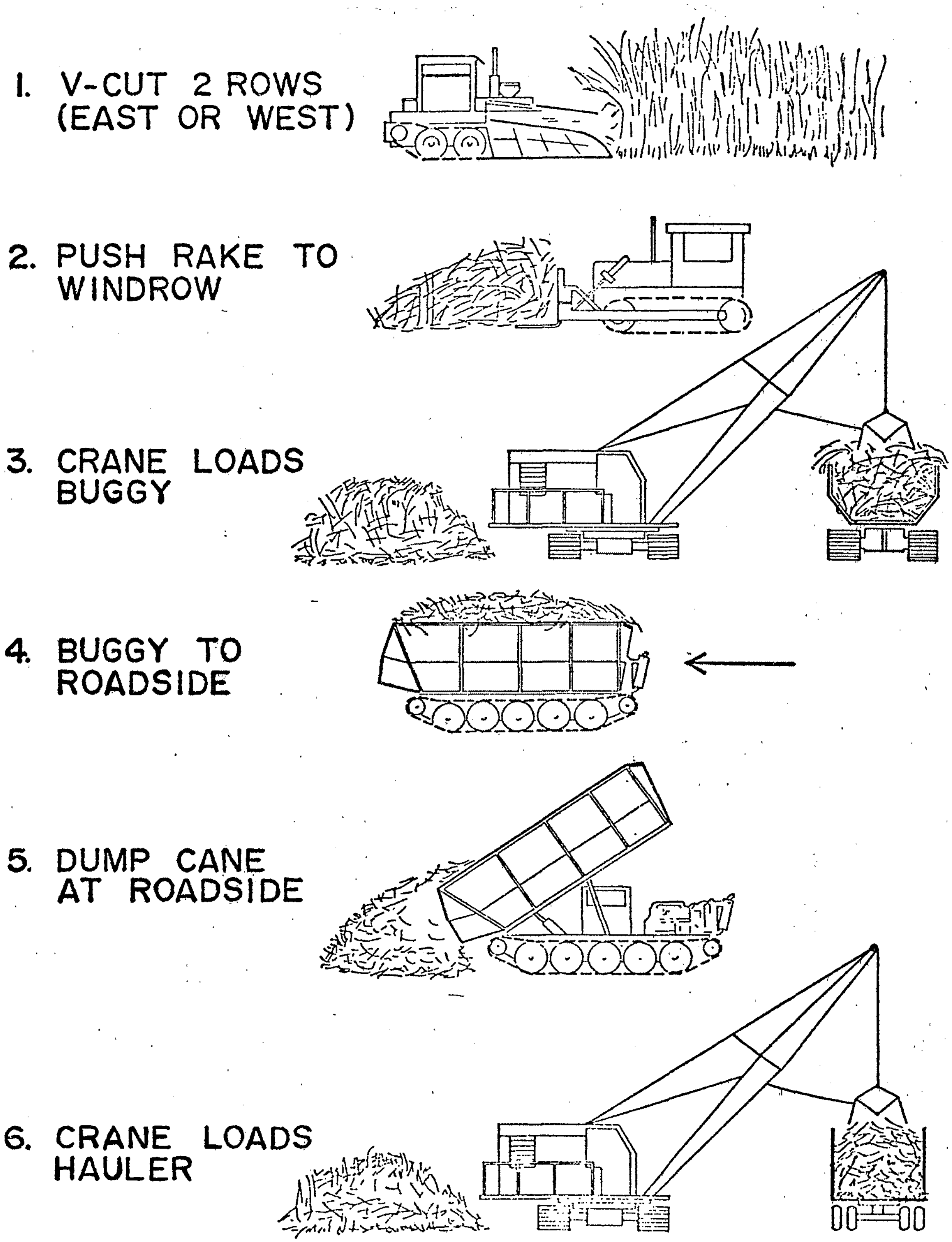


FIGURE 10

HARVESTING WITH BUGGY ON NON-IRRIGATED PLANTATION percent extraneous material and, during times of heavy rainfall, as much as 70 percent.

Such high loads of extraneous material are undesirable from both a waste water and a processing point of view. As discussed below, the mud, dirt, and trash content of cane directly influences the waste waters generated by cane washing and the quantities of filter mud produced by a plant. In terms of processing, a high content of extraneous material means a relatively low sugar production for the processing effort required.

In contrast to Hawaii, southern Florida is the only cane growing area in the United States where a sustantial amount of manual harvesting is employed. While one reason for this is the availability of Jamaican labor, probably a more important reason is the nature of the Florida cane which makes mechanical harvesting difficult. The soft muck of the cane fields and the weak root systems of the Florida cane prevents the cane from standing straight.

As in Hawaii, the Florida cane fields are burned prior to harvesting. However, the primary reason is not the reduction of trash content, since this can be accomplished by manual stripping of the cane stalk, but for increased accessibility of the fields to the workers and reduction of the danger of snake bites.

Following manual cutting, the cane is mechanically loaded onto trucks and hauled to the factory. The content of extraneous material in the cane is relatively low--about five percent--due to the manual cutting.

From interviews with the management of the Florida factories, it would appear that complete mechanical harvesting would be desirable when and if it becomes available. The 1972-1973 harvesting season in Florida witnessed the first major application of complete mechanization of harvesting at one factory operation. Within five to ten years, if mechanical harvesters become more adapted to the Florida cane, it can be expected that all Florida factories will be using mechanical harvesting. If this is the case, the extraneous material content in sugar cane delivered to the Florida factories may increase. Considerable research and development is being undertaken at this time in an effort to minimize anticipated increases in trash content through the use of harvesting equipment which would leave the bulk of extraneous material in the fields.

Mechanization of Louisiana cane harvesting was accomplished, as in Hawaii, as a result of the labor shortage of World War II and the subsequent period of rising labor costs. Unlike the northern Everglades in Florida, the soils of the river and bayou valley's in southern Louisiana support sugarcane that grows upright in a normal season and is relatively adaptable to mechanical harvesting. During a normal season, the extraneous material content does not exceed 20 percent; however, heavy rainfalls can increase this figure. Also, a hurricane passing over the fields prior to the harvest can leave the cane in a tangled mess and the subsequent mechanical harvesting can result in more than 50 percent extraneous material in the harvested cane.

In contrast to Florida and Hawaii cane, the Louisiana cane is burned after mechanical cutting, while lying on the ground. This reduces the amount of particulate matter which becomes airbourne. As in Hawaii, the purpose of burning is to reduce trash content. After burning of the field, the cane is machine-gathered and loaded onto specially constructed trailers which are towed by tractors to the sugar factories.

In Puerto Rico, about 75 percent of all cane is mechanically harvested; however, the cane received by individual factories may range from very little to almost total mechanically harvested cane, and the amount of extraneous material varies accordingly. The trend of increased mechanization can be expected to increase in Puerto Rico; however, some bastions of hand harvesting will probably survive on the island as long as there are small farms and farms on extremely hilly terrain.

Transportation and Storage of Cane

The transportation of cane from the fields to the factory is generally accomplished by truck in Florida, Puerto Rico, and Hawaii, and by tractor and trailer in Louisiana. In some cases in Hawaii where the factory is at a considerably lower elevation than the fields, hydraulic flumes are used. It is obviously desirable to the truckers to transport as much cane as possible in each load, and the result is often a considerable amount of cane loss during transporation. This can create a substantial non-point source of water pollution during rainy conditions.

The haul distance should be short for economic reasons, but in practice it may vary from a few hundred feet to several miles. In a number of cases where the factory and the fields have the same owner, or when growers are contracted to particular factories, loads of cane will pass by one or more factories on their way to another factory.

Upon arrival at the designated factory, each load of cane is weighed, and the tare weight of the transporting vehicle subtracted. Quantity control of the entire factory operation is usually based on this weighing since weighing of the raw sugar product is normally done as the sugar is sold, and this may follow production by many months.

In most cases, the grower receives payment for the cane on the basis of the gross weight delivered, but with adjustments for sucrose content. Samples of the cane produced by each grower are checked for sucrose content and the grower is awarded extra payment for a sucrose content higher than a set figure, or is penalized for a content lower than the set figure.

Due to the fact that harvesting and tranportation of cane generally occur only in daylight hours while processing at the factory is a twenty-four hour operation, a stockpile of cane must be maintained at the factory. Under ideal management, the cane yard should contain almost no cane when the first load arrives from the fields in the morning and should hold enough when the last load arrives in the evening for continuous factory operation through the night. In practice, the stockpile can vary considerably from an inadequate supply to an over supply, although as long as the stockpile has a detention time short enough to prevent inversion, the former is the greater process problem. The exception to only daylight harvesting occurs in Hawaii where cane is harvested and transported to the factory over a twenty-four hour period.

Cane Cleaning

The actual manufacturing of raw sugar begins with the extraction of juice from the sugarcane. With the extensive replacement of hand cutting by mechanical harvesting and the resulting increase of mud and dirt content in the cane, many factories find washing of the cane prior to extraction to be necessary. Figure 11 is a diagram which illustrates those unit operations which are employed at a factory which washes cane.

The type of washing operation may depend to some extent on location, soil characteristics, and type of harvester and harvesting method in use. In Louisiana, where soil is rock-free, the cane is usually washed by a spray of warm barometric condenser cooling water that is sprayed onto the carrier. In Hawaii, where over 25 percent of the gross weight of cane delivered to a typical mill consists of rocks, earth, and cane trash, the cane cleaning operations have to be elaborate and costly. Rocks are removed by floating the cane across a water or mud bath and then the cane is washed on an elevated conveyer called a cascade. Elaborate systems, some costing in excess of a million dollars, have also been installed in Puerto Rico where mechanical harvesting has experienced rapid growth in recent years.

Cane washing is avoided at a number of Puerto Rico factories and at most Florida factories. The lack of washing at the Puerto Rico factories can be attributed to a combination of soil conditions, percentage of incoming cane that has been hand harvested, and management policy. In regard to the last factor, some factory managers would rather tolerate decreased factory efficiency than the expenses and associated problems of cane washing. The hand harvesting employed by Florida factories generally precludes the need for cane washing.

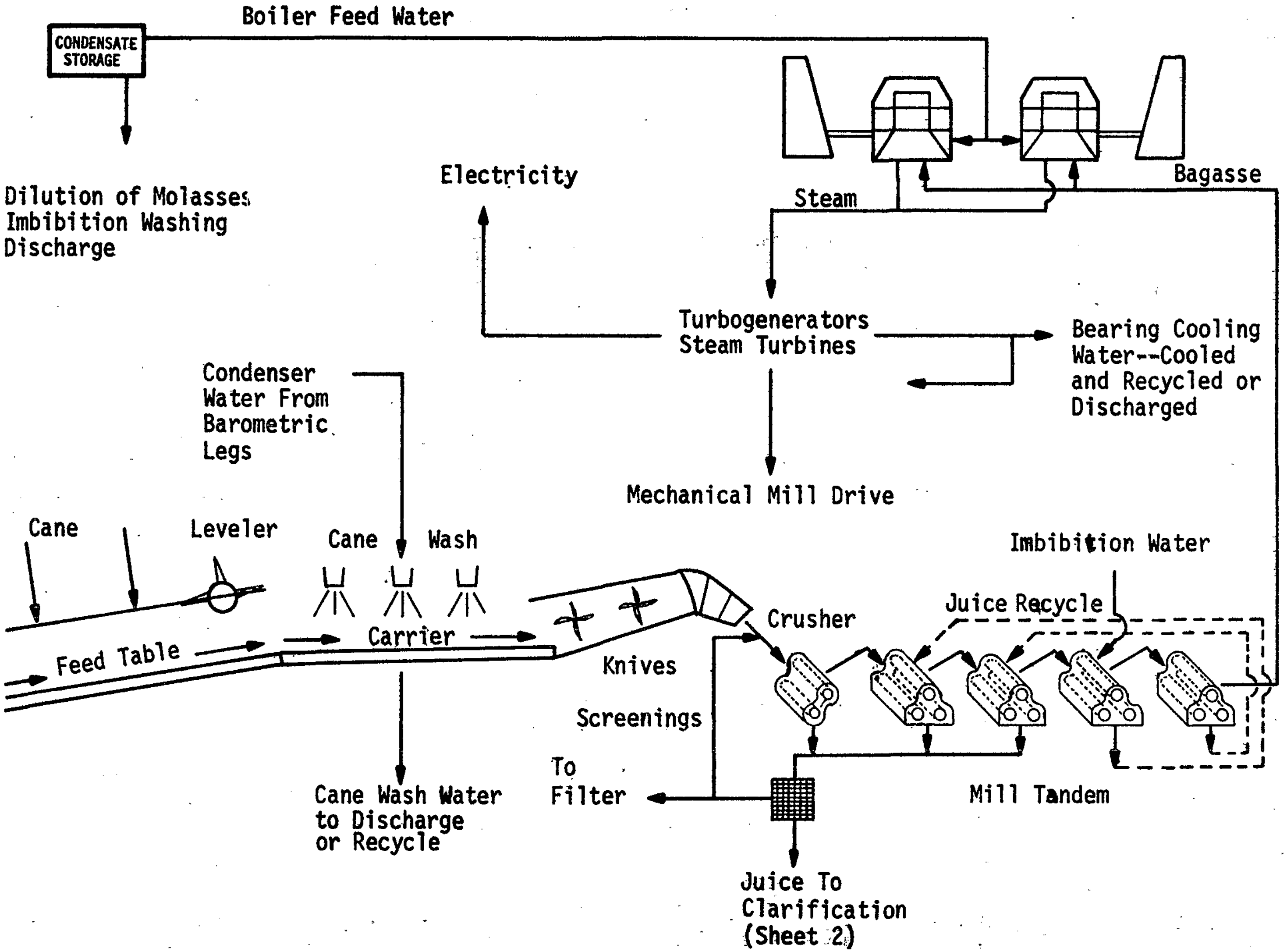


FIGURE 11

TYPICAL SUGAR FACTORY WITH CANE WASH

Sheet 1 of 3

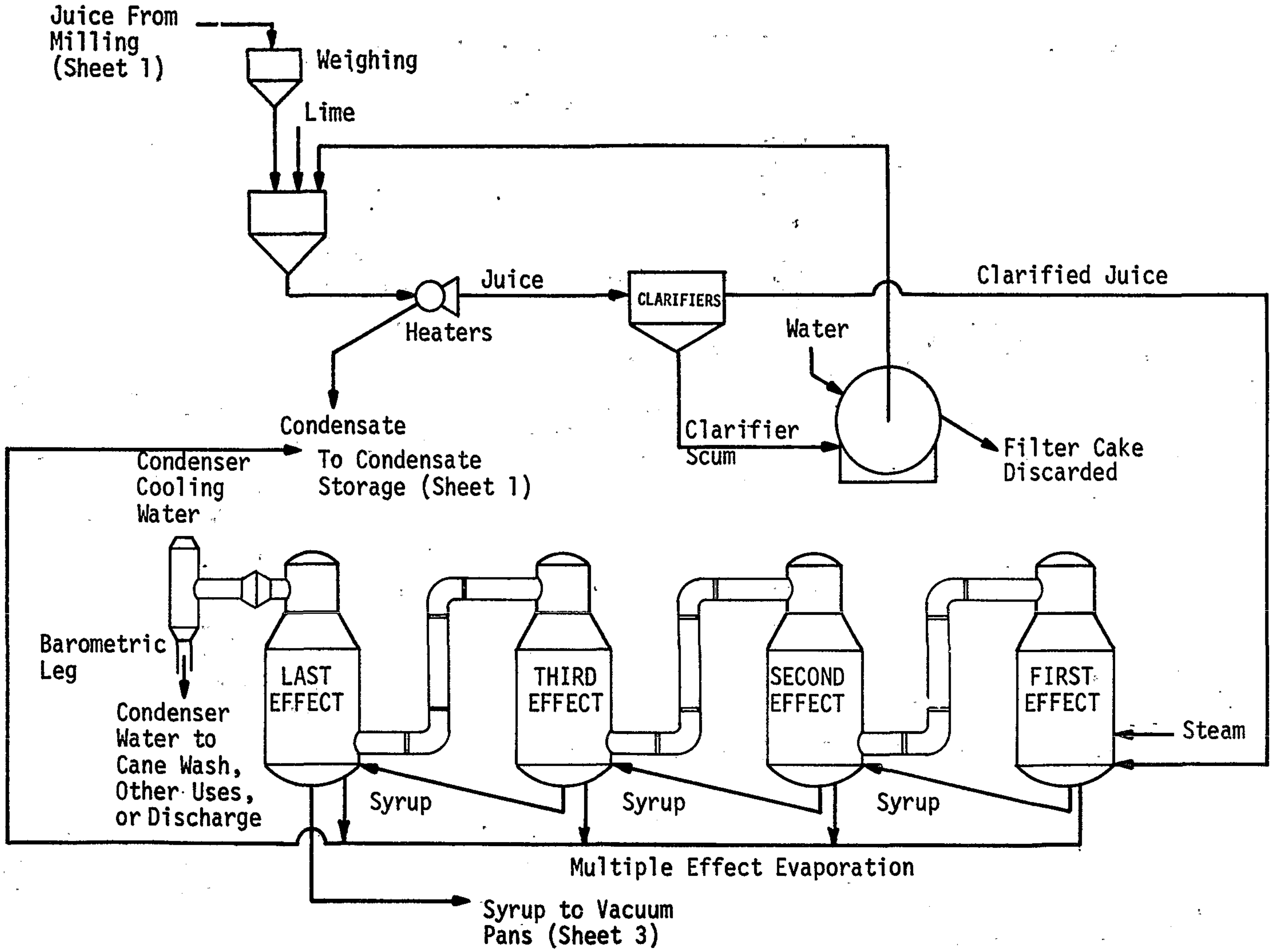


FIGURE 11 (CONTINUED)

TYPICAL EVAPORATION SYSTEM

Sheet 2 of 3

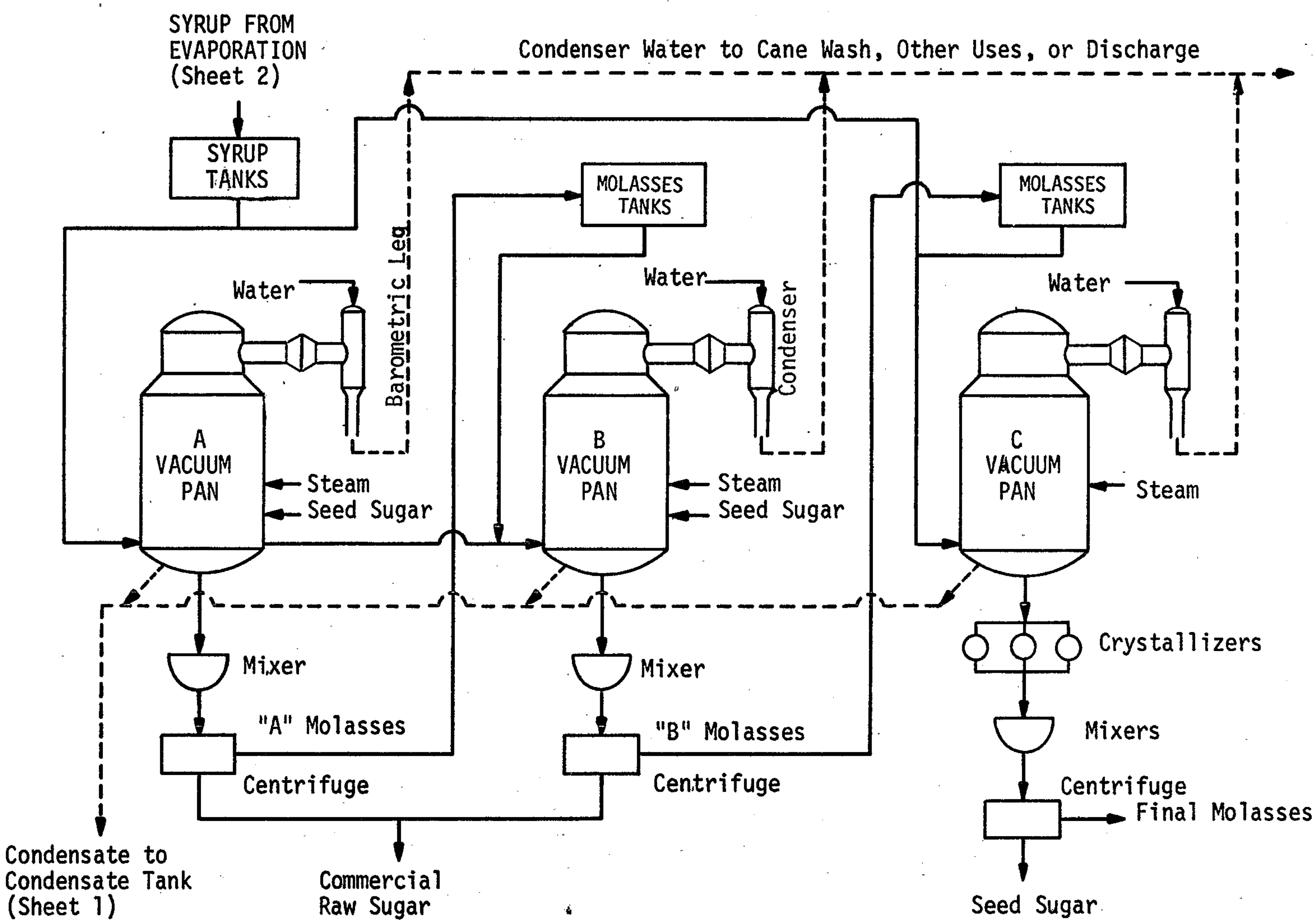


FIGURE 11 (CONTINUED)

TYPICAL SUGAR BOILING SYSTEM

Sheet 3 of 3

Since the washing of cane requires substantial volumes of water, produces a major waste water stream, and reduces the sucrose content of cane, research into dry cleaning methods dates back many years. Recently, dry cleaning techniques have been introduced with varying success at full scale operations where high velocity air streams remove soil and trash from the cane without affecting the sucrose content. The efficiency of these methods for removal of soil and trash is less than that of water washing. A further discussion of dry cleaning techniques will be presented in Section VII, Control and Treatment Technology.

The Milling Process (Extraction)

The purpose of the milling process is to extract juice from the cane stalk. This is usually accomplished with revolving cane knives, shredders, crushers, and mills.

Revolving knives are used to cut the cane into chips to prepare the cane for grinding and to provide a more even feed to the mills. Shredders further prepare the cane for grinding and help attain greater juice extraction. Both of these operations increase mill capacity. Crushers usually consist of two or three deeply grooved rollers which crush the cane and extract from 40 to 70 percent of the juice.

Modern milling plants consist of several three-roll mills in tandem with each being about 0.91 meters (36 inches) in diameter and 1.22 to 2.14 meters (four to seven feet) long. A typical mill train is composed of three to seven such sets of rollers preceded by two revolving knives. With this equipment it is possible to remove 85 to 93 percent of the juice. In order to improve juice extraction, it is universal practice to wet the cane after each mill with warm water or thin juices. This use of water to dissolve sucrose is termed "imbibition", "saturation", or "maceration". The most common type of imbibition is "compound imbibition" and is applicable to trains of four or more mills. Water is applied to the cane fiber (bagasse) going to the last mill or last two mills, the last mill juice is returned to the bagasse going to the next to last mill, this juice in turn goes back to bagasse from the preceding mill, etc. Table 6 shows the concentrations of juice from the different mills in compound imbibition processes. The juice along with the imbibition water is approximately equal to the weight of the cane going to the mills.

The bagasse, which is drawn from the last mill and normally amounts to about 30 percent by weight of the cane entering the operation, contains about 50 percent moisture, and is usually taken to a boiler where it is used as fuel to produce steam. It may in some cases be used for the manufacture of pulp, wall board, furfural, and other by-products. Commonly, however, bagasse in excess of that required for

TABLE 6

COMPOSITION OF MILL JUICES FROM COMPOUND IMBIBITION

Source of Samples	Brix	Polarization	Purity
Double crusher	17.16	14.50	84.50
First mill			
Front roll	17.08	14.12	82.67
Back roll	16.13	13.06	80.97
Second mill			
Front roll	7.63	5.83	76.41
Back roll	9.37	7.31	78.01
Third mill			
Front roll	5.04	3.73	73.94
Back roll	6.14	4.54	74.01
Fourth mill			
Front roll	3.00	2.18	70.60
Back roll	4.52	3.26	72.12
Fifth mill			
Front roll	1.31	0.88	67.18
Back roll	2.55	1.78	69.80

boiler fuel is hauled to land fill, or, in rare cases, slurried and discharged.

The boiler plant, fueled primarily by bagasse from the milling operation, generates all the steam required in the operation of the factory. During start-ups or abnormal conditions, natural gas or Bunker C fuel oil is used as auxiliary fuel. The boiler plant normally operates on externally-treated zeolite-softened fresh water at the beginning of the grinding operations, but subsequently is able to make exclusive use of the condensate from the processing operation. The amount of condensate produced by the evaporation of cane juice and the condensation of steam from all turbines is sufficient to supply all boiler feed water needs. Some condensate is used at various places in the process and the excess is discarded.

The steam generated by the boilers, ususally at pressures of 11 to 28 atmospheres (one Hawaiian mill generates steam at a pressure of 80 atmospheres), is used to operate the milling plant and the turbo-generators which furnish electricity for the plant. The generated voltage is usually 42,000, 23,000 or 480 volts. Plants with higher steam pressures and higher voltages reduce the voltage near points of use to 480 in sub-stations. A utility tie-in sub-station or diesel generator is normally installed for emergency and off season electric power. The exhaust from prime-movers in the milling plant is usually 2.0 to 2.4 atmospheres. Any deficiency in exhaust steam is alleviated by an automatic pressure regulating station. Any excess exhaust that might be present is released to the atmosphere by an automatic relief valve.

Clarification

The juice from the mill contains a considerable amount of impurities including fine particles of bagasse as well as fats, waxes, and gums. Screening removes the coarser particles (cush-cush) which are returned to the mills. A substantial portion of the remaining impurities are removed by clarification.

In the manufacture of the raw sugar product, lime, heat, and a small amount of phosphate are used to remove as much of the remaining impurities as possible. This is the oldest and most effective method of purifying the juice, and is known as the "defecation" process. Usually sufficient lime is added to neutralize the organic acids present in the juice and raise the pH to 7.3 to 7.8. The temperature of the juice is raised to about 102 to 105 degrees Centigrade (215 to 220 degrees Fahrenheit) and a flocculent precipitate of a complex composition is formed which consists largely of insoluble lime salts, and includes calcium phosphates, coagulated albumin, fats, acids, gums, iron, alumina, and other materials. Most of the suspended material remaining in the juice is occluded and carried down with the precipitate. Separation of the precipitate is accomplished by settling and decantation in continuous clarifiers.

Variations of the clarification process are sometimes used and various other chemicals can be added to enhance clarification. The most significant recent development in clarification has probably been the introduction of polyelectrolytes as an aid in flocculation. In the production of white sugar directly from cane without remelting and recrystallization, raw clarification must be more complete and for this reason it is common to add sulfur dioxide or carbon dioxide in conjunction with lime. These processes are known as sulphitation and carbonation, respectively. At present, however, they are seldom used in the manufacture of raw sugar in the United States and Puerto Rico.

Filtration

As a result of clarification, the juice is divided into two portions: (1) the clarified juice and (2) the precipitated sludge (muds). The clarified juice makes up about 80 to 90 percent of the original juice and is usually taken directly to the evaporator system. The sludge is usually thickened by rotary vacuum filters.

In the past the most common type of filter used to separate the solids in the sludge was a simple and efficient plate and frame filter which allowed the filtered juice to be mixed directly with the clarified juice and to be sent to the evaporators. A main drawback of the plate and frame filter, however, was the labor required to take the filter apart in order to remove and wash the filter cake.

Rotary vacuum filters have almost completely replaced filter presses in the United States and Puerto Rico. These filters are not as effective as the filter presses and the filtered juice must be taken back through the clarifiers, but this disadvantage is more than compensated for by the reduction in labor. A rotary filter consists of a rotating drum covered with a perforated plate or cloth which dips into a bath containing the sludge water. As the drum rotates, suction is applied to the surface and a thin layer of cake is formed on the filtering surface. The cake is washed and discarded onto a conveyor by scraping from the filtering surface. Usually a small amount of fine bagasse particles (bagacillo) is mixed with the muds to improve filtration. Various improvements on the rotary vacuum filter system have been devised in order to produce a filtrate that can be taken directly to the clarifier.

The amount of filter cake produced fluctuates between 20 and 75 kilograms per metric ton (40-150 pounds per ton) of cane ground, depending upon cane conditions. It has a moisture content ranging between 70 and 80 percent.

The remaining solids consist mostly of organic material with 15 to 30 percent lime phosphate salts. The sucrose content in the cake is about three percent. The filter cake that is discarded in the filtering process can be handled dry or in slurry form. The dry filter cake is more difficult and expensive to handle, but it can be spread on fields as a soil conditioner and fertilizer. When the cake is slurried with water, it is easier to handle in the plant but the ultimate disposal problem becomes more difficult. At the present time both dry and slurry handling methods are common. In those cases where filter cake slurries are discharged as waste water, they become a very significant source of water pollution produced by a sugar factory.

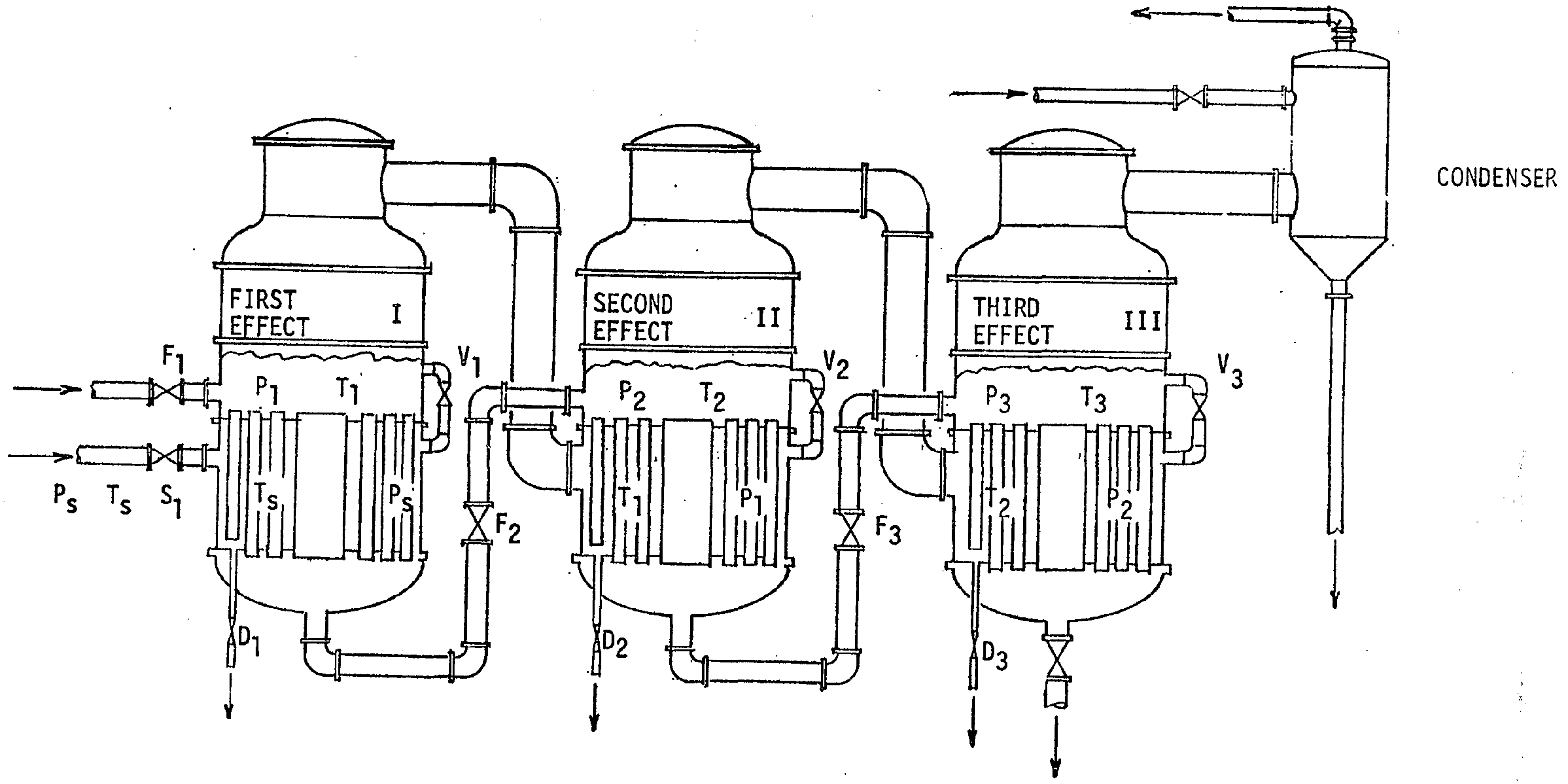
Evaporation

The juice from the clarification systems is about 85 percent water and 15 percent solids. Before the juice can be crystallized, sufficient water must be removed to obtain a syrup of about 60 percent solids. Evaporators are used to accomplish this concentration and most plants use multiple-effect evaporators for better fuel economy.

An evaporator is a closed vessel heated by steam and placed under a vacuum. The basic principle is that the juice enters the evaporator at a temperature higher than its boiling temperature under the reduced pressure, or is heated to that temperature. The result is evaporation and the principle allows evaporators to be operated in a series of several units. This practice is called multiple-effect evaporation, with each evaporation step called an "effect," which is illustrated in Figure 12. In general, the vacuum in each effect is created by the condensation of the vapors from that effect in the subsequent effect. The heat of vaporization of the juice in each effect is supplied by the vapors from the previous effect, with the exception of the first and last effects. The first effect normally has exhaust steam provided to it, and the last effect has a vacuum caused by the condensation of its vapors in the condenser. The temperature and pressure of each effect are, therefore, lower than the preceding effect. Typically the liquid in the first effect may be boiling at pressures of 1.4 to 1.7 atmospheres while the liquid in the last effect will be boiling at about 0.13 atmospheres.

The cane sugar industry commonly uses triple, quadruple, or quintuple effect evaporation with the short tube or "calandria" type of evaporator (as illustrated in Figure 12), although the Lillie film evaporator is used in some installations.

Condensation of the vapors from the last effect may be provided by one of several condenser designs, but the barometric condenser is used almost exclusively in sugar factories. This works on the principle of relatively cold water passing through a cylindrical vessel, contacting the hot vapors, and condensing them. The resulting hot water leaves through a long vertical pipe called a barometric leg. Air is removed



D_1,D_2,D_3, CONDENSATE VALVES
F_1,F_2,F_3, FEED VALVES
V_1,V_2,V_3, VENT VALVES
P_s,P_1,P_2,P_3,PRESSURES
T_s,T_1,T_2,T_3,TEMPERATURES
S_1 STEAM VALVE

FIGURE 12

MULTIPLE EFFECT EVAPORATION

from the system by a vacuum pump or steam ejector. The barometric condenser cooling water (barometric leg water) at a flow rate of perhaps 160,000 cubic meters (43 million gallons) per day in a large factory, is the largest volume of water used in a raw sugar factory. It is usually untreated surface water that is unsuitable for reuse in any part of the manufacturing process except cane washing. The barometric condenser is illustrated in Figure 13.

A problem common to the sugar industry in its attempt to prevent sugar loss and to the environmentalist in the attempt to prevent pollution is the entrainment of sugar in the vapors from the evaporators. The condensed steam from the first effect does not have direct contact with the juice and is essentially pure water. It is used as feed water for the steam boilers. The condensates from the other effects experience relatively little sugar entrainment and are used either for boiler feed water or process water; however, in some cases "excess" condensate may be discharged as a waste stream. The major problem is with the vapor from the last effect which tends to have greater entrainment than the other effects and, due to its mixing with the barometric condenser cooling water, becomes a volume too large for any reuse other than for cane washing.

Various methods of reducing entrainment are used in the industry, but all are based on either the principle of gravity or centrifugal action or the principle of direct impact; i.e., by changing the direction of vapor flow so that liquid droplets may veer away from the vapor, be impinged on a surface, and ultimately be returned to the liquid body or, by allowing the vapor to come into direct contact with a wet surface. A schematic of various methods commonly used is shown in Figure 14.

The distance between the liquid level in the evaporator and the top of the cylindrical portion of the body is called the "vapor belt". This distance is important with regard to entrainment because the higher the vapor has to rise the more opportunity liquid droplets have to drop out. Most vapor belts range from one and a half to six meters (five to twenty feet) between the calandria and the top of the vapor belt. A distance of at least two times the tube length is required to obtain reasonably good gravity separation.

Raw sugar factories often monitor sucrose concentrations in condensate and barometric condenser cooling water to avoid the addition of sugar to boiler feed waters, where it can damage boiler tubes, and to avoid sugar loss in condenser water. The frequency of monitoring may vary from continuous (automatic analyzers) to hourly, daily, or weekly. The methods of analysis for sucrose are the "resorcinol test" or, more commonly, the "alphanaphthol test". Both methods are based on a color change which occurs with the reaction of the test reagent with sucrose. Neither test is considered to be highly accurate in quantitative terms, but they serve the purpose of indicating excessive

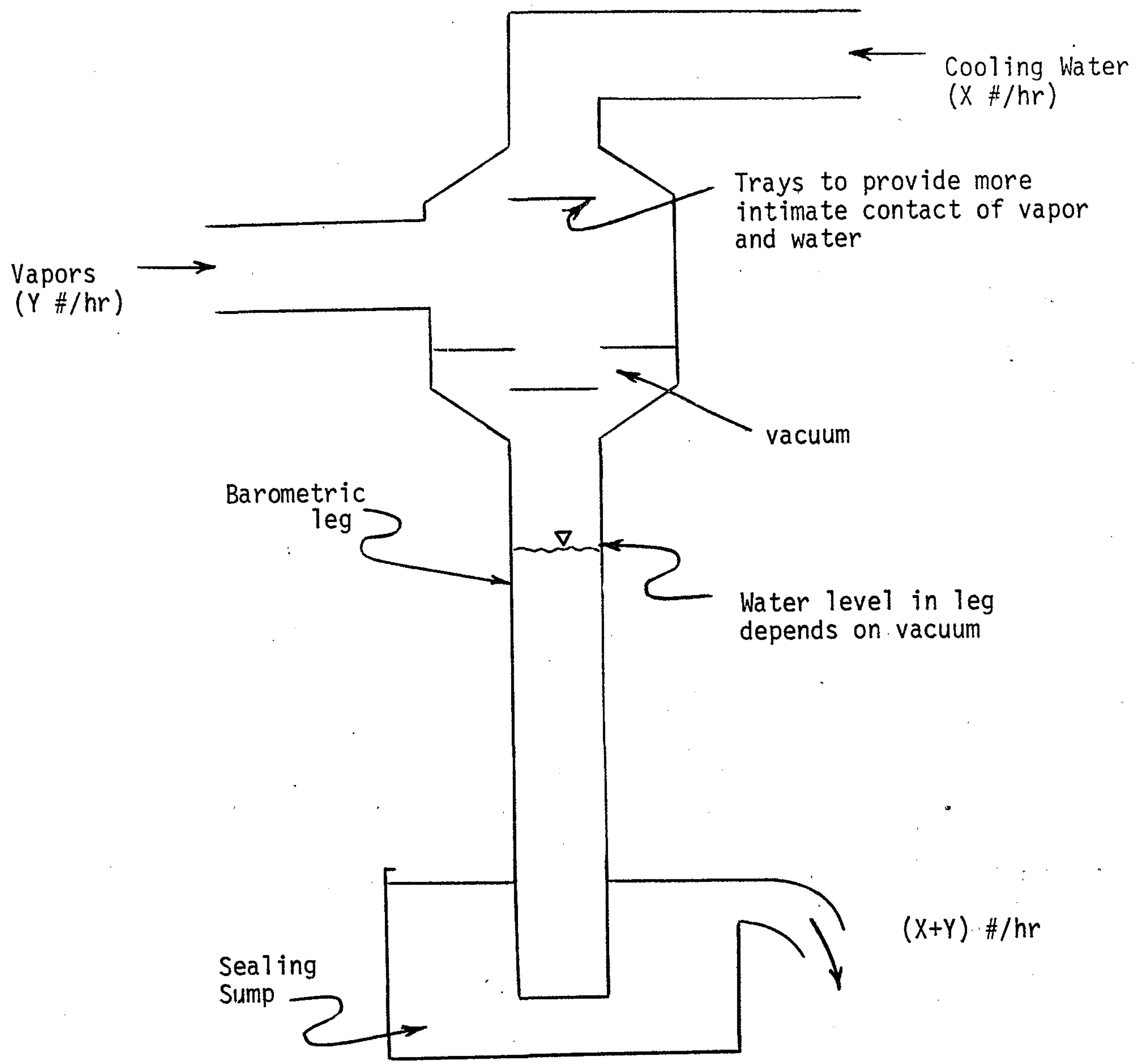
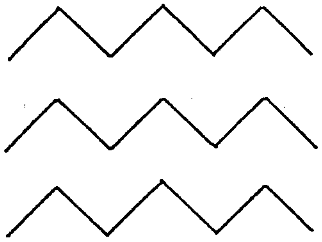
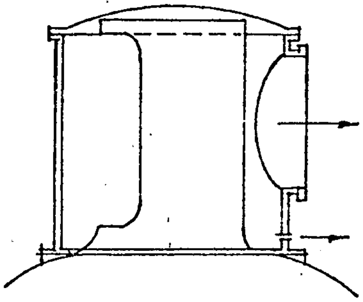


FIGURE 13

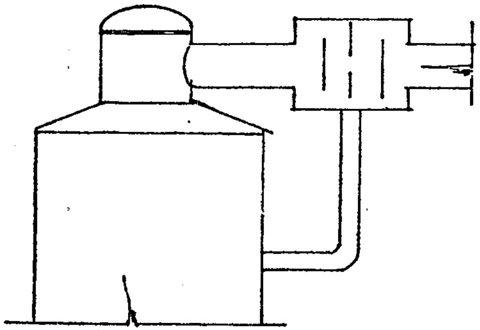
BAROMETRIC CONDENSER



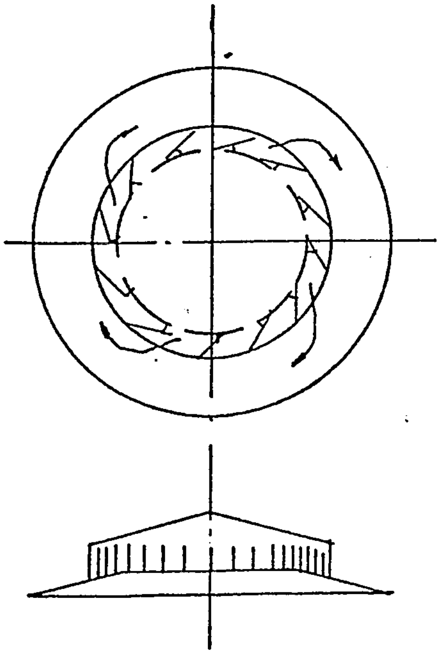
(A) Zig-Zag Baffle



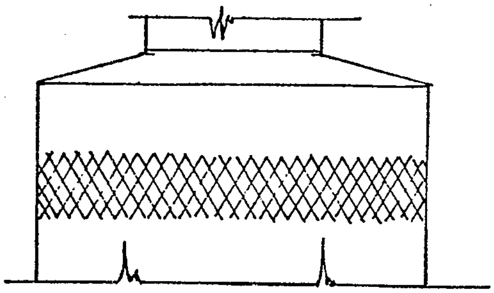
(B) Catch All



(D) In-Line Baffle Box



(C) Cyclone Separator



(E) Demister

FIGURE 14

DEVICES TO REDUCE ENTRAINMENT

sucrose concentrations and, therefore, indicating that a problem exists in the system. Normally, until such time that the problem can be defined and corrected, the contaminated waters are discharged with the cooling waters.

Crystallization

After concentration in evaporators, the juice is crystallized in single effect, batch type evaporators called "vacuum pans". Calandria pans are commonly used. These are similar to the calandria evaporator described above except the pans have shorter tubes of larger diameter in order to handle the more concentrated juice. Vacuum pans are operated by either exhaust steam, or vapor from the first stage evaporators; the resulting condensates are used as previously described for evaporators.

In order for sugar crystals to grow in a vacuum pan, the sugar solution must be supersaturated. There are three phases of supersaturation in sugar boiling: the metastable phase in which existing crystals grow but new crystals do not form, the intermediate phase in which existing crystals grow and also new crystals form, and the labile phase in which new crystals form spontaneously without the presence of others. The formation of new or "false" crystals is undesirable and the pan must be maintained in that narrow range of sucrose concentration and temperature which provides for the metastable phase and for the growth of the seed crystals which are introduced into the vacuum pan at the beginning of the operation. Automatic controls for pan operation are beginning to be used in raw sugar boiling.

Since vacuum pans are essentially single effect evaporators, each pan must have a vacuum source and a condenser as described above for evaporators. Sugar entrainment is a potential problem, particularly during start-ups or upsets, and various "catch-alls", centrifugal separators, or baffle arrangements are used along with sucrose monitoring.

After the formation of crystals in the pans, the massecuite (mixture of sugar crystals and syrup) is discharged into a mixer where it is gently agitated, and then into high speed centrifugals where crystals are separated from the syrup. The crystals remaining in the centrifuge are washed with hot water to remove remaining syrup, and the crystalline sugar is discharged to storage.

As shown in Figure 11, vacuum pans operate in series with each pan crystallizing a different grade of massecuite. The series may consist of two, three (as illustrated), or four pans normally designated as "A," "B," "C," etc. The "A" pan is fed with concentrated juice and produces raw sugar and "A" molasses. The "A" molasses is fed to a "footing" of seed in pan "B" which in turn produces raw sugar and "B" molasses. The last pan produces low grade sugar and "final molasses". The final molasses is considered to contain insufficient sucrose for further crystallization. The low grade sugar produced in the last pan is melted into a syrup called "remelt" and mixed with the syrup from the evaporators.

The final pan cannot completely or even adequately exhaust the massecuite of sucrose. Therefore, the massecuite from the final boiling is commonly discharged to a crystallizer in which it is gently agitated and cooled and where crystallization is encouraged by decreased solubility resulting from lower temperature.

Product Handling

The raw sugar from the centrifugals is conveyed to shipping or to storage warehouses by various means, the most common of which are belt or screw conveyors. Modern practice is to store raw sugar in the bulk form. From the warehouse, the sugar is transported as the market requires, by truck, rail, or ship to refineries. Three factories in Puerto Rico, one in Florida, and three in Louisiana operate in direct conjunction with refining operations.

The final or "blackstrap" molasses, from which sugar is unrecoverable by ordinary means, is usually sold for various uses. Approximately two-thirds of the blackstrap molasses production in the United States is used for animal feeds. A large portion of Puerto Rican blackstrap is utilized for the production of rum. Other uses in the United States include the production of ethyl and butyl alcohols, and acetic and citric acids.

SECTION IV

INDUSTRY SUBCATEGORIZATION

In the development of effluent limitations and guidelines and standards of performance for the cane sugar industry, it was necessary to determine whether significant differences exist which form a basis for subcategorization of the industry. The rationale for subcategorization was based on emphasized differences and similarities in the following factors: (1) constituents and/or quantity of waste produced, (2) the engineering feasibility of treatment and resulting effluent reduction, and (3) the cost of treatment. While factors such as process employed, plant age and size, and nature of raw material utilized tend to affect the constituents and quantity of waste produced, the emphasis herein is not merely on an analyzation of these factors but on the resulting differences in waste production, engineering feasibility, and cost.

The cane sugar industry had been preliminarily categorized into Standard Industrial Classification (SIC) Code 2061, Cane Sugar Except Refining Only, and SIC Code 2062, Cane Sugar Refining. Despite the fact that eight cane sugar factories also operate refineries, it was felt that just as the cane and beet sugar industries are subjects of independent studies, factories and refineries should be considered independently due to the substantial differences in processes employed and waste water quality and quantity, even if the independent studies lead to the same effluent guidelines. Therefore, the recommended effluent limitations and standards for cane sugar <u>refining</u> have been published in a separate document (43 and 44).

Several factors or elements were considered with regard to identifying any relevant subcategorization. These factors included:

1. Raw materials
2. Harvesting techniques
3. Land availability for treatment and disposal
4. Length of grinding season
5. Climatic variations
6. Size of plants
7. Nature of soil
8. Process variations
9. Age of plants
10. Nature of water supply

It should be noted that these elements are in some cases independent and in other cases interdependent. Raw materials and factory age, for example, are essentially independent of the other elements and of each other while the length of the harvesting season has a definite influence on factory size. Essentially all of the elements vary with geographical location.

After consideration of all of the above factors it is concluded that the raw cane sugar processing segment can be treated as five subcategories of the sugar processing category, and can be described by their various geographical locations as follows:

Subcategory I - This subcategory includes those cane sugar factories which process sugarcane into a raw sugar product and are located within the State of Louisiana.

Subcategory II - This subcategory includes those cane sugar factories which process sugarcane into a raw sugar product and are located within the States of Florida and Texas.

Subcategory III - This subcategory includes those cane sugar factories which process sugarcane into a raw sugar product and are located on the Hilo-Hamakua Coast of the Island of Hawaii in the State of Hawaii.

Subcategory IV - This subcategory includes those cane sugar factories not included in Subcategory III, which process sugarcane into a raw sugar product and are located in the State of Hawaii.

Subcategory V - This subcategory includes those cane sugar factories which process sugarcane into a raw sugar product and are located on the Island of Puerto Rico.

The rationale for the above subcategorization is as follows:

Nature of Raw Materials

All cane sugar factories process raw sugar cane. There are a number of different varieties of sugar cane grown, but in terms of waste water generation the variations have negligible effects.

The factor which does have a significant influence on operation and waste water characteristics is the condition of the cane upon arrival to the factory -- how much mud and trash it contains. The greater the quantity of mud and trash entering the factory the greater the increase in (1) the amount of bagasse produced which in turn may result in more air pollution by increasing fly ash emissions, (2) the quantity of filter mud produced, and (3) the amount of pollutants in the cane wash effluent. In general, as the quantities of mud and trash entering the factory increase, it is necessary that the factory operate at an increased rate to produce a reduced amount of raw sugar. This can create severe economic problems, as has been experienced by those factories which form Subcategory V.

The nature of the field cane entering a factory is affected by several factors including harvesting techniques and climatic conditions, which will be discussed below, and sucrose content and soil conditions. As documented in Section V, the field cane entering Subcategory II factories is relatively clean due to the method of harvesting and is a factor that allows these factories to omit cane washing. Again due to harvesting techniques, the cane entering the factories of Subcategories III and IV has an extremely high mud and trash content. The field cane processed by the factories of Subcategories I and V is of intermediate cleanliness; however, that of Subcategory V has a higher fiber content than the other subcategories. These differences in waste water characteristics result in the following groupings: those factories which form (1) Subcategories I and V, (2) Subcategory II, and (3) Subcategories III and IV.

Harvesting Techniques

As was discussed above, cane harvesting techniques affect the amounts of mud, dirt, and rocks entering a factory as well as the amount of trash in the harvested cane. The effects on the factory include: the presence or absence of cane wash operations and the quality of spent cane wash water, the efficiency of sucrose production, and the amounts of filter mud and bagasse produced.

There are three distinct harvesting techniques employed in the American sugar industry, each causing differing amounts of extraneous materials to enter a factory. The Subcategory II factories, with two exceptions, process hand-harvested cane. The relative cleanliness of the hand harvesting operation is a major factor in allowing the Subcategory II factories to avoid cane washing.

The Subcategory I factories process mechanically harvested cane exclusively and as a result must deal with considerably higher extraneous material contents than do the Subcategory II factories. Cane washing is universal within this subcategory and the waste waters generated differ from those of Subcategory II accordingly.

The factories in Subcategories III and IV also process mechanically harvested cane, but this method of harvesting involves the use of push-rakes to push the cane into windrows. The cane entering the factories contains a substantially higher extraneous material content than the cane processed by either the Subcategory I or Subcategory II factories. Cane washing is practiced in Subcategories III and IV. The resulting waste waters contain considerably higher concentrations and loadings of pollutants than do the waste waters generated by the factories in Subcategories I or II.

The factories in Subcategory V generally process a mixture of hand harvested and mechanically harvested cane. Mechanical harvesting has experienced increasing use during the recent past in this subcategory, and while it is expected that the effects on waste water characteristics are similar to those of Subcategory I, the data base currently accumulated for Subcategory V is limited because of the lack of historical data corresponding to current operating practices.

The overall result of varying harvesting techniques is to further substantiate the subcategorization.

Land Availability

Land availability may be defined as the ownership or potential ownership of land, or the use or potential use of land owned by others with their permission, with the land being in adequate quantity to allow waste water treatment and disposal, and with the added stipulation that the value of the land does not prohibit its use in such manner. Therefore, land availability is considered a secondary factor affecting the feasibility of waste water treatment.

As discussed in Section VII, those factories in Subcategories II and IV have land availability to such an extent that no discharge of polluted waste waters is practicable except under emergency conditions. Although factories in Subcategories I and V have variable land availability, it is assumed that adequate land is available for the application of the control and treatment alternatives discussed in Section VII. Subcategory III factories have very limited availability of land for treatment facilities due to the limiting slopes upon which they are located. The control and treatment technologies developed in Section VII for Subcategory III take this limitation into account.

The overall effect of land availability on control and treatment technology is further substantiation of the previously discussed groupings as well as justification for separating Subcategories III and IV into distinct subcategories.

Length of Processing Season

The length of the processing season for a factory is generally dependent on climate. Processing seasons can range from approximately two months in Subcategory I to almost 12 months in Subcategories III and IV.

The length of the processing season is an important factor in an evaluation of potential control and treatment technologies. For example, biological treatment in the form of activated sludge becomes less practical for short processing seasons while waste stabilization becomes more practical. The length of the processing season has been taken into account with regard to control and treatment technology; this provides further substantiation for the subcategorization of the industry.

Climatic Variations

Substantial variations in average temperatures, temperature ranges, radiation, and seasons exist among the various subcategories of the raw cane sugar processing segment which affect varietal selections, cultural practices, processing practices, and the age of cane at harvest. The age of cane at harvest has a direct bearing on the mechanical and operational constraints imposed upon harvesting systems used in the agricultural operations affiliated with the factories. The average age of cane at harvest exceeds twenty months in Hawaii as compared to an average age of approximately one year in other growing areas. This does not provide a basis for further subcategorization of the segment but is a significant factor in isolating Subcategories III and IV, and lends support to the subcategorization.

Another factor which varies significantly from region to region is rainfall. This factor can affect the chosen method of waste water disposal or treatment. The Subcategory IV factories are, for the most part, located on lands that require irrigation and are thereby favored with a waste water disposal method of considerable economic attractiveness. The factories in Subcategories I and III do not employ irrigation techniques; irrigation is practiced to some extent in Subcategory V. The cane fields of the Subcategory II factories require water level control, i.e., either drainage or irrigation at various times to maintain a proper water table level; however, since the processing season corresponds to the dry season, irrigation during this time of the year is more prevalent than drainage.

The presence or absence of irrigation as a result of climatic variations and the resulting waste water disposal alternatives are considered in Section VII. This factor offers further justification for the subcategorization defined in this section. The waste water characteristics which result from cane washing can be affected by rainfall during the harvesting operations, i.e., by an increase in the mud and trash entering the factory. Also, particularly in the case of Subcategory II factories, adverse climatic conditions such as hurricanes during the time the cane is growing can twist and bend the cane. Mechanical harvesting under such conditions can lead to substantial increases in mud and dirt in the harvested cane.

The effects of rainfall during harvesting can randomly cause variations for individual factories. The effects of adverse conditions during cane growth can cause intersubcategory but not intrasubcategory variations. Therefore, climatic variations, while providing support for the previously stated subcategorization, do not provide support for further subcategorization.

Size of Plants

As was shown in Tables 2 through 5, in Section III of this document, in terms of metric tons per day of gross cane ground, raw sugar factories range from 68 to 11,000 metric tons per day (75 to 12,000 tons). The larger factories are concentrated in Subcategory II with an average grind of 8,000 metric tons (9,000 tons) per day. The smaller grinds or smaller capacity factories, located in Subcategories

I and V, are the result of the relatively large number of factories operating in those cane growing areas. The factories in Subcategories III and IV are also small, but this fact can be misleading in view of their annual production which is greater than that of the factories in Subcategory II. This is due to their longer grinding season.

It might be assumed that larger factories are capable of better management, and it must be noted that the larger factories of Subcategory II are also the most modern; however, on a unit basis little difference exists between factories of different sizes. For example, Figure 15 shows a data distribution for barometric condenser cooling water flow versus factory grinding rate. While more consistency in flow rates may be indicated for larger factories, it is not apparent that the larger factories use less water on a unit basis.

In the cost analysis of Section VIII, factory size becomes a factor in that larger factories require more expensive facilities but at the same time enjoy the benefits of economy of scale. The single distinct size difference is that Subcategory II factories are considerably larger than those of other subcategories. This factor is secondary justification for treating Subcategory II as a separate subcategory.

Nature of Soil

The nature of the soil in which cane is grown affects the condition of the harvested cane in two ways: (a) directly by the amount of soil which adheres to the cane and (b) indirectly by affecting harvesting techniques which in turn affect the amount of mud and trash delivered to the factory.

As a result, the nature of the soil affects the characteristics of spent cane wash water, filter mud, and other wastes that contain the soil. The nature of the soil also affects the sucrose yield of cane and influences the operating efficiency of factories. Finally, the soil of the cane fields affects the ability of a factory to irrigate with waste water and spread land with solid waste such as filter mud. Significant variations in soil occur among the previously established subcategories but not within them. Therefore, variations in the nature of soil are not considered a justifiable element for further subcategorization.

Process Variation

While the production of raw sugar from sugar cane is a similar process in any factory, certain significant variations in process do occur. These may be necessitated in some cases by raw material quality, desired quality of end product, policies of factory management, or other reasons.

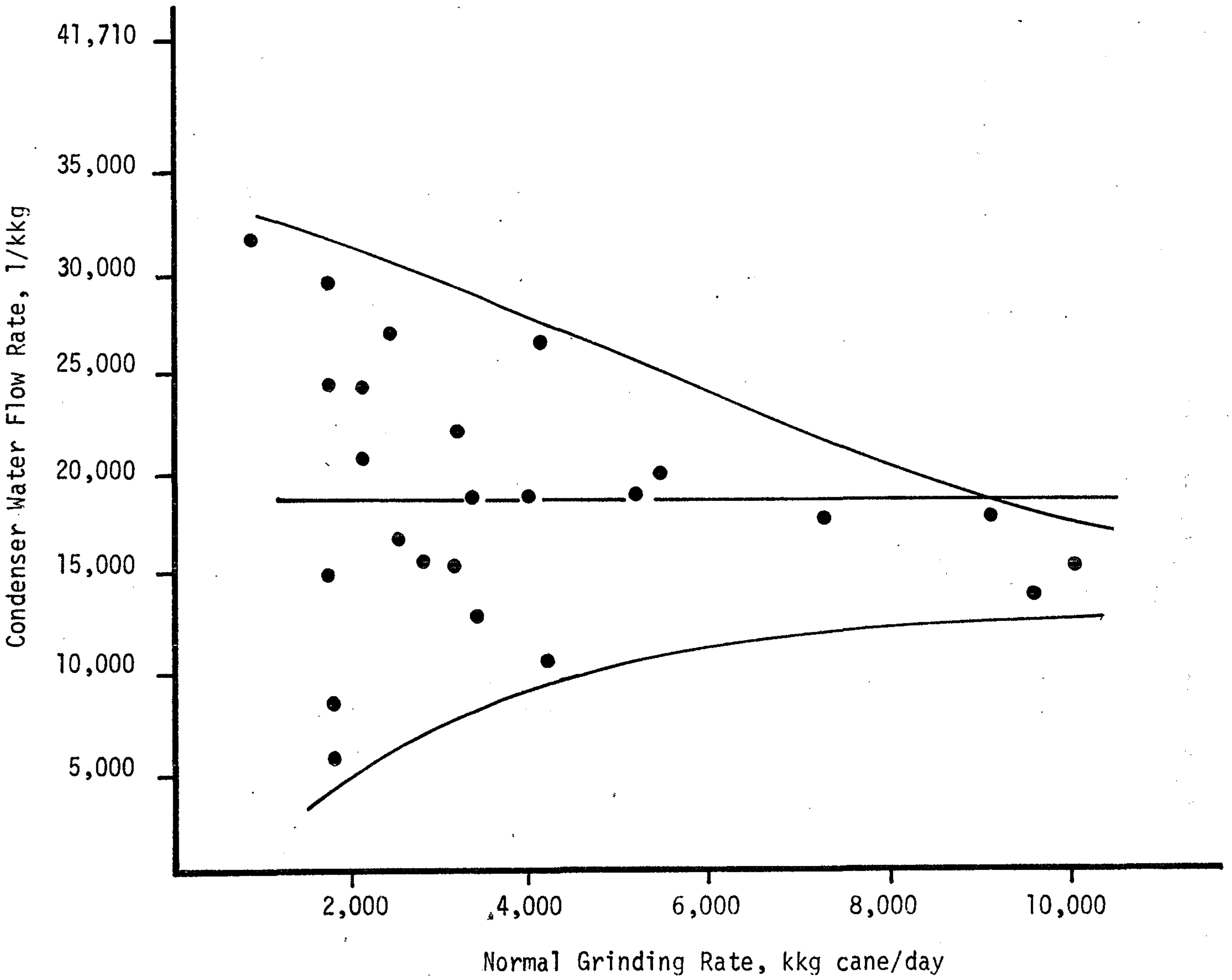


FIGURE 15

DISTRIBUTION OF CONDENSER WATER UNIT FLOW RATES IN TERMS OF FACTORY CAPACITY

The most significant process variation in terms of waste water generation is the presence or absence of cane washing. The effects of harvesting techniques, climatic conditions, and other factors on the presence or absence of cane washing have been discussed earlier and the characteristics of the major waste water stream produced by cane wash water are discussed in Section V.

Another major factor may be management policy -- the decision whether to wash cane and handle the extra water required and generate a major waste stream, or to not wash cane and handle the extraneous material within the process. While hand harvesting is prevalent in Subcategory II, two factories within this subcategory employ mechanical harvesting but choose not to wash cane except on occasional instances of extremely high extraneous material content in the cane.

Process variation may be considered as a secondary element which substantiates the previously stated subcategorization.

Age of Plants

The more modern plants are generally contained in Subcategory II due to the fact that the majority of the growth of the sugar industry in that subcategory has occurred during the last decade. Many of the factories in the other areas were originally constructed during the nineteenth century (in some cases using component parts from even earlier eras) and have received various degress of modernization over the years.

The history of an individual factory is generally unknown beyond the memory of current management and the age of component parts is, therefore, indeterminable. Therefore, age is not a factor that affects subcategorization.

Nature of Water Supply

The quantity and quality of fresh water supplies utilized by factories were originally considered as potential elements for industry subcategorization because of possible prohibitive factors that could be encountered in resulting control and treatment technology. It was found that fresh water sources for sugar factories varied from relatively high quality ground water to relatively low quality surface water, and some factories were found to be utilizing saline ocean water. The quantity of water available for factory use was found to be generally adequate with potential shortages being observed on the south coast of Puerto Rico and in certain areas of Hawaii.

It was generally observed that in those cases where low quality raw water presented potential problems, the problems were either not significant or the reduction in water usage in control and treatment (recycle and reuse) provided the alternative of higher quality water supplies. Therefore, the nature of water supplies was rejected as a possible element for further subcategorization.

SECTION V

WATER USE AND WASTE CHARACTERIZATION

Water is used in various ways in cane sugar factories and a variety of waste waters result. This section describes the water usage and characterizes the waste waters associated with the subcategories identified in Section IV. For each subcategory discussed herein, a representative model is developed and defined in terms of waste water flow and characteristics.

It should be carefully noted that within this document the process unit employed for cane sugar factories, unless otherwise specified, is metric tons (tons) of gross (field) cane processed by the factory per day, and that all pollutant concentrations and loadings, unless otherwise specified, are in terms of net units, i.e., do not include any pollutants entering the factory in the fresh water supply.

WATER USAGE AND WASTE WATER QUANTITIES

The uses of water in cane sugar factories include water used for: (1) the washing of cane, (2) the cooling of vapors in barometric condensers, (3) the slurrying of filter cake, boiler bottom ash, and boiler fly ash, (4) boiler makeup, (5) maceration, (6) floor wash and miscellaneous clean-up, and (7) miscellaneous cooling. Figure 16 shows a schematic diagram of water usage and waste water flows in a cane sugar factory. It is generally applicable to all subcategories except Subcategory II which does not employ cane washing.

Water use varies considerably even within subcategories due to dissimilar water conservation and recirculation techniques. Not all factories will use water in all the processes listed above. For example, a number of factories, particularly in Subcategory I, use spent barometric condenser cooling water for washing sugarcane and thereby eliminate the necessity for fresh water intake for cane washing. Various factories may handle filter cake and/or ashes in a "dry" form and dispose of them on land. A number of factories, notably in Subcategory II and Subcategory V, do not wash cane.

The quantities of waste water generated by a factory do not necessarily correspond to the quantities of fresh water brought into the factory, for the following reasons: (1) the moisture content of sugarcane is approximately 70 to 75 percent, representing a water input to a factory of 710 to 750 liters per metric ton (170 to 180 gallons per ton) of net cane entering the factory, (2) a portion of the fresh water entering the factory enters into the filter cake and bagasse, and (3) a portion of the fresh water is lost due to evaporation.

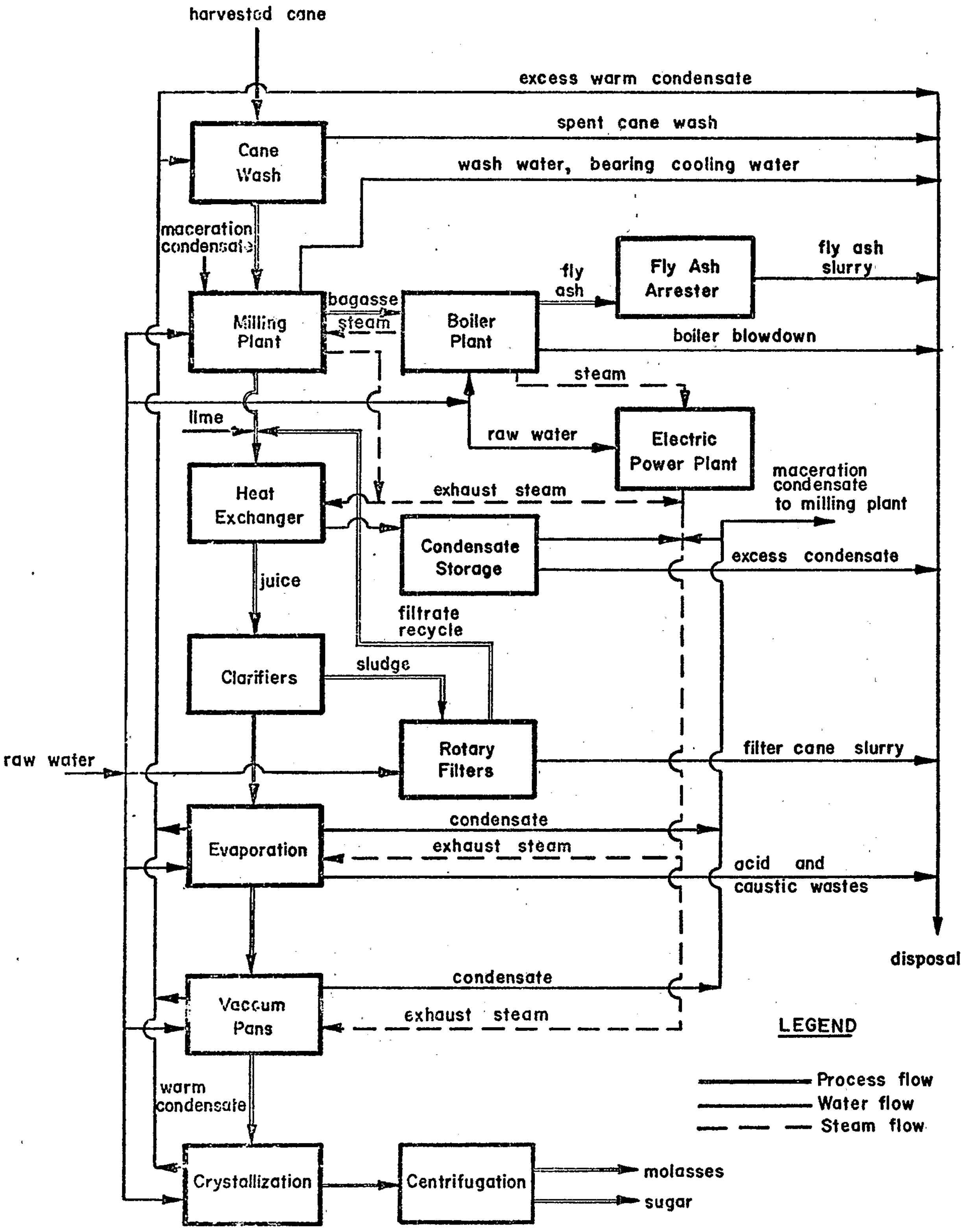


FIGURE 16

WATER USAGE IN A TYPICAL CANE SUGAR FACTORY

Water Usage and Waste Water Quantities -- Subcategory I

Tables 7A and 7B show total fresh water intake and discharge quantities of major waste streams for Subcategory I. Table 7A presents the information in terms of cubic meters of water used per day and Table 7B in terms of liters of water used per metric ton of gross cane. For those factories presented, the range of fresh water intake ranges from 1,800 to 30,100 liters per metric ton (432 to 7,230 gallons per ton). The mean intake is 13,200 liters per metric ton (3,170 gallons per ton) and the mean total discharge exclusive of those factories which stabilize all wastes is 12,900 liters per metric ton (3,100 gallons per ton) of gross cane.

Cane Wash Water - Washing cane for removal of dirt and other extraneous material is practiced extensively in Louisiana. The flow of water varies widely depending upon the condition of the cane, the availability and cost of water, and the policy of factory management. An example of these variable conditions is the hurricane which passed through southern Louisiana in the summer of 1971 leaving the sugar cane tangled and bent to the ground rather than in its normal upright stance. Consequently, excessive quantities of mud were included with the harvested cane, necessitating increased amounts of water for cane washing.

Historically cane washing has been a once-through operation requiring an increasing amount of water usage with the increase in use of mechanical harvesting equipment. In Louisiana, the quantities of water used in cane washing range from about 890 to 20,000 liters per metric ton (214 to 4,800 gallons per ton) of gross cane, with an average of 7,230 liters per metric ton (1,740 gallons per ton). As can be seen in Table 7B, some Louisiana factories either partially or totally recycle their cane wash water and some stabilize the discharge stream. The average discharge of those factories which discharge cane wash water directly (employ no stabilization) is 5,920 liters per metric ton (1,420 gallons per ton) of gross cane.

Barometric Condenser Cooling Water - Ancther process generated waste water, condenser water, is necessary for all sugar factories. Barometric condensers are utilized and normally, the greatest amount of water used in a factory is employed as barometric condenser cooling water. Condenser water is used to condense vapors from the last-effect evaporators and from the vacuum pans. The amount of barometric condenser cooling water used per process unit of cane will depend upon (1) the availability and cost of water, (2) the policy of factory management toward water conservation, (3) the extent of automatic control of evaporators and vacuum pans, and (4) the thermodynamic relationship between the injection water and the vapors to be condensed, i.e., the higher the temperature of the condenser water influent, the larger the theoretical volume of cooling water required for condensation of the vapors.

TABLE 7A

WATER USE AND WASTEWATER QUANTITIES

SUBCATEGORY I

		Total		Condenser		Cane Wash					
Factory	Grind	Intake	Discharge	Flow	Discharge	Flow	Discharge	Filter Mud	Boiler Blowdown	Ash Slurry	Misc.
1	1,820	18,900	13,840	15,200	13,800	13,600	0*	680	10	680	14
3	2,730	25,600	23,300	32,700	0	21,800	21,800	820	140	550	2
5	2,270	16,300	0*	43,600	0*	13,600	0*	1,360		Dry	10
7	5,000	90,000	84,600	76,400	65,500	19,100	19,100	Dry	40	5,450	26
8	3,730	8,180	0*	49,100	0	27,300	0*	545	19	Dry	2,730
9	1,490	32,700	30,400	30,100	29,900	21,800	0	436	46	Dry	54
10	2,000	53,000	53,000	51,900	21,400	30,500	30,500	273			
11	2,820	43,600	43,700	43,600	42,500	17,500	128	1,100	38	**	N/A
13	1,680	30,000	27,300	27,300	27,300	1,640	0*	545	4	N/A	4
14	2,730		32,700	32,700	32,700	54,500	0	1,280	27	N/A	13
16	2,180	35,000	35,000	35,000	27,700	7,270[1]	7,270[1]	N/A	N/A	N/A	N/A
17	3,680	21,800	3,270	32,700	3,270	19,100	0*	Dry		N/A	N/A
18	4,550	69,400	0*	67,400	0*	27,300	0*	820	270	N/A	1,300
21	2,730	26,500	1,100	27,300	1,100	24,500	0*	820	11	N/A	2,730
22	2,270	13,900	12,000	51,900	0	10,400	10,400	Dry	680	410	550
23	3,630	6,520	0*	70,900	0	16,400	0*	Dry	17	1,100	277
24	5,000	81,800	0	43,600	0	32,700	0	Dry	23	N/A	5,450
26	3,360	54,500	54,500	43,600	21,800	32,700	32,700	545	22	545	26
29	4,360	16,400	0*	65,500	0	13,600	0*	1,640	0	N/A	14
31	4,550	65,500	0*	65,500	0*	32,700	0*	1,640	55	N/A	230
32	3,500	33,100	16,900	63,300	16,900	35,500	0*	820	30	1,100	25
33	2,800	11,200	0*	43,600	0	11,000	0*	Dry	6	164	12
34	3,180	19,200	5,450	65,500	5,450	21,800	0	Dry	22	Dry	11
37	2,800	9,630	0*	54,500	2,730	21,800	0*	1,100	576	N/A	7
39	3,270	61,600	60,200	59,300	59,300	16,400	0*	570	32	273	8
40	2,360	43,600	44,200	43,600	25,600	16,400	16,400	1,640	27	N/A	565
41	2,730	53,500	43,600	43,600	43,600	15,300	0*	820	163	N/A	173
42	1,100	27,500	24,500	24,500	24,500	N/A	N/A	273		Dry	2,730
43	3,360	101,000	0*	73,600	0*	24,500	0*	820	14	1,100	966

NOTE: Grind as metric tons/day. All other values as cubic meters of water/day.
* No discharge until after at least 90 days of stabilization after the grinding season ends.
** Flow included with filter mud streams.
[1] Flow includes miscellaneous streams.
N/A Not Applicable.

TABLE 7B

UNIT WATER USE AND WASTEWATER QUANTITIES

SUBCATEGORY I

		Total		Condenser		Cane Wash					
Factory	Grind	Intake	Discharge	Flow	Discharge	Flow	Discharge	Filter Mud	Boiler Blowdown	Ash Slurry	Misc.
1	1,820	10,400	7,600	8,350	7,600	7,500	0*	370	5.5	370	7.7
3	2,730	9,380	8,530	12,000	0	8,000	8,000	300	51.3	200	0.7
5	2,270	7,180	0*	19,200	0*	6,000	0*	600		Dry	4.4
7	5,000	18,000	16,900	15,300	13,100	3,820	3,820	Dry	8.0	1,100	5.2
8	3,730	2,190	0*	13,200	0	7,320	1,460	146	5.1	Dry	732
9	1,490	21,950	20,400	20,200	20,100	14,600	0	293	30.8	Dry	3.6
10	2,000	26,500	26,500	26,000	10,700	15,300	15,300	137			
11	2,820	15,500	15,500	15,500	15,100	6,200	45	387	13.5	**	N/A
13	1,680	17,900	16,300	16,250	16,250	980	0*	320	2.4	N/A	2.4
14	2,730		12,900	12,000	12,000	20,000	0	470	9.9		4.8
16	2,180	16,100	16,100	16,100	12,700	3,400[1]	3,400[1]				N/A
17	3,680	5,900	890	8,900	890	5,200	0*	Dry		Dry	N/A
18	4,550	15,300	0*	14,800	0*	6,000	0*	180	59.3	N/A	286
21	2,730	9,700	400	10,000	400	9,000	0*	300	4.0	N/A	1,000
22	2,270	6,100	5,300	22,800	0	4,560	4,560	Dry	300	180	240
23	3,630	1,800	0*	19,500	0	4,520	0*	Dry	4.7	300	76
24	5,000	16,400	0	8,720	0	6,540	0	Dry	4.6	N/A	1,100
26	3,360	16,200	16,200	13,000	6,500	9,700	9,700	160	6.5	160	7.7
29	4,360	3,760	0*	15,000	0	3,120	0*	376	12.6	N/A	3.2
31	4,550	14,400	0*	14,400	0*	7,200	0*	360	12.5	N/A	51
32	3,500	9,450	4,830	18,100	4,830	10,100	0*	234	8.6	314	7.1
33	2,800	4,000	0*	15,600	0	3,930	0*	Dry	2.0	59	4.3
34	3,180	6,040	1,700	20,600	1,700	6,860	0	Dry	6.9	Dry	3.6
37	2,800	3,440	0*	19,500	975	7,800	0*	393	206	N/A	2.5
39	3,270	18,800	18,400	18,100	18,100	5,000	0*	170	9.8	84	2.4
40	2,360	18,500	18,700	18,500	10,800	6,950	6,950	694	11.4	N/A	239
41	2,730	19,600	16,000	16,000	16,000	5,600	0*	300	59.7	N/A	63.4
42	1,100	25,000	22,300	22,300	22,300	N/A	N/A	248		Dry	2480
43	3,360	30,100	0*	21,900	0*	7,290	0*	244	4.2	327	288

NOTE: Grind as metric tons/day. All other values as liters of water per metric ton of cane.
* No discharge until after at least 90 days of stabilization after the grinding season ends.
** Flow included with filter mud stream.
1 Flow includes miscellaneous streams.
N/A Not Applicable.

The average barometric condenser cooling water usage for Subcategory I factories is 16,300 liters per metric ton (3,910 gallons per ton) of gross cane, ranging in usage from 8,350 to 26,000 liters per metric ton (2,010 to 6,240 gallons per ton) of gross cane. Several factories recirculate barometric condenser cooling water with the average discharge, exclusive of those factories which stabilize the barometric condenser cooling water stream, equivalent to 7,600 liters per metric ton (1,830 gallons per ton) of gross cane.

It might be anticipated that those factories recirculating barometric condenser cooling water would require larger volumes of water due to a higher intake temperature. However, those Louisiana factories, which recirculate barometric condenser cooling water have an average condenser water usage of 16,300 liters per metric ton (3,910 gallons per ton) of gross cane, or approximately the same average as that for all the factories.

Miscellaneous Water Uses - In many cases excess condensate is used or supplemented with fresh water for minor water needs in a sugar factory. Boiler feed water, for example, almost universally consists of condensate from the first one or two evaporator effects, but generally boiler start up is accomplished with fresh water. Also, while excess condensate may be used for imbibition water, the condensate must first be cooled to avoid the melting of waxes in the cane. Also many factories find it simpler to use fresh water or condenser water rather than excess condensate to slurry filter mud, fly ash, and boiler ash.

The discharge streams for the miscellaneous water uses account for only a small percentage of total factory discharge. As shown in Table 7B, filter muds and boiler and fly ash are often handled dry, eliminating two waste streams. In factories where filter mud is slurried, the average discharge is 318 liters per metric ton (76 gallons per ton). When ash is slurried, the discharge averages 309 liters per metric ton (74 gallons per ton). Other miscellaneous discharges include boiler blowdown, floor and equipment washings, excess sweetwater, and acid and caustic wastes. Totally, the average discharge amounts to 300 liters per metric ton (72 gallons per ton).

Water Usage and Waste Water Quantities - Subcategory II

The most notable difference in water usage between the factories in Subcategory II and other cane sugar factories results from the lack of cane washing. Cane is harvested by hand in all Florida and Texas factories but two, and cane is washed only intermittently in two Subcategory II factories. For this reason, cane wash water has been omitted as a major discharge stream in the presentation of data relative to this subcategory. Subcategory II factories are on the whole newer and larger than those in the other subcategories, having an average daily grind of 7,800 metric tons (8,600 tons) of gross cane, as shown in Table 8A. Table 8A also lists the total fresh water intake, barometric condenser cooling water flow, and waste water discharges from the factory in terms of cubic meters of water per day. Table 8B presents the same data in terms of unit flow (liters of water per metric ton of gross cane).

Fresh water intake values differ greatly in Subcategory II factories, depending on the degree of barometric condenser cooling water recirculation and on the degree of in-plant reuse of water. The values range from 7 to 18,300 liters per metric ton (2 to 4,400 gallons per ton) of gross cane, with an average of 3,960 liters per metric ton (950 gallons per ton). The average amount of waste water discharged from a Subcategory II factory is 3,410 liters per metric ton (819 gallons per ton) of gross cane. Barometric condenser cooling water usage ranges from 13,800 to 21,100 liters per metric ton (3,310 - 5,070 gallons per ton) of gross cane, with the average usage amounting to 17,300 liters per metric ton (4,160 gallons per ton) of gross cane.

Water Usage and Waste Water Quantities - Subcategories III and IV

Factories fitting the requirements of Subcategories III and IV are sufficiently similar in sizes, processes, and water and waste flows that their water usage and waste water quantities may be discussed jointly. From Tables 9A and 10A which show the water usages and waste water quantities for the Subcategory III and IV factories, an average daily grind of 3,360 metric tons (3,700 tons) of gross cane is observed. Corresponding water usages given in terms of liters per metric ton of gross cane are presented in Tables 9B and 10B. Fresh water intake values range from 3,900 to 27,100 liters per metric ton (940 to 6,510 gallons per ton) of gross cane, with an average of 13,400 liters per metric ton (3,220 gallons per ton). The average factory discharge, 13,700 liters per metric ton (3,290 gallons per ton) of gross cane, differs from the intake by 300 liters per metric ton (70 gallons per ton), a difference which is probably attributable to the water extruded from the sugarcane.

The factories of Subcategories III and IV historically have not been concerned with the minimization of water usage for various reasons. Many Subcategory IV mills utilize tremendous quantities of water for irrigation purposes and factory waste water makes up only a fraction of the total irrigation water. Those factories which have been hampered with a tailwater discharge problem have recently begun to look into various alternatives which will minimize water usage to alleviate the problem of tailwater discharge of factory generated process waste waters. Subcategory III factories historically have not practiced waste water treatment and the use of large quantities of water has been the general practice. Data relating to Factory 66, which has undergone an extensive program of development of waste

TABLE 8A

WATER USE AND WASTE WATER QUANTITIES
SUBCATEGORY II

		Total		Condenser		Discharge			
Factory	Grind	Intake	Discharge	Flow	Discharge	Filter Mud	Boiler Blowdown	Ash Slurry	Misc.
44	5,200	n.a.	265	98,100	0	Dry	38	Dry	227
47	5,400	38	103	114,000	0	95	n.a.	Dry	8
48	9,100	3,030	3,510	164,000	344	Dry	273	2,840	57
49	7,730	141,100	141,100	131,000	131,000	2,180	273	n.a.	638[1]
50	10,000	5,680	1,450	153,000	4	757	189	227	273
51	9,500	5,830	14,700	131,000	1,400	2,180	*	2,420	8,710

NOTE: Grind as metric tons of gross cane per day.
All other values given as cubic meters of water per day.
n.a.: Not available.
[1] Can be as high as 7,750 cu.m/day if cane is washed.
*Included in miscellaneous discharge.

TABLE 8B

UNIT WATER USE AND WASTE WATER QUANTITIES
SUBCATEGORY II

		Total		Condenser		Discharge			
Factory	Grind	Intake	Discharge	Flow	Discharge	Filter Mud	Boiler Blowdown	Ash Slurry	Misc.
44	5,200	n.a.	51	18,900	0	Dry	7	Dry	44
47	5,400	7	19	21,100	0	17	n.a.	Dry	2
48	9,100	333	386	18,000	38	Dry	30	312	6
49	7,730	18,300	18,300	16,900	16,900	282	35	n.a.	83[1]
50	10,000	568	145	15,300	0.4	76	19	23	27
51	9,500	614	1,550	13,800	147	229	*	255	917

NOTE: Grind as metric tons of gross cane per day.
All other values given as liters of water per metric ton of gross cane.
n.a: Not available.

[1] Can be as high as 1000 liters/metric ton of gross cane if cane is washed.

*Included in miscellaneous discharge.

TABLE 9A

WATER USE AND WASTE WATER QUANTITIES
SUBCATEGORY III

Factory	Grind	Total		Condenser		Cane Wash		Discharge			
		Intake	Discharge	Flow	Discharge	Flow	Discharge	Filter Mud	Boiler Blowdown	Ash Slurry	Misc.
66	2,490	34,800	35,500	34,600	7,080	27,500	27,500	946	n.a.	n.a.	n.a.
66[1]	4,130	16,100	17,100	34,100	12,300	13,300	13,300	Dry	n.a.	3,790	n.a.
67	3,750	30,300	30,300	30,300	11,400	18,900	18,900	Dry	n.a.	n.a.	n.a.
69	2,840	37,300	37,900	15,600	4,740	30,200	30,200	216	n.a.	2,180[2]	545
70	2,360	63,900	63,900	17,900	17,900	46,000	38,900	n.a.	n.a.	7,150[2]	n.a.

NOTE: Grind as metric tons of gross cane per day.
All other values given as cubic meters of water per day.
n.a.: Not available
[1] Projected water usage based on plant modification and reuse of water.
[2] Have since put in a system to dry haul boiler ash.

TABLE 9B

UNIT WATER USE AND WASTE WATER QUANTITIES
SUBCATEGORY III

		Total		Condenser		Cane Wash		Discharge			
Factory	Grind	Intake	Discharge	Flow	Discharge	Flow	Discharge	Filter Mud	Boiler Blowdown	Ash Slurry	Misc.
66	2,490	14,000	14,300	13,900	2,840	11,000	11,000	380	n.a.	n.a.	n.a.
66[1]	4,130	3,900	4,140	8,260	3,000	3,220	3,220	Dry	n.a.	918	n.a.
67	3,750	8,080	8,080	8,080	3,040	5,040	5,040	Dry	n.a.	n.a.	n.a.
69	2,840	13,100	13,300	5,490	1,670	10,600	10,600	76	n.a.	768[2]	192
70	2,360	27,100	27,100	7,580	7,580	19,500	16,500	n.a.	n.a.	3,030[2]	n.a.

NOTE: Grind as metric tons of gross cane per day.
All other values given as liters of water per metric ton of gross cane.
n.a.: Not available.

[1] Projected water usage based on plant modification and reuse of water.

[2] Have since put in a system to dry haul boiler ash.

TABLE 10A

WATER USE AND WASTE WATER QUANTITIES
SUBCATEGORY IV

		Total		Condenser		Cane Wash		Discharge			
Factory	Grind	Intake	Discharge	Flow	Discharge	Flow	Discharge	Filter Mud	Boiler Blowdown	Ash Slurry	Misc.
72	3,610	46,200	46,600	46,300	21,300	64,900	24,500	n.a.	327	436	n.a.
76	2,190	19,200	20,100	20,100	0	20,100	20,100	n.a.	n.a.	n.a.	n.a.
80	5,310	95,400	98,000	94,600	29,100	64,300	64,300	273	n.a.	1,640	2,730
82	2,670	42,000	44,300	42,000	42,000	38,200	38,200	1,140	n.a.	1,100	n.a.

NOTE: Grind as metric tons of gross cane per day.
All other values given as cubic meters of water per day.
n.a.: Not available.

TABLE 10B

UNIT WATER USE AND WASTE WATER QUANTITIES
SUBCATEGORY IV

		Total		Condenser		Cane Wash		Discharge			
Factory	Grind	Intake	Discharge	Flow	Discharge	Flow	Discharge	Filter Mud	Boiler Blowdown	Ash Slurry	Misc.
72	3,610	12,800	12,900	12,800	5,900	18,000	6,790	n.a.	91	121	n.a.
76	2,190	8,770	9,180	9,180	0	9,180	9,180	n.a.	n.a.	n.a.	n.a.
80	5,310	18,000	18,500	17,800	5,480	12,100	12,100	51	n.a.	309	514
82	2,670	15,700	16,600	15,700	15,700	14,300	14,300	427	n.a.	412	n.a.

NOTE: Grind as metric tons of gross cane per day.
All other values given as cubic meters of water per day.
n.a.: Not available.

treatment facilities, is presented in Tables 9A and 9B. Considerable effort has been undertaken with regard to waste water management and now, although processing 1.66 times as much gross cane, only one-half as much water will be discharged. This indicates that where an incentive to reduce water usage exists, considerable reductions are attainable.

Cane Wash Water - As in Louisiana, the factories in Hawaii practice cane washing extensively. The cane is mechanically harvested by raking it into windrows before collection, and elaborate washing systems have been developed to handle the large amounts of mud that come in with the cane. In fact, compared to Subcategory I, Subcategory III and IV factories utilize considerably more water for cane washing. As presented in Tables 9B and 10B, the average cane wash water flow is 11,500 liters per metric ton (2,760 gallons per ton) of gross cane. Actual factory discharge of cane wash water, however, averages only 9,720 liters per metric ton (2,330 gallons per ton), indicating the recirculation or reuse of the wash water for slurrying filter cake, bottom ash, and fly ash.

Barometric Condenser Cooling Water - In Hawaii almost all plants partially or totally recirculate barometric condenser cooling water back into the condensers or reuse it as cane wash water. Because of this recirculation, less than half of the barometric condenser cooling water flow for Subcategories III and IV represents an actual factory discharge. As presented in Tables 9B and 10B, the average barometric condenser cooling water flow for Subcategory III is 7,350 liters per metric ton (1,770 gallons per ton) of gross cane with an average discharge of 3,820 liters per metric ton (917 gallons per ton) of gross cane. The evidence of the recirculation of barometric condenser cooling water is substantiated by Subcategory IV data, showing an average flow and discharge of 13,900 liters per metric ton (3,340 gallons per ton) and 6,770 liters per metric ton (1,630 gallons per ton), respectively.

Miscellaneous Water Usage - Along with fresh water, excess condensate and cane wash water are used to meet the needs of minor water uses in Subcategory III and IV raw sugar factories. Most often fresh water is used for slurrying filter mud, a discharge which varies from 51 to 427 liters per metric ton (12 to 103 gallons per ton), while averaging 234 liters per metric ton (56 gallons per ton) of gross cane. Ashes are slurried with either fresh water or cane wash water and waste water flow can be as high as 3,030 liters per metric ton (728 gallons per ton), but averages 926 liters per metric ton (222 gallons per ton) of gross cane. Other minor discharge flows, including boiler blowdown and floor and equipment washings vary from plant to plant depending on the degree of recirculation and on the water conservation techniques employed.

Water Usage and Waste Water Quantities - Subcategory V

The existing data on water use and waste water discharges from the factories in Subcategory V are presented in Tables 11A and 11B. From these tables it can be seen that an average of 3,850 metric tons (4,240 tons) of gross cane is ground daily. Fresh water intake varies from 12,300 to 37,000 liters per metric ton (2,950 to 8,890 gallons per ton) of gross cane, all of which is discharged from the factories.

Cane Wash Water - In each case where cane washing is reported, the water supply is spent barometric condenser cooling water. An average of 8,690 liters of water per metric ton (2,090 gallons per ton) of gross cane is reported by the factories listed in Table 10B which wash cane, with the entire amount being discharged from the factory. At the time of data collection, one factory did not wash cane, yet plans indicate that in the future, a somewhat less than average supply of water will be used for this purpose.

Barometric Condenser Cooling Water - The greatest use of fresh water in Subcategory V factories is for the barometric leg condensers. It can be seen in the tables that almost 100 percent of the fresh water intake is used as barometric condenser cooling water and that a portion is usually reused in cane washing, slurrying filter cake, and for cleaning purposes, although actual factory discharge of barometric condenser cooling water varies anywhere from 0 to 27,000 liters per metric ton (0 to 6,480 gallons per ton) of gross cane. The average water usage is 20,500 liters per metric ton (4,920 gallons per ton) of gross cane, and the average discharge is 13,800 liters per metric ton (3,310 gallons per ton) of gross cane.

Miscellaneous Water Usage - In Puerto Rican factories, either fresh water or spent barometric condenser cooling water is used to supply the miscellaneous needs. Sufficient information is not available on boiler blowdown and ash slurries for characterization of these waste flows. Filter muds, however, are slurried with quantities of water ranging from 1,040 to 1,180 liters per metric ton (250 to 280 gallons per ton) of gross cane.

WASTE WATER CHARACTERISTICS

Figure 16 presented a schematic diagram of waste water flows from a typical cane sugar factory. The characteristics of the total waste water discharge depend upon the characteristics of the component waste streams and, most importantly, upon the extent to which recirculation and reuse of water is practiced.

The major waste streams produced by a cane sugar factory are filter mud, barometric condenser cooling water, and cane wash water. Numerous small streams also contribute to the total pollutant loading.

TABLE 11A

WATER USE AND WASTE WATER QUANTITIES
SUBCATEGORY V

		Total		Condenser		Cane Wash		Discharge			
Factory	Grind	Intake	Discharge	Flow	Discharge	Flow	Discharge	Filter Mud	Boiler Blowdown	Ash Slurry	Misc.
52	4,800	n.a.	73,800	68,100	68,100	Dry	Dry	5,680	n.a.	n.a.	30
53	3,630	44,700	44,700	43,600	0	43,600	43,600	Dry	n.a.	1,090	n.a.
63	2,630	97,400	97,400	97,400	70,900	23,800	23,800	2,730	n.a.	n.a.	n.a.
64	4,350	82,500	82,500	81,800	60,000	21,800	21,800	Dry	*	Dry	736

NOTE: Grind as metric tons of gross cane per day.
All other values given as cubic meters of water per day.
n.a.: Not available.
* Included in miscellaneous waste stream.

TABLE 11B

UNIT WATER USE AND WASTE WATER QUANTITIES SUBCATEGORY V

		Total		Condenser		Cane Wash		Discharge			
Factory	Grind	Intake	Discharge	Flow	Discharge	Flow	Discharge	Filter Mud	Boiler Blowdown	Ash Slurry	Misc.
52	4,800	n.a.	15,400	14,200	14,200	Dry	Dry	1,180	n.a.	n.a.	6
53	3,630	12,300	12,300	12,000	0	12,000	12,000	Dry	n.a.	300	n.a.
63	2,630	37,000	37,000	37,000	27,000	9,050	9,050	1,040	n.a.	n.a.	n.a.
64	4,350	19,000	19,000	18,800	13,800	5,010	5,010	Dry	*	Dry	169

NOTE: Grind as metric tons of gross cane per day.
All other values given as liters of water per metric ton of gross cane.
n.a.: Not available.
* Included in miscellaneous waste stream.

SUBCATEGORY I

Cane Wash Water - In Subcategory I factories, cane washing is practiced extensively, and in many instances barometric condenser cooling water is used as the source for cane wash water. Its waste composition will vary depending upon the amount of extraneous material in the cane on any particular day. Other determining factors include the availability of water, soil types, management policies, and the condition of the cane upon harvesting.

A paper by Hendrickson and Grillot (3) shows Louisiana factories with an average BOD_5 concentration of 240 mg/l in cane wash water. Their other findings on factory waste characteristics are presented in Table 12 with the cane wash water COD concentration listed as 570 mg/l and total solids listed as 4,030 mg/l. Other data pertaining to individual factories are listed in terms of pollutant concentrations in Table 13 and pollutant loadings in Table 14. BOD_5 concentrations in untreated cane wash water discharge vary from 81 to 562 mg/l, averaging 274 mg/l, a value which compares favorably to that reported by Hendrickson and Grillot. The average BOD_5 raw waste loading for those factories listed in Table 14 is 1.46 kilograms per metric ton (2.92 pounds per ton) of gross cane. COD concentrations lie within the range of 293 to 1,430 mg/l with an average pollutant loading of 3.69 kilograms per metric ton (7.38 pounds per ton) of gross cane. Because trash content in the gross cane is highly variable from factory to factory, the suspended solids loading in cane wash water ranges from a low of 0.69 kilograms per metric ton (1.38 pounds per ton) to a high of 36.0 kilograms per metric ton (72.0 pounds per ton) of gross cane. The average loading is equivalent to 17.0 kilograms per metric ton (34.0 pounds per ton) of gross cane.

Barometric Condenser Cooling Water - The major pollutants in barometric condenser cooling water are sucrose and heat. The sucrose originates from entrainment in last-effect evaporators and vacuum pans, and heat originates from the heat exchange between the cooling water and the condensed vapors. In terms of waste water characteristics, sucrose appears in barometric condenser cooling water as BOD_5, COD, and dissolved solids. In actuality, as indicated in Table 15, relatively small concentrations of other constituents appear. In some cases these are already present in the barometric leg condenser water and some are a result of impurities in the molasses. It is perhaps important to note that in a number of instances, data for individual factories show net negative values for suspended solids, nutrients, and other parameters. A negative value has been presented in Table 15 as having a zero value. Negative values are probably due to variability in sampling and analytical techniques used by the many sources of data referred to in this report.

As reported by Hendrickson and Grillot (3) in Table 12, the BOD_5 and COD concentrations of barometric condenser cooling water are

TABLE 12

TYPICAL CHARACTERISTICS OF MILL WASTE SOLIDS AND LIQUIDS*

Discharge	Flow M3/day	BOD5 mg/l	 kg/day	COD mg/l	 kg/day	TS mg/l	 kg/day
Cane Wash Water	6,100	240	1,500	570	3,500	4,030	24,600
Condenser Water	8,700	36	310	83	720	52	450
Filter Mud			3,100		7,500		19,600
Ash Slurry			50		1,300		2,700
Bagasse Fiber							134,500

*On the basis of 900 metric tons of net cane ground per day.

TABLE 13

POLLUTANT CONCENTRATIONS IN CANE WASH WATER
SUBCATEGORY I

Factory	Capacity kkg/day	Flow Used M3/day	Discharge M3/day	BOD mg/l	COD mg/l	SS mg/l	TS mg/l	TP mg/l	KN mg/l	Source*
1 (Treated)	1,820	13,600	100	19	78	210				2
10	2,000	30,500	30,500	128	339	2,350				3
16	1,720	6,400	6,400	209	752	1,470				3
22	2,370	10,400	10,400	81	293	2,210				1
32	3,370	35,500	13,600	392	1,430	8,120				2
34	2,360	21,800	10,900	562	729	150	409	1.1		1
38 (Treated)	3,820	24,500	2,120	0	42	30	130	18.4	0	2

*Source codes listed in Table 1, Section III.

TABLE 14

POLLUTANT LOADINGS IN CANE WASH WATER
SUBCATEGORY I

Factory	Capacity kkg/day	Flow Used l/kkg	Discharge l/kkg	BOD kg/kkg	COD kg/kkg	SS kg/kkg	TS kg/kkg	TP kg/kkg	KN kg/kkg	Source*
1 (Treated)	1,820	7,470	55	0.001	0.004	0.012				2
10	2,000	15,300	15,300	1.96	5.19	36.0				3
16	1,720	3,720	3,720	0.78	2.80	5.48				3
22	2,370	4,390	4,390	0.36	1.29	9.72				1
32	3,370	10,500	4,040	1.59	5.79	32.9				2
34	2,360	9,240	4,620	2.60	3.37	0.69	1.89	0.005		1
38 (Treated)	3,820	6,410	555	0	0.023	0.017	0.07	0.01	0	2

*Source codes listed in Table 1, Section III.

TABLE 15

POLLUTANT CONCENTRATIONS IN CONDENSER WATER SUBCATEGORY I

Factory	Capacity kkg/day	Flow Used M3/day	Discharge M3/day	BOD mg/l	COD mg/l	SS mg/l	TS mg/l	TP mg/l	KN mg/l	Source*
1	1,820	15,200	15,200	15	252	21	444		0.71	2
10	2,000	51,900	51,900	169	254	22.7				3
13	1,360	27,300	27,300	50						2
16	1,720	35,000	35,000	35						2
17	3,380	32,700	21,800	91	189	17	479		0.35	1
22	2,370	51,900	10,400	224	388	148				1
32	3,370	63,300	63,300	33	61					2
34	2,360	65,500	5,450	110	61	0	0	2.16	4.32	1
38	3,820	60,000	10,900	16	5	0	21	2.8	0.07	2
42	871	24,500	24,500	11	20	0	0	0	0	1

*Source codes listed in Table 1, Section III.

TABLE 16

POLLUTANT LOADINGS IN CONDENSER WATER
SUBCATEGORY I

Factory	Capacity kkg/day	Flow Used l/kkg	Discharge l/kkg	BOD kg/kkg	COD kg/kkg	SS kg/kkg	TS kg/kkg	TP kg/kkg	KN kg/kkg	Source*
1	1,820	8,350	8,350	0.125	2.11	0.176	3.71		0.006	2
10	2,000	26,000	26,000	4.40	6.61	0.59				3
13	1,360	20,100	20,100	1.01						2
16	1,720	20,300	20,300	0.71						2
17	3,380	9,700	6,450	0.59	1.22	0.11	3.09		0.002	1
22	2,370	21,900	4,390	0.98	1.71	0.65				1
32	3,370	18,800	18,800	0.62	1.15					2
34	2,360	27,800	2,310	0.254	0.14	0	0	0.005	0.01	1
38	3,820	15,700	2,850	0.046	0.014	0	0.06	0.008	0.0002	2
42	871	28,100	28,100	0.31	0.563	0	0	0	0	1

*Source codes listed in Table 1, Section III.

relatively low, 36 mg/l and 83 mg/l, respectively. The values in Table 15 are similar, with BOD5 concentrations ranging from 11 to 224 mg/l and COD concentrations ranging from 5 to 388 mg/l.

Pollutant loadings for Subcategory I barometric condenser cooling waters are listed in Table 16. The average BOD5 loading is 0.90 kg/kkg (1.8 pounds per ton); the average BOD5 loading, omitting both the high and the low value, is 0.57 kilograms per metric ton (1.14 pounds per ton) of gross cane. COD loadings average 1.69 kilograms per metric ton (3.38 pounds per ton) of gross cane.

Filter Mud - Filter mud originates from juice clarification and the rotary vacuum filters which are used to separate solids from the juice clarification sludge. Based on data supplied by factories which dry haul filter cake, between 26 and 100 kilograms of filter cake per metric ton (52 to 200 pounds of filter cake per ton) of gross cane are produced depending in part upon cane conditions. The unslurried filter cake has a moisture content ranging between 70 and 80 percent and a sugar content of about 1 to 4 percent (4, 5). In those factories which produce a filter mud by slurrying the filter cake with water, this stream can be the most significant source of organics and solids within the factory.

As shown in Table 17, the average concentrations of BOD5, COD, and suspended solids are, respectively, 14,700, 42,900, and 79,400 mg/l. These concentrations, however, vary widely among factories depending upon the quantity of cake produced and the volume of water used for slurrying.

Floor Washings - The primary pollutant loading in floor wash originates in the mill house area and consists of juice spills and pump seal leakages. Spillage of raw sugar from conveyer belts in loading areas or at loading docks may contribute significant sucrose concentrations. Spills or leakages of molasses cause slug loadings having high concentrations of organics. During wet weather, large quantities of mud can enter factories and result in a high concentration of solids in the floor wash effluents. Volumes and concentrations depend upon equipment conditions and general housekeeping practices. The BOD5 of floor wash may approach 700 mg/l and suspended solids may be in concentrations as high as 1,000 mg/l, but the total discharge volume is sufficiently low that floor wash is a relatively minor contributor to overall pollutant loadings. However, during periods following factory shutdown when the factory is given a thorough clean-up, the discharge of floor wash is generally the major waste water discharge.

Ash - The sources of ash in a sugar factory are associated with boiler operations. Upon burning of the bagasse, a residual ash remains in the boiler which may be removed dry and handled as a solid waste or slurried and discharged as a waste stream. Associated with the

TABLE 17

POLLUTANT CONCENTRATIONS IN MISCELLANEOUS STREAMS SUBCATEGORY I

Stream	Discharge Flow (M3/day)	BOD5 (mg/l)	COD (mg/l)	TSS (mg/l)	TS (mg/l)
Filter Mud	820	14,700	42,900	79,400	
Ash Slurry	200	323	7,440	10,400	11,700
Boiler Blowdown	680	139	312	80	347
Excess Condensate		13	41	153	327
Floor and Equipment Wash		600	900	750	2,100

"bottom" ash is fly ash which normally leaves the boiler through the stacks. In cases where wet scrubbers are used to remove fly ash, an added waste stream results. Characteristics of these two waste streams are generally similar as essentially the same material is present in both waste streams. As shown in Table 17, the BOD5 concentration of ash slurries in Louisiana is typically on the order of 300 mg/l. The corresponding concentration of suspended solids averages 10,400 mg/l.

Boiler Blowdown - Boiler blowdown results from the necessity of maintaining a high quality of boiler feed water by continuously or intermittently discharging a portion of the feed water. The pollutants in boiler blowdown result from internal boiler water treatment with caustic soda for pH control, organic dispersants, phosphates used for scale removal, and sulphite or hydrazine used for oxygen removal. The characteristics of boiler blowdown are independent of the manufacturing process and can be considered to be a function of boiler operation regardless of what the industrial process is in which the boiler is being used. Nevertheless, boiler blowdown comprises a discrete, if minor, component of the total waste water discharge from a cane sugar factory. As seen in Table 17, boiler blowdown contributes some pollutional loading to the total factory raw waste loading.

Acid and Caustic Wastes - The removal of scale deposits in a sugar factory is normally accomplished by the use of concentrated caustic soda and dilute hydrochloric acid solutions. The caustic solutions are usually collected and reused; the resulting waste is the sludge from the collection tanks. Hydrochloric acid solutions are normally discharged directly after use. The total acid-caustic waste stream is normally low in organic matter but experiences wide variations in pH and contains high inorganic solids concentrations. It is common practice in the raw sugar industry to totally impound this waste stream.

Condensates - During the evaporation of cane juice the vapor or steam entering the calandria section of the evaporator does not come into contact with the juice, and the resulting condensate would theoretically contain no sugar. However, if the boiling is too violent or if the liquid level in the evaporator is too high, droplets of juice may be entrained in the vapor. Since factories generally use the condensate as a source of feed water for their steam generation, good control in terms of operation and entrainment prevention is usually maintained. Contaminated condensate is usually discharged with the barometric cooling water.

SUBCATEGORY II

Since cane washing is generally not practiced by factories in this subcategory, one of the major waste streams is not existent; in the worst case, where cane washing is employed, it is done so intermittently. Therefore the majority of pollutants in the effluent waste stream are contributed by the filter mud slurry. Barometric condenser cooling water accounts for a large waste flow but pollutant loadings are smaller in comparison to those of filter mud. Other miscellaneous waste streams have waste characteristics and loadings similar to those presented in Subcategory I and will not be discussed further. Table 18 shows pollutant loadings found in some of these miscellaneous waste streams.

Barometric Condenser Cooling Water - Seven of the nine factories which makeup Subcategory II either partially or totally recycle barometric condenser cooling water. Because generally these factories have proper vapor heights and have good operational controls, the barometric condenser cooling water is of relatively high quality and can be reused without the reduction of plant efficiencies and sugar recovery. The pollutant concentrations presented in Table 19 are quite variable, with BOD5 ranging from 6 to 2,110 mg/l. These irregularities in chemical composition can be attributed to variable operational parameters, the extent and type of recirculation employed, and other factors. Table 20, which presents barometric condenser cooling water loadings, shows an average BOD5 loading of 0.18 kilograms per metric ton (0.36 pounds per ton) of gross cane, if Factory 47 is considered to discharge directly (although this factory recirculates barometric condenser cooling water through a recirculation canal system). Thus a five to one reduction in sucrose entrainment is exhibited by factories presented in Table 20 when compared to those Subcategory I factories presented in Table 16.

Filter Mud - Presenting the greatest pollutional problem in these factories, filter mud slurries carry relatively large amounts of BOD5, COD, and suspended solids. Although the average discharge flow is 1,300 cubic meters per day (0.34 million gallons per day) as compared to an average barometric condenser cooling water flow of 128,000 cubic meters per day (33.8 million gallons per day), the pollutant concentrations and respective loadings are considerably higher. In Table 18 the BOD5, COD, and suspended solids loadings are listed as 1.89 kilograms per metric ton (3.78 pounds per ton), 12.9 kilograms per metric ton (25.8 pounds per ton), and 7.32 kilograms per metric ton (14.6 pounds per ton) for suspended solids, respectively.

SUBCATEGORY III

The characteristics of the total waste water discharge from factories in this subcategory are presented in Tables 21 and 22 in terms of concentrations (mg/l) and loadings (kilograms per metric ton of gross cane), respectively. The average of these data indicate a waste water discharge of 15,800 liters per metric ton (3,800 gallons per ton) of gross cane with a total BOD5 loading of 6.5 kilograms per metric ton (13.0 pounds per ton) of gross cane. The average suspended solids

TABLE 18

POLLUTANT LOADINGS IN MISCELLANEOUS STREAMS

Stream	Discharge Range (l/kkg)	Average Discharge (l/kkg)	BOD5 (kg/kkg)	COD (kg/kkg)	TSS (kg/kkg)	TS (kg/kkg)
Filter Slurry	31-282	150	1.89	12.9	7.32	11.7
Ash Slurry	23-312	200	0.22	0.69	0.31	-
Boiler Blowdown	6-54	25	-	-	-	-
Excess Condensate	10-2660	1340	0.004	0.012	0.0014	-
Floor & Equipment Washings	2-71	36	-	-	-	-

TABLE 19

SUBCATEGORY II
POLLUTANT CONCENTRATIONS IN CONDENSER WATER

Factory	Grind (kkg/day)	Flow Used (M3/day)	Discharge (M3/day)	BOD5 (mg/l)	COD (mg/l)	TSS (mg/l)	TS (mg/l)	TP (mg/l)	KN (mg/l)	Source*
44	5,200	98,100	0		41					2
47	5,400	114,000	0	6						1
48	9,100	164,000	344	2,110	4,910	343				2
49	7,730	131,000	131,000	28						2
51	9,500	131,000	1,400	200	320	10				3

*Source codes listed in Table 1, Section III.

TABLE 20

SUBCATEGORY II
POLLUTANT LOADINGS IN CONDENSER WATER

Factory	Grind (kkg/day)	Flow Used (l/kkg)	Discharge (l/kkg)	BOD5 (kg/kkg)	COD (kg/kkg)	TSS (kg/kkg)	TS (kg/kkg)	TP (kg/kkg)	KN (kg/kkg)	Source*
44	5,200	18,900	0		0**					2
47	5,400	21,100	0	0***						1
48	9,100	18,000	38	0.08	0.19	0.013				2
49	7,730	16,900	16,900	0.47						2
51	9,500	13,800	147	0.029	0.047	0.0015				3

*Source codes listed in Table 1, Section III.
**If discharged this would amount to a COD discharge of 0.77 kg/kkg of gross cane.
***If discharged this would amount to a BOD5 discharge of 0.13 kg/kkg of gross cane.

TABLE 21

POLLUTANT CONCENTRATIONS IN TOTAL DISCHARGE WATER
SUBCATEGORY III

Factory	Grind (kkg/day)	Flow Used (M3/day)	Discharge (M3/day)	BOD5 (mg/l)	COD (mg/l)	TSS (mg/l)	TS (mg/l)	TP (mg/l)	KN (mg/l)	Source*	(YR.)
66	2,490	35,500	35,500	699	2,340	3,590	4,500	20	44	5	(67-68)
66	3,310	37,900	37,900	631	-	3,250				5	(74)
67	3,750	30,300	30,300	674	-	3,420				5	(74)
69	2,540	50,800	50,800	600	-	2,760				5	(74)
69	2,840	37,900	37,900	414	942	2,460	3,040	2.2	6.5	3	(74)
70	2,370	63,950	63,950	115	-	915				5	(74)

*Source codes listed in Table 1, Section III.

TABLE 22

POLLUTANT LOADINGS IN TOTAL DISCHARGE WATER
SUBCATEGORY III

Factory	Grind (kkg/day)	Flow Used (l/kkg)	Discharge (l/kkg)	BOD5 (kg/kkg)	COD (kg/kkg)	TSS (kg/kkg)	TS (kg/kkg)	TP (kg/kkg)	KN (kg/kkg)	Source*	(YR.)
66	2,490	14,300	14,300	10.0	33.4	51.3	64.4	0.29	0.63	5	(67-68)
66	3,310	11,450	11,450	7.2	-	37.3				5	(74)
67	3,750	8,100	8,100	5.5	-	27.7				5	(74)
69	2,540	20,000	20,000	12.0	-	55.2				5	(74)
69	2,840	13,300	13,300	5.5	12.6	32.8	40.5	0.03	0.087	3	(74)
70	2,370	27,000	27,000	3.1	-	24.7				5	(74)

*Source codes lited in Table 1, Section III.

loading is 35.2 kilograms per metric ton (70.4 pounds per ton) of gross cane.

Cane Wash Water - Factories in Subcategory III practice cane washing extensively. The trash content of the gross cane may approach 50 percent, ranging from 33 to 51 percent for the factories represented in Tables 21 and 22. Because of the high trash content, the pollutant concentrations and loadings in the cane wash water are quite high as shown in Tables 23 and 24. Comparing these concentrations and loadings to those representative of Subcategory I cane wash water, the difference is clearly evident. Average BOD_5 and suspended solids loadings are, respectively, 5.0 kilograms per metric ton (10.0 pounds per ton) of gross cane, and 31.7 kilograms per metric ton (63.4 pounds per ton) of gross cane. These values are considerably higher than those experienced by cane sugar factories outside of Hawaii.

Barometric Condenser Cooling Water - The Hawaii Sugar Industry Waste Study (6) observed a BOD_5 loading of 1.18 kilograms per metric ton (2.36 pounds per ton) of net cane processed for Factory 66. Other available data, as presented in Tables 25 and 26, show concentrations and loadings in terms of net cane. The average BOD_5 loading omitting the data discussed above is 0.34 kilograms per metric ton (0.68 pounds per ton) of net cane. The low values for pollutant loadings in barometric condenser cooling water correspond to those observed for other subcategories.

Miscellaneous Waste Streams - Data regarding miscellaneous waste discharges are limited and available data are presented in Tables 27 and 28.

Data regarding slurried filter mud indicates a relatively low pollutant load for this subcategory. The average waste discharge is 230 liters per metric ton (55 gallons per ton) of gross cane with characteristic loadings as follows: BOD_5, 0.56 kilograms per metric ton (1.11 pounds per ton) of gross cane; TSS, 2.16 kilograms per metric ton (4.32 pounds per ton) of gross cane; and total solids, 2.68 kilograms per metric ton (5.35 pounds per ton) of gross cane.

Other waste streams such as ash slurry, excess condensate, boiler blowdown, and floor and equipment washings are minor and contribute little to the total factory effluent. The discussion of these streams under Subcategory I is applicable to this subcategory.

SUBCATEGORY IV

The characteristics of the total waste water discharge from factories in this subcategory are presented in Tables 29 and 30 in terms of concentrations (mg/l) and loadings (kilograms per metric ton of gross cane), respectively. The average of these data indicate a waste water discharge of 14,300 liters per metric ton (3,430 gallons per ton) of

TABLE 23

POLLUTANT CONCENTRATIONS IN CANE WASH WATER SUBCATEGORY III

Factory	Grind (kkg/day)	Flow (M3/day)	Discharge (M3/day)	BOD5 (mg/l)	COD (mg/l)	TSS (mg/l)	TS (mg/l)	TP (mg/l)	KN (mg/l)	Source*	(YR.)
66	2,490	27,500	27,500	765	2,670	4,350	5,400	23	50	5	(67-68) (includes boiler ash)
66	3,310	20,100	20,100	1,190	-	6,130				5	(74)
69	2,840	30,200	30,200	469	726	2,970	3,850	2.7	3.1	3	(74)
70	2,370	38,900	38,900	140	-	1,280				5	(74)

TABLE 24

POLLUTANT LOADINGS IN CANE WASH WATER SUBCATEGORY III

Factory	Grind (kkg/day)	Flow (l/kkg)	Discharge (l/kkg)	BOD5 (kg/kkg)	COD (kg/kkg)	TSS (kg/kkg)	TS (kg/kkg)	TP (kg/kkg)	KN (kg/kkg)	Source*	(YR.)
66	2,490	11,000	11,000	8.42	29.4	47.9	59.4	0.25	0.55	5	(67-68) (includes boiler ash)
66	3,310	6,070	6,070	7.22	-	37.2				5	(74)
69	2,840	10,600	10,600	4.97	7.70	31.5	40.8	0.029	0.033	3	(74)
70	2,370	16,400	16,400	2.30	-	21.0				5	(74)

*Source codes listed in Table 1, Section III.

TABLE 25

POLLUTANT CONCENTRATION IN CONDENSER WATER
SUBCATEGORY III (NET CANE)

Factory	Grind (kkg/day)	Flow (M3/day)	Discharge (M3/day)	BOD5 (mg/l)	COD (mg/l)	TSS (mg/l)	TS (mg/l)	TP (mg/l)	KN (mg/l)	Source*	(YR.)
66	1,320	34,600	34,600	45	88	24	95	0.058	0.64	5	(67-68)
69	1,380	15,600	15,600	33	121	5	262	0.11	2.6	3	(74)
70	1,200	17,900	17,900	20	-	11				5	(74)

TABLE 26

POLLUTANT LOADINGS IN CONDENSER WATER
SUBCATEGORY III (NET CANE)

Factory	Grind (kkg/day)	Flow (l/kkg)	Discharge (l/kkg)	BOD5 (kg/kkg)	COD (kg/kkg)	TSS (kg/kkg)	TS (kg/kkg)	TP (kg/kkg)	KN (kg/kkg)	Source*	(YR.)
66	1,320	26,200	26,200	1.18	2.31	0.63	2.49	.0015	.017	5	(67-68)
69	1,380	11,300	11,300	0.37	1.37	0.057	2.96	.0012	.029	3	(74)
70	1,200	14,900	14,900	0.30	-	0.16				5	(74)

*Source codes listed in Table 1, Section III.

TABLE 27

POLLUTANT CONCENTRATIONS IN MISCELLANEOUS STREAMS SUBCATEGORY III

Factory	Grind (kkg/day)	Flow Used (M3/day)	Discharge (M3/day)	BOD5 (mg/l)	COD (mg/l)	TSS (mg/l)	TS (mg/l)	TP (mg/l)	KN (mg/l)	Source*	(YR.)
Ash & Filter Slurry											
70	2,370	7,150	7,150	222	-	1,170				5	(74)
Filter Slurry											
66	2,490	950	950	2,480	7,370	8,050	9,610	76	186	5	(67-68)
69	2,840	218	218	2,140	4,853	16,100	21,800	2	10	3	(74)

TABLE 28

POLLUTANT LOADINGS IN MISCELLANEOUS STREAMS SUBCATEGORY III

Factory	Grind (kkg/day)	Flow Used (l/kkg)	Discharge (l/kkg)	BOD5 (kg/kkg)	COD (kg/kkg)	TSS (kg/kkg)	TS (kg/kkg)	TP (kg/kkg)	KN (kg/kkg)	Source*	(YR.)
Ash & Filter Slurry											
70	2,370	3,020	3,020	0.67	-	3.53				5	(74)
Filter Slurry											
66	2,490	382	382	0.95	2.82	3.08	3.67	0.029	0.071	5	(67-68)
69	2,840	77	77	0.16	0.37	1.24	1.68	0.00015	0.00079	3	(74)

*Source codes listed in Table 1, Section III.

TABLE 29

POLLUTANT CONCENTRATIONS IN TOTAL DISCHARGE WATER
SUBCATEGORY IV

Factory	Grind (kkg/day)	Flow Used (M3/day)	Discharge (M3/day)	BOD5 (mg/l)	COD (mg/l)	TSS (mg/l)	TS (mg/l)	TP (mg/l)	KN (mg/l)	Source*	(YR)
72	3,610	46,600	46,600	374	992	1,360	2,290	0.0023	0.076	3	(74)
76	2,190	20,100	20,100	795	2,290	10,600	11,700	13	44	5	(67-68)
76	2,180	22,700	22,700	518	687	450				4	(71) (after primary settling)
80	5,310	98,000	98,000	297	465	2,876	6,320	0.38	17	3	(74)
82	2,670	42,000	44,300	307	627	1,400	2,250	0.45	4.6	3	(74)

*Source codes listed in Table 1, Section III.

TABLE 30

POLLUTANT LOADINGS IN TOTAL DISCHARGE WATER SUBCATEGORY IV

Factory	Grind (kkg/day)	Flow Used (l/kkg)	Discharge (l/kkg)	BOD5 (kg/kkg)	COD (kg/kkg)	TSS (kg/kkg)	TS (kg/kkg)	TP (kg/kkg)	KN (kg/kkg)	Source*	(YR)
72	3,610	12,900	12,900	4.8	12.8	17.5	29.5	0.00003	0.001	3	(74)
76	2,190	9,180	9,180	7.3	21.0	97.4	107	0.12	0.40	5	(67-68)
76	2,180	10,400	10,400	5.4	7.1	4.7				4 (after primary settling)	(71)
80	5,310	18,500	18,500	5.5	8.6	53.2	117	0.007	0.31	3	(74)
82	2,670	15,700	16,600	5.1	10.4	23.2	37.4	0.0075	0.077	3	(74)

*Source codes listed in Table 1, Section III.

gross cane with a total BOD5 loading of 5.7 kilograms per metric ton (11.4 pounds per ton) of gross cane. The average suspended solids loading is 47.8 kilograms per metric ton (95.6 pounds per ton) of gross cane.

Cane Wash Water - Factories in Subcategory IV practice cane washing extensively. The trash content of the gross cane ranges from 25 to 33 percent for the factories represented in Tables 29 and 30. The average cane wash water BOD5 and suspended solids loadings of those factories represented in Tables 31 and 32 (omitting the second entry for Factory 82 to enable direct comparison with Tables 29 and 30) are 5.1 kilograms per metric ton (10.2 pounds per ton) of gross cane and 45.3 kilograms per metric ton (90.6 pounds per ton) of gross cane, respectively.

Barometric Condenser Cooling Water - As presented in Tables 33 and 34, the average BOD5 loading for barometric condenser cooling water discharges (omitting the second entry for Factory 82 to allow direct comparison with Tables 29 and 30) is 0.33 kilograms per metric ton (0.66 pounds per ton) of net cane. This compares very favorably to the average observed for Subcategory III factories.

Miscellaneous Waste Streams - Data regarding miscellaneous waste discharges is limited and available data are presented in Tables 35 and 36.

Data regarding slurried filter mud indicates a relatively low pollutant load for this subcategory. The average waste discharge is 239 liters per metric ton (57 gallons per ton) of gross cane with characteristic loadings as follows: BOD5, 0.66 kilograms per metric ton (1.31 pounds per ton) of gross cane; TSS, 3.81 kilograms per metric ton (7.62 pounds per ton) of gross cane; and total solids, 4.96 kilograms per metric ton (9.92 pounds per ton) of gross cane.

Data regarding slurried boiler ash indicates an average waste discharge of 281 liters per metric ton (67 gallons per ton) of gross cane. The characteristic loadings are: BOD5, 0.014 kilograms per metric ton (0.028 pounds per ton) of gross cane; TSS, 0.69 kilograms per metric ton (1.4 pounds per ton) of gross cane, and total solids, 1.1 kilograms per metric ton (2.2 pounds per ton) of gross cane.

Other waste streams such as excess condensate, boiler blowdown, and floor and equipment washings are minor and contribute little to the total factory effluent. The discussion of these streams under Subcategory I is applicable to this subcategory.

SUBCATEGORY V

The sugar industry in Puerto Rico is currently undergoing a transition from hand harvesting of sugarcane to the mechanization of the

TABLE 31

POLLUTANT CONCENTRATIONS IN CANE WASH WATER SUBCATEGORY IV

Factory	Grind (kkg/day)	Flow Used (M3/day)	Discharge (M3/day)	BOD5 (mg/l)	COD (mg/l)	TSS (mg/l)	TS (mg/l)	TP (mg/l)	KN (mg/l)	Source*	(YR.)
72	3,610	64,900	64,900	247	678	956	1,630	0.011	0	3	(74)
76	2,190	20,100	20,100	786	2,250	10,600	11,700	13	44	5	(67-68)
80	5,310	64,300	64,300	375	584	4,060	9,010	0.50	23	3	(74)
82	2,670	38,200	38,200	284	487	1,240	2,130	0.49	3.1	3	(74)
82	2,790	33,300	33,300	664	1,110	5,400	8,690	8.4	23	5	(67-68)

TABLE 32

POLLUTANT LOADINGS IN CANE WASH WATER SUBCATEGORY IV

Factory	Grind (kkg/day)	Flow Used (l/kkg)	Discharge (l/kkg)	BOD5 (kg/kkg)	COD (kg/kkg)	TSS (kg/kkg)	TS (kg/kkg)	TP (kg/kkg)	KN (kg/kkg)	Source*	(YR.)
72	3,610	18,000	18,000	4.44	12.2	17.2	29.3	0.0002	0	3	(74)
76	2,190	9,180	9,180	7.22	20.7	97.3	107	0.12	0.40	5	(67-68)
80	5,310	12,100	12,100	4.54	7.07	49.1	109	0.006	0.28	3	(74)
82	2,670	14,300	14,300	4.06	6.96	17.7	30.5	0.007	0.044	3	(74)
82	2,790	11,900	11,900	7.90	13.2	64.3	103	0.10	0.27	5	(67-68)

*Source codes listed in Table 1, Section III.

TABLE 33

POLLUTANT CONCENTRATIONS IN CONDENSER WATER SUBCATEGORY IV (NET CANE BASIS)

Factory	Grind (kkg/day)	Flow Used (M3/day)	Discharge (M3/day)	BOD5 (mg/l)	COD (mg/l)	TSS (mg/l)	TS (mg/l)	TP (mg/l)	KN (mg/l)	Source*	(YR)
72	2,410	46,300	46,300	25	29	0	0	0	0	3	(74)
76	1,560	20,100	20,100	6	36	7	54	0.08	0.13	5	(67-68)
80	3,980	94,600	94,600	27	47	3	117	0	0.71	3	(74)
82	1,950	42,000	42,000	6	113	1	0	0	0.52	3	(74)
82	1,960	30,500	30,500	71	124	13	1,870	0.35	1.2	5	(67-68)

TABLE 34

POLLUTANT LOADINGS IN CONDENSER WATER SUBCATEGORY IV (NET CANE BASIS)

Factory	Grind (kkg/day)	Flow Used (l/kkg)	Discharge (l/kkg)	BOD5 (kg/kkg)	COD (kg/kkg)	TSS (kg/kkg)	TS (kg/kkg)	TP (kg/kkg)	KN (kg/kkg)	Source*	(YR)
72	2,410	19,200	19,200	0.48	0.56	0	0	0	0	3	(74)
76	1,560	12,900	12,900	0.08	0.46	0.09	0.70	0.001	0.002	5	(67-68)
80	3,980	23,800	23,800	0.64	1.12	0.071	2.8	0	0.017	3	(74)
82	1,950	21,500	21,500	0.13	2.43	0.022	0	0	0.011	3	(74)
82	1,960	15,600	15,600	1.10	1.93	0.20	29.2	0.0055	0.019	5	(67-68)

*Source codes listed in Table 1, Section III.

TABLE 35

POLLUTANT CONCENTRATIONS IN MISCELLANEOUS STREAMS
SUBCATEGORY IV

Factory	Grind (kkg/day)	Flow Used (M3/day)	Discharge (M3/day)	BOD5 (mg/l)	COD (mg/l)	TSS (mg/l)	TS (mg/l)	TP (mg/l)	KN (mg/l)	Source*	(YR)
Boiler Ash											
72	3,610	436	436	-	160	1,640	1,713	0.030	3.8	3	(74)
80	5,310	1,640	1,640	38	60	2,500	3,830	0.86	1.6	3	(74)
Boiler Blowdown and Boiler Ash											
82	2,670	1,100	1,100	35	240	2,693	4,888	0.81	3.7	3	(74)
Filter Mud											
80	5,310	273	273	7,144	10,200	63,500	97,400	1.06	262	3	(74)
82	2,670	1,140	1,140	2,190	3,600	10,200	11,500	0.43	53	3	(74)

*Source codes listed in Table 1, Section III.

TABLE 36

POLLUTANT LOADINGS IN MISCELLANEOUS STREAMS
SUBCATEGORY IV

Factory	Grind (kkg/day)	Flow Used (1/kkg)	Discharge (1/kkg)	BOD5 (kg/kkg)	COD (kg/kkg)	TSS (kg/kkg)	TS (kg/kkg)	TP (kg/kkg)	KN (kg/kkg)	Source*	(YR)
Boiler Ash											
72	3,610	121	121	-	0.019	0.20	0.21	0.000004	0.0005	3	(74)
80	5,310	309	309	0.012	0.019	0.77	1.18	0.0003	0.0005	3	(74)
Boiler Blowdown and Boiler Ash											
82	2,670	412	412	0.015	0.099	1.11	2.01	0.0003	0.0015	3	(74)
Filter Mud											
80	5,310	51.4	51.4	0.37	0.52	3.26	5.01	0.00005	0.013	3	(74)
82	2,670	427	427	0.94	1.54	4.36	4.91	0.0002	0.023	3	(74)

*Source codes listed in Table 1, Section III.

harvesting operation. This has resulted in a change in the properties and characteristics of waste waters discharged from the Puerto Rican sugar factories, due to the need to wash the cane before it is processed. The types of mechanical harvesting currently employed in Puerto Rico cause increases in the amount of extraneous material brought into the factory over that associated with hand harvested sugarcane. As discussed previously the major waste streams discharged from a cane sugar factory are barometric condenser cooling water, cane wash water, and floor and equipment washings and other miscellaneous waste waters. The usual practice in Puerto Rico is to mix the miscellaneous waste waters with barometric condenser cooling water and either utilize this as cane wash water or, if the washing of cane is not practiced, discharge this stream directly.

Candelario, et al. (42), report the characterization of liquid waste waters discharged from four cane sugar factories in 1972. Table 37 summarizes the ranges of values observed and the average value for various parameters. Candelario, et al., explain that most reliable data available correspond to the period when mechanical harvesting was not employed, with the literature being totally devoid of information on the quantities of water actually used in Puerto Rican mills for washing mechanically harvested cane. They go on to characterize water requirements for sugar mills in Puerto Rico at 12,000 liters per day for each metric ton of cane processed per day (2,880 gallons per day for each ton of cane processed per day). It is reported that the fraction of this water used as cane wash water varies depending upon the amount of cane which has been mechanically harvested. It is stated that the quantities of waste water generated from Puerto Rican mills which process mechanically harvested cane are at present the same as for those which process hand-harvested cane.

By applying the average values of the various parameters to the characteristic flow, one can arrive at unit raw waste loadings. Table 38 reports the average raw waste loadings of Puerto Rican cane sugar factories based on the work of Candelario, et al.

Tables 39 and 40 present additional data regarding pollutant concentrations and loadings in total plant discharge waters. The average factory has a grind of 3,900 metric tons per day (4,390 tons per day) of gross cane, and has a BOD_5 loading between 1.45 and 3.37 kilograms per metric ton (2.90 and 6.74 pounds per ton) of gross cane. The suspended solids loadings range from 2.25 kilograms per metric ton (4.50 pounds per ton) to 5.29 kilograms per metric ton (10.6 pounds per ton) of gross cane.

Cane Wash Water - Cane washing is practiced by the majority of factories in this subcategory to varying degrees. Tables 41 and 42 present data specific to the cane wash water discharge stream, regarding pollutant concentrations and loadings. The average BOD_5 and suspended solids loadings are 1.87 kilograms per metric ton (3.74

TABLE 37

CHARACTERIZATION OF PUERTO RICAN CANE SUGAR FACTORY WASTE WATERS

Parameter	Range of Values Observed	Average Value
pH	5.3 - 8.8	6.8
BOD_5, (mg/l)	112 - 225	180
COD, (mg/l)	385 - 978	591
TSS, (mg/l)	100 - 700	375
TS, (mg/l)	500 - 1,400	740
Temperature, (°C)	31° - 49°	45°

TABLE 38

UNIT RAW WASTE LOADINGS FOR TOTAL DISCHARGE FROM PUERTO RICAN CANE SUGAR FACTORIES, BASED ON THE WORK OF CANDELARIO, ET AL. (42)

Parameter	Unit Raw Waste Loading
Flow	12,000 l/kkg
BOD_5	2.16 kg/kkg
COD	7.09 kg/kkg
TSS	4.50 kg/kkg
TS	8.88 kg/kkg

TABLE 39

POLLUTANT CONCENTRATIONS IN TOTAL PLANT DISCHARGE WATERS SUBCATEGORY V

Factory	Average Grind (kkg/day)	Flow Used (M3/day)	Discharge (M3/day)	BOD5 (mg/l)	COD (mg/l)	TSS (mg/l)	TS (mg/l)	TP (mg/l)	KN (mg/l)	Source*
53	3,630	44,700	44,700	307	1,520	430	1,900	13	0.13	3
64	4,350	82,500	82,500	76	324	118	700	0.15	0.46	3

TABLE 40

POLLUTANT LOADINGS IN TOTAL PLANT DISCHARGE WATERS SUBCATEGORY V

Factory	Average Grind (kkg/day)	Flow Used (l/kkg)	Discharge (l/kkg)	BOD5 (kg/kkg)	COD (kg/kkg)	TSS (kg/kkg)	TS (kg/kkg)	TP (kg/kkg)	KN (kg/kkg)	Source*
53	3,630	12,300	12,300	3.77	18.7	5.29	23.4	0.16	0.0016	3
64	4,350	19,000	19,000	1.45	6.15	2.25	13.3	0.0028	0.0087	3

*Source codes listed in Table 1, Section III.

TABLE 41

POLLUTANT CONCENTRATIONS IN CANE WASH WATER SUBCATEGORY V

Factory	Average Grind (kkg/day)	Flow Used (M3/day)	Discharge (M3/day)	BOD5 (mg/l)	COD (mg/l)	TSS (mg/l)	TS (mg/l)	TP (mg/l)	KN (mg/l)	Source*
53	3,630	43,600	43,600	290	1,490	435	1,940	13	0.13	3
53	3,630	43,600	43,600	180	4,040	1,640	2,280	2.3	7.6	1
64	4,350	21,800	21,800	184	666	372	1,990	0.24	1.5	3

TABLE 42

POLLUTANT LOADINGS IN CANE WASH WATER SUBCATEGORY V

Factory	Average Grind (kkg/day)	Flow Used (l/kkg)	Discharge (l/kkg)	BOD5 (kg/kkg)	COD (kg/kkg)	TSS (kg/kkg)	TS (kg/kkg)	TP (kg/kkg)	KN (kg/kkg)	Source*
53	3,630	12,000	12,000	3.48	17.9	5.22	23.3	0.16	0.0016	3
53	3,630	12,000	12,000	2.16	48.5	19.7	27.4	0.028	0.091	1
64	4,350	5,010	5,010	0.92	3.34	1.86	9.97	0.0012	0.0075	3

*Source codes listed in Table 1, Section III.

pounds per ton) of gross cane and 7.18 kilograms per metric ton (14.4 pounds per ton) of gross cane, respectively.

Barometric Condenser Cooling Water - In Puerto Rico most of the cooling waters are used on a once-through basis. High BOD5 concentrations in this water is evidence that considerable sugar entrainment is occurring. Studies by Biaggi in 1968 (2) and the cane sugar industry in 1959 (7) found BOD5 concentrations in barometric condenser cooling water to range from 32 to 185 mg/l. The average BOD5 concentration in the barometric condenser cooling water discharge from all factories studied by Biaggi was 98 mg/l, while the average of those factories studied by Biaggi which continue to operate, was 89 mg/l. In terms of BOD5 loadings, Biaggi (2) showed barometric condenser cooling water loadings to range from 0.14 to 4.68 kilograms per metric ton (0.28 to 9.36 pounds per ton) of gross cane with an average of 1.59 kilograms per metric ton (3.18 pounds per ton) of gross cane. Biaggi reports that the high BOD5 concentrations in barometric condenser cooling water is clear evidence that too much sugar is being lost to entrainment.

Tables 43 and 44 present more recent data pertaining to pollutant concentrations and loadings in the barometric condenser cooling water discharge stream. The average of the most recent data indicates a BOD5 loading of 0.62 kilograms per metric ton (1.24 pounds per ton) of gross cane, which is in the lower range of the data presented by Biaggi.

Miscellaneous Waste Streams - Biaggi (2) reports an average of 0.2 percent sucrose retained in the filter cake. He reports that for those Puerto Rican factories which slurry the filter cake, an average BOD5 concentration of 15,800 mg/l, suspended solids concentration of 41,000, and total solids concentration of 64,500 mg/l results. Biaggi reports filter cake production on the order of 30 kilograms per metric ton (60 pounds per ton) of gross cane, within the range of values found to be characteristic of Louisiana cane sugar factories.

Although the smaller waste streams could contain high pollutant concentrations, their volume is small and sometimes sporadic in comparison with barometric condenser cooling water, cane wash water, and filter mud slurry, and their effect on total effluent loadings is usually negligible. Tables 45 and 46 present recent data pertaining to pollutant concentrations and loadings for certain miscellaneous waste water discharge streams.

MODEL CANE SUGAR FACTORIES

One hypothetical sugar factory (model plant) has been selected to adequately represent each subcategory. The models are intended to be representative of the subcategory as it presently exists, but cannot be expected to be identical to any particular factory. It is felt

TABLE 43

POLLUTANT CONCENTRATIONS IN CONDENSER WATER SUBCATEGORY V

Factory	Average Grind (kkg/day)	Flow Used (M3/day)	Discharge (M3/day)	BOD5 (mg/l)	COD (mg/l)	TSS (mg/l)	TS (mg/l)	TP (mg/l)	KN (mg/l)	Source*
52	4,800	68,100	68,100	83	2,780	220	1,380	0.36	0.87	1
53	3,630	43,600	43,600	24	58	5.4	0	0	0	3
53	3,630	43,600	43,600	130	267	111	2.4	0	0.50	1
64	4,350	81,800	60,000	28	76	21	54	0.03	0	3

TABLE 44

POLLUTANT LOADINGS IN CONDENSER WATER SUBCATEGORY V

Factory	Average Grind (kkg/day)	Flow Used (l/kkg)	Discharge (l/kkg)	BOD5 (kg/kkg)	COD (kg/kkg)	TSS (kg/kkg)	TS (kg/kkg)	TP (kg/kkg)	KN (kg/kkg)	Source*
52	4,800	14,200	14,200	1.18	39.5	3.12	19.6	0.0051	0.012	1
53	3,630	12,000	12,000	0.29	0.70	0.065	0	0	0	3
53	3,630	12,000	12,000	1.56	3.20	1.33	0.029	0	0.006	1
64	4,350	18,800	13,800	0.39	1.05	0.29	0.75	.0004	0	3

*Source codes listed in Table 1, Section III.

TABLE 45

POLLUTANT CONCENTRATIONS IN MISCELLANEOUS WATERS SUBCATEGORY V

Factory	Average Grind (kkg/day)	Flow Used (M3/day)	Discharge (M3/day)	BOD5 (mg/l)	COD (mg/l)	TSS (mg/l)	TS (mg/l)	TP (mg/l)	KN (mg/l)	Source*
Ash Slurry 53	3,630	1,090	1,090	11	191	13	247	0.2	0.15	3
Floor Wash Boiler Blowdown Acids & Caustics 64	4,350	736	736	-	10,400	574	15,300	7.1	7.3	3

TABLE 46

POLLUTANT LOADINGS IN MISCELLANEOUS WATERS SUBCATEGORY V

Factory	Average Grind (kkg/day)	Flow Used (l/kkg)	Discharge (l/kkg)	BOD5 (kg/kkg)	COD (kg/kkg)	TSS (kg/kkg)	TS (kg/kkg)	TP (kg/kkg)	KN (kg/kkg)	Source*
Ash Slurry 53	3,630	300	300	.0033	.057	.0039	.074	.0001	0.00005	3
Floor Wash Boiler Blowdown Acids & Caustics 64	4,350	169	169	-	1.76	.097	2.59	.0012	0.0012	3

*Source codes listed in Table 1, Section III.

that the models are representative of their respective subcategories and, in all cases, the models are considered adequate for the purpose of identifying control and treatment technology (Section VII) and for conducting cost analyses (Section VIII).

The models for all subcategories have the following features in common:

1. All evaporators have liquid level controls. The last bodies of evaporators have absolute pressure controls.
2. Baffles used for entrainment control consist of two 1.27 centimeter (0.5 inch) plates.
3. All vacuum pans have domes.
4. Juice height in evaporator tubes = 0.91 meter (3 feet).
5. Process assumptions:
    a. Juice inlet temperature 29°C (84°F)

    b. Syrup brix 60°

    c. Overall maceration heater, heat transfer coefficient.
    kg-cal/hr-sq.m-°C 590
    (BTU/hr-sq.ft-°F) 120

    d.

Condensate usage	kg/hr-kkg	lb/hr-ton
Filters	1.7	3.4
Miscellaneous	1.0	2.0
Molasses dilution, washing	2.0	4.0

SUBCATEGORY I MODEL PLANT

In addition to the above features, the Subcategory I model plant is assumed to process on a daily basis 2,730 metric tons (3,000 tons) of field (gross) cane. It operates seven days per week for a total of 70 consecutive days per year, beginning in late October and ending in early January. The discharge from barometric condenser cooling is used for cane washing, but more barometric condenser cooling water is generated than is required for washing. It employs quadruple effect evaporation with three meter (10 foot) diameter evaporator bodies. It requires 65,500 kilograms (144,000 pounds) of steam per hour of operation. It has the following process characteristics:

1. Maceration, percent cane = 30

2. Bagasse, percent cane = 33

3. Dilute juice brix = 12.5°

4. Volume of boiler ash will approximate 0.45 kilograms (1.0 pounds) per hour for every 45 kilograms (100 pounds) per hour of steam generated. If ash is handled in a slurry form, 280 liters (75 gallons) of water per minute are used for sluicing.

5. A production of 50 kilograms of filter cake per metric ton (100 pounds of filter cake per ton) of gross cane is assumed. If filter cake is handled in a slurry form, 280 liters (75 gallons) of water per minute are used for slurrying.

6. Exhaust requirement to pre-evaporator,

   13.5 kg/hr-kkg (27.0 lb/hr-ton) for evaporators
   9.0 kg/hr-kkg (18.0 lb/hr-ton) for vacuum pans

7. Vapors from pre-evaporator to heater, 5.7 kg/hr-kkg (11.4 lb/hr-ton)

8. Vapors from first evaporator to second, 6.07 kg/hr-kkg (12.14 lb/hr-ton)

9. Vapors from second evaporator to third, 6.43 kg/hr-kkg (12.86 lb/hr-ton)

10. Vapors from third evaporator to fourth, 6.93 kg/hr-kkg (13.86 lb/hr-ton)

11. Condensate usage

Condensate usage	kg/hr-kkg	lb/hr-ton
Maceration =	12.5	25.0
Boiler feed =	24.8	49.5
Excess makeup to injection =	5.7	11.4

12. Muriatic acid usage = 0.18 kilograms per metric ton (0.36 pounds per ton) of cane.

13. Caustic soda (50 percent solution) = 0.6 kilograms per metric ton (1.2 pounds per ton) of cane.

Tables 47 and 47A give waste water characteristics for the major waste streams generated by the model plant. Figure 17 shows a water balance for the plant. The water usage and raw waste loadings are based on an analysis of data presented previously in this section, and are derived from a basis of average rather than exemplary values.

TABLE 47

WASTE WATER DISCHARGE CHARACTERISTICS FOR INDIVIDUAL WASTE STREAMS MODEL PLANT -- SUBCATEGORY I

Waste Stream	Flow (cu.m/day)	Flow (l/kkg)	BOD5 (mg/l)	BOD5 (kg/kkg)	TSS (mg/l)	TSS (kg/kkg)
Barometric Condenser Cooling Water	44,200	16,200	31	0.50	0	0
Cane Wash	16,900	6,200	242	1.50	2,820	17.5
Boiler Blowdown	82	30	1,700	0.051	850	0.025
Excess Condensate	1,490	546	10	0.0055	0	0
Floor Wash	115	42	600	0.025	750	0.03

TABLE 47A

WASTE WATER DISCHARGE CHARACTERISTICS MODEL PLANT -- SUBCATEGORY I

Waste Stream	Discharge (cu.m/day)	Flow (l/kkg)	BOD5 (mg/l)	BOD5 (kg/kkg)	TSS (mg/l)	TSS (kg/kkg)
Barometric Condenser Cooling Water	27,300	10,000	31	0.31	0	0
Cane Wash	16,900	6,200	273	1.69	2,820	17.5
Boiler Blowdown	82	30	1,700	0.051	850	0.025
Excess Condensate	1,380	504	10	0.0050	0	0
Floor Wash	115	42	605	0.025	750	0.032
Total Raw Waste	45,800	16,800	124	2.08	1,045	17.56

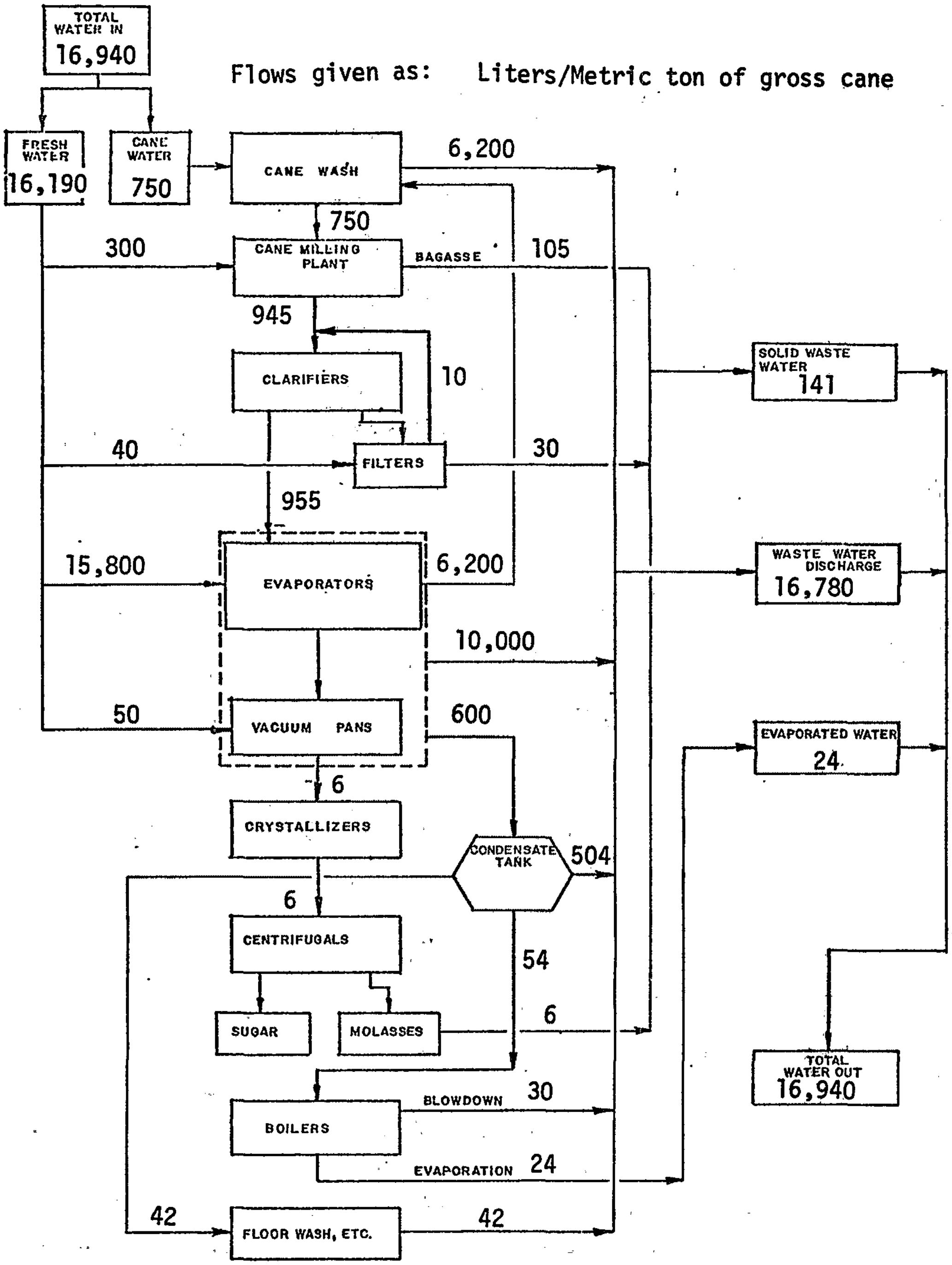


FIGURE 17

MODEL PLANT WATER BALANCE
SUBCATEGORY I

SUBCATEGORY II MODEL PLANT

The Subcategory II model plant has a daily grind of 7,300 metric tons (8,000 tons) of field (gross) cane. It employs a pre-evaporator and a triple effect evaporator. The evaporator bodies are 4.1 meters (13.5 feet) in diameter. The plant requires 182,000 kilograms (400,000 pounds) of steam per hour of operation.

The following process factors are assumed:

1. Maceration, percent cane = 25
2. Bagasse, percent cane = 30
3. Dilute juice brix = 15°
4. Exhaust requirement, kg/hr-kkg, lb/hr-ton

Exhaust requirement,	kg/hr-kkg,	lb/hr-ton
Pre-evaporator =	7.5	15
Pans =	10	20

5. Vapors from pre-evaporator to heater, 5.5 kg/hr-kkg (11 lb/hr-ton)
6. Vapors from first evaporator to second, 8 kg/hr-kkg (16 lb/hr-ton)
7. Vapors from second evaporator to third, 8.8 kg/hr-kkg (17.6 lb/hr-ton).
8. Condensate usage

Condensate usage	kg/hr-kkg	lb/hr-ton
Maceration =	10.4	20.8
Boiler feed =	25.8	51.5
Excess makeup to injection =	5.0	9.9

Tables 48 and 48A list the waste water characteristics of the model plant. Figure 18 shows a water balance for the plant. The water usage and raw waste loadings are based on an analysis of data presented previously in this section, and are derived from a basis of average rather than exemplary values.

SUBCATEGORY III MODEL PLANT

The Subcategory III model plant is assumed to have a daily grind of 3,340 metric tons (3,675 tons) of net cane per day. This is based on the projected increases in capacities presented in Table 5 of Section III. Extraneous material contents experienced in cane harvested at Subcategory III factories were found to range from 31 to 51 percent of gross cane on a yearly basis. The model plant assumes a net to gross cane ratio of 0.50. Process features similar to the Subcategory I

TABLE 48

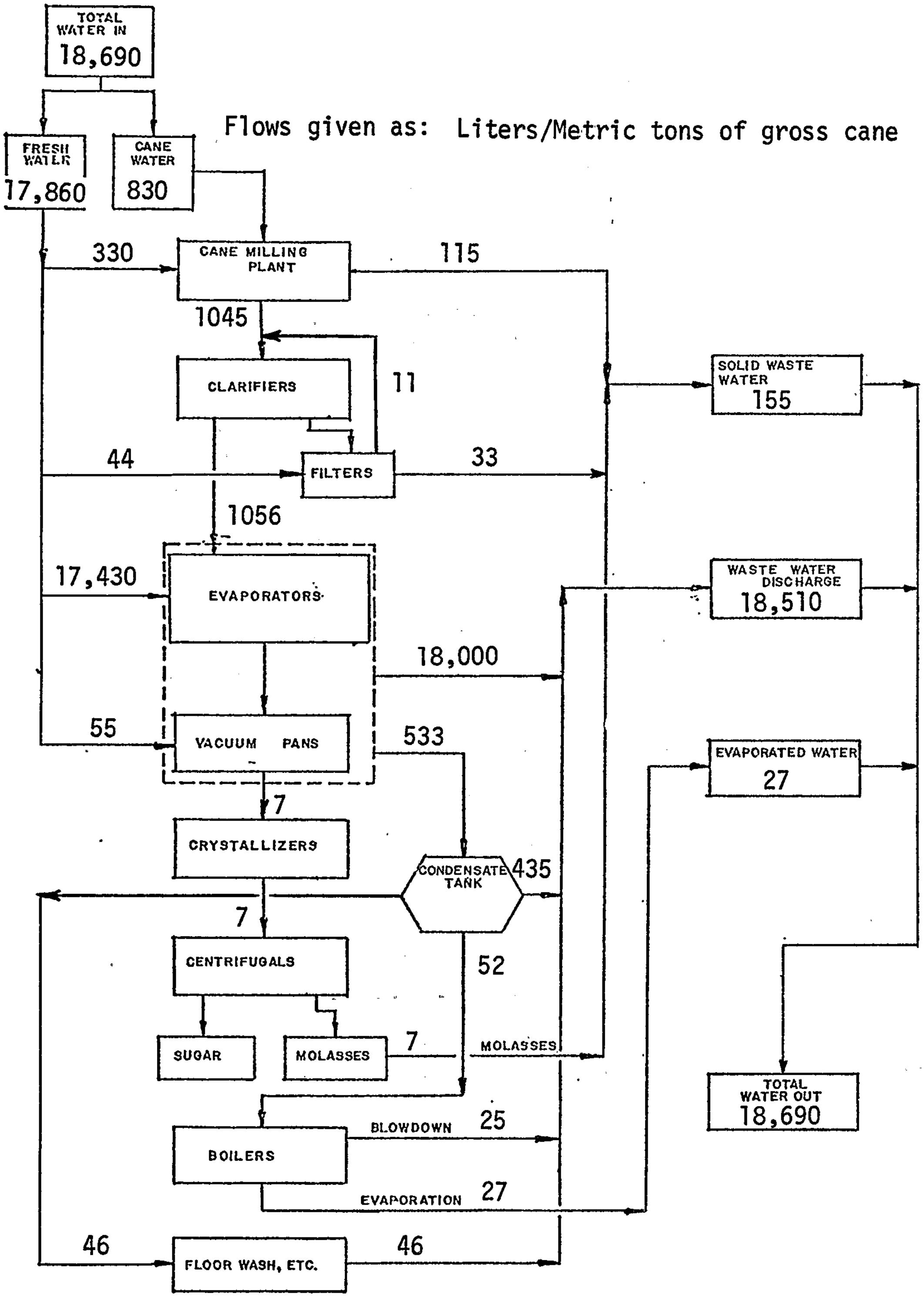
WASTE WATER DISCHARGE CHARACTERISTICS FOR INDIVIDUAL WASTE STREAMS MODEL PLANT -- SUBCATEGORY II

Waste Stream	Flow (cu.m/day)	Flow (l/kkg)	BOD5 (mg/l)	BOD5 (kg/kkg)	TSS (mg/l)	TSS (kg/kkg)
Barometric Condenser Cooling Water	13,000	18,000	20	0.36	0	0
Boiler Blowdown	183	25	2,240	0.056	1,120	0.028
Excess Condensate	3,510	481	10	0.0048	0	0
Floor Wash	336	46	600	0.028	750	0.035

TABLE 48A

WASTE WATER DISCHARGE CHARACTERISTICS
MODEL PLANT -- SUBCATEGORY II

Waste Stream	Discharge (cu.m/day)	Flow (l/kkg)	BOD5 (mg/l)	BOD5 (kg/kkg)	TSS (mg/l)	TSS (kg/kkg)
Barometric Condenser Cooling Water	131,000	18,000	20	0.36	0	0
Boiler Blowdown	183	25	2,240	0.056	1,120	0.028
Excess Condensate	3,180	435	10	0.0044	0	0
Floor Wash	336	46	619	0.028	750	0.035
Total Raw Waste	134,700	18,500	24	0.45	3.4	0.063



Flows given as: Liters/Metric tons of gross cane

FIGURE 18

MODEL PLANT WATER BALANCE
SUBCATEGORY II

model plant were assumed, except that the Subcategory III model plant is assumed to operate 250 days per year.

A simplified waste water flow diagram for the model plant is shown in Figure 19, with flows expressed in terms of liters per metric ton of net cane ground. Corresponding waste characteristics are presented in Tables 49 and 49A. Flows are based on data previously presented in Section V. Barometric condenser cooling water unit volume and unit loadings are essentially averages of values presented in Tables 9A and 9B and Tables 25 and 26; a net cane basis was used. Cane wash water unit volume is based on that of Factory 67 which employs a cascading system of cane washing to optimize water usage. As shown in Table 9B, Factory 67 employs 5,040 liters of cane wash water per metric ton (1,210 gallons per ton) of gross cane. Assuming a net to gross cane ratio of 0.50, a unit flow of 10,080 liters per metric ton (2,420 gallons per ton) of net cane is obtained. This unit flow is attainable based on the experience at Factory 67 (which in actuality uses 7,530 l/kkg (1,810 gallons/ton) of net cane, based on a net to gross cane ratio of 0.67) and based on the projected water usage at Factory 66 of 3,220 liters per metric ton (770 gallons per ton) of gross cane or 4,870 liters per metric ton (1,170 gallons per ton) of net cane at a projected net to gross cane ratio of 0.66. Raw waste loadings for the cane wash water discharge stream are based on prior analyses by industry, which included an estimate of anticipated raw waste loadings based on a projection of data to include the entire range of weather conditions anticipated. As can be seen in Tables 23 and 24, recent short-term data do not support these projected loadings. Data of a long-term nature are becoming available due to permit requirements for the Hilo-Hamakua Coast factories. Should these long-term data contradict information included in this document pertaining to the model plant for Subcategory III, appropriate revisions will be made during future analyses.

SUBCATEGORY IV MODEL PLANT

The Subcategory IV model plant is assumed to have a daily grind of 3,000 metric tons (3,300 tons) of net cane per day. Extraneous material contents experienced in cane harvested at Subcategory IV factories were found to range from 18 to 42 percent on a yearly basis. The model plant assumes a net to gross cane ratio of 0.66. Process features similar to the Subcategory I model plant were assumed.

The same waste water flow diagram (Figure 19), as was employed to represent the Subcategory III factories, is considered applicable to Subcategory IV factories as well. Tables 50 and 50A list the waste water characteristics of the model plant. The raw waste loadings are based on data presented previously in Section V and are essentially average values.

TABLE 49

WASTE WATER DISCHARGE CHARACTERISTICS FOR INDIVIDUAL WASTE STREAMS MODEL PLANT -- SUBCATEGORY III (NET CANE BASIS)*

Waste Stream	Flow (cu.m/day)	Flow (l/kkg)	BOD5 (mg/l)	BOD5 (kg/kkg)	TSS (mg/l)	TSS (kg/kkg)
Barometric Condenser Cooling Water	40,100	12,000	28	0.34	0	0
Cane Wash	33,700	10,080	952	9.6	16,870	170
Filter Mud	700	210	9,520	2.0	55,700	11.7
Ash Slurry	1,000	300	1,000	0.30	41,000	12.3
Boiler Blowdown	100	30	1,940	0.058	970	0.029
Floor Washings	160	48	600	0.029	750	0.036
Excess Condensate	2,140	642	10	0.0064	0	0

*To obtain a gross cane basis divide unit flows and unit loadings by 2.

TABLE 49A

WASTE WATER DISCHARGE CHARACTERISTICS
MODEL PLANT -- SUBCATEGORY III
(NET CANE BASIS)*

Waste Stream	Discharge (cu.m/day)	Flow (l/kkg)	BOD5		TSS	
			(mg/l)	(kg/kkg)	(mg/l)	(kg/kkg)
Barometric Condenser Cooling Water	6,400	1,920	28	0.054	0	0
Cane Wash	33,700	10,080	980	9.9	16,870	170
Filter Mud	700	210	9,520	2.0	55,700	11.7
Ash Slurry	1,000	300	1,000	0.30	41,000	12.3
Boiler Blowdown	100	30	1,940	0.058	970	0.029
Floor Washings	160	48	614	0.029	750	0.036
Excess Condensate	240	72	10	0.00072	0	0
Total Raw Waste	42,300	12,700	970	12.3	15,300	194

*To obtain a gross cane basis divide unit flows and unit loadings by 2.

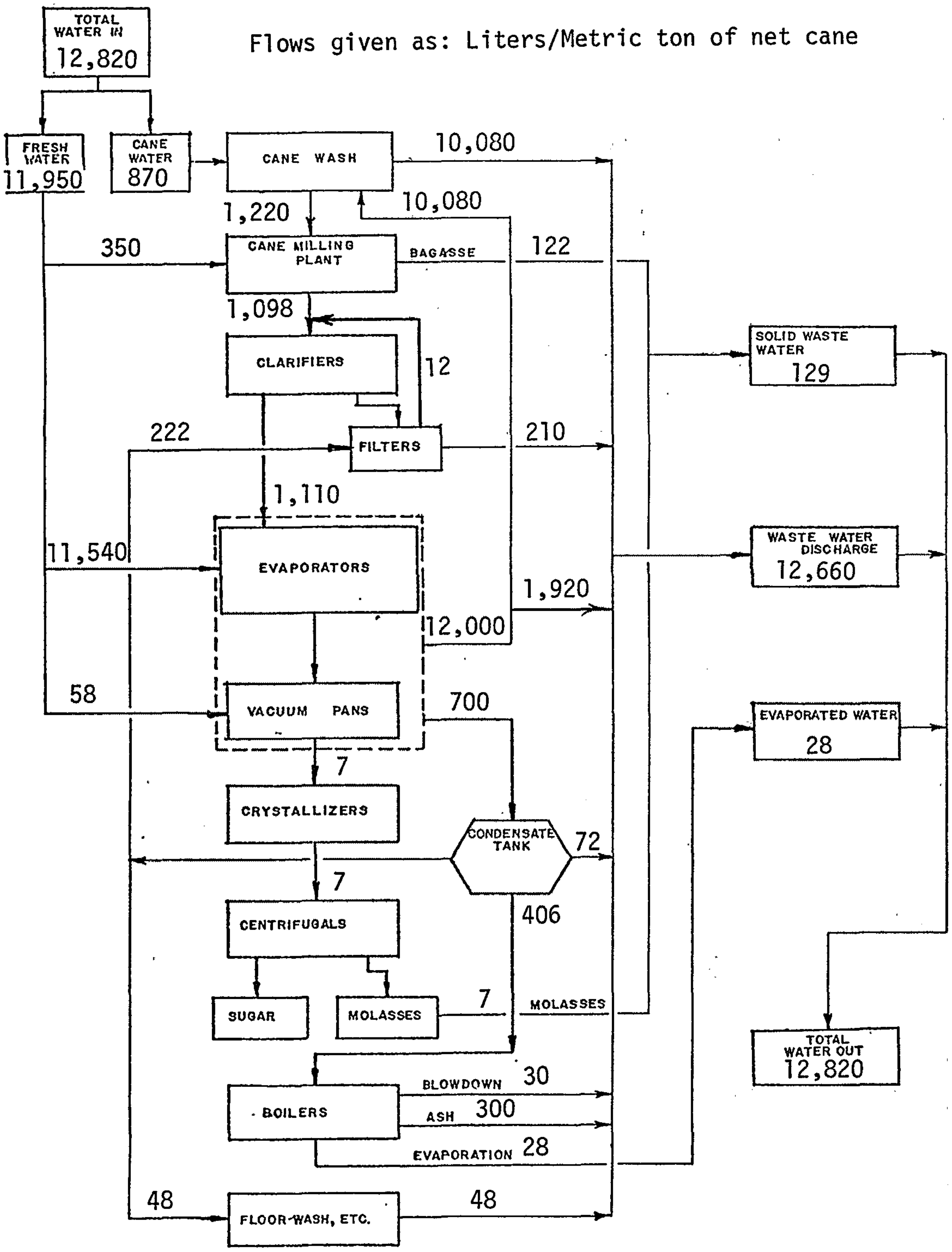


FIGURE 19

MODEL PLANT WATER BALANCE
SUBCATEGORIES III AND IV

TABLE 50

WASTE WATER DISCHARGE CHARACTERISTICS FOR INDIVIDUAL WASTE STREAMS MODEL PLANT -- SUBCATEGORY IV (NET CANE BASIS)*

Waste Stream	Flow (cu.m/day)	Flow (l/kkg)	BOD5 (mg/l)	BOD5 (kg/kkg)	TSS (mg/l)	TSS (kg/kkg)
Barometric Condenser Cooling Water	36,000	12,000	28	0.34	0	0
Cane Wash	30,200	10,080	794	8.0	6,940	70
Filter Mud	630	210	9,520	2.0	55,700	11.7
Ash Slurry	900	300	1,000	0.30	41,000	12.3
Boiler Blowdown	90	30	1,940	0.058	970	0.029
Floor Washings	144	48	600	0.029	750	0.036
Excess Condensate	1,930	642	10	0.0064	0	0

*To obtain a gross cane basis divide unit flows and unit loadings by 1.5.

TABLE 50A

WASTE WATER DISCHARGE CHARACTERISTICS
MODEL PLANT -- SUBCATEGORY IV
(NET CANE BASIS)*

Waste Stream	Discharge (cu.m/day)	Flow (l/kkg)	BOD5		TSS	
			(mg/l)	(kg/kkg)	(mg/l)	(kg/kkg)
Barometric Condenser Cooling Water	5,760	1,920	28	0.054	0	0
Cane Wash	30,200	10,080	823	8.3	6,940	70
Filter Mud	630	210	9,520	2.0	55,700	11.7
Ash Slurry	900	300	1,000	0.30	41,000	12.3
Boiler Blowdown	90	30	1,940	0.058	970	0.029
Floor Washings	144	48	614	0.029	750	0.036
Excess Condensate	216	72	10	0.00072	0	0
Total Raw Waste	38,000	12,700	840	10.7	7,410	94

*To obtain a gross cane basis divide unit flows and unit loadings by 1.5.

SUBCATEGORY V MODEL PLANT

As discussed previously in this document, wide variations exist within the sugar industry of Puerto Rico and the industry is currently in a state of flux. The present trend in the industry has been an increase in the use of mechanical harvesting which has necessitated the increasing usage of cane wash water. It can be generalized that the model plant should therefore be some combination of both Subcategory I and Subcategory II conditions. The limited data available indicate this to be the case, with an indication of raw waste loadings in the range of those found in Subcategories I and II. Because the trend is toward the complete use of mechanical harvesting techniques, the same model plant as has been considered to be representative of Subcategory I (which includes total usage of mechanical harvesting techniques) has been chosen to be the model plant for Subcategory V. It has been assumed that the model plant operates for a period of 120 days per year.

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

PRELIMINARY SELECTION OF POLLUTANT PARAMETERS

In the previous section, the waste waters associated with the raw cane sugar processing segment were characterized. Based on the results of the waste water characterization, this section indicates the rationale for the selection of pollutant parameters for which effluent limitations should be established.

During the project planning phase, a review of existing literature, Refuse Act Permit Program applications, and other information led to a preliminary listing of pollutant parameters of potential pollutional significance. These parameters include BOD (five-day, 20° Centigrade), COD, total suspended solids, pH, temperature, alkalinity, sucrose, total coliforms, fecal coliforms, total dissolved solids, and nutrients (forms of nitrogen and phosphorus).

Following the waste characterization program and further literature reviews, a determination was made concerning whether the pollutant is present in sufficient concentration to warrant further consideration as a pollutant to be controlled or treated. Some pollutant parameters were eliminated from further consideration on the basis of low concentrations or inconclusive data. On the basis of all evidence reviewed, there does not exist any purely hazardous or toxic pollutants (e.g., heavy metals, pesticides) in wastes discharged from cane sugar factories.

POLLUTANT PARAMETERS

Measurement of Organics

Biochemical Oxygen Demand (BOD). Biochemical oxygen demand (BOD) is a measure of the oxygen consuming capabilities of organic matter. The BOD does not in itself cause direct harm to a water system, but it does exert an indirect effect by depressing the oxygen content of the water. Sewage and other organic effluents during their processes of decomposition exert a BOD, which can have a catastrophic effect on the ecosystem by depleting the oxygen supply. Conditions are reached frequently where all of the oxygen is used and the continuing decay process causes the production of noxious gases such as hydrogen sulfide and methane. Water with a high BOD indicates the presence of decomposing organic matter and subsequent high bacterial counts that degrade its quality and potential uses.

Dissolved oxygen (DO) is a water quality constituent that, in appropriate concentrations, is essential not only to keep organisms living but also to sustain species reproduction, vigor, and the development of populations. Organisms undergo stress at reduced DO concentrations that make them less competitive and able to sustain their species within the aquatic environment. For example, reduced DO concentrations have been shown to interfere with fish population through delayed hatching of eggs, reduced size and vigor of embryos, production of deformities in young, interference with food digestion, acceleration of blood clotting, decreased tolerance to certain toxicants, reduced food efficiency and growth rate, and reduced maximum sustained swimming speed. Fish food organisms are likewise affected adversely in conditions with suppressed DO. Since all aerobic aquatic organisms need a certain amount of oxygen, the consequences of total lack of dissolved oxygen due to a high BOD can kill all inhabitants of the affected area.

If a high BOD is present, the quality of the water is usually visually degraded by the presence of decomposing materials and algae blooms due to the uptake of degraded materials that form the foodstuffs of the algal populations. Biochemical oxygen demand (BOD) is contributed by sucrose entrainment into barometric condenser cooling waters, dissolution of sugar during the washing of sugarcane and floors, and sucrose and other organic matter present in the juice being adsorbed by the filter cake. Biochemical oxygen demand is a particularly applicable parameter for the sugar industry because sucrose is highly biodegradable. It is significant to ground water pollution control in that it is possible for biodegradable organics to seep into ground water from earthen settling or impounding basins.

Chemical Oxygen Demand. Chemical oxygen demand (COD) is contributed by sucrose entrainment into barometric condenser cooling waters, dissolution of sugar during the washing of sugarcane and floors and equipment, and sucrose and other organic matter present in the juice being adsorbed by the filter cake. Its effects on the receiving waters are identical to those caused by the biochemical oxygen demand, because for this industry segment, BOD and COD are essentially a measure of the same parameter, organic matter. Control of BOD will adequately control the adverse effects of COD.

Bacteriological Characteristics

Fecal Coliforms. The presence of fecal coliforms in water indicates the potential presence of pathogenic bacteria and viruses because of their common origin within the intestinal tract of warm blooded animals. For this reason, a measurement of fecal coliform bacteria may be used as an indicator of the presence of pathogenic bacteria and viruses.

In general, the presence of fecal coliform organisms indicates recent and possibly dangerous fecal contamination. When the fecal coliform count exceeds 2,000 per 100 ml there is a high correlation with increased numbers of both pathogenic viruses and bacteria.

Many microorganisms, pathogenic to humans and animals, may be carried in surface water, particularly that derived from effluent sources which find their way into surface water from municipal and industrial wastes. The diseases associated with bacteria include bacillary and amoebic dysentery, Salmonella gastroenteritis, typhoid and paratyphoid fevers, leptospirosis, cholera, vibriosis, and infectious hepatitis. Recent studies have emphasized the value of fecal coliform density in assessing the occurrence of Salmonella, a common bacterial pathogen in surface water. Field studies involving irrigation water, field crops, and soils indicate that when the fecal coliform density in stream waters exceeded 1,000 per 100 ml, the occurrence of Salmonella was 53.5 percent.

Coliform organisms in cane wash water are attributable primarily to soil bacteria and secondarily to animal excrement in the cane fields. The existence, at least occasionally, of pathogenic organisms such as Salmonella is possible.

Other Bacteriological Considerations. Theoretically, if bacteria are present in surface water used for barometric condenser cooling water injection, bacterial growth can occur in the heated condenser water with the presence of entrained sucrose. It is also possible that thermal shock will kill these organisms.

No bacteriological problems are presented in the raw sugar product due to the fact that any bacteria present in the product prior to evaporation are destroyed in the evaporation process. Furthermore, raw sugar is not considered to be an edible product and is purified prior to human consumption.

Bacteriological problems in waste waters are minimized by in-plant recirculation and reuse of water, waste water retention, and land disposal. However, in the last case adequate protection of ground water must be maintained by seepage control.

While the limited available data indicate that coliform bacteria may be a problem on an individual factory basis, data do not indicate that this potential pollutant parameter is of sufficient significance on an industry-wide basis to warrant its inclusion as a controlled parameter.

pH

The term pH is a logarithmic expression of the concentration of hydrogen ions. At a pH of 7, the hydrogen and hydroxyl ion concentrations are essentially equal and the water is neutral. Lower pH values indicate acidity, while higher values indicate alkalinity. The relationship between pH and acidity or alkalinity is not necessarily linear or direct.

Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add such constituents to drinking water as iron, copper, zinc, cadmium, and lead. The hydrogen ion concentration can affect the "taste" of the water. At a low pH water tastes "sour". The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to 7. This is very significant for providing safe drinking water.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Dead fish, associated algal blooms, and foul stenches are aesthetic liabilities of any waterway. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in pH. The toxicity of metalocyanide complexes can increase a thousand-fold with a drop of 1.5 pH units. The availability of many nutrient substances varies with the alkalinity and acidity. Ammonia is more lethal with a higher pH.

The lacrimal fluid of the human eye has a pH of approximately 7.0 and a deviation of 0.1 pH unit from the norm may result in eye irritation for the swimmer. Appreciable irritation will cause severe pain.

Within the raw cane sugar processing segment, pH is an important criterion for in-process quality control, odor control, and bacterial growth retardation. Highly acidic or caustic solutions can be harmful to aquatic environments and can interfere with water or waste water treatment processes.

Temperature

Temperature is one of the most important and influential water quality characteristics. Temperature determines those species that may be present, activates the hatching of young, regulates their activity, and stimulates or suppresses their growth and development. It attracts, and may kill when water is heated or becomes chilled too suddenly. Colder water generally suppresses development, while warmer water generally accelerates activity and may be a primary cause of aquatic plant nuisances when other environmental factors are suitable.

Temperature is a prime regulator of natural processes within the water environment. It governs physiological functions in organisms and, acting directly or indirectly in combination with other water quality constituents, it affects aquatic life with each change. Temperature affects chemical reaction rates, enzymatic functions, molecular movements, and molecular exchanges between membranes within and between the physiological systems and the organs of an animal.

Chemical reaction rates vary with temperature and generally increase as the temperature is increased. The solubility of gases in water varies with temperature. Dissolved oxygen is decreased by the decay or decomposition of dissolved organic substances; the decay rate increases as the temperature of the water increases, reaching a maximum at about 30°C (86°F). The temperature of stream water, even during summer, is below the optimum for pollution-associated bacteria. Increasing the water temperature increases the bacterial multiplication rate under favorable environmental conditions.

Reproduction cycles may be changed significantly by increased temperature because this function takes place under restricted temperature ranges. Spawning may not occur at all because temperatures are too high. Thus, a fish population may exist in a heated area only by continued immigration. Disregarding the decreased reproductive potential, water temperatures need not reach lethal levels to decimate a species. Temperatures that favor competitors, predators, parasites, and disease can destroy a species at levels far below those that are lethal.

Fish food organisms are altered severely when temperatures approach or exceed 90°F. Predominant algal species change, primary production is decreased, and bottom associated organisms may be depleted or altered drastically in numbers and distribution. Increased water temperatures may enhance the presence of aquatic plant nuisances when other environmental factors are favorable.

Synergistic actions of pollutants are more severe at higher water temperatures. Given amounts of domestic sewage, refinery wastes, oils, tars, insecticides, detergents, and fertilizers more rapidly deplete oxygen in water at higher temperatures, and the respective toxicities are likewise increased.

When water temperatures increase, the predominant algal species may change from diatoms to green algae, and finally at high temperatures to blue-green algae, because of species temperature preferentials. Blue-green algae can cause serious odor problems. The number and distribution of benthic organisms decreases as water temperatures increase above 90°F, which is close to the tolerance limit for the population. This could seriously affect certain fish that depend on benthic organisms as a food source.

The cost of fish being attracted to heated water in winter months may be considerable, due to fish mortalities that may result when the fish return to cooler water.

Rising temperatures stimulate the decomposition of sludge, formation of sludge gas, multiplication of saprophytic bacteria and fungi (particularly in the presence of organic wastes), and the consumption of oxygen by putrefactive processes, thus affecting the esthetic value of a water course.

In general, marine water temperatures do not change as rapidly or range as widely as those of fresh waters. Marine and estuarine fishes, therefore, are less tolerant of temperature variation. Although this limited tolerance is greater in estuarine than in open water marine species, temperature changes are more important to those fishes in estuaries and bays than to those in open marine areas, because of the nursery and replenishment functions of the estuary.

The temperatures of waste waters discharged from cane sugar factories may present a problem in the case of barometric condenser cooling water and other miscellaneous cooling waters. These streams are normally discharged at temperatures in the range of 16° to 43°C (60° to 110°F), but may in some instances be as high as 63°C (145°F). The discharge of these heated waters, with inadequate dilution or removal of heat, may result in serious consequences to aquatic environments. While the available data indicate that temperature may be a problem on an individual factory basis, data do not indicate that this potential pollutant parameter is of sufficient significance on an industry-wide basis to warrant its inclusion as a controlled parameter.

Acidity and Alkalinity

Acidity and alkalinity are reciprocal terms. Acidity is produced by substances that yield hydrogen ions upon hydrolysis and alkalinity is produced by substances that yield hydroxyl ions. The terms "total acidity" and "total alkalinity" are often used to express the buffering capacity of a solution. Acidity in natural waters is caused by carbon dioxide, mineral acids, weakly dissociated acids, and the salts of strong acids and weak bases. Alkalinity is caused by strong bases and the salts of strong alkalies (such as hydroxide, carbonate, and bicarbonate) and weak acids.

Both acidity or alkalinity may be contributed by waste waters resulting from the production of raw cane sugar. The control of pH, however, will adequately control the potential adverse effects of acidity and alkalinity.

Nutrients

Nitrogenous Compounds - Ammonia, Nitrates, Nitrites. Ammonia is a common product of the decomposition of organic matter. Dead and decaying animals and plants along with human and animal body wastes account for much of the ammonia entering the aquatic ecosystem. Ammonia exists in its non-ionized form only at higher pH levels and is the most toxic in this state. The lower the pH, the more ionized ammonia is formed and its toxicity decreases. Ammonia, in the presence of dissolved oxygen, is converted to nitrate (NO_3) by nitrifying bacteria. Nitrite (NO_2), which is an intermediate product between ammonia and nitrate, sometimes occurs in quantity when depressed oxygen conditions permit. Ammonia can exist in several other chemical combinations including ammonium chloride and other salts.

Nitrates are considered to be among the poisonous ingredients of mineralized waters, with potassium nitrate being more poisonous than sodium nitrate. Excess nitrates cause irritation of the mucous linings of the gastrointestinal tract and the bladder; the symptoms are diarrhea and diuresis. Drinking one liter of water containing 500 mg/l of nitrate can cause such symptoms.

Infant methemoglobinemia, a disease characterized by certain specific blood changes and cyanosis, may be caused by high nitrate concentrations in the water used for preparing feeding formulae. While it is still impossible to state precise concentration limits, it has been widely recommended that water containing more than 10 mg/l of nitrate nitrogen (NO_3-N) should not be used for infants. Nitrates are also harmful in fermentation processes and can cause disagreeable tastes in beer. In most natural water the pH range is such that ammonium ions (NH_4^+) predominate. In alkaline waters, however, high concentrations of non-ionized ammonia in undissociated ammonium hydroxide increase the toxicity of ammonia solutions. In streams polluted with sewage, up to one half of the nitrogen in the sewage may be in the form of free ammonia; sewage may carry up to 35 mg/l of total nitrogen. It has been shown that at a level of 1.0 mg/l non-ionized ammonia, the ability of hemoglobin to combine with oxygen is impaired and fish may suffocate. Evidence indicates that ammonia exerts a considerable toxic effect on all aquatic life within a range of less than 1.0 mg/l to 25 mg/l, depending on the pH and dissolved oxygen level present.

Ammonia can add to the problem of eutrophication by supplying nitrogen through its reaction products. Some lakes in warmer climates, and others that are aging quickly are sometimes limited by the available nitrogen. Any increase in nitrogen will speed up the plant growth and decay process.

Ammonia nitrogen may be entrained in barometric condenser cooling water along with vapors. Under aerobic conditions it is oxidized to nitrite and ultimately to nitrate nitrogen.

While various forms of nitrogenous compounds are present in waste waters resulting from the production of raw cane sugar, it has been determined that this potential pollutant is not present at a sufficient level to warrant treatment.

Phosphorus. During the past 30 years, a formidable case has developed for the belief that increasing standing crops of aquatic plant growths, which often interfere with water uses and are nuisances to man, frequently are caused by increasing supplies of phosphorus. Such phenomena are associated with a condition of accelerated eutrophication or aging of waters. It is generally recognized that phosphorus is not the sole cause of eutrophication, but there is evidence to substantiate that it is frequently the key element of all of the elements required by fresh water plants and is generally present in the least amount relative to need. Therefore, an increase in phosphorus allows the use of other, already present nutrients for plant growths. Phosphorus is usually described, for this reason, as a "limiting factor."

When a plant population is stimulated in production and attains a nuisance status, a large number of associated liabilities are immediately apparent. Dense populations of pond weeds make swimming dangerous. Boating and water skiing and sometimes fishing may be impossible because of the mass of vegetation that serves as a physical impediment to such activities. Plant populations have been associated with stunted fish populations and with poor fishing. Plant nuisances emit vile stenches, impart tastes and odors to water supplies, reduce the efficiency of industrial and municipal water treatment, impair aesthetic beauty, reduce or restrict resort trade, lower waterfront property values, cause skin rashes to man during water contact, and serve as a desired substrate and breeding ground for flies.

Phosphorus in the elemental form is particularly toxic and subject to bioaccumulation in much the same way as mercury. Colloidal elemental phosphorus will poison marine fish (causing skin tissue breakdown and discoloration). Also, phosphorus is capable of being concentrated and will accumulate in organs and soft tissues. Experiments have shown that marine fish will concentrate phosphorus from water containing as little as 1 ug/l.

Phosphorus compounds are commonly used in the raw cane sugar processing segment to prevent scaling in boilers; therefore, orthophosphate may be present in boiler blowdowns. The use of phosphate detergents for general cleaning can contribute phosphates to total waste water discharges. When applied to the soil phosphorus normally is fixed by minerals in the soil and movement to the ground water is precluded.

While phosphorous compounds are present in waste waters resulting from the production of raw cane sugar, it has been determined that this potential pollutant is not present at a sufficient level to warrant treatment.

Total Dissolved Solids

In natural waters the dissolved solids consist mainly of carbonates, chlorides, sulfates, phosphates, and possibly nitrates of calcium, magnesium, sodium, and potassium, with traces of iron, manganese, and other substances.

Many communities in the United States and in other countries use water supplies containing 2,000 to 4,000 mg/l of dissolved salts, when better water is not available. Such waters are not palatable, may not quench thirst, and may have a laxative action on new users. Waters containing more than 4,000 mg/l of total salts are generally considered unfit for human use, although in hot climates such higher salt concentrations can be tolerated. Waters containing 5,000 mg/l or more are reported to be bitter and act as bladder and intestinal irritants. It is generally agreed that the salt concentration of good, palatable water should not exceed 500 mg/l.

Limiting concentrations of dissolved solids for fresh-water fish may range from 5,000 to 10,000 mg/l, according to species and prior acclimatization. Some fish are adapted to living in more saline waters, and a few species of fresh-water forms have been found in natural waters with a salt concentration of 15,000 to 20,000 mg/l. Fish can slowly become acclimatized to higher salinities, but fish in waters of low salinity cannot survive sudden exposure to high salinities, such as those resulting from discharges of oil-well brines. Dissolved solids may influence the toxicity of heavy metals and organic compounds to fish and other aquatic life, primarily because of the antagonistic effect of hardness on metals.

Waters with total dissolved solids over 500 mg/l have decreasing utility as irrigation water. At 5,000 mg/l, water has little or no value for irrigation.

Dissolved solids in industrial waters can cause foaming in boilers and cause interference with the cleanliness, color, or taste of many finished products. High contents of dissolved solids also tend to accelerate corrosion.

Total dissolved solids may reach levels of 1,000 milligrams per liter in factory waste waters. In barometric condenser cooling water, the concentration of dissolved solids is typically on the order of 60 milligrams per liter. When land impoundage is used, the dissolved solids concentrations in seepage may considerably exceed raw waste water values.

The quantity of total dissolved solids in water is of little meaning unless the nature of the solids is defined. In domestic water supplies, dissolved solids are usually inorganic salts with small amounts of dissolved organics. In raw cane sugar factory effluents, dissolved solids are more often organic in nature, originating from sucrose, and the control of organics results in control of dissolved solids.

Total Suspended Solids

Suspended solids include both organic and inorganic materials. The inorganic components include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, animal and vegetable fats, various fibers, sawdust, hair, and various materials from sewers. These solids may settle out rapidly and bottom deposits are often a mixture of both organic and inorganic solids. They adversely affect fisheries by covering the bottom of the stream or lake with a blanket of material that destroys the fish-food bottom fauna or the spawning grounds of fish. Deposits containing organic materials may deplete bottom oxygen supplies and produce hydrogen sulfide, carbon dioxide, methane, and other noxious gases.

In raw water sources for domestic use, State and regional agencies generally specify that suspended solids in streams shall not be present in sufficient concentration to be objectionable or to interfere with normal treatment processes. Suspended solids in water may interfere with many industrial processes, and cause foaming in boilers, or encrustations on equipment exposed to water, especially as the temperature rises. Suspended solids are undesirable in raw water used in the textile, paper and pulp, beverage, dairy products, laundry, dyeing, photography, and power generating industries. Suspended particles also serve as a transport mechanism for pesticides and other substances which are readily sorbed into or onto clay particles.

Solids may be suspended in water for a time, and then settle to the bed of the stream or lake. These settleable solids discharged with man's wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, they increase the turbidity of the water, reduce light penetration, and impair the photosynthetic activity of aquatic plants.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the stream or lake bed, suspended solids are often damaging to the life in water, and they retain the capacity to displease the senses. Solids, when transformed to sludge deposits, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. When of an organic and therefore decomposable nature, solids use a portion or all of the dissolved oxygen available in the area. Organic materials also serve as a seemingly inexhaustible food source for sludgeworms and associated organisms.

Total suspended solids serve as a parameter for measuring the efficiency of waste water treatment facilities and for the design of such facilities. In cane sugar waste waters, most suspended solids are inorganic in nature, originating from process flows such as cane wash and cleaning water. Barometric condenser cooling water is essentially free of net suspended solids.

Sugar Analysis

Analysis for sucrose content is important in process control as an indicator of sugar loss. The two common tests used are the alphanaphthol and resorcinol methods. Neither of these methods provides high accuracy at low sucrose concentrations, but each may serve a useful purpose by indicating slug loads of sugar and thus provide a danger signal for improper operation of evaporators or vacuum pans, or for spills of sugar or molasses. The control of BOD will adequately control the potential adverse effects resulting from sugar losses.

FINAL SELECTION OF POLLUTANT PARAMETERS

After the preliminary selection of pollutant parameters and further data analysis, a final selection of pollutant parameters was necessary. While the preliminary selection step eliminated parameters because of their low concentrations, the final selection step eliminated additional pollutants from consideration based on:

1. The pollutant not being harmful when selected parameters are controlled. For example, alkalinity and acidity are controlled when pH is controlled; COD, TOC, and sucrose (measured by sugar analysis) are controlled by controlling BOD.

2. The pollutant not being readily controllable. Total dissolved solids is a waste water constituent which is not readily controllable with current technology.

3. The pollutant not being present at a level which warrants treatment. Examples of this are nutrients (forms of nitrogen and phosphorus). It has been determined that the raw waste waters resulting from the processing of sugar cane are low in nutrient content.

4. The pollutant possibly being a problem on an individual-case basis but not on an industry-wide basis. Examples of this are coliforms and temperature; however, the available data do not indicate that these potential pollutants are of sufficient significance on an industry-wide basis to warrant their inclusion as controlled parameters.

The pollutant parameters for which effluent limitations guidelines will be developed in Section VII, Control and Treatment Technology, are Biochemical Oxygen Demand (BOD5), suspended solids (TSS), and pH.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

This section identifies, documents, and verifies as completely as possible the full range of control and treatment technology which exists or has the potential to exist within each industrial subcategory identified in Section IV. In addition, it develops the control and treatment alternatives applicable to the model plants developed in Section V.

IN-PLANT CONTROL AND TREATMENT TECHNOLOGY

Waste water treatment and disposal in cane sugar factories range from essentially no treatment to complete land retention (by irrigation or other means) resulting in no discharge to navigable streams. In-plant process control for the reduction of waste water generation has consisted primarily of the reduction of entrainment of sucrose into barometric condenser cooling water; recirculation of barometric condenser cooling water through cooling towers, ponds, or canals; dry hauling of filter mud; and recirculation of cane wash water. Efforts to reduce pollution by modifying cane harvesting techniques might also be considered as an in-plant process control, in that reductions in raw waste loadings result.

Cane Harvesting

Two of the major waste sources, cane wash water and filter muds, are directly affected by cane harvesting techniques. Cane may be harvested by hand cutting or by mechanical harvesters, but Florida is the only major cane growing area where the majority of cane is harvested by hand cutting. Only a small portion of cane is hand cut in Puerto Rico and essentially none is hand cut in Louisiana and Hawaii.

The extraneous material in harvested cane is directly dependent upon harvesting techniques and soil and weather conditions. Hand cut cane in Florida may contain up to 7 percent extraneous matter. Louisiana, which has only a one-year growing season as compared with the two or more years in Hawaii, usually averages less than 20 percent extraneous material. From 9.2 to 15.3 percent of the gross tonnage of cane brought to the factories during the 1973 grinding season was mud, dirt, or other trash (8). The Puerto Rican cane sugar factories are rapidly switching from hand cutting to mechanical harvesting due to lack of labor and high labor cost. Because of the variety of techniques presently under experimentation in Puerto Rico, no specific statement can be made concerning percentages of extraneous material. It would be expected that the quantity of extraneous material in

Puerto Rican cane would range between that of hand cut Florida cane and that of mechanically harvested Louisiana cane.

This extraneous material, composed of leaves, dirt, rocks, etc., is the major source of waste in many sugar factories. It must be separated from the sugar cane and removed either in the cane wash water, filter muds, or in the bagasse. In simple terms, the more extraneous material in the gross cane brought into the factory, the more waste must be removed in the cane wash water, bagasse, and filter mud. Excess material in the bagasse is not only harmful to the boiler but can become part of a waste water discharge if the boiler ash is disposed of in a slurry form.

Extensive studies are presently being conducted on new cane harvesting techniques in an effort to reduce extraneous material to a minimum. This research has its main focus on the development of new machine harvesting systems which can harvest the cane and transport it to the factory without the cane coming into contact with the ground. Other systems being tested would dry clean the cane either in the field or at the factory.

Two different designs are being evaluated in Hawaii (9). The Brewer system first cuts the cane and stacks it in windrows. The harvester then collects the cane and chops it into short pieces for leaf and soil removal by air jets caused by fans and blowers. Rocks and soil are also removed through bar gaps in the conveyor system. The Toft system cuts, chops, and cleans the cane in a single operation; the object is to minimize cane contact with the ground, thus reducing the amount of mud or dirt brought into the factory.

Preliminary tests indicate that both designs show merit in that a great deal of soil and other extraneous matter can be removed in the fields. Problems common to both systems are loss of cane due to inefficient pick-up and difficulty in operation under varied terrain and field conditions. The problem of cane loss is not easily resolved because attempts at efficient pick-up result in greater soil loads.

In preliminary tests (9) under adverse conditions to compare the Brewer harvester system with conventional techniques, the total harvested weight contained about 30 percent extraneous material compared to 60 percent by conventional techniques. This system delivers cane to the factory which is suitable for dry cleaning procedures. With the Toft harvester, foreign material averaged 10 percent of the total weight compared to averages of 40 to 50 percent by conventional means. This harvester delivers cane directly to the mills, by-passing conventional cleaning processes.

There are several other harvesting systems being evaluated in Puerto Rico, Florida, and Louisiana which show encouraging results. In the future, as these systems are perfected, they should significantly affect the total quantity of extraneous material entering a cane sugar factory. The goal is to lower the extraneous material to such a level that cane washing is not necessary. Again, it should be noted that these mechanical harvesting techniques are in the developmental stage and all systems are not as yet perfected. Similar systems have been applied in the Australian raw cane sugar industry and have been developed to the extent that cane washing is unnecessary.

Cane Wash Water

The source of cane wash water may be fresh water, barometric leg water, or recycled cane wash water. Most factories that do not recycle barometric condenser cooling water (and many that do) utilize the discharge for cane washing, thus reducing the overall water usage in the factory if not the pollutant loading. Figure 20 shows one method of cane wash recycle in which the recirculated water is again used as the initial wash for the cane and fresh water is used for final washing. Cane wash water treatment to provide recirculation will be discussed in detail in the discussion of end-of-line treatment below.

As previously discussed, cane washing is economically undesirable from an operating viewpoint due to the loss of sucrose from the washed cane. Therefore, at many factories an attempt is made to minimize the extent of cane washing, or, in a few cases, avoid washing altogether by choosing to accept the consequences of unwashed cane entering the process.

For some time the Hawaiian Sugar Planters' Association has worked on the development of a cane cleaning process that avoids the use of water. The design has been further developed by the Hilo Coast Processing Company which currently has two full scale facilities - one in limited operation and one under construction. Ideally, the facility can provide adequate cane cleaning pneumatically with a final rinsing with cane juice, thereby eliminating cane wash water as a waste water source. Preliminary results of the dry cleaning system show a potential increase in sugar recovery of up to 5%. Kenda and Stephen-Hassard give a detailed description of the dry cleaning system and the principles which govern its operability (10). The dry cleaning facilities have not been demonstrated in full scale commercial operation under a complete range of operating conditions, and therefore at the present time cannot be considered as currently demonstrated technology.

Filter Mud

Filter mud or cake is discharged from vacuum filters which are used to dewater the settled sludge resulting from juice clarification. The mud can be handled either in a wet or dry condition. If handled dry, the cake is carried by a belt or screw conveyor to a holding bin or

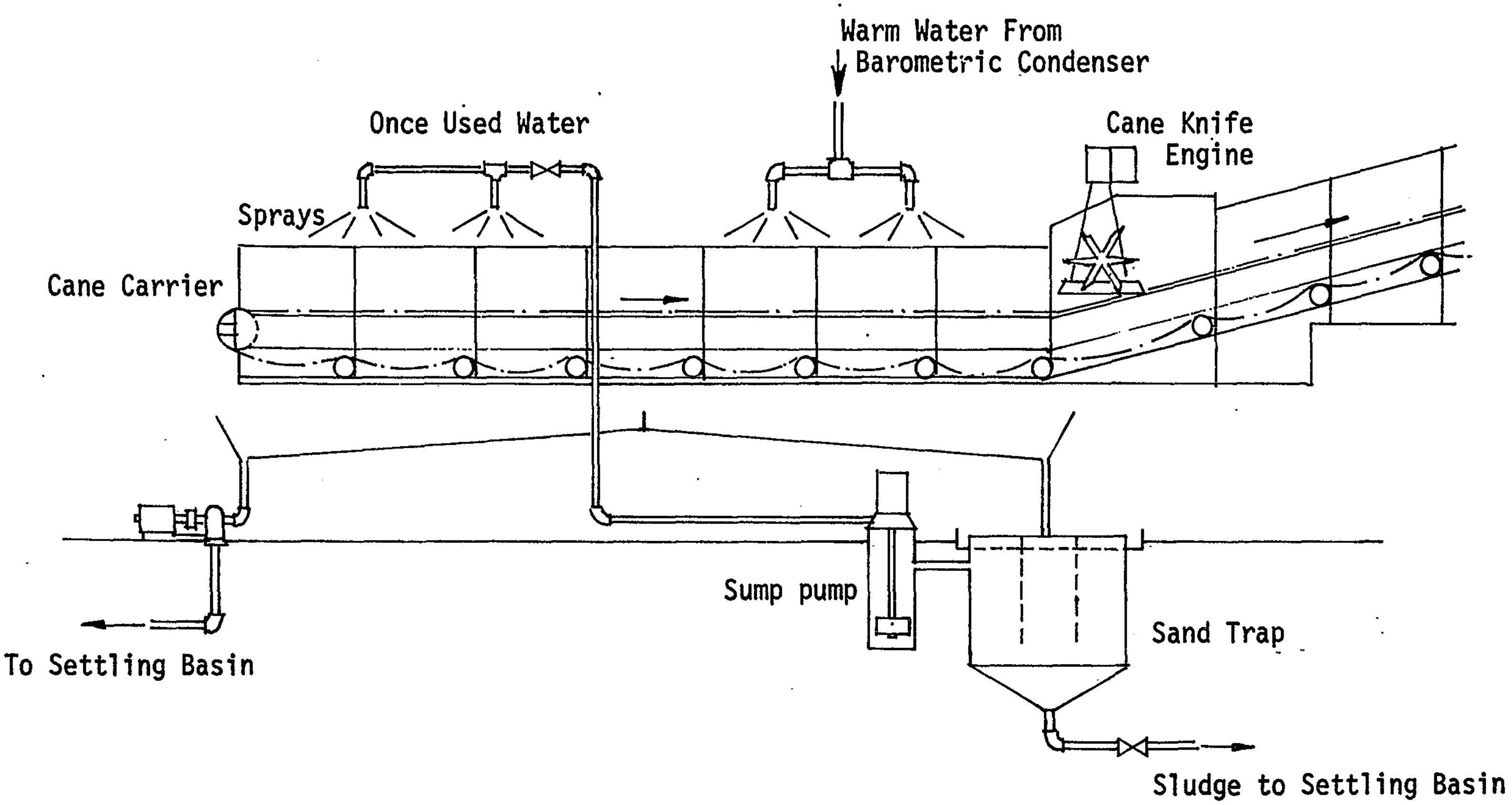


FIGURE 20

CANE WASH RECYCLE SYSTEM

directly to a truck. The cake can then be carried to cane fields or other areas for land disposal. The second method of handling filter mud is to mix the mud with sufficient water so that it can be pumped as a slurry. This slurry can either be discharged directly, settled with discharge of the supernatant, or totally impounded.

In Florida, three factories handle the mud in a dry form and five pump it to impounding ponds from which no discharge occurs. In Louisiana, where data is available for 42 mills, twelve handle filter cake dry, 29 impound with eighteen discharging after stabilization, and three discharge without treatment (two mills have the capability to either impound or dry haul). In Hawaii, four mills report dry handling, ten contain filter mud slurry on their cwn property, and two discharge directly to the ocean. The situation in Puerto Rico is similar; five mills dry haul filter cake with the remaining mills impounding filter mud.

Filter mud is a major waste source from cane sugar factories. The technology now being utilized by a large portion of the industry allows for zero discharge of filter mud either by dry handling and land disposal or by impounding the slurried mud.

Barometric Condenser Cooling Water

The introduction of the calandria type evaporator and vacuum pan in the sugar industry has allowed increased evaporation rates, but, at the same time, has increased the possibility of sucrose entrainment into barometric condenser cooling water. As discussed in Section V, sucrose entrainment can represent a significant waste load. All cane sugar factories employ some method of reduction of sucrose entrainment, with the main motive being an economic one. However, barometric condenser cooling water has become known as one of the major waste water sources in a cane sugar factory and concern is being shown from an environmental standpoint.

Entrainment is a result of liquid droplets being carried into the barometric leg along with the water vapor. There are three important factors which affect the efficiency of entrainment control:

1. Vapor height
2. Operation and maintenance
3. Liquid-vapor separation devices

One of the most important factors in determining liquid carryover is the height the liquid bubbles must rise before entering the relatively high velocity area of the discharge tube. If the vapor height is of sufficient magnitude, most liquid droplets will fall back into the boiling liquor due to the force of gravity. It has been found from experience that the vapor height should be at least 250 percent of the height of the calandria tubes to minimize entrainment. A wide range of vapor heights may be found in existing installations depending upon the age and original design of the factory. If existing vapor heights are insufficient, they can be increased by installing a spacer in existing equipment. This has been done in several instances with a resulting increase in evaporation capacity and a reduction in sucrose entrainment.

In addition to proper design, proper operation and maintenance of evaporators and pans are essential in order to maintain minimal entrainment. Liquid levels should be maintained at the design level as increasing liquid levels decrease existing vapor heights. The pressure within the vessel must be carefully controlled. If the pressure is suddenly decreased, the resulting increase in boiling is likely to cause liquid carryover. Automatic controls are available for operation of evaporators and pans and these are presently being utilized in a number of factories. A typical factory will have automatic liquid level controls on all evaporator bodies and absolute pressure control on last bodies of multiple effect evaporators and on vacuum pans.

In addition to proper design and operation, a number of devices can be installed to separate liquid droplets from the vapors. Baffle arrangements which operate on either centrifugal or impingement principals are commonly used. The Serner separator (11) is used in several factories and can significantly reduce carryover. Demister devices, which consist basically of a fine wire mesh screen which serves the dual purpose of impingement and direction change, were used extensively in the Cuban sugar industry, but have found limited use in the United States, possibly due to complaints of clogging problems.

It would appear from the data in Section V that no single device offers optimum entrainment control but that the best results are attained by the proper combination of controls and operation. For example, Factory 80 employs demisters on last effect evaporators and pans and prevents clogging by cleaning the screens each time the bodies are cleaned. Factory 82 does not use demisters on last effects and vacuum pans because the management believes that clogging would be unavoidable. The data in Section V shows that while both factories have low concentrations of organics in the barometric condenser cooling water discharge, Factory 82 achieves lower concentrations without demisters.

The overall effect of equipment and operation can be observed in a comparison of Subcategories III and IV with Subcategory I. The generally higher level of entrainment control sophistication in Subcategories III and IV results in an average BOD_5 loading of some one-half of that of Subcategory I. In general, while available data show a wide range of BOD and COD concentrations in the barometric condenser cooling water discharge, no correlation is evident regarding the BOD_5 loading in barometric condenser cooling water and the size of a factory. Figure 21 compares the BOD5 loading to size for all factories for which data is available with regard to the barometric condenser cooling water waste stream. It was necessary that all factories be compared on as common a base as possible. Therefore, a net cane basis was chosen because boiling house operations are a function of the amount of net sugarcane processed at the factory. It was assumed that all Subcategory I and V factories were operating at a net to gross cane ratio of 0.86 and that Subcategory II factories were operating at a 0.95 ratio; this corresponds to a trash percentage of 14 and 5 percent, respectively. It is illustrated by Figure 21 that small as well as large factories are capable of maintaining low levels of sucrose entrainment into barometric condenser cooling waters. It is felt that if proper liquid level control, proper vapor heights, and proper operating procedures are maintained, BOD5 loadings in barometric condenser cooling water can be maintained at low levels.

Considerable discussion has been carried on concerning the potential of using surface condensers to replace barometric condensers. A surface condenser operates with a metal wall between the cooling water and the vapors being condensed. Since the efficiency of heat transfer is reduced over that of a barometric condenser, a larger volume of cooling water is required. Due to the non-contact nature of cooling water associated with surface condensers, entrained sucrose is maintained separate from the cooling water stream and is concentrated in a much smaller volume. Upon initial investigation, it would appear that a benefit would be derived from having the BOD entrained in the vapors present in a much smaller volume. However, surface condensation is not the only means available to accomplish this goal. The recirculation of barometric condenser cooling water also allows the concentration of BOD into a smaller discharge stream which may be smaller in volume than that associated with a surface condenser. For example, if a 6,820 metric ton per day (7,500 tons per day) mill utilized surface condensers, the BOD would be concentrated in 109,000 kilograms per hour (240,000 pounds per hour) of water. If a recirculating barometric condenser cooling water system were utilized, the BOD could be concentrated into only 68,200 kilograms per hour (150,000 pounds per hour) of cooling system blowdown water. Also, it must be noted that a surface condenser does not reduce the BOD entrained in the vapors from the evaporators and pans. Reportedly, because of a slower response time to variations in vacuum, sucrose losses could be increased until operators become more experienced with the operation of the surface condenser system.

A potential problem with surface condensers is fouling. A number of factories throughout the industry, but particularly in Subcategories I and II, use relatively low quality water for condenser cooling. While surface condensers have not been utilized in conjunction with the evaporation and vacuum pan unit operations in raw sugar factories, a comparison can be made with surface heat exchangers used for air and

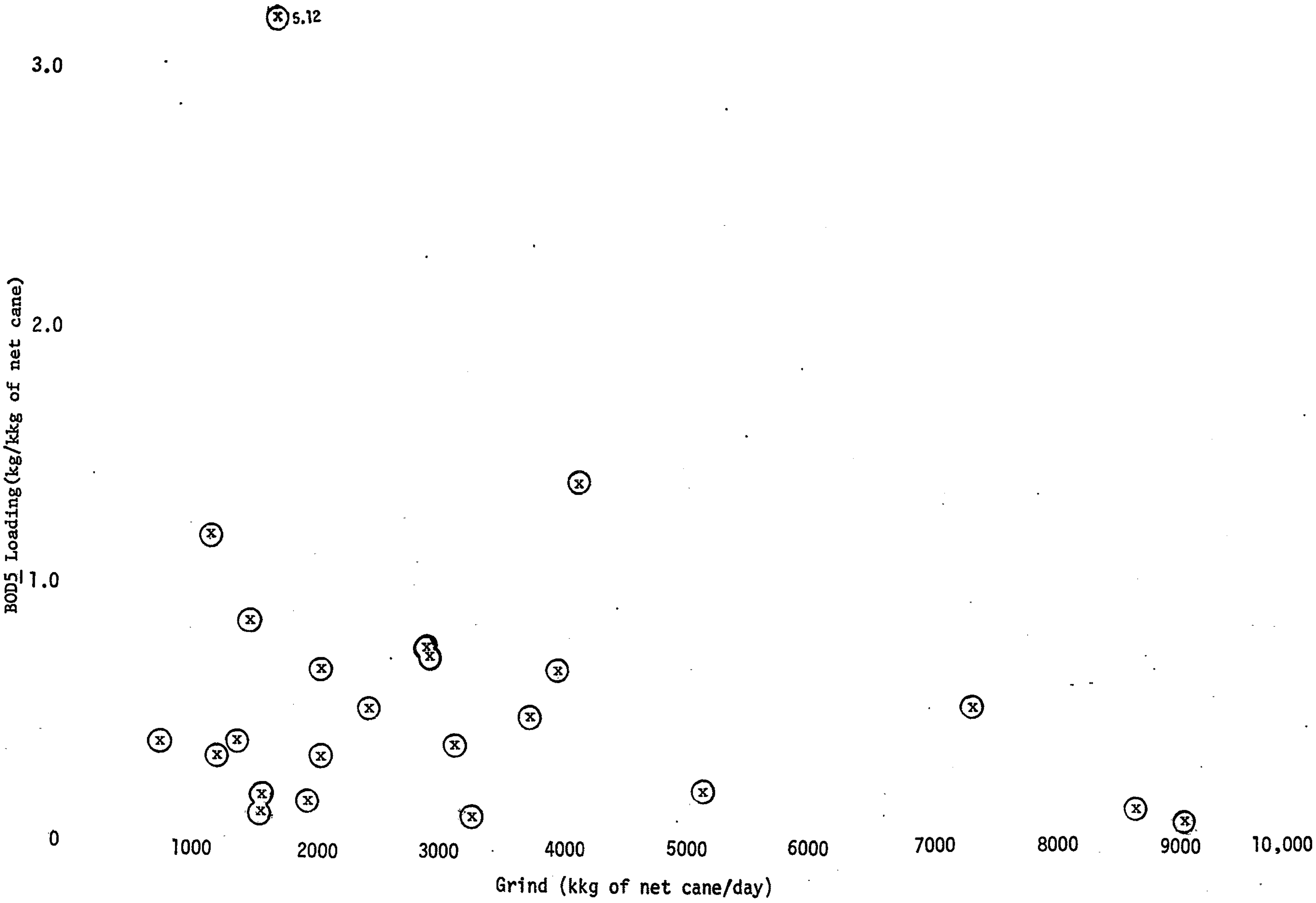


FIGURE 21

COMPARISON OF BOD5 LOADING IN BAROMETRIC CONDENSER COOLING WATER TO SIZE OF FACTORY oil coolers of turbine generators in which experience has shown that low quality water can cause fouling(12).

A second potential problem area in the use of surface condensers is vacuum control on the vacuum pans. For proper operation of a vacuum pan, an absolute pressure with a tolerance of plus or minus 0.003 atmospheres (0.1 inches of Mercury) must be maintained. Adjustments to this absolute pressure, made necessary by variations in calandria steam pressure, feed density, and non-condensible leakage, can be made with a barometric condenser by changing the flow in the condenser. In the case of a surface condenser, the associated lag time could make absolute pressure control considerably more difficult.

The physical installation of surface condensers could be a problem in certain factories and in some cases could be an almost insurmountable one. Vertical height when unavailable can be obtained by raising the factory roof, but horizontal space can be acquired only with considerable difficulty. The weight of surface condensers could potentially cause structural problems in older factories. A detailed structural analysis might be required to ensure the feasibility of the installation of surface condensers.

Based on the above discussion plus considerations of additional requirements concerning pumping energy, electrical energy, raw water supplies, and steam capacity, surface condensers, although potentially applicable, have not been further considered as a treatment alternative for the raw cane sugar processing segment. It is possible, however, for an individual factory to replace existing barometric condensers with surface condensers.

Of the 42 factories in Subcategory I for which in-plant information is available, 19 recirculate barometric condenser cooling water through the use of cooling towers, spray ponds, or cooling ponds. In Subcategory II, seven of nine factories recirculate barometric condenser cooling water through cooling towers, spray ponds, lagoons, or canals, and the other two factories contain all waste waters onsite. In general, Subcategory III factories re-use condenser water for cane washing and then discharge the cane wash effluent; however, one factory has installed a barometric condenser cooling water recirculation system, utilizing a spray pond, which went on-line during the spring of 1974. Subcategory IV factories also use condenser water discharges for cane wash, but the cane wash effluent is retained onsite for irrigation or other purposes. Of the eleven mills still operating in Puerto Rico, two recirculate barometric condenser cooling water through either spray ponds or cooling ponds. Two other Subcategory V mills cool the barometric condenser cooling water prior to discharge; some recycle would appear to be feasible.

Acid and Caustic Waste

Acid and caustic waste is a minor stream resulting from the cleaning of evaporators, pans, and other equipment. Acid and caustic water is presently discharged directly, combined with the main waste stream and impounded, or impounded separately. Data indicate that the quantity of acid and caustic waste is not sufficient to significantly affect the pH of the combined waste flow; it is mixed with the total flow in most Subcategory IV factories and utilized as irrigation water. In general, it can be stated that there is existing technology which will allow zero discharge of acid and caustic wastes.

Floor Wash

A significant source of pollutant loadings can be attributed to poor housekeeping practices resulting in accidental spills of sugar and molasses, and to poorly maintained machinery and equipment. These housekeeping contributions are generally surge loadings that occur during daily or weekly maintenance and washdown periods. Sources of oil in these waste waters can be attributed to machinery leakage, oil pick-up in bearing cooling waters, or accidental spillage. Significant amounts of sugar have been observed in floor wash and drainage waters. Syrups or molasses spills and overflows also provide prime contributions to the problem. Costs of effective in-plant control of these sources of pollution are negligible when compared to the costs of treatment of polluted effluents.

Measures for the control and minimization of these sources of pollution can be effected by general good practice in housekeeping and maintenance. Bearing cooling water, which in many mills is discharged with floor wash water, can be recycled. Recent designs utilize a small cooling tower for bearing cooling water alone. Makeup water is excess condensate water or deionized water. The installation of a bearing cooling water recirculation system not only reduces waste water discharge but reduces bearing maintenance requirements.

Boiler Ash and Fly Ash

Boiler ash is the residue remaining in the boiler after burning bagasse. Fly ash is removed from the exhaust from the boiler in those factories where air pollution control is practiced. Boiler ash is often removed in a slurry form and fly ash is always carried by water when wet scrubbers are used.

At least sixteen factories in the United States and Puerto Rico are presently dry handling boiler ash, and at least 39 factories retain both boiler ash and fly ash onsite by impounding or land irrigation. Therefore, existing technology allows for no discharge of these materials.

Summary of In-Plant Control and Treatment Technology

Table 51 presents a summary of in-plant control and treatment technology for the raw sugar processing segment of the cane sugar processing industry. It is probable that no sugar factory can be found in the United States that has optimum in-plant control, but it is also probable that no factory exists that does not practice some degree of in-plant control. Also, it is not always economically desirable for an individual plant to achieve the best in-plant controls possible, e.g., for a factory with certain unique topographical, climatological, or geographical advantages, money spent for in-plant modifications might well be wasted. The model treatment technologies developed later in this section and the cost analyses of Section VIII are based upon reasonable steps taken in-plant to reduce pollutant loadings.

EXISTING END-OF-LINE WASTE WATER TREATMENT

Waste water treatment at cane sugar factories consists of generally non-complex systems such as primary settling before discharge, impoundage, waste stabilization, or irrigation. More sophisticated biological or chemical treatment systems have had limited application in this industry segment.

SUBCATEGORY I

Table 52 shows the existing treatment practices employed by raw sugar factories in Subcategory I. Of the 42 factories surveyed within this subcategory, five (12 percent) report no discharge of contaminated waters by means of complete impoundage with four of the five impounding waste waters in large swampy areas owned or leased by the factory. Twenty-three factories (55 percent) use barometric condenser cooling water for cane wash water. Nineteen (45 percent) recycle barometric condenser cooling water to some extent. Sixteen (38 percent) recycle cane wash water to some extent and thirty-nine (93 percent) have settling ponds and/or impoundment facilities for the cane wash water prior to discharge. Twenty-seven (64 percent) of the factories retain the cane wash water for the entire season and for at least 30 days after the end of the season prior to discharge, thus in effect accomplishing waste stabilization. The general practice is to provide settling in a small impoundment area prior to discharge into a larger impoundment area in which the wastes are contained for the entire season.

Twenty-one (50 percent) of the factories either dry haul or completely contain filter mud slurries, eighteen (43 percent) stabilize the mud slurry prior to discharge, and, of the remaining factories, only one discharges filter muds without some kind of impoundment. Fifteen (36 percent) of the factories discharge boiler ash, but only two do so without some type of treatment. Factories that do not discharge ash, either completely retain the ash slurry, dry haul the ashes, or do not burn bagasse.

TABLE 51

SUMMARY OF IN-PLANT CONTROL AND TREATMENT TECHNOLOGIES

Waste Water Source	In-Plant Controls	Remarks
Cane Wash Water	1. New Harvesting techniques. 2. Dry cleaning.	1. Experimentation being conducted. 2. Experimentation being conducted in Hawaii and Puerto Rico, not fully demonstrated.
Filter Mud	1. Dry haul; impound.	1. No discharge is technically feasible.
Bottom Ash	1. Dry haul, impound.	1. No discharge is technically feasible.
Barometric Condenser Cooling Water	1. Reduction of entrainment.	1. Reductions in net BOD entrained into condenser water.
Acid and Caustic Waste	1. Impoundment.	1. No discharge is technically feasible.
Floor Wash and Miscellaneous Wastes	1. Improve maintenance and house keeping practices; use water only when necessary and reuse when possible.	1. Significant BOD and suspended solids reductions achievable.

TABLE 52

EXISTING TREATMENT PRACTICES
SUBCATEGORY I

	CONDENSER WATER					CANE WASH WATER					FILTER MUD			ASH			MISC. WATERS	
FACTORY NUMBER	USE FOR CANE WASH	RECYCLE	IMPOUND	IRRIGATION	DISCHARGE	PRIMARY SETTLE	RECYCLE	IMPOUND	DISCHARGE	IRRIGATION	DRY HAUL	IMPOUND	DISCHARGE	DRY HAUL	IMPOUND	DISCHARGE	IMPOUND	DISCHARGE
1					X	X	X	X	Ⓧ			X			X		X	Ⓧ
2	X	SP			X			X	Ⓧ			X	Ⓧ				X	
3	X	SP				X		X	X			X			X	X	X	X
4																		
5	X	SP						X	Ⓧ			X		X			X	
6		SP			X			X	Ⓧ			X	Ⓧ		X	Ⓧ	X	Ⓧ
7	X				X			X	X		X				X		X	
8		SP				X	X	X	Ⓧ			X		X			X	Ⓧ
9	X				X	X	X	X	Ⓧ			X		X			X	
10	X				X	X	X	X	Ⓧ			X	X		X	X		X
11					X	X	X		Ⓧ				X			X		X
12			X					X			X						X	
13					X			X	Ⓧ			X	Ⓧ				X	Ⓧ
14					X	X	X	X				X	Ⓧ				X	Ⓧ
15					X			X	Ⓧ			X	Ⓧ		X	Ⓧ	X	Ⓧ
16	X				X	X		X	X								X	X
17	X	CP			X		X	X	Ⓧ		X						X	X
18	X		X		Ⓧ	X		X	Ⓧ			X	Ⓧ				X	Ⓧ
19			X		X	X		X	X			X					X	
20			X					X			X				X		X	
21	X	SP			X	X		X	Ⓧ			X	Ⓧ				X	Ⓧ
22	X	SP							X		X					X		X
23	X	SP	X		Ⓧ	X	X	X	Ⓧ		X				X	Ⓧ	X	
24			X					X			X						X	
25			X		X			X	Ⓧ									
26	X		X		Ⓧ	X		X	Ⓧ			X	Ⓧ		X	Ⓧ	X	Ⓧ
27		CP			X	X	X	X	Ⓧ			X	Ⓧ		X	Ⓧ	X	Ⓧ
28	X	SP				X		X				X			X		X	
29	X	SP				X		X	Ⓧ		X	X	Ⓧ				X	Ⓧ
30	X				X				X			X	Ⓧ		X	Ⓧ		X
31	X		X		Ⓧ	X		X	Ⓧ			X	Ⓧ				X	Ⓧ
32	X	SP			X		X	X	Ⓧ			X	Ⓧ		X	Ⓧ	X	Ⓧ
33	X	SP						X	Ⓧ		X			X			X	Ⓧ
34		SP			X	X	X	X			X			X			X	
35	X							X			X			X			X	
36		SP	X		Ⓧ	X	X	X	Ⓧ			X	Ⓧ		X	Ⓧ	X	Ⓧ
37	X	SP	X		Ⓧ	X	X	X	Ⓧ			A	Ⓧ				X	Ⓧ
38	X	SP	X		X	X	X	X	Ⓧ		X	X	Ⓧ		X	Ⓧ	X	Ⓧ
39		CT	X		Ⓧ		X	X	Ⓧ			A	Ⓧ		X	X	A	Ⓧ
40	X		X		X	X		X	X			X	X				X	X
41					X	X	X	X	Ⓧ			X					X	Ⓧ
42					X							X		X			X	
43			X		Ⓧ	X		X	Ⓧ			X	Ⓧ		X	Ⓧ	X	Ⓧ

LEGEND

Ⓧ	DISCHARGE AFTER STABILIZATION
A	AERATION
SP	SPRAY POND
CT	COOLING TOWER
CP	COOLING POND
I	IRRIGATED

Effluent suspended solid concentrations from several existing cane wash settling ponds are presented in Table 53. Effluent concentrations from impoundment ponds, in which the wastes were contained for the entire season and discharged after stabilization prior to the beginning of the following grinding season, are listed in Table 54.

Twelve of the factories surveyed employed recirculation of the cane wash water stream with stabilization and discharge after the end of the season. In all, twenty-seven factories practice waste stabilization of the cane wash and other miscellaneous discharge streams. A typical such operation is found at Factory 11 where a double horseshoe settling pond and chlorination at a rate of 9 to 14 kilograms/day (4.1 to 6.4 pounds/day) of chlorine per 400 l/sec (6340 gpm) are employed. The factory discharges the spent cane wash water after stabilization at the end of the season and dredges the pond once a year to remove settled material. At Factory 38 a similar system is employed; the effluent concentrations after stabilization are listed in Table 49. Keller and Huckabay (5) give a detailed discussion of oxidation ponds and recommended design of said ponds. It is also reported by Keller that BOD concentrations of 50 to 60 mg/l can be expected out of oxidation ponds (7). According to work done by Chen, et al. (13) at a Louisiana factory, stabilization of the wash water will reduce the BOD of wastes to 10-45 mg/l. The use and design of oxidation ponds at the factories which comprise Subcategory I have been greatly influenced by the works of Keller (5) and Wheeler (14), which concluded that aerobic oxidation of sugar waste is feasible. Wheeler (14) in his work found that phosphorus addition did not enhance stabilization but that nitrogen addition to about 20 mg/l increases the rate of stabilization significantly.

SUBCATEGORY II

Table 55 shows the existing treatment practices employed by raw sugar factories in Subcategory II. Of the nine plants making up this subcategory, none discharges process waste waters under normal operating conditions.

At Factory 44, acid and caustic wastes are completely impounded and filter cake is dry hauled to the cane fields. Other waste streams, including barometric condenser cooling water, are discharged to a private canal system which provides several square kilometers of irrigation to the cane fields. The private canal system currently connects with public waters. At the point of connection, the private canal carries agricultural runoff along with, theoretically, a small amount of factory process water. Figure 22 shows the BOD_5 concentration in the private canal at its point of connection with public waters. It should be noted that during a substantial part of the time that the factory is in operation, the flow of water is from the public water into the private canal. The average BOD_5 concen-

TABLE 53

EFFLUENT SUSPENDED SOLIDS CONCENTRATIONS FROM CANE WASH SETTLING PONDS

Factory	Effluent TSS (mg/1)
10	730
16	376
22	588*
34	160

*Not actually a settling pond, but a long ditch.

TABLE 54

EFFLUENT CONCENTRATIONS FOR STABILIZED WASTES DISCHARGED AFTER THE GRINDING SEASON

Factory	Effluent BOD (mg/1)	Effluent COD (mg/1)	Effluent TSS (mg/1)
1	19	--	210
9	10	97	26
10(Pond#1)	--	74	55
10(Pond#2)	--	41	40
38	6	--	56

TABLE 55

SUBCATEGORY II
EXISTING TREATMENT PRACTICES

FACTORY	CONDENSER WATER				FILTER MUD		ASH		MISC. WATERS
	IRRIGATION	RECIRCULATE--CANALS	RECIRCULATE-COOLING TOWER	RECIRCULATE-SPRAY POND	DRY HAUL	IMPOUND	IMPOUND	DRY HAUL	IMPOUND
44	X	X			X			X	X
45	X	X			X			X	X
46	X	X				X	X		X
47		X				X		X	X
48			X		X		X		X
49	X					X	X		X
50			X			X	X		X
51				X		X	X		X
85	X		X		X		X		X

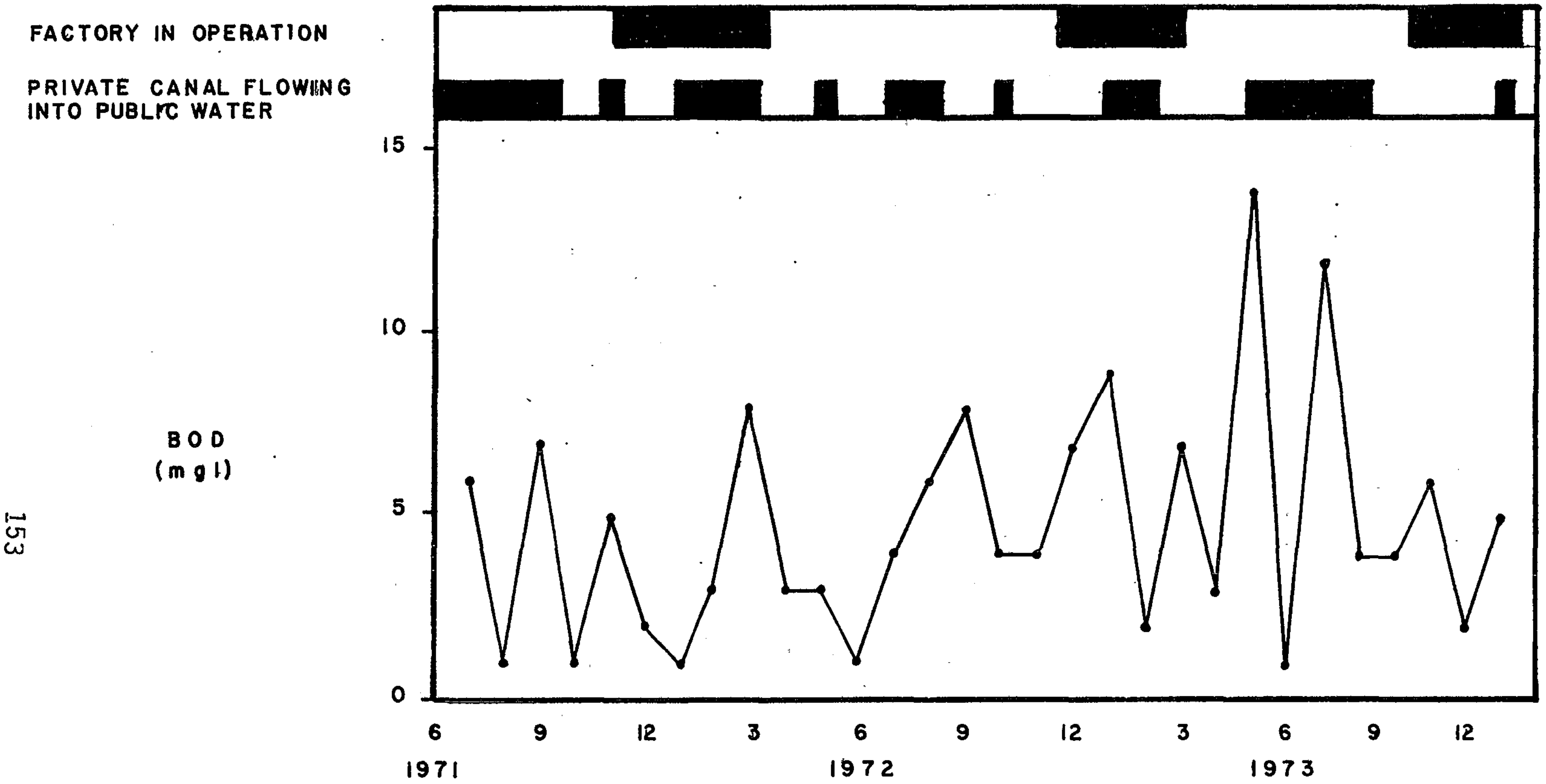


FIGURE 22

BOD CONCENTRATION OF WATERS IN PRIVATE CANAL SYSTEM, FACTORY 44, JULY 8, 1971 THROUGH JANUARY 14, 1974 tration for the entire period of record is 4.76 mg/l. The average for the periods of time in which the factory was operating is slightly less than the overall average, and the average for the periods of time in which the factory was not operating (and during which time the private canal was carrying only agricultural runoff) was slightly higher than the overall average. These data would appear to indicate that if the process waste water is contributing organic loadings to public waters, the amount is undetectable when compared to agricultural runoff.

At Factory 45, filter mud slurry is impounded, acids and caustics and miscellaneous wastes are impounded, and barometric condenser cooling water is recirculated via a cooling lagoon with no discharge of blowdown. Overflow from impoundage ponds could possibly occur during extreme rainfall conditions.

Factory 46 is similar to Factory 44 in that barometric condenser cooling water is recycled through a private canal system. Filter mud and acid and caustic wastes are impounded. Other miscellaneous wastes are discharged into a private canal system separate from the condenser water system, and ultimately into an impoundment area which has no discharge to public waters even during extreme rainfall. The barometric condenser cooling water is recycled through some 19 kilometers (12 miles) of canal before being reused. A gate separates the private canal system from public waters. A pumping station is provided for emergency discharges when extreme rainfall threatens to flood the cane fields.

At Factory 47, barometric condenser cooling water is recirculated through about 19 kilometers (12 miles) of private canals. All other waste waters, except boiler blowdown which is discharged to the private canal system, are impounded. Discharge from the private canal system to public waters rarely occurs. According to plant personnel, a five centimeter (two inch) rainfall occurring within 24 hours is necessary for pumping to be required. The last time this much rainfall occurred at Factory 47 during the processing season was December 30, 1963. Figure 23 shows the BOD_5 concentration in the private canal (at the point where pumping would occur if it becomes necessary) for the period of December 4, 1971, through January 19, 1973.

At Factory 48, barometric condenser cooling water is recirculated through a cooling tower. The blowdown from the cooling tower is impounded along with all other waste waters. Filter cake is dry hauled to land disposal. Any overflow from the impoundment ponds or from yard runoff is deposited into a deep well. The factory has no discharge of process waste waters to public waters.

At Factory 49, barometric condenser cooling water and spent cane wash water (when cane is washed) is discharged into 13 kilometers (8 miles)

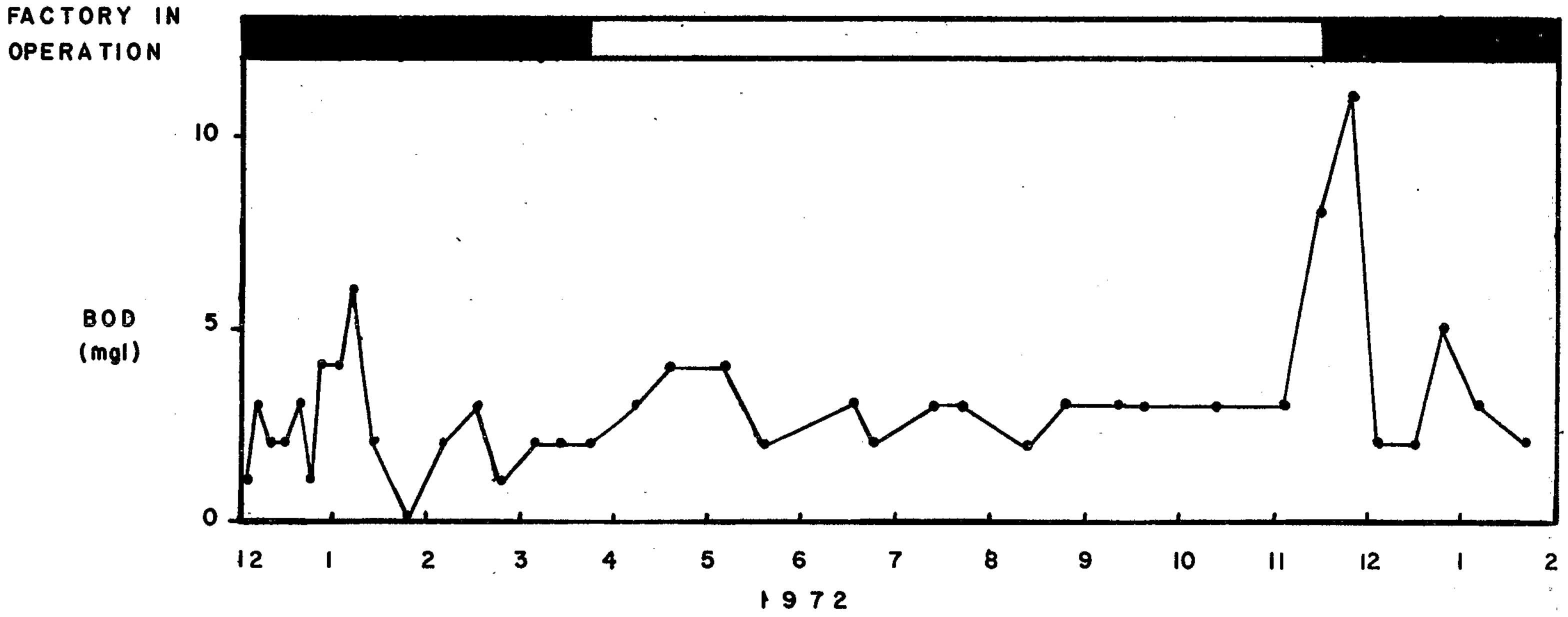


FIGURE 23

BOD CONCENTRATION OF WATERS IN
PRIVATE CANAL SYSTEM, FACTORY 47,
DECEMBER 1971 THROUGH JANUARY 1973

of private canals. All other waste waters are impounded. Discharge from the private canals into public waters rarely occurs during the processing season; the last such event was during the 1969-70 season.

At Factories 50 and 51 barometric condenser cooling water is recirculated; Factory 50 employs a cooling tower and Factory 51 employs a spray pond. All other waste waters are impounded.

At Factory 85, a cooling tower is utilized for recirculation of barometric condenser cooling water. All other waste waters are treated in a stabilization pond which is designed for 96 percent removal of BOD. This factory has been in operation for one year and adequate data for substantiation of the design efficiency is not available. The discharge from the stabilization pond is used for irrigation. Normally there is no discharge from the irrigation system; however, during excessive rainfalls it is expected that tailwater discharges could occur.

SUBCATEGORY III

Historically, the Subcategory III factories have discharged all waste streams without treatment. Recently, however, considerable research and development have been and are being undertaken in the areas of waste water treatment, solid waste disposal, and sugar cane harvesting. Treatment methods which have been employed within the last two years include the dry handling of filter cake, the dry hauling of ash, the screening and disposal of leafy trash, the disposal of rocks which enter the factory with the sugarcane, and the elimination of a discharge of excess bagasse. Experimentation and development of new harvesting systems (discussed earlier in this section) have been undertaken with the ultimate goal of leaving the bulk of extraneous material in the cane fields. Research and development is also being accomplished with regard to a dry cleaning system which would clean sugarcane by means of mechanical shaking, stripping, and air blowing followed by washing with cane juice which would act as a recoverable dry cleaning solution. This dry cleaning system is as yet undemonstrated over all operating conditions with much work to be accomplished before it can be considered currently available technology.

The technical staff which operate Factory 66 have undertaken the development of a sedimentation system to settle, with polymer addition, the cane wash and other miscellaneous waste water discharges. This research and developmental work, which includes a pilot-scale clarification unit with solids handling capabilities, has resulted in the design of a heavy duty thickener to clarify the waste stream and a rotary vacuum filter to be utilized for mud dewatering. The resultant sludge is to be disposed on fields which are to be plowed for new plantings of cane. Certain details of optimization regarding numbers of filtration units, polymer, and filter aid, are being determined at the present time and to date, no ultimate decisions have been made. This sedimentation system is expected to be on-line during the next processing season. Installed at Factory 66 are a cascading cane wash system which minimizes water usage, a system to dry haul filter cake, a leafy trash disposal system, and a barometric condenser cooling water recirculation system. This mill employs spray irrigation for approximately six months of the year and the management is contemplating the construction of a system which would enable the use of waste water for irrigation purposes.

Factory 67 is currently developing the Toft harvesting system to enable the delivery of a "clean" raw material to the milling operation. This factory has undergone an expansion of facilities and already installed at this mill are a cascading cane wash system, a system to dry haul filter cake, and a leafy trash disposal system.

Factory 69 has undergone considerable expansion of sugarcane handling capabilities. A dry cleaning system is under construction at the present time. The ultimate objective of this system is to eliminate the necessity for cane wash water. Already installed is the highest pressure bagasse-fired boiler in the United States, operating at a pressure of 85 atmospheres (1250 psi) at 150,000 kilograms per hour (330,000 pounds per hour) and producing some 100,000,000 kilowatt hours of energy annually or 20% of the Island of Hawaii's demand (10). A system to dry haul bottom ash has been installed at this factory, with work being accomplished toward the goal of eliminating the discharge of filter muds and leafy trash (which will be dewatered and burned in the boiler). Developmental work with regard to waste water treatment has been undertaken and efforts are being made to coordinate the successful operation of all aspects of the systems approach to effluent abatement.

At Factory 70, experimentation with regard to a full-scale dry cleaning system is being undertaken. Much of the understanding of the proper design and operation of the dry cleaning system has been derived from the operating experiences at this mill. Presently, the final juice wash and other details have yet to be finalized and research and developmental work is continuing. A system to dry haul bottom ash has been installed at this factory, with work being accomplished toward the goal of eliminating the discharge of filter muds and leafy trash.

SUBCATEGORY IV

It can be stated generally that all of the cane sugar factories which comprise Subcategory IV employ end-of-pipe methods to the extent that no discharge of waste water pollutants to navigable waters is achieved. Various methods such as recirculation and reuse techniques, impoundment concepts, and irrigation methods are now employed. Of the thirteen factories which comprise Subcategory IV, eleven factories utilize waste water for irrigation of cane fields and two employ impoundage techniques resulting in a reclamation of land. At two factories filter cake is dry hauled; at the remaining factories filter mud is either impounded or mixed with waste water and used for irrigation or land reclamation purposes. At least one factory employs dry hauling of bottom ashes with all of the remainder (for which information is available) mixing the ashes with the waste water.

Eleven of the Subcategory IV cane sugar factories currently practice effective end-of-line treatment by means of crop irrigation, with the only discharge being the occasional overflow of tailwater from the cane fields. An exact definition of the effectiveness of these systems is difficult, and a precise documentation of the magnitudes and frequencies of discharges would have to be performed on a plant by plant basis. At present, no data pertaining to tailwater discharges, associated with factory waste waters used for irrigation purposes, has been submitted or obtained. These discharges, by their nature, would include substantial quantities of agricultural run-off water; to generate data of statistical significance with regard to agricultural versus process tailwater discharges is beyond the scope of this study.

Generally irrigation is preceeded by primary clarification, either in the form of settling ponds or hydroseparators (circular clarifiers), or, in the case of one factory, a battery of hydrocyclones. The EPA (6) sampled one hydroseparator in 1971 and found suspended solids removals ranging from 60 to over 98 percent.

Table 56 presents a summary of influent and effluent concentrations relating to the performance of hydroseparators operating at three factories. In general the hydroseparators are overloaded with solids. Problems are encountered at Factory 72 with the clarifier turning septic. Factories which irrigate with settled waste water are not concerned with a high degree of treatment efficiency, but in reducing the suspended solids sufficiently so that the water will not harm the sugar cane or plug up the irrigation ditches. Therefore, most of the clarifiers are overloaded with a resulting decrease in treatment efficiency..

Characteristics of the irrigated plantations in Subcategory IV are shown in Table 57. Four of these plantations have some fields located at higher elevations where rainfall supplies the entire water requirements of the sugarcane and therefore are not totally irrigated.

The irrigated plantations are characterized by higher sugar yields. In 1971, one sugar company reported sugar yields of 30.3 metric tons/hectare (13.5 tons/acre) from irrigated fields, but only 18.4 metric tons/hectare (8.2 tons/acre) from non-irrigated fields, giving an overall yield of 27.8 metric tons/hectare (12.4 tons/acre). Factory 74, with total irrigation, reported sugar yields of 30.8 metric tons/hectare (13.7 tons/acre) in 1971. Factories 77 and 78,

TABLE 56

SUMMARY OF HYDROSEPARATOR PERFORMANCE FOR FACTORIES IN SUBCATEGORY IV

	Suspended Solids		BOD5		COD		Data
Factory	Influent	Effluent	Influent	Effluent	Influent	Effluent	Source
72	2,500	1,014	450	440	1,900	1,650	'73 Internal
72	1,710	890	597	615	1,488	800	ESE '74
72	1,745	1,175	636	535	1,200	880	ESE '74
76	9,200	1,600	610	475	1,850	680	'67 FWPCA
76	11,000	1,100	540	590	2,800	930	'67 FWPCA
76	12,000	3,200	1,250	900	2,200	1,100	'68 FWPCA
80	1,040	705	420	300	-	-	ESE '74
80	5,310	605	396	432	-	-	ESE '74
80	5,865	1,260	412	334	-	-	ESE '74
Average							
	5,597	1,283	590	513	1,906	1,007	

TABLE 57

SUMMARY OF CHARACTERISTICS OF SUBCATEGORY IV IRRIGATED PLANTATIONS

Plantation	Total Irrigated Water (cu.m/day)	Irrigated Hectares	Non-Irrigated Hectares	Hectares Per 1000 cu.m of Irrigation Water	Waste Water Volume (cu.m/day)	Liters Waste Water/Metric Ton of Net Cane Processed	Hecatres Irrigated with Waste Water	Hectares/ 1000 cu.m of Waste Water	Coastline (Meters)	%Coast Using Waste Water
74	200,000-230,000	3,200	0	13.9-16.0	38,000	15,000	810[a]	21.3	--	--
75	180,000	2,940	0	16.3	17,000	8,300	290	17.1	5,200	67.6
76	190,000	2,310	122	12.2	22,700	15,400	243	10.7	10,400	55.9
77	150,000-190,000	1,980	2,140	10.4-13.2	34,100	17,100	375	11.0	1,070	85.7
78	270,000	4,150	2,160	15.4	75,700[b]	20,800	603	8.0	8,610	65.5
79&80	1,360,000	12,400	0	9.1	155,000	16,200	1,860	12.0	3,510	56.5
81	150,000	2,030	0	13.5	13,200-15,100	7,490-8,740	172	11.4-13.0	305	0
82	390,000	3,790	0	9.7	38,000[c]	16,700	122[d]	3.2	10,200	32.8
83	850,000	8,100	0	9.5	60,600	16,700	608	10.0	--	--
84	570,000	3,890	690	6.8	38,000	10,400	243	6.4	--	--

[a] To be expanded to 2110 hectares.

[b] To be reduced to 45,400 cu.m/day.

[c] To be reduced to 20,800 cu.m/day.

[d] Exclusive of an additional 284 hectares for cooling water and excess mill water.

both with a substantial acreage of non-irrigated fields, reported lower sugar yields of 16.7 and 24.0 metric tons/hectare (7.45 and 10.71 tons/acre), respectively (15).

Water is applied at regular intervals at a rate roughly equivalent to 93,500 liters/day per hectare (10,000 gal/day per acre) or 9,350 cu.m/day per 100 hectares (1 MGD per 100 acres). Application rates vary among the different plantations as shown in Table 52. Factory 57 applies the most water with 6.8 hectares per 1,000 cu.m/day (64 acres/mgd), while Factory 75 applies the least with 16.3 hectares per 1,000 cu.m/day (152 acres/mgd). However, part of the water requirement may be made up by rainfall. All of the plantations recycle mill waste waters for irrigation purposes following the usual irrigation procedures with the exception perhaps of Factories 78 and 82, which are applying effluent at significantly greater irrigation rates. Both Factory 78 and Factory 82, however, are working to reduce waste water quantities.

According to Ekern (16), the evapotranspiration rate of sugar cane is nearly equivalent to the vacuum pan evaporation rate. Such data are presented in Table 58, with the average monthly values ranging from 13.1 centimeters (5.16 inches) to 20.1 centimeters (7.91 inches). The average monthly pan evaporation rate is on the order of 16.5 centimeters (6.50 inches) and represents the monthly water requirement for sugar cane. By comparison, the average application rate per month assuming a 14 day interval at 9,350 cu.m/day per hectare (1 mgd/100 acres) is 26.4 centimeters (10.4 inches), which is roughly twice as great as the evapotranspiration rate (17). This would indicate an irrigation efficiency on the order of 50 percent. The Hawaiian Sugar Planters' Association has been coordinating developmental work regarding spray and drip irrigation techniques to develop a more efficient irrigation technique.

In general, factory waste water accounts for approximately 10 percent of the total irrigation quantity. The water use coefficient ranges from about 7,490 to 20,800 l/kkg (1,800 to 5,000 gal/ton) of net cane processed. A major part of this water is used first as turbogenerator cooling water, then as barometric condenser cooling water, and then for cane washing. The waste water is settled and then recycled to the fields for irrigation. Only two factories, numbers 74 and 84, discharge turbogenerator cooling waters directly. Both utilize brackish water which is unsuitable for use in the milling process or for irrigation.

Overflows of process waters from the furrows can occasionally occur and could possibly result in discharge into receiving water bodies. However, only those plantations with fields which receive effluent and are bordering on water bodies are of concern. Plantations located inland have sufficient land buffer capable of entirely containing the tailwater overflows within the plantation property. There are seven

TABLE 58

PAN EVAPORATION DATA

Plantation	Pan Evaporation (centimeters)			
	Avg. Monthly	Min. Monthly	Max. Monthly	Avg. Annual
65	14.1	8.53	23.0	168.6
66	16.9	9.14	27.7	202.7
70	13.1	4.19	19.8	157.3
73	14.7	7.80	22.1	176.5
75	18.7	13.5	25.5	224.9
76	18.2	8.51	28.3	218.5
77	14.2	5.64	31.2	170.7
78	16.2	7.85	25.0	194.2
80	18.9	6.99	37.9	227.1
82	20.1	10.7	31.5	241.4
83	17.6	7.80	29.3	211.2
84	15.1	6.38	24.5	181.7

plantations with fields immediately bordering the receiving waters. Factories 83 and 84 have sufficient land buffer such that tailwater discharges would occur to receiving waters only under extreme conditions of rainfall when storm runoff would be the overriding water quality factor.

The occurrence of tailwater is dependent upon the judgment and experience of the irrigator, who controls the water application rate either manually or automatically. The application rate is dependent on the infiltration and percolation rates in the furrows which in turn would be dependent upon antecedent rainfall or other climatological factors. Under these conditions it is improbable that precise infiltration rates can be maintained at all times. Therefore, the possibility exists that the irrigation quantity could either be insufficient or in excess of that necessary to optimize cane growth. Considering the irrigation method employed, the variability of factors controlling performance, and the experience with this method, it follows that tailwater overflows are inherent to the ridge and furrow irrigation method. All of the plantations which utilize factory waste water for irrigation purposes have either already installed or are installing systems which employ tailwater catch ponds which eliminate the discharge of tailwater to navigable waters except during periods of adverse rainfall events or due to accidental over-irrigation. Rainfall can lead to runoff from the fields despite a furrow depth of 35.6 centimeters (14 inches). The slopes of furrows are set at about 11 percent which limit the extent of storage in the fields. It has been reported (6) that 80 percent of a 8.9 centimeter (3.5 inch) rainfall in 12 hours was retained in the fields as storage or by infiltration and percolation; the remainder occurred as runoff.

The factors which govern whether or not tailwater discharges can occur include the number of irrigation rounds applied per year, the area of cropland irrigated, the volume of waste water and other irrigation water utilized, the linear length of the fields bordering on navigable waters, and the fraction of water overflowing the furrows (which is dependent on rainfall events among other things). Sunn, Low, Tom & Hara, Inc. (17) have presented detailed results based on a theoretical calculation of the volumes of tailwater discharges which might be expected to occur based on the above factors and on several assumptions. It is however, recognized that this evaluation is not precise; there are little data available for a more complete evaluation. Nevertheless, the results developed can serve as a useful guide to decisions regarding waste water management.

SUBCATEGORY V

Of the eleven factories in Subcategory V operating in 1974, eight are located in areas where irrigation should prove feasible as a means of waste water disposal and three are in areas that receive rainfall in such amounts that irrigation is not necessary. As shown in Table 59, which presents existing treatment practices for the thirteen Subcategory V factories operating in 1973, four factories were using land irrigation for disposal of process generated waste water. These factories, and all of those for which irrigation is feasible, are located on the relatively dry south coast of Puerto Rico.

Of the four factories that employed irrigation as a method of waste water disposal in 1973, all four used it for the disposal of cane wash water and two also for disposal of miscellenous wastes such as floor wash and ash slurry. Factory 55 used a cooling tower for barometric condenser cooling water recycle, and Factories 61 and 62 employed a cooling pond and a spray pond, respectively, for the same purpose. Factories 55 and 62 also used spent barometric condenser cooling water for cane washing.

Six of the thirteen factories listed in Table 59 employed some form of impoundment of cane wash water prior to discharge and of these, three settled prior to impounding. None of the thirteen factories discharge filter mud directly, and ten of the factories accomplished no discharge of filter cake either by dry disposal or complete retention of a mud slurry. At least two factories discharge ash slurries and most of the factories discharge miscellaneous wastes.

Existing treatment technology in Subcategory V is quite similar to that employed in Subcategory I. Treatment consists of settling of the cane wash water and some use of waste stabilization. Guzman (18) experimented with retention (stabilization) ponds similar to those used in Subcategory I but with shorter detention times. These stabilization ponds which were applied to concentrated wastes (floor washings, boiler blowdown, spillages, and other miscellaneous streams) resulted in effluent BOD_5 levels of less than 100 mg/l. At the time of Guzman's study, cane washing was not employed in Puerto Rico.

In general, current operating practices are that wastes are not retained by Subcategory V factories for as long as those of Subcategory I. An additional difference between the two subcategories is that while a similar percentage of the factories in Subcategory V cool and recycle barometric condenser cooling water, none of the factories recycles cane wash water. In addition, a number of factories have the option of applying irrigation techniques, while none in Subcategory I can do so.

POTENTIAL END-OF-LINE TECHNOLOGY

Existing end-of-line treatment technology in the cane sugar industry, as described in this section, is generally rudimentary. Several potential technologies are applicable to the raw sugar industry as discussed below.

TABLE 59

SUBCATEGORY V
EXISTING TREATMENT PRACTICES

	CONDENSER WATER						CANE WASH WATER					FILTER MUD				ASH			MISC. WATERS		
PUERTO RICO	USE FOR CANE WASH	RECYCLE	IMPOUND	IRRIGATION	DISCHARGE	COOLING	PRIMARY SETTLE	RECYCLE	IMPOUND	DISCHARGE	IRRIGATION	DRY HAUL	IMPOUND	DISCHARGE	IRRIGATION	DRY HAUL	IMPOUND	DISCHARGE	CANE WASH	IMPOUND	DISCHARGE
52					X		X		X		I		X	X			X	X			X
53	X									X		X				X		X			X
54					X					X			X	X						X	
55*	X	CT									I	X									X
56					X	CP	DRY PROCESS					X									X
57**		CP								X			X				X				X
58					X		DRY PROCESS						X			X					X
59**	X		X		X		X			X			X			X					X
60												X		X							
61*		CP							X		I		X				X	I			X
62	X	SP					X		X		I	X									I
63	X		X		X		X		X	ⓧ			X	X						X	X
64	X				X	SP	X			X		X				X				X	X

LEGEND

ⓧ DISCHARGE AFTER STABILIZATION
A AERATION
SP SPRAY POND
CT COOLING TOWER
CP COOLING POND
I IRRIGATION

* CLOSED
** REPORTEDLY CLOSED, BUT EFFORTS ARE BEING MADE IN ORDER THAT THESE PLANTS REMAIN OPERATIONAL.

Biological Treatment

Waste waters similar in nature to those generated by sugar factories by virtue of their containing sucrose and other sugars have been effectively treated by the activated sludge process (19, 20).

Biological treatment of sugar waste has been demonstrated in both bench and pilot plant tests. Bhaskaran and Chakrabarty (21) conducted pilot plant studies in India on both anerobic and aerobic ponds for treating cane sugar waste. With a loading rate of 0.25 kilograms per day per cubic meter (0.0155 pounds per day per cubic foot) of BOD, the anerobic lagoon treatment efficiency was 61.5 percent. The oxidation pond with a seven day detention time was able to average 68 percent BOD removal, acting on a waste with an average concentration of 272 mg/l corresponding to a loading of 330 kilograms/day per hectare (290 pounds/day per acre). Miller (22) reports on an activated sludge pilot study which showed that waste water BOD concentrations of 800 to 1,000 mg/l from a cane factory could be reduced to 20 to 40 mg/l. Some difficulty was reported, however, with filamentous bacterial growth and problems were also encountered in the control of suspended solids in the effluent from the pilot plant.

Flume water in the beet sugar industry has been reported to be effectively treated by the activated sludge process with treatment efficiencies for BOD removal ranging from 83 to 97 percent (23). Maximum BOD values of 50 mg/l in the effluent were reported.

Simpson and Hemens (24) conducted an investigation of the effect of nitrogen and phosphorus addition on the rate of COD removal from cane sugar factory effluent. A laboratory continuous-flow aeration unit, completely mixed and supplied with compressed air, received waste from a Natal raw sugar factory. The investigators concluded that efficient activated sludge treatment of sugar factory effluent is possible if supplementary nitrogen and phosphorus are added. The minimum COD:N:P ratio in the influent was found to be 100:2:0.4. The optimum load factor was found to be 0.6 g COD/day/g MLSS with an average sludge volume index of 53 mg/l. The average settled COD and BOD values of a well stabilized effluent were observed to be 97 and 13 mg/l, respectively. It was further observed that the waste activated sludge could be dried on a conventional drying bed without pretreatment.

Due to the seasonal nature of the sugar industry in Subcategories I, II, and V and the length of time required for an activated sludge system to reach an equilibrium, activated sludge has not been considered as a treatment alternative for these subcategories. As the processing season approaches a full year, as in the case of Subcategories III and IV, activated sludge shows more promise as a potential treatment alternative. While the use of oxidation ponds is currently demonstrated, a technology which has limited current application is the use of aerated lagoons. The use of aerated lagoons is particularly worth considering where land is not abundant or is expensive as in Subcategory V. The work of Keller (5, 7), Wheeler (14), Bevan (25), and Miller (22) indicate the feasibility of the application of aerated lagoons with supplemental nutrient addition.

Chemical-Physical Treatment

Two rather extensive research studies have been carried out in Hawaii to develop methods of removing solids from cane wash water. Factory 72 has carried out laboratory settling tests as well as applying a pilot clarification unit. Figure 24 and Table 60 present the data collected in laboratory settling tests without the use of coagulants. These results indicate that good settling and effluent concentrations of below 300 mg/l are possible. The results of the final pilot plant runs are presented in Table 61. Testing with the use of tube settlers indicates that the overflow rate is five times that of a conventional clarifier. It was also reported that the results of clarification with operating parameters properly controlled indicated a median effluent suspended solids of 50 mg/l in the effluent (10, 26). In one case (with Akaka soils), the suspended solids was found to be 200 mg/l.

Considerable developmental and optimization work has been undertaken by the technical staff of Factory 66 to accomplish the following goals:

1. Reduce the flow of cane wash water and other streams discharged to a treatment system.
2. Minimize the soil loading in the waste water discharge by certain modifications to the present cane washing system.
3. Design of a treatment system to adequately handle the projected raw waste loading.

These efforts were initiated in a series of laboratory analyses leading to the development of bench-scale models and finally the operation of a pilot plant to simulate what was thought to be the actual system of cleaning plant waste water treatment.

Initial results of laboratory studies indicate that settling of the waste water stream without the addition of polymer will not take place in less than two hours. However, the addition of polymer or lime was found to immediately correct that situation and cause rapid settling. Optimum polymer dosages were determined to be about 1.0 mg/l; liming to a pH of 11 was required to attain comparable settling results and a superior supernatant liquid.

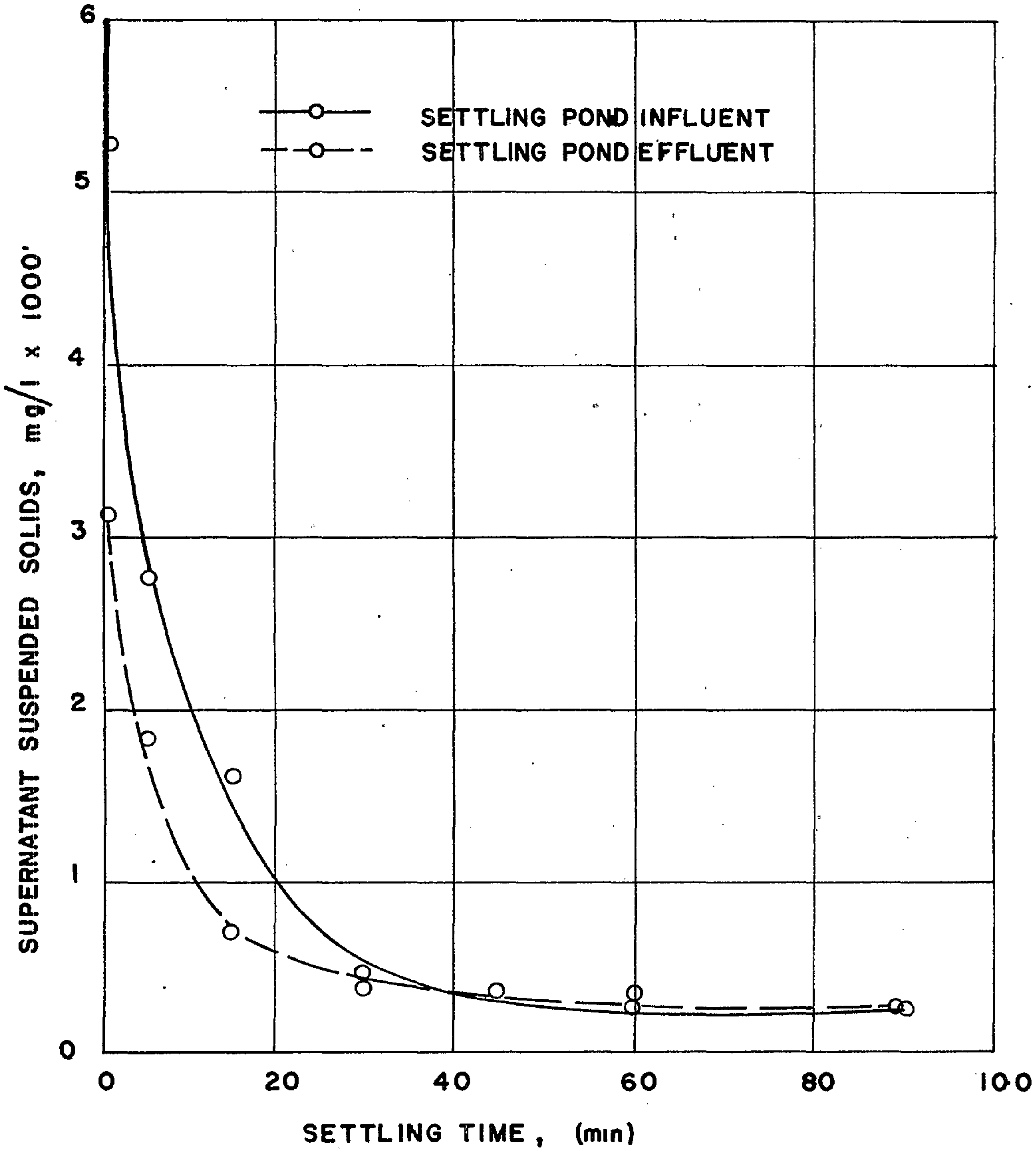


FIGURE 24

SUSPENDED SOLIDS REDUCTION
BY PLAIN SEDIMENTATION

TABLE 60

SUSPENDED SOLIDS REMOVALS* BY PLAIN SEDIMENTATION WITHOUT CHEMICAL ADDITION

Settling Time (Min.)	A		B		C		D		Mean	
	TSS (mg/l)	% Rem.	TSS (mg/l)	% Rem.	TSS (mg/l)	% Rem.	TSS (mg/l)	% Rem.	TSS (mg/l)	% Rem.
0	8872	-	3228	-	5048	-	4148	-	5324	-
5	5460	38.5	1956	39.4	2328	53.9	1384	66.6	2782	47.7
10	4712	46.9	-	-	-	-	-	-	-	-
15	3788	57.3	752	76.7	1144	77.3	740	82.2	1606	69.8
30	344	96.1	496	84.6	252	95.0	484	88.3	394	92.6
45	-	-	356	89.0	-	-	-	-	-	-
60	248	97.2	304	90.6	364	92.8	212	94.9	282	94.7
90	296	96.7	-	-	376	92.6	164	96.0	279	94.8

*TESTS:
A: 4/2/69, 10 a.m.
B: 4/2/69, 2 p.m.
C: 4/3/69, 6 a.m.
D: 4/3/69, 2 p.m.

TABLE 61

SUSPENDED SOLIDS REMOVALS - FINAL PILOT PLANT SERIES

Sample Date: Time	Influent TSS (mg/l)	Effluent TSS (mg/l)	Removal Efficiency (%)
7/01: 12:30	8,396	452	94.6
12:50	8,408	240	97.1
13:15	8,768	400	95.4
13:35	9,800	624	93.6
14:15	26,932	216	99.2
14:25	12,888	440	96.6
15:00	5,532	672	87.9
7/02: 10:10	2,368	556	76.5
10:20	2,952	188	93.6
12:15	8,956	536	94.0
12:25	8,068	516	93.6
12:40	4,648	400	91.4
12:55	4,480	272	93.9
13:05	9,056	292	96.8
13:15	7,920	220	97.2
14:10	6,572	152	97.7
MEAN:	8,484	386	95.5

Laboratory work on a bench-scale continued and the result was the design of a heavy-duty thickener which will clarify the waste water stream and thicken the resultant sludge to the extent that dewatering can be accomplished by means of vacuum filtration (high rainfalls measured in tens of feet per year are thought to preclude the use of sludge drying ponds). Laboratory filter leaf studies using several types of cloth media were also carried out which indicated variable filtration rates. Some values as low as 15 kg/hr/sq.m (3 lb/hr/sq.ft) were obtained, but the average was generally about 39 kg/hr/sq.m (8 lb/hr/sq.ft). The use of lime was found to improve filtration when the mud slurry was allowed to stand for long periods of time (48 hours).

A pilot scale thickener was constructed and operated. The size of particles was found to have practically no effect on the settling rate and the addition of 1.5 mg/l of polymer to influent waste water caused good settling to occur in a short time. In general, higher filtration rates were obtained than previously. It was also determined that the filtration rate with a stainless steel screen substituted for cloth was higher. Liming of the thickener underflow improved the filtration rate when mud slurry was allowed to stand for long periods of time (2 to 24 hours).

Work continued with regard to the elimination of soil discharged to the thickener and it was found that secondary screening (1.0 mm spacings) resulted in a 61.8% removal of soil under varied harvesting conditions (poor to good burns). The settling properties of the screened effluent were checked and settleability was effective with polymer addition. Similar filtration rates as experienced previously were obtained, comparable to those for unscreened effluent, for both cloth and stainless steel filter media. Filtration rates were found to increase with the addition of bagasse used as a filter aid. In a continued effort to reduce water usage, a spray pond was installed at the factory to recirculate barometric condenser cooling water.

An entire pilot-scale treatment system, including screens, thickener, and vacuum filter was constructed and operated. Many factors were varied in an effort to optimize the system and this work is continuing at the time of this publication. Secondary screening (0.5 mm spacings) yielded a 72% reduction in soil loading to the thickener. The elimination of coarse particles by screening had no affect on solid-settling in the thickener or on the filtering operation. In fact, it was reported that filtration appeared to be better with a mud slurry devoid of coarse particles. Good filtration rates without lime addition were obtained on the pilot scale unit even when mud was allowed to stand for 66 hours. Filtration rates increased greatly through the use of stainless steel media, and were on the order of 245 kg/hr/sq.m (50 lb/hr/sq.ft). It was found that the filtrate from the vacuum filter must be recycled to the thickener due to its high turbidity. Separate tests in the laboratory revealed that the solids returning with the filtrate settle quite easily without the addition of polymer.

In general, it appears that a suspended solids effluent concentration of 200 mg/l or better is feasible from the effluent of a properly designed thickener with polymer or lime addition, under the operating conditions typical of Subcategory III factories. However, this is a conclusion reached as a result of bench and pilot-scale experimental work and not actual operating data.

SELECTED CONTROL AND TREATMENT TECHNOLOGIES APPLIED TO MODEL PLANTS

In Section V, model plants were developed to represent factories in each subcategory and assumptions as to existing in-plant treatment technology were made. In this section additional assumptions to account for the addition of end-of-line treatment will be added, the model factories will be adjusted when necessary, and alternative control and treatment technologies will be presented along with a discussion of anticipated waste loading reductions.

SUBCATEGORY I

In Section V the model plant for this subcategory was developed with the following assumptions:

1. Filter cake is dry hauled or impounded without discharge.
2. Barometric condenser cooling water is employed for washing cane.
3. Boiler ash is dry hauled or impounded without discharge.
4. Non-contact cooling waters such as bearing cooling water are segregated from the factory waste waters.
5. Acid and caustic wastes are not discharged directly, either by means of recirculation, impoundment, or both.
6. Condensate has a BOD_5 of approximately 10 mg/l.
7. Excess condensate is used for the washing of floors, etc.

It is felt that this level of in-plant technology is predominantly in practice and would require minimal expenses for the factories which do not attain this level of technology. No additional end-of-line treatment is assumed even though more than half of the factories impound cane wash water and do not discharge until after the occurrence of waste stabilization. Table 52 summarizes the existing technology employed at Subcategory I factories in more detail.

The model plant representative of Subcategory I factories has the following raw waste loadings.

Flow: 16,800 l/kkg (4,040 gallons/ton) of gross cane.
BOD5: 2.08 kg/kkg (4.16 lbs/ton) of gross cane.
TSS: 17.56 kg/kkg (35.1 lbs/ton) of gross cane.

Eight alternative treatment schemes were chosen to be applied as treatment of the effluent from the model plant. These systems are described in detail and a summary of the removal efficiencies of the various alternatives is presented in Table 62. Figure 25 presents a schematic diagram of the model factory for Subcategory I.

Alternative A - Alternative A assumes no additional treatment and control technology to be added to the model. The efficiencies of BOD5 and suspended solids removal are zero.

Alternative B - This alternative consists of adding those in-plant controls and modifications which may or may not be practiced at an individual factory, but would enable a factory to attain the level of technology typified by the model plant. These procedures include:

1. Filter cake handling.
    a. Dry handling of filter cake.
    b. Impoundage of filter mud slurry.
2. Ash handling.
    a. Dry handling of ash.
    b. Impoundage of ash slurry.
3. Entrainment control for evaporators and vaccuum pans.
    a. Proper operation and good maintenance.
    b. Addition of baffles.
    c. Addition of monitoring equipment.
    d. Increase in vapor height.
    e. Addition of centrifugal separators on the evaporators and vacuum pans.
    f. Addition of external separators to the evaporators.

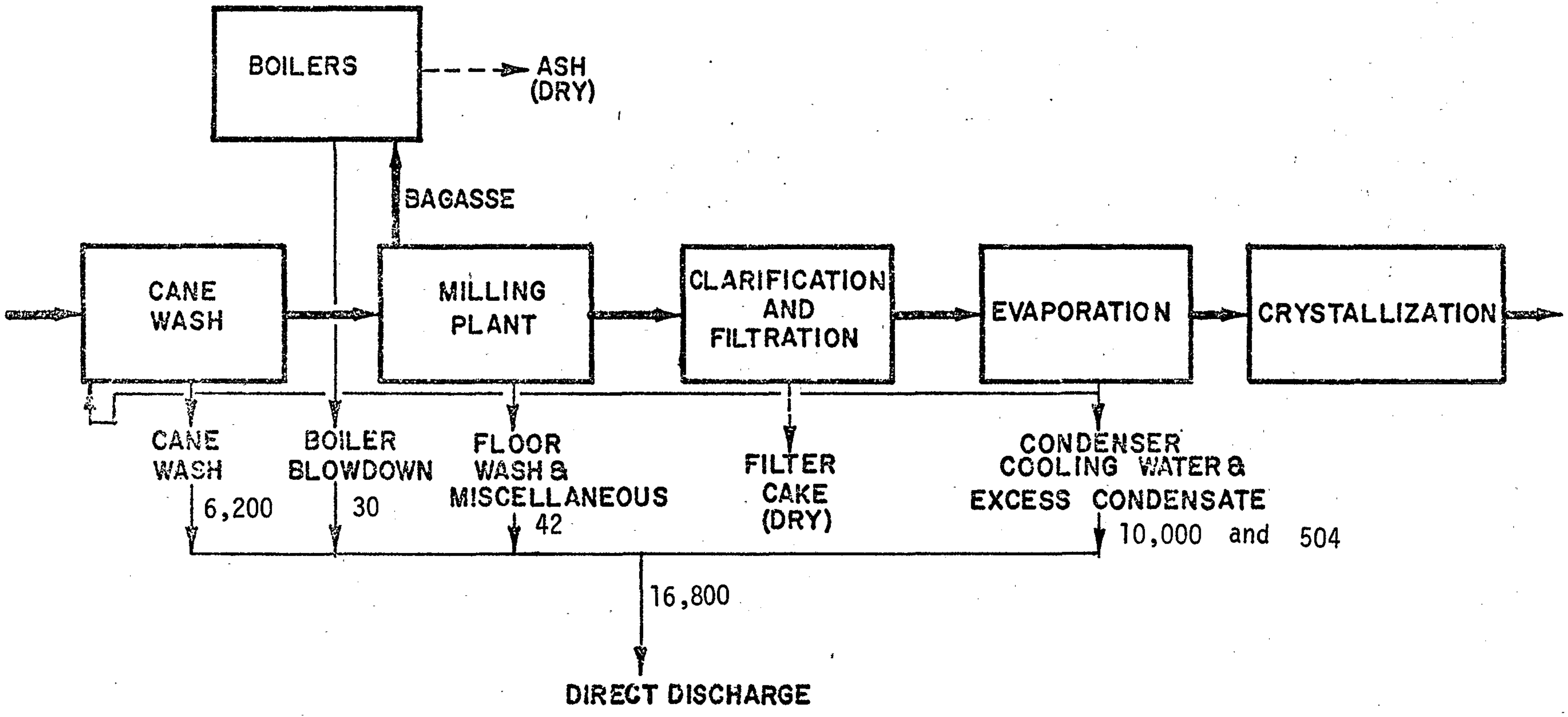
Not all factories which experience high losses of sucrose into barometric condenser cooling water would have to employ all of the techniques listed above but would in all probability utilize certain of these procedures.

Good entrainment control not only achieves a reduction in the discharge of BOD5, but also results in sucrose recovery. To take into

TABLE 62

SUMMARY OF REMOVAL EFFICIENCIES FOR VARIOUS TREATMENT ALTERNATIVES SUBCATEGORY I

Alternative	BOD5 Loading (kg/kkg)	%BOD5 Reduction	TSS Loading (kg/kkg)	% TSS Reduction
A	2.08	0%	17.56	0%
B	2.08	0	17.56	0
C	2.08	0	2.51	85.7
D	0.63	69.7	0.47	97.3
E	0.63	69.7	0.47	97.3
F	0.53	74.5	0.080	99.5
G	0.050	97.6	0.080	99.5
H	0.050	97.6	0.080	99.5



Flows expressed in terms of liters per metric ton of gross cane.

FIGURE 25

MODEL FACTORY FOR SUBCATEGORY I

account the sucrose recovery and subsequent sugar savings, it is estimated that 75 percent of the BOD5 that is removed from the barometric condenser cooling water can be converted to sucrose and that the ratio of BOD5 to sucrose on a weight basis is 1.125. In addition, increased molasses production is achieved. It is also assumed that the concentration of BOD5 at a plant which experiences a high sugar loss into barometric condenser cooling waters is 100 mg/l.

The application of the in-plant modifications which are discussed as Alternative B would result in the reduction of all BOD5 and suspended solids associated with the filter mud and ash discharge streams and a reduction of BOD5 entrained in the barometric condenser cooling water to that level of the model plant, 0.50 kg/kkg (1.0 lb/ton) of gross cane.

Alternative C - Figure 26 presents a schematic diagram of Alternative C. This alternative consists of the addition to Alternative B of a sedimentation pond to settle all waste waters, with the exception of barometric condenser cooling water and excess condensate. Four settling ponds were assumed which would be operated in parallel with each having an effective depth of 3.05 meters (10 feet) and a combined detention time of 32 hours. Operation of the ponds was assumed to require the filling of each pond with mud to a depth of 0.91 meters (three feet) at which time a clean pond would be used. The filled pond would then be decanted, allowed to dry, and finally dredged to clean and allow reuse. The resulting muds are assumed to be truck hauled to a landfill or to cane fields where they may be spread thinly over the soil without harming the crop. An effluent suspended solids concentration of 400 mg/l is assumed. No BOD5 removal is assumed although removals cn the order of ten to twenty percent would be expected to occur.

The overall effect of Alternative C is a suspended solids reduction of 85.7 percent.

Alternative D - Figure 27 shows a schematic diagram of Alternative D. This alternative consists of the addition to Alternative C of an oxidation pond to treat the effluent from the settling ponds. The oxidation pond is assumed to have a detention time equivalent to the entire grinding season, and to have a loading of 56.1 kilograms of BOD5/day per hectare (50.0 pounds of BOD5/day per acre). It is assumed that the oxidation pond is drained when waste stabilization occurs, prior to the next grinding season. The resulting BOD5 and suspended solids concentrations are predicted to be less than 50 mg/l and 75 mg/l, respectively. It is assumed that nitrogen addition is required, based on oxidation studies that have been conducted with sugar wastes.

The overall effect of Alternative D is a BOD5 reduction of 69.7 percent and a suspended solids reduction of 97.3 percent.

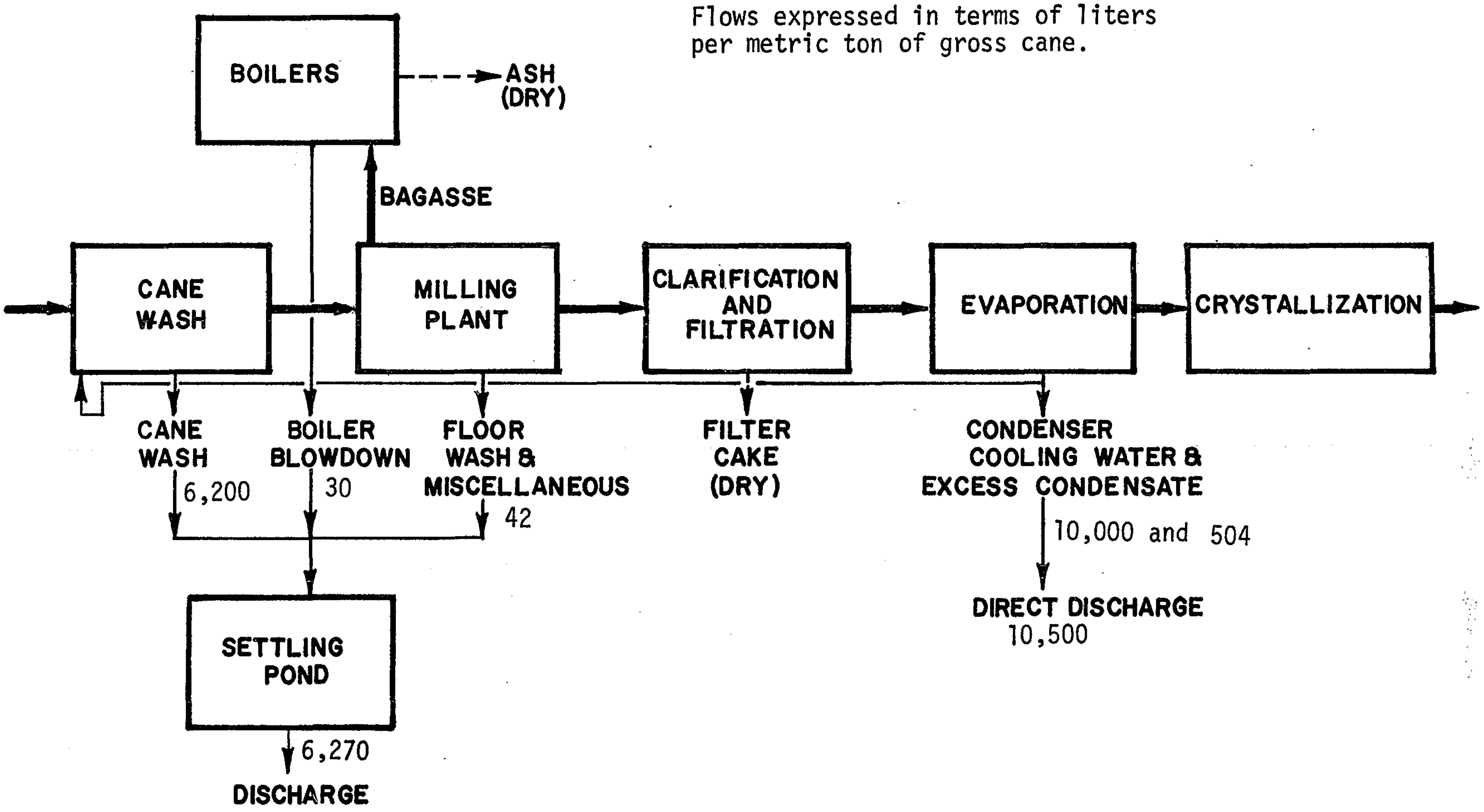
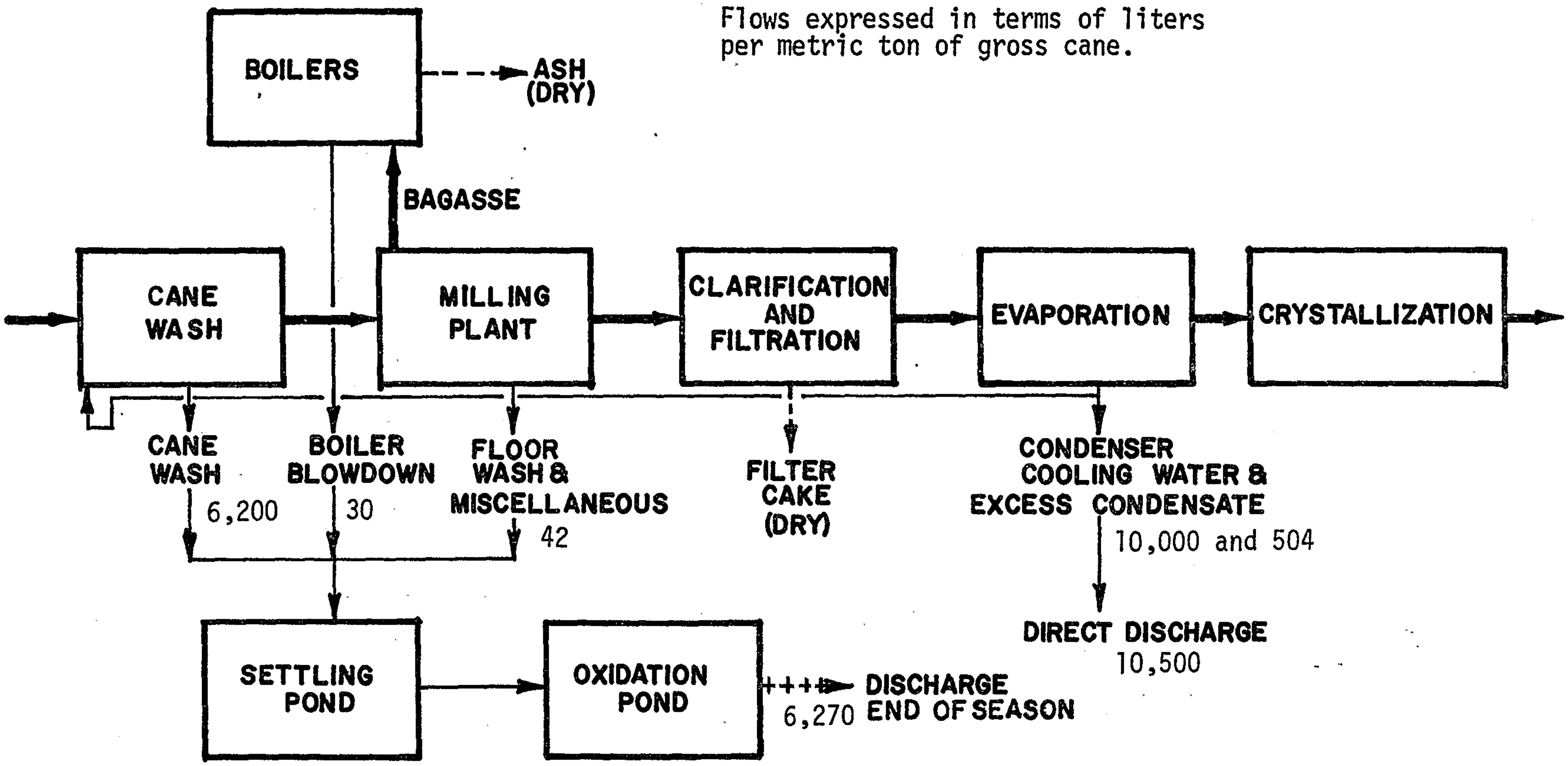


FIGURE 26

CONTROL AND TREATMENT
ALTERNATIVE C FOR SUBCATEGORY I



Flows expressed in terms of liters per metric ton of gross cane.

FIGURE 27

CONTROL AND TREATMENT
ALTERNATIVE D FOR SUBCATEGORY I

Alternative E - Figure 28 shows a schematic diagram of Alternative E. This alternative consists of the addition to Alternative C of an aerated lagoon to treat the effluent from the settling ponds. The aerated lagoon was designed with a detention time of 9.5 days, and included a quiescent zone. As with the oxidation pond in Alternative D, it is assumed that nitrogen addition is necessary for proper treatment of BOD5. Predicted BOD5 and suspended solids concentrations in the effluent from the aerated lagoon are 50 mg/l and 75 mg/l, respectively.

The overall effect of Alternative E is a BOD5 reduction of 69.7 percent and a suspended solids reduction of 97.3 percent.

Alternative F - Figure 29 shows a schematic diagram of Alternative F. This alternative consists of the addition to Alternative B of a cane wash water recirculation system and an oxidation pond to treat the blowdown from the settling ponds.

The design of the settling ponds for this alternative is the same as that for Alternative C with the additional assumption that the cane wash water recirculation system is operated with a blowdown of five percent. In addition, occasional chemical addition to the recycled cane wash water has been assumed in order that potential septic conditions and the associated odor problems be avoided. As was discussed previously in this section, this is the practice at certain Louisiana cane sugar factories.

The design of the oxidation pond is based on total retention for the entire season and discharge after waste stabilization occurs, prior to the next grinding season. As in the previously discussed alternatives, nitrogen addition is assumed. The pond was designed for a depth of 1.22 meters (five feet). The predicted effluent concentrations, assuming no dilution, are expected to be less than 75 mg/l for suspended solids and 50 mg/l for BOD5. For the calculation of final effluent loadings, the conservative estimate of a fifteen percent blowdown from the cane wash recirculation system is assumed, although the five percent blowdown used for design purposes is well documented by current operating practices.

The overall effect of Alternative F is a BOD5 reduction of 82.2 percent and a suspended solids reduction of 99.5 percent.

Alternative G - Figure 30 shows a schematic diagram of Alternative G. This alternative consists of the addition to Alternative B of a barometric condenser cooling water recirculation system, a cane wash water recirculation system, and an oxidation pond. The design assumptions for the settling ponds and the oxidation pond employed in this alternative are the same as those in Alternative F. It is assumed that the barometric condenser cooling water is recycled with a blowdown equivalent to 2 percent of the total flow. The blowdown is

Flows expressed in terms of liters per metric ton of gross cane.

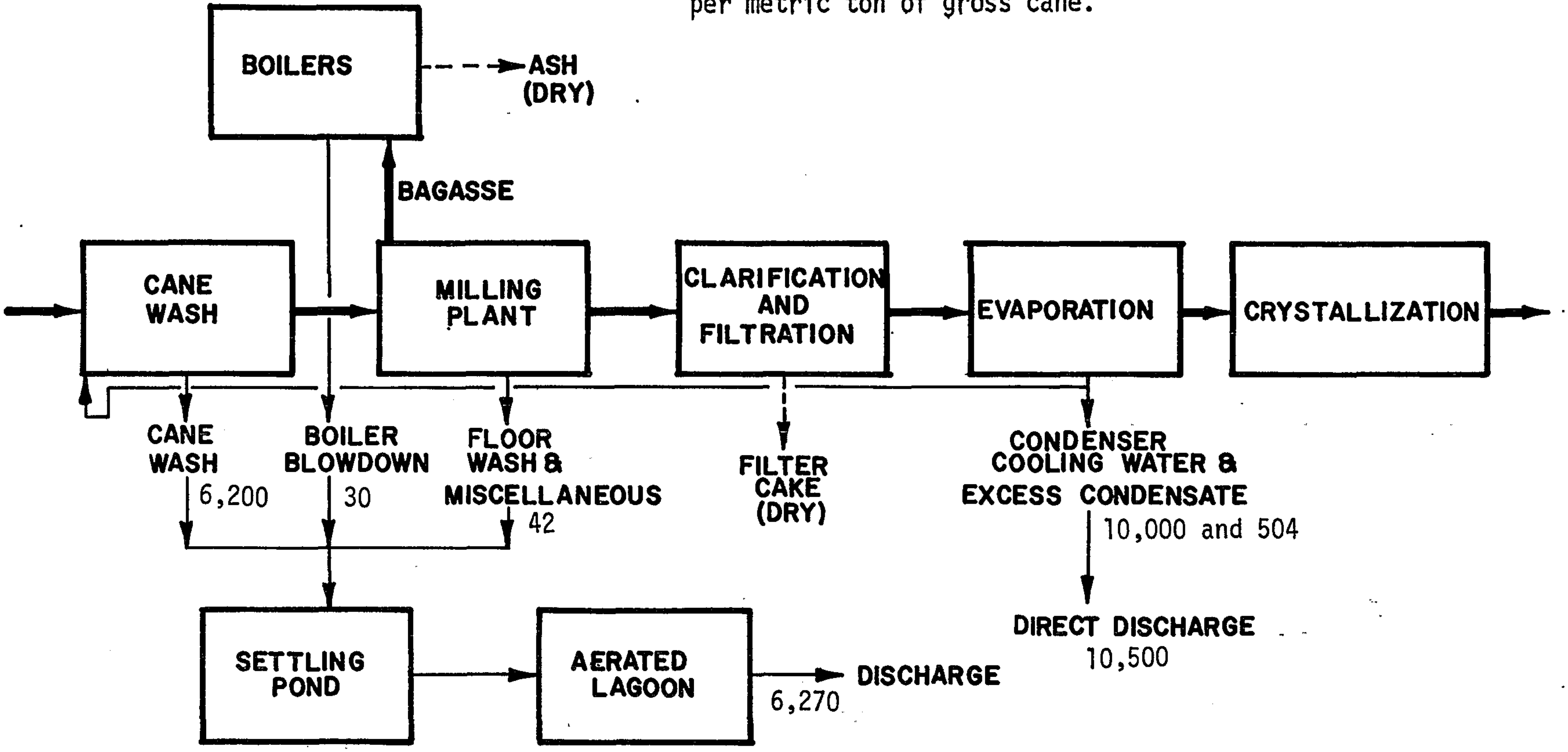


FIGURE 28

CONTROL AND TREATMENT
ALTERNATIVE E FOR SUBCATEGORY I

Flows expressed in terms of liters per metric ton of gross cane.

Values in parentheses are those used in the calculation of resulting effluent loadings.

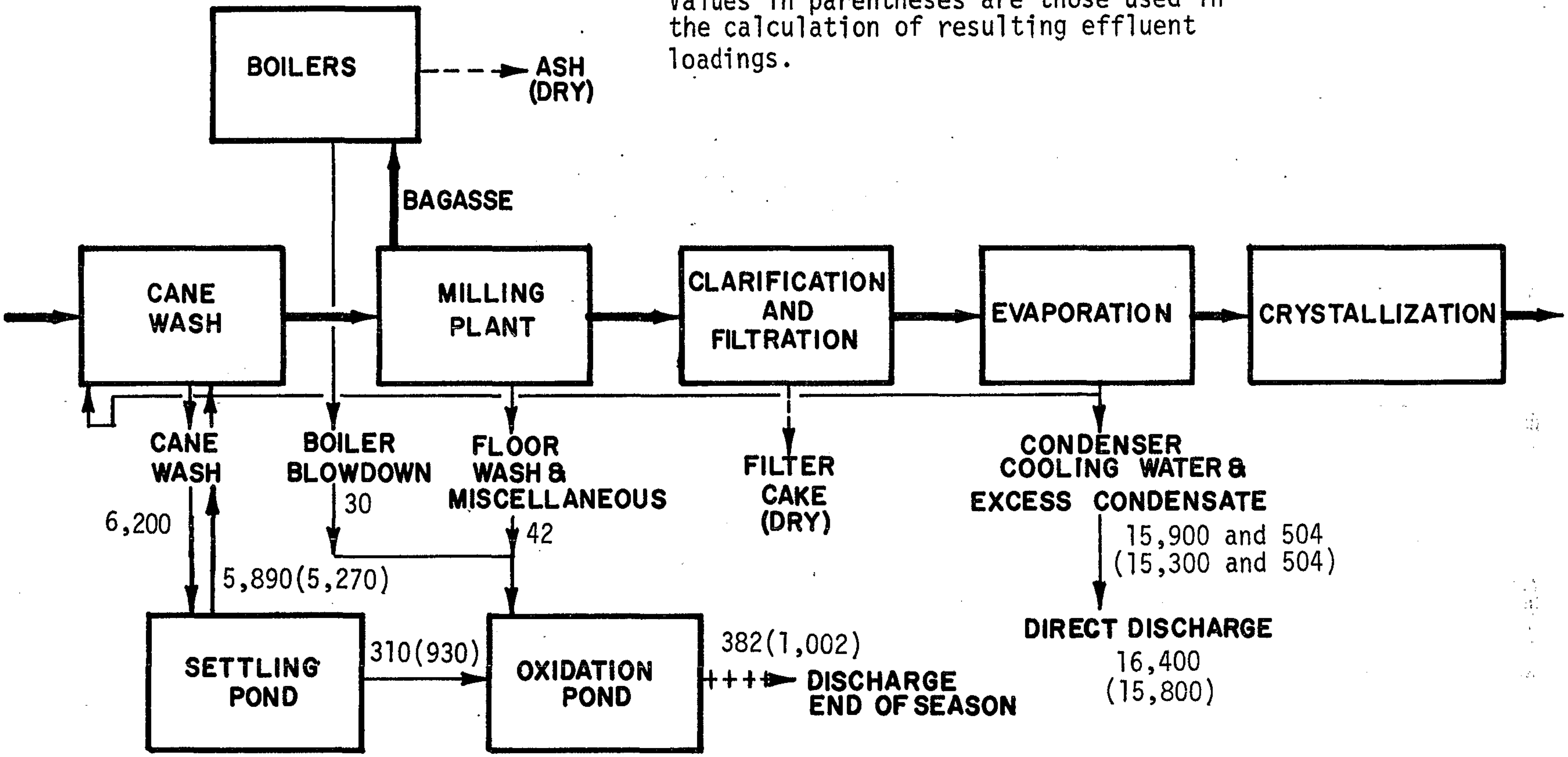


FIGURE 29

CONTROL AND TREATMENT
ALTERNATIVE F FOR SUBCATEGORY I

Flows expressed in terms of liters per metric ton of gross cane.

Values in parentheses are those used in the calculation of resulting effluent loadings.

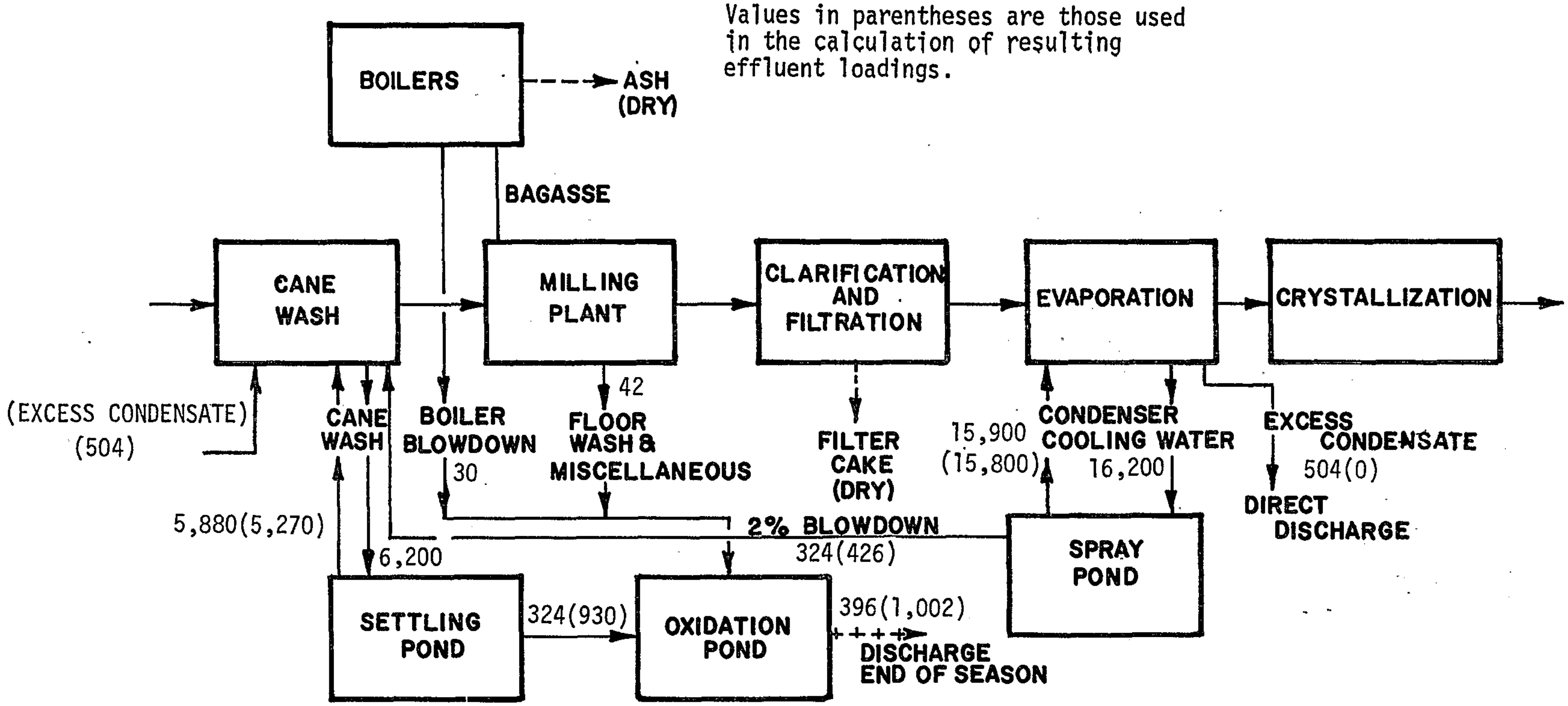


FIGURE 30

CONTROL AND TREATMENT
ALTERNATIVE G FOR SUBCATEGORY I

used as makeup to the cane wash recirculation system and the blowdown from the cane wash recirculation system is treated in an oxidation pond. The predicted effluent concentrations for BOD5 and suspended solids from the oxidation pond, assuming no dilution, are expected to be less than 50 mg/l and 75 mg/l, respectively. For the calculation of final effluent loadings, the conservative estimate of a fifteen percent blowdown from the cane wash recirculation system is assumed, although the five percent blowdown used for design purposes is well documented by current operating practices.

The overall effect of Alternative G is a BOD5 reduction of 97.6 percent and a suspended solids reduction of 99.5 percent.

Alternative H - Figure 31 shows a schematic diagram of Alternative H. This alternative is the same as Alternative G but with an aerated lagoon substituted for the oxidation pond. The aerated lagoon was designed in a similar fashion as that in Alternative E. Due to the high influent concentrations into the aeration pond, two aerated lagoons were designed of equal size to be operated in series. The design was based on a detention time of 14 days per pond and includes a quiescent zone. The predicted effluent concentrations are 50 mg/l of BOD5 and 75 mg/l of suspended solids.

The overall effect of Alternative H is a BOD5 reduction of 97.6 percent and a suspended solids reduction of 99.5 percent.

SUBCATEGORY II

In Section V the model plant for this category was developed with the following assumptions:

1. Filter cake is dry hauled or impounded without discharge.
2. Boiler ash is dry hauled or impounded without discharge.
3. Non-contact cooling waters such as bearing cooling water are segregated from the factory waste waters.
4. Acid and caustic wastes are not discharged directly, either by means of recirculation, impoundment, or both.
5. Condensate has a BOD5 of 10 mg/l.
6. Excess condensate is used for the washing of floors, etc.

It is felt that this level of in-plant control is predominantly practiced and would require minimal expenses for the factories that do not. It should be noted that seven of the nine factories in Subcategory II recycle barometric condenser cooling water by means of canals, spray ponds, or cooling towers. In addition, none of the

Flows expressed in terms of liters per metric ton of gross cane.

Values in parentheses are those used in the calculation of resulting effluent loadings.

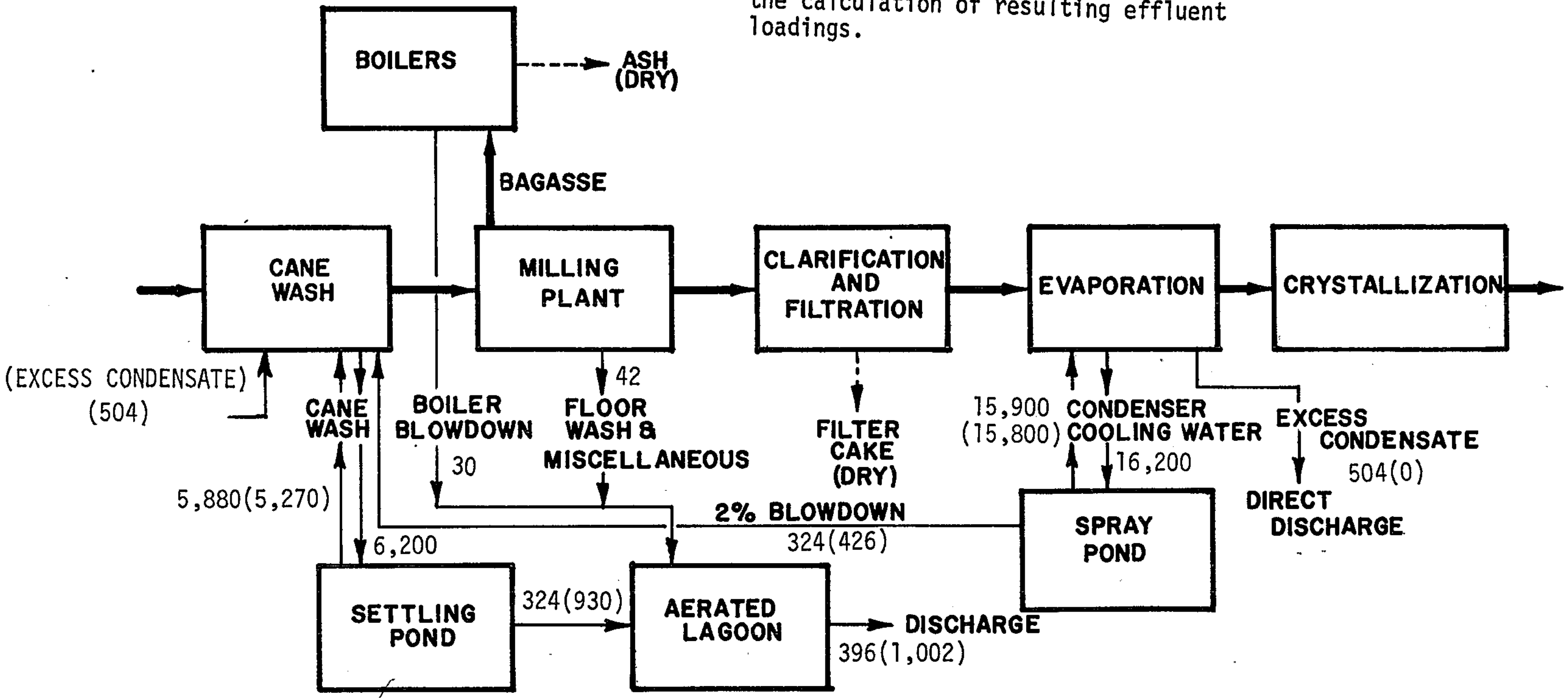


FIGURE 31

CONTROL AND TREATMENT
ALTERNATIVE H FOR SUBCATEGORY I

factories discharge waste water under normal conditions. Discharges occur at a few of the factories but only during times of heavy rainfall and as previously discussed in this section, BOD5 increases over normal background levels cannot be established from existing information. It is thus felt that the model factory in Subcategory II achieves a zero discharge limitation, and no additional control and treatment technology is necessary. Figure 32 shows a schematic diagram of the model Subcategory II factory.

SUBCATEGORY III

In Section V the model plant for Subcategory III was developed with the following assumptions:

1. Filter cake is discharged in slurry form.
2. Spent barometric condenser cooling water is used for cane wash water.
3. Boiler ashes are slurried and discharged.
4. Non-contact cooling waters such as bearing cooling water and hydrogenerator cooling water are segregated from the factory waste waters.
5. Acid and caustic wastes are not discharged.
6. BOD5 loading in the barometric condenser cooling water is 0.34 kg/kkg (0.68 lb/ton) of net cane.
7. Condensate has a BOD5 of 10 mg/l.
8. Excess condensate is used for slurrying filter cake, ash, and for the washing of floors, etc.
9. Excess bagasse is dry hauled.
10. Cane trash is discharged.
11. Rocks and associated mud are dry hauled.

It is felt that this level of in-plant technology is typical of factories in Subcategory III. End-of-line treatment is currently being developed at factories in this subcategory but none is assumed to exist at the model plant. The model for Subcategory III thus corresponds to that developed in Section V; a schematic diagram of the model factory is presented in Figure 33 and the corresponding waste loadings are:

Flow: 12,700 l/kkg (3,050 gal/ton) of net cane

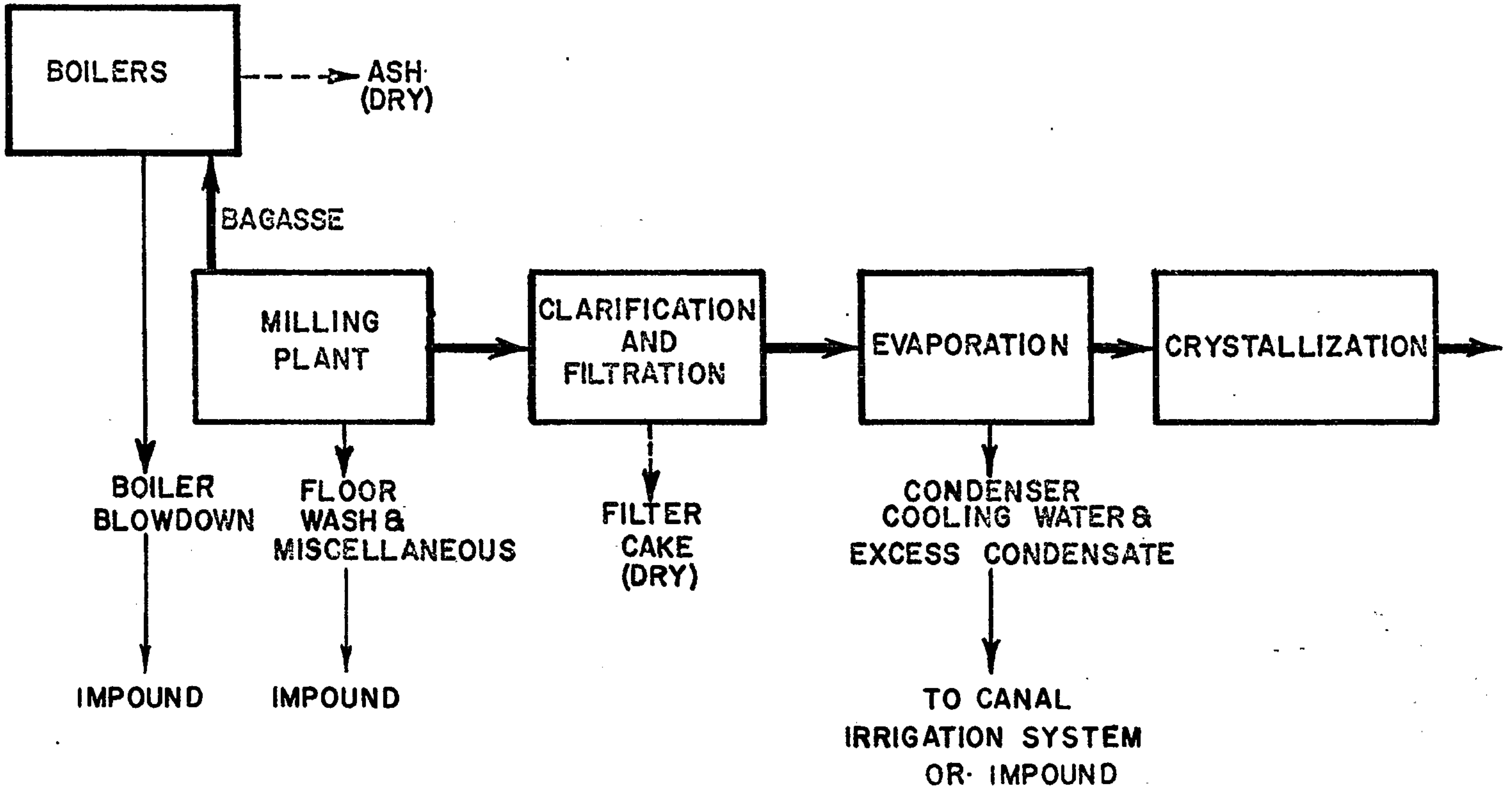


FIGURE 32

MODEL FACTORY FOR SUBCATEGORY II

Flows expressed in terms of liters per metric ton of net cane.

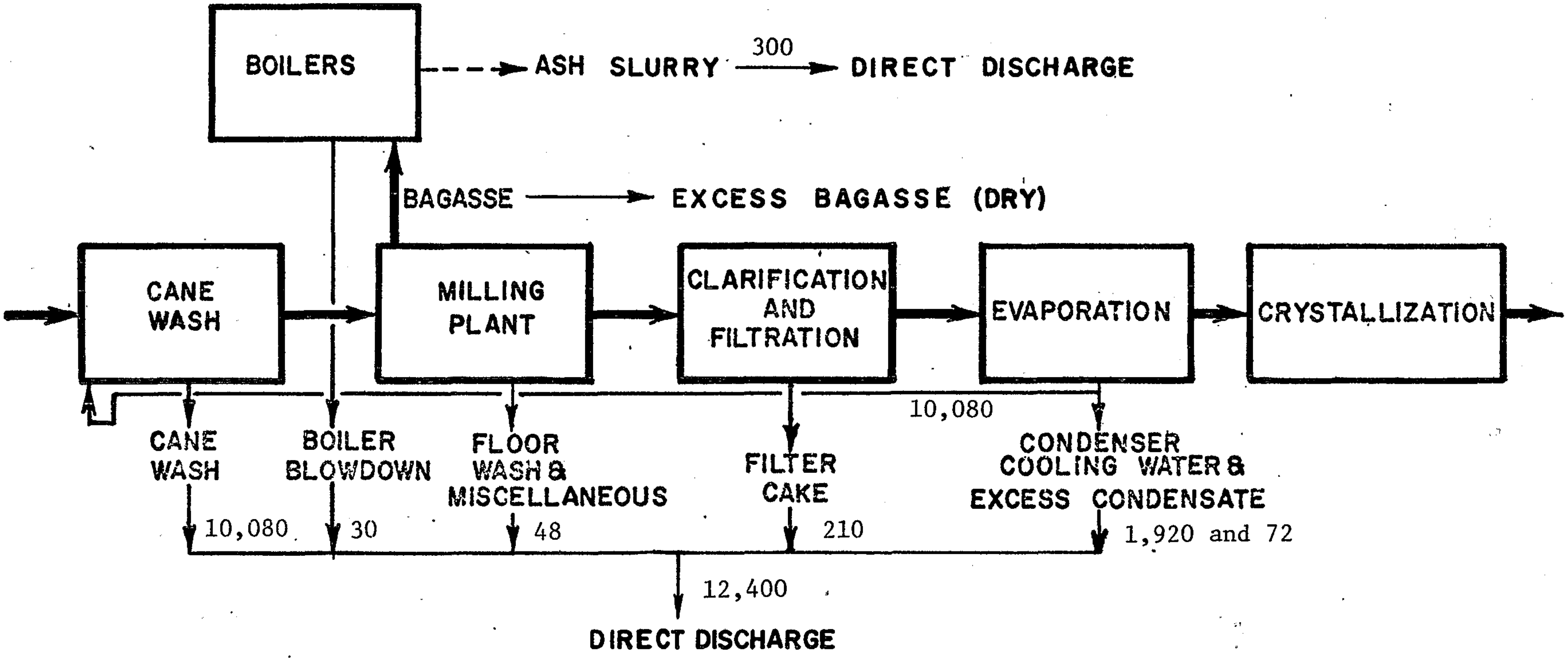


FIGURE 33

MODEL FACTORY FOR SUBCATEGORY III

BOD: 12.3 kg/kkg (24.6 lb/ton) of net cane
TSS: 194 kg/kkg (388 lb/ton) of net cane
Trash: 400 kg (880 lb) of solids per kkg (1.1 tons) of net cane

Eight alternative treatment schemes were chosen for treatment of the effluent from the model plant. These systems are described in detail and a summary of the removal efficiencies of the alternatives is presented in Table 63.

Alternative A - Alternative A involves no added control or treatment. The efficiencies of BOD5 and suspended solids removals are zero.

Should an individual factory not attain that degree of control of entrainment of sucrose into barometric condenser cooling water which is exhibited by the model plant, a reduction of BOD5 entrainment into barometric condenser cooling water is necessary. This can be accomplished by the following procedures:

- Good maintenance and proper operation
- Monitoring of barometric condenser cooling water
- Addition of centrifugal separators to the evaporators and vacuum pans
- Addition of external separators to the evaporators

The addition of these control measures allows for a reduction in the amount of BOD5 discharged to those levels typified by the model plant. The reduction of BOD5 entrainment into the barometric condenser cooling water increases sucrose and molasses production. To take into account the sucrose recovery and subsequent sugar savings, it is estimated that 75 percent of the BOD5 that is removed from the barometric condenser cooling water can be converted to sucrose and that the ratio of BOD5 to sucrose on a weight basis is 1.125. In addition, increased molasses production is achieved. It is also assumed that the concentration of BOD5 at a factory which experiences a high sugar loss into barometric condenser cooling waters is 50 mg/l.

Alternative B - Figure 34 presents an illustrative diagram of Alternative B. This alternative consists of the following in-plant modifications:

1. B-1: Dry hauling of filter cake.

2. B-2: Dry hauling of boiler ash.

3. B-3: Screening and hauling of trash.

For the hauling of mud and ash it was assumed that:

1. Fifteen cubic meter (twenty cubic yards) trucks would be used.

TABLE 63

SUMMARY OF REMOVAL EFFICIENCIES FOR VARIOUS TREATMENT ALTERNATIVES SUBCATEGORY III

Alternative	BOD5 Loading* (kg/kkg)	%BOD5 Reduction	TSS Loading* (kg/kkg)	% TSS Reduction
A	12.3	0	194	0
B	10.0	18.7	170	12.4
C	10.0	18.7	2.1	98.9
D	0.83	93.3	1.1	99.4
E	0.57	95.4	0.61	99.7
F	(1-x)0.48+0.36	95.9**	(1-x)1.01+0.0080	99.8**
G	(1-x)(0.095)+0.36	96.8**	(1-x)0.21+0.0080	99.9**
H	The greater of: 0.76(1-x)+0.0060 or 0.11	98.1**	The greater of: 1.01(1-x)+0.0080 or 0.13	99.8**

*Net cane basis.
**Assumes a 70% usage of advanced harvesting systems.

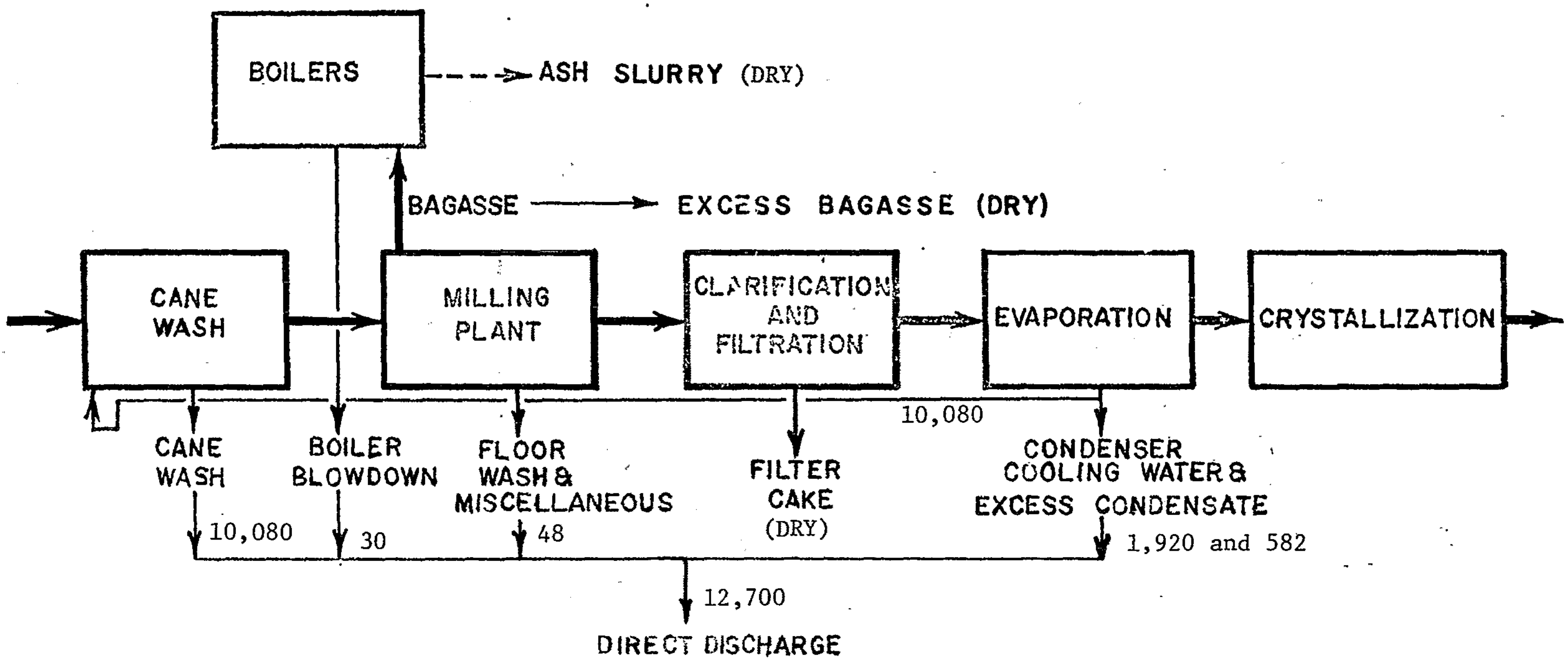


FIGURE 34

CONTROL AND TREATMENT
ALTERNATIVE B FOR SUBCATEGORY III

2. The mud and ash are disposed on land to a depth of 1.22 meters (4.0 feet).

3. If cane growing areas are taken out of production, the disposal site could not be used to grow cane for a period of three years.

4. The densities of both mud and ash are assumed to be 650 kg/cu. meter (40 lb/cu. ft).

5. The dry weight of filter cake and ash produced are 15 kg/kkg (30 lb/ton) of net cane and 17.5 kg/kkg (35 lb/ton) of net cane, respectively.

For the screening and dry hauling of trash it was assumed that:

1. All of the trash could be removed by screening.

2. Thirty-seven cubic meter (fifty cubic yard) trucks are used.

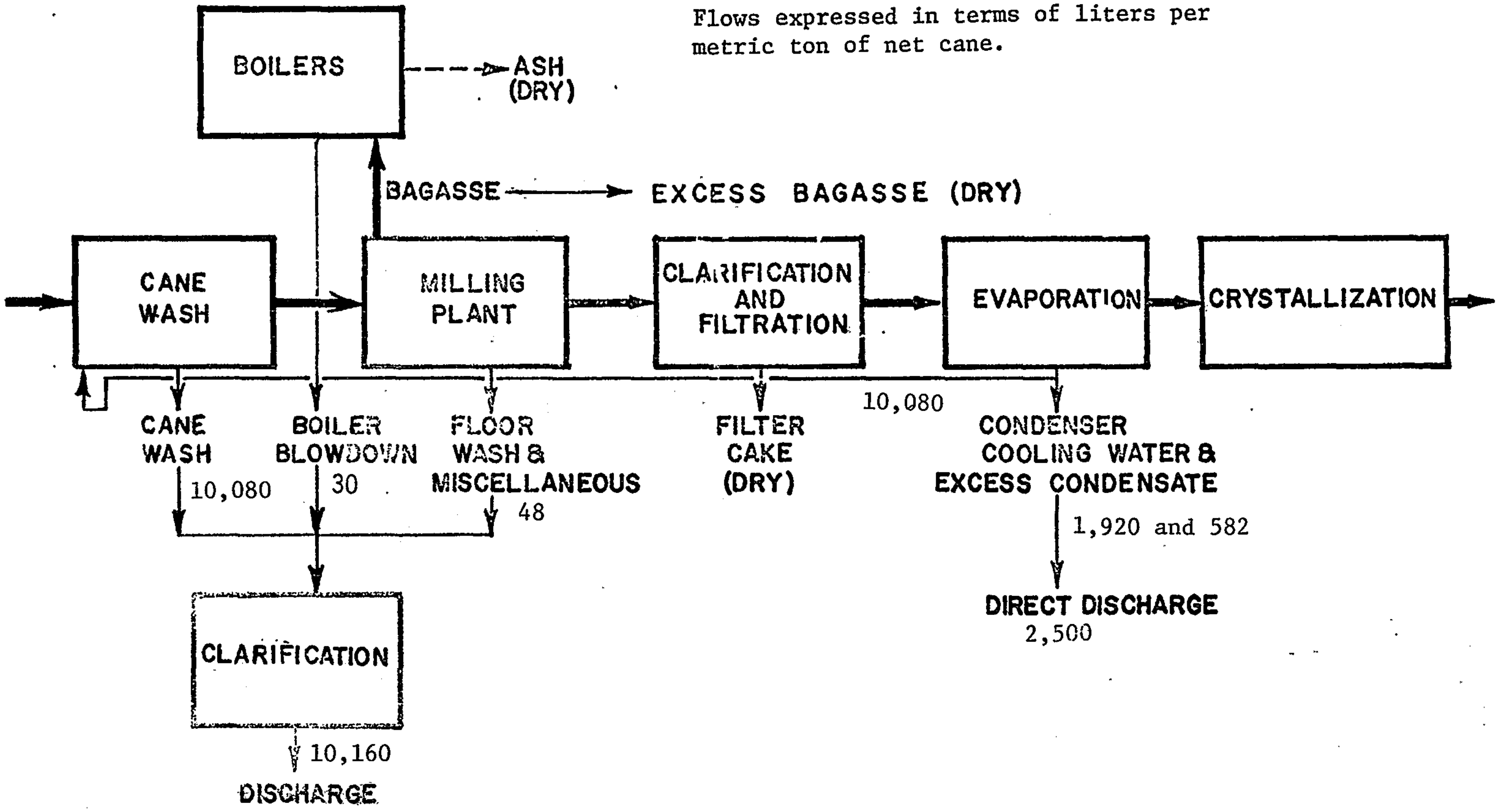
3. The bulk density of wet trash is 650 kg/cubic meter (40 lbs/cu. ft.).

4. The trash can be disposed on land to a depth of 1.5 meters (five feet).

5. If cane growing areas are taken out of production, the disposal site could not be used to grow cane for a period of five years.

The resulting reductions of BOD5 and suspended solids due to the application of the techniques described as Alternative B are 18.7 percent and 12.4 percent, respectively, in addition to complete removal of the cane trash.

Alternative C - Figure 35 presents an illustrative diagram of Alternative C. This alternative includes clarification with polymer addition of the cane wash water, boiler blowdown, and floor wash discharge streams. The design assumes grit removal followed by polymer addition and mixing, and settling in a heavy-duty thickener. The thickened sludge is dewatered by means of vacuum filtration. This is a similar system to that currently being designed to be applied at Factory 66. It is assumed that the resulting dewatered sludge is hauled in 15.1 cubic meter (20.0 cubic yard) trucks and spread on land to a depth of 1.22 meters (4.0 feet). If cane growing areas are taken out of production, the disposal site is assumed to be unsuitable for growing cane for a period of three years. The predicted effluent concentration from the thickener is 200 mg/l of suspended solids. No



Flows expressed in terms of liters per metric ton of net cane.

FIGURE 35

CONTROL AND TREATMENT
ALTERNATIVE C FOR SUBCATEGORY III

BOD_5 is considered to be removed in the thickener although removals on the order of 10 to 20 percent would be expected to occur.

The overall effects of Alternative C are a BOD_5 reduction of 18.7 percent and a suspended solids reduction of 98.9 percent.

Alternative D - Figure 36 presents an illustrative diagram of Alternative D. This alternative consists of the addition of two aerated lagoons operated in series to treat the effluent from the thickerner described in Alternative C. The aerated lagoons were designed with a total detention time of eight days and included a quiescent zone. Nutrient addition is also assumed as indications are that nitrogen must be added for good biological treatment. The predicted effluent concentrations are a BOD_5 concentration of 75 mg/l and a suspended solids concentration of 100 mg/l.

The overall effects of this alternative are a BOD_5 reduction of 93.3 percent and a suspended solids reduction of 99.4 percent.

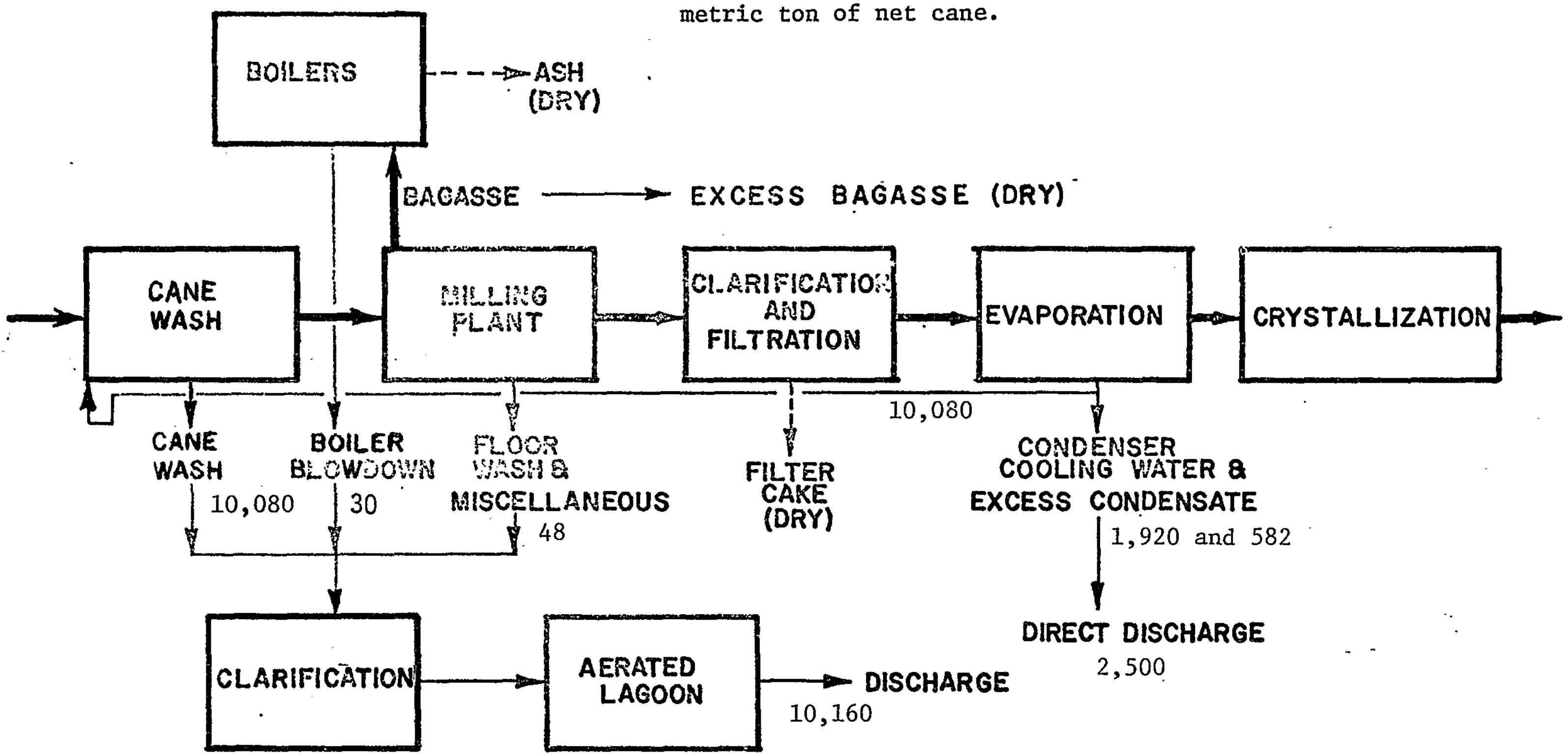
Alternative E - Figure 37 presents an illustrative diagram of Alternative E. This alternative consists of the addition of an activated sludge unit to treat the effluent from the thickener described in Alternative C. The activated sludge process assumes:

1. Aeration basin.
2. Secondary clarifier.
3. Aerobic digester.
4. Additional vacuum filtration.
5. Additional sludge hauling.
6. Nutrient addition.

Solid waste handling capacities were assumed to be increased by 10 percent over that of Alternative C to handle the resulting waste activated sludge. As with the disposal of mud it is assumed that waste activated sludge is disposed on land to a depth of 1.22 meters (4.0 feet) and that if cane growing areas are taken out of production, the disposal site is not suitable for cane growing for a period of three years.

Consideration of the Use of Advanced Harvesting Systems

As discussed previously in this section, considerable research and development are being accomplished at the present time with regard to the usage of advanced harvesting systems capable of delivering sugarcane to the factory mills which can be processed without the



Flows expressed in terms of liters per metric ton of net cane.

FIGURE 36

CONTROL AND TREATMENT ALTERNATIVE D FOR SUBCATEGORY III

Flows expressed in terms of liters per metric ton of net cane.

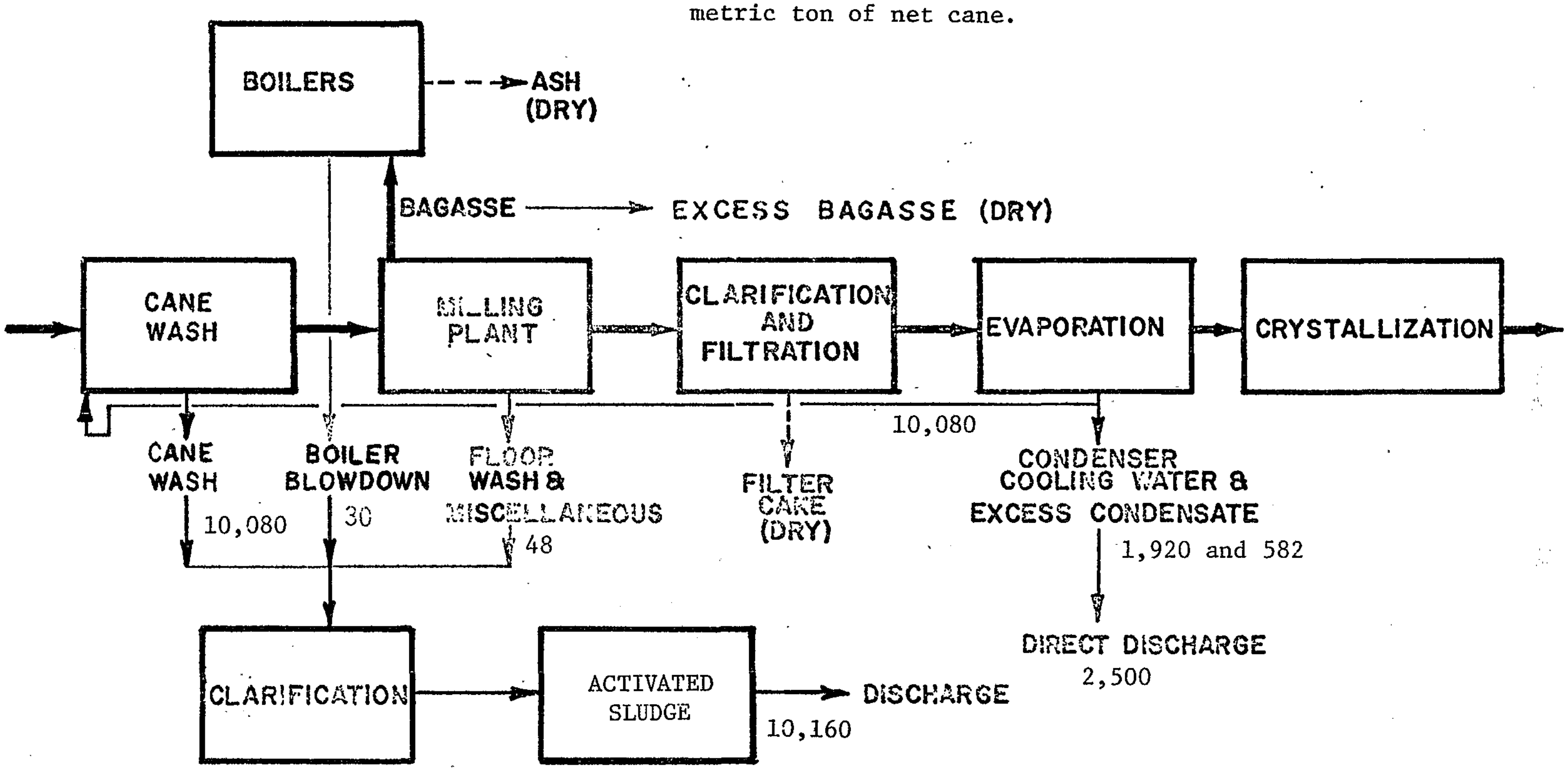


FIGURE 37

CONTROL AND TREATMENT
ALTERNATIVE E FOR SUBCATEGORY III

necessity of a washing step. It is expected that such a system will be employed at the Subcategory III factories between 1977 and 1983, and will enable an individual factory to eliminate the portion of the cane wash water stream currently associated with that fraction (x) of the net sugarcane which would be harvested by the advanced systems. A further assumption is that the same unit waste loadings as developed for the model factory are applicable to that portion of the net sugarcane which is not harvested by the advanced systems.

The following treatment alternatives include the aforementioned assumption that a fraction (x) of the net sugarcane processed at a factory is harvested by the advanced harvesting systems.

Alternative F - This alternative involves the assumption that Subcategory III factories will have employed the currently developed technology of improved cane harvesting systems which will enable a factory to eliminate that portion of the cane wash water stream associated with that fraction (x) of cane harvested by the advanced systems. Alternative F involves the treatment of the cane wash water and miscellaneous discharge streams in two aerated lagoons operated in series and designed with a total detention time of eight days and including a quiescent zone. Nutrient addition is assumed to ensure good biological treatment. The predicted effluent concentrations are a BOD5 concentration of 75 mg/l and a suspended solids concentration of 100 mg/l.

The overall effects of this alternative, assuming a 70 percent usage of the advanced harvesting systems, are a BOD5 reduction of 95.9 percent and a suspended solids reduction of 99.8 percent.

Alternative G - This alternative involves similar assumptions with regard to the model plant as Alternative F. Alternative G incorporates a cane wash water recirculation system with discharge of a twenty percent blowdown and the miscellaneous waste water discharge streams to two aerated lagoons operated in series and designed with a total detention time of nineteen days and including a quiescent zone. Nutrient addition is assumed to ensure good biological treatment. The predicted effluent concentrations are a BOD5 concentration of 75 mg/l and a suspended solids concentration of 100 mg/l.

The overall effects of this alternative, assuming a 70 percent usage of the advanced harvesting systems, are a BOD5 reduction of 96.8 percent and a suspended solids reduction of 99.9 percent.

Alternative H - This alternative involves similar assumptions with regard to the model plant as Alternative F. Alternative H incorporates the addition of a barometric condenser cooling water recirculation system, with discharge of the blowdown to the cane wash water system, and the addition of a biological system in the form of two aerated lagoons operated in series to treat the resulting

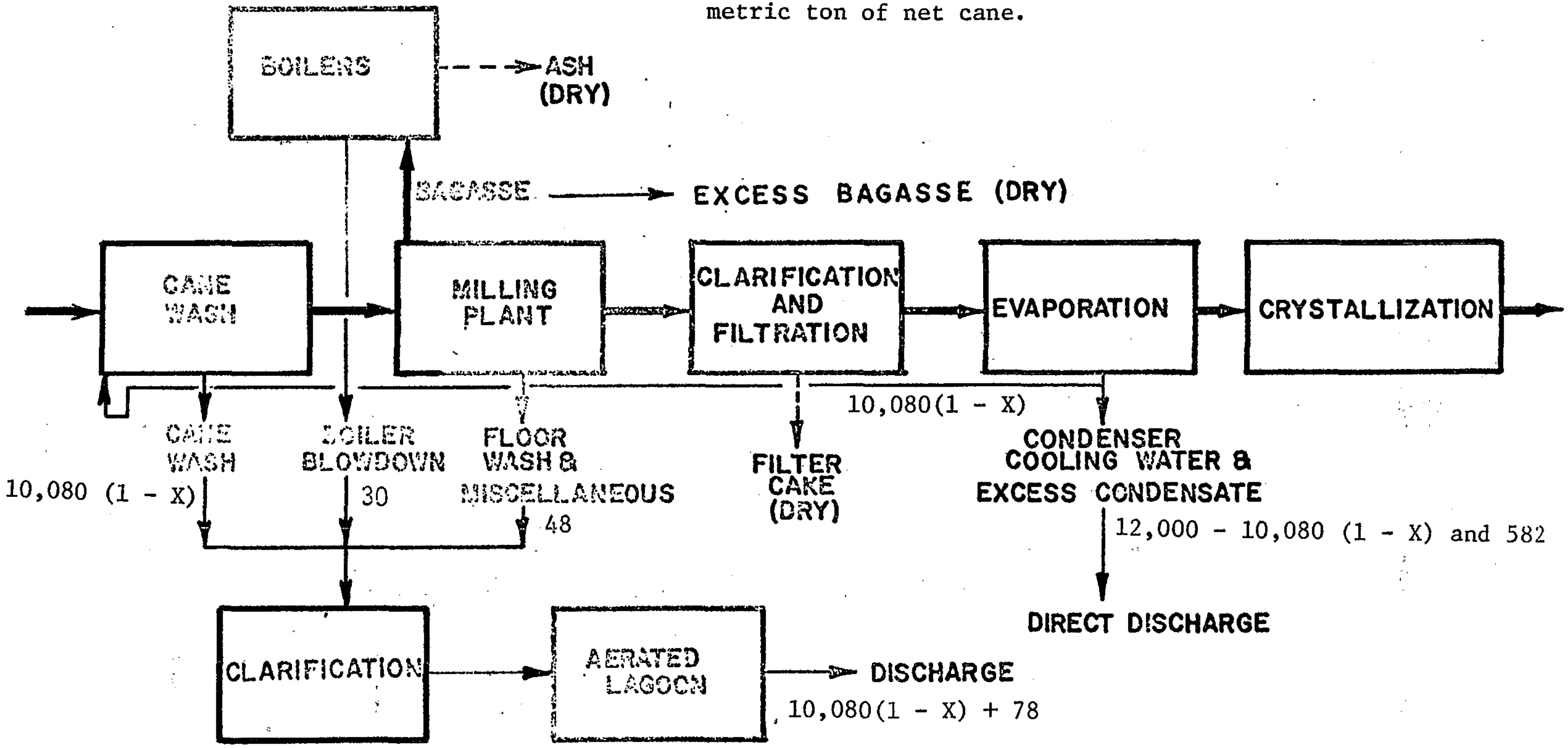

Flows expressed in terms of liters per metric ton of net cane.

FIGURE 38

CONTROL AND TREATMENT ALTERNATIVE F FOR SUBCATEGORY III

Flows expressed in terms of liters per metric ton of net cane.

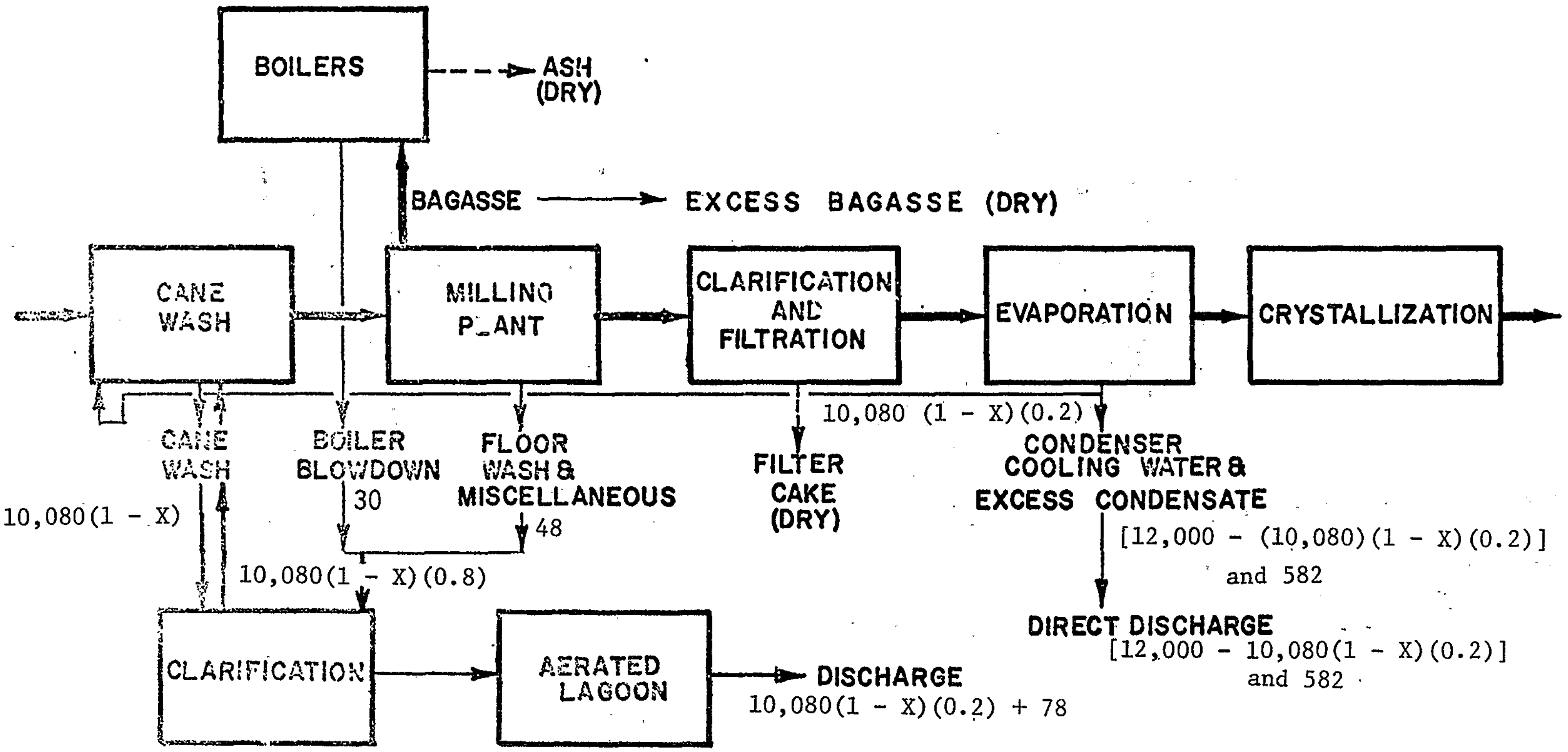


FIGURE 39

CONTROL AND TREATMENT
ALTERNATIVE G FOR SUBCATEGORY III

Flows expressed in terms of liters per metric ton of net cane.

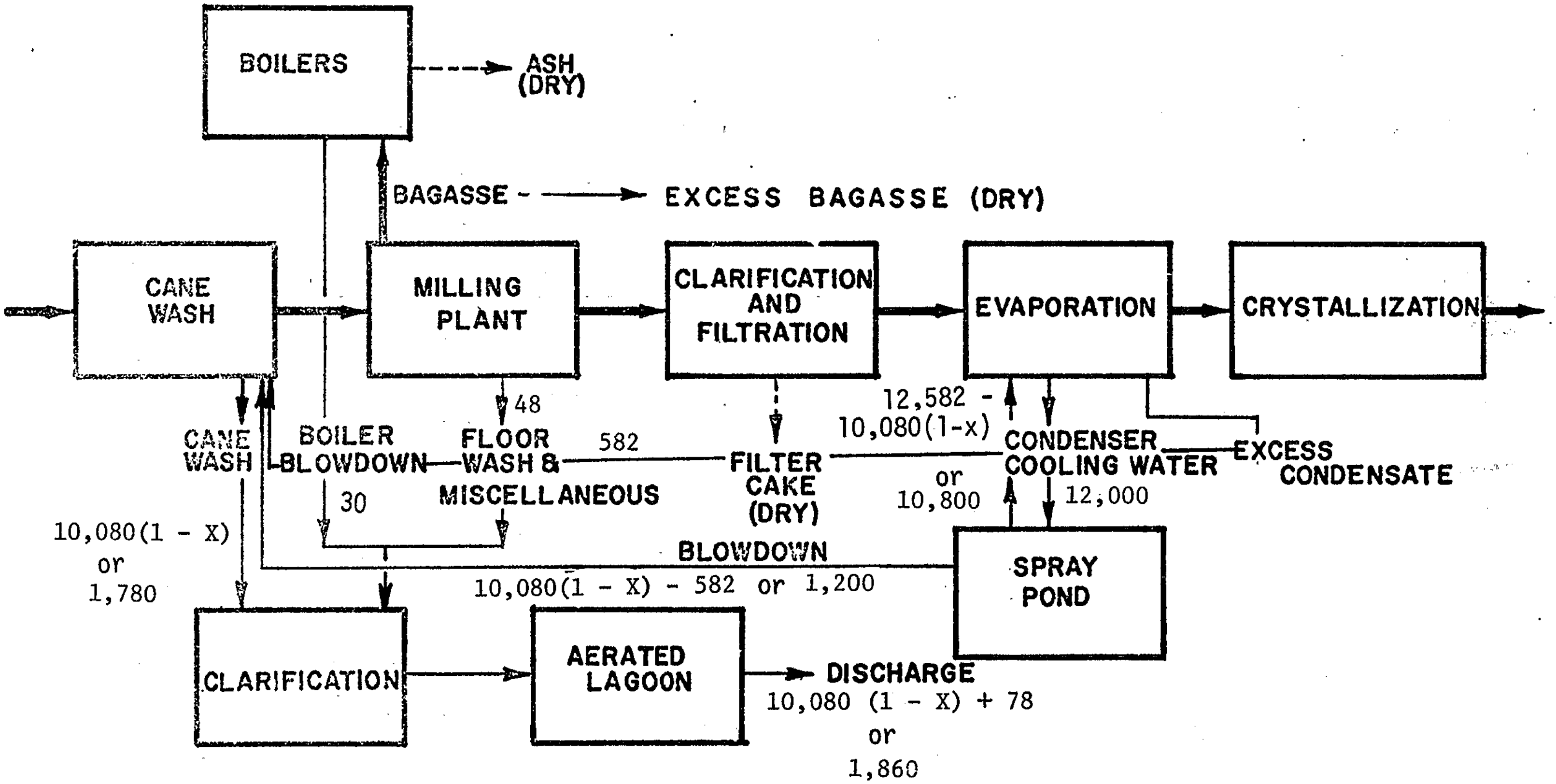


FIGURE 40

CONTROL AND TREATMENT
ALTERNATIVE H FOR SUBCATEGORY III

discharge stream. The design includes a quiescent zone and a total detention time of 8.5 days.

Nutrient addition is assumed to ensure adequate biological treatment. The predicted effluent concentrations are a BOD_5 concentration of 75 mg/l and a suspended solids concentration of 100 mg/l.

The overall effects of this alternative, assuming a 70 percent usage of the advanced harvesting systems, are a BOD_5 reduction of 98.1 percent and a suspended solids reduction of 99.8 percent.

SUBCATEGORY IV

In Section V the model plant for this subcategory was developed. Present end-of-line treatment technology in Subcategory IV consists of clarification of all process-generated waste waters and irrigation or total impoundage of the settled effluent. Those factories which employ irrigation accomplish a zero discharge of waste water under normal operating conditions. Abnormal conditions occur during times of heavy rainfall, and as previously discussed in this section, the discharges are expected to be quite dilute and indistiguishable from normal agricultural runoff. It is thus felt that the model factory in Subcategory IV achieves a zero discharge limitation and no additional control and treatment technology is necessary. Figure 41 shows a schematic diagram of the model factory.

SUBCATEGORY V

As discussed in Section V, limited data are available from which to characterize this sector of the industry. It was discussed in Section V that the model plant for Subcategory I is applicable to factories which form Subcategory V. The same assumptions on which the Subcategory I model factory was based are applied to Subcategory V.

Existing end-of-line treatment technologies are presented in Table 59, ranging from irrigation with factory waste water for some factories located in arrid regions to partial impoundment or no treatment in others. The same control and treatment alternatives applied to the Subcategory I model plant are applicable in Subcategory V as well. Therefore, the discussion in this section pertaining to control and treatment alternatives applied to the Subcategory I model plant is applicable to Subcategory V.

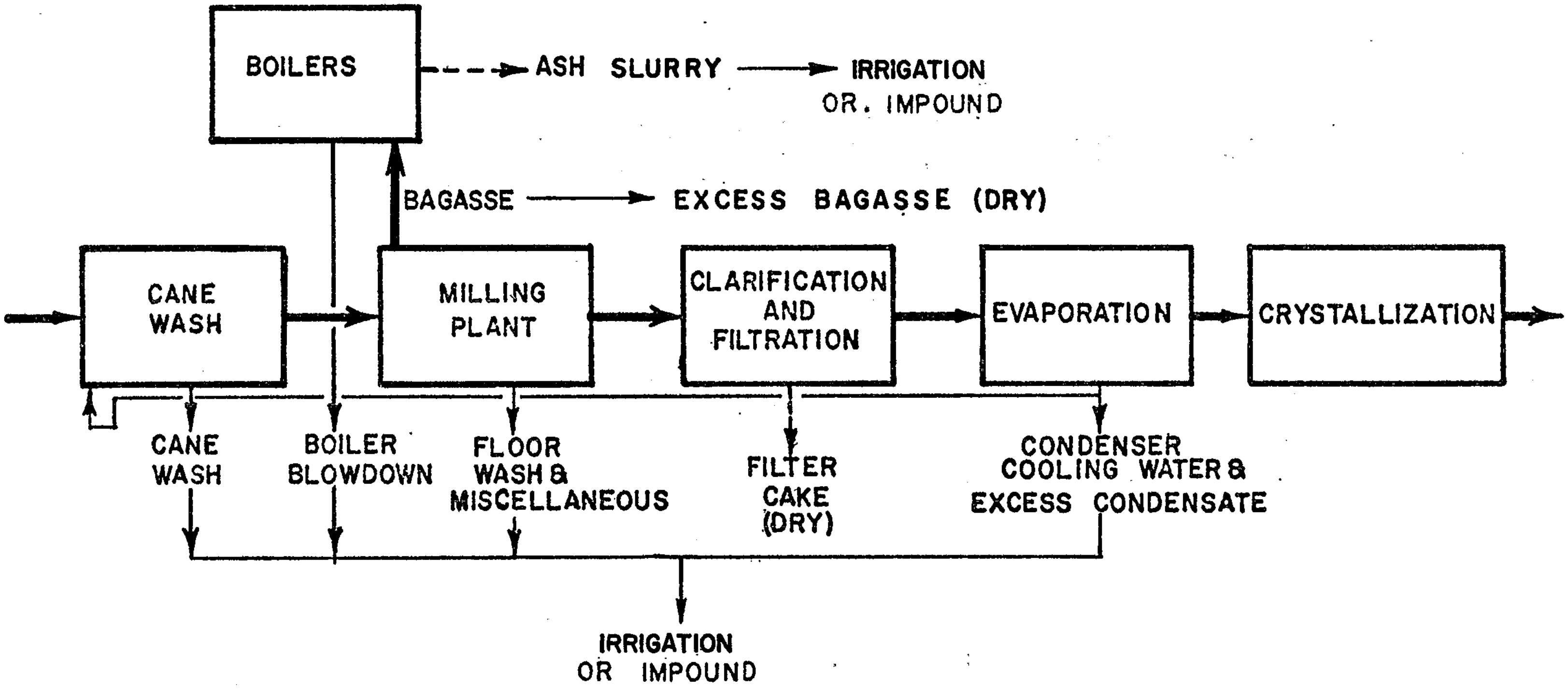


FIGURE 41

MODEL FACTORY FOR SUBCATEGORY IV

SECTION VIII

COST, ENERGY AND NON-WATER QUALITY ASPECTS

This section presents an evaluation of the costs, energy requirements, and non-water quality aspects associated with the treatment and control alternatives developed in Section VII in terms of the model processes and factories developed in Section V.

In absence of complete cost information for individual processes, the cost figures developed herein are based on reliable actual cost figures reported for various installations coupled with engineering estimates. An estimate completely applicable to all members of an entire industry is obviously impossible. For instance, it must be realized that land costs vary widely. Construction cost, in terms of both labor and material costs, is another element that is highly variable. The costs presented herein have been developed for the different industry subcategories, rather than the entire industry, thus reducing some of the variability expected in costs.

The following assumptions are common for all of the cost estimates in this section:

1. All costs are reported in August 1971 dollars.
2. Annual interest rate for capital cost is assumed at 8 percent.
3. All investment cost is depreciated over a period of twenty years except for trucks and bulldozers which are depreciated over ten years.
4. Salvage value is assumed to be zero at the end of the depreciation period.
5. Depreciation is straight line.
6. Total Yearly Cost = (Investment cost /2) (0.08) + Yearly Depreciation Cost + Yearly Operating Cost.

SUBCATEGORY I

A model factory representative of Subcategory I factories was developed in Section V for the purpose of applying various control and treatment alternatives which are applicable to reduce the resulting waste loadings from the model factory. Eight alternatives were selected in Section VII as being applicable engineering alternatives. These alternatives provide for various levels of waste reductions for the model factory, which grinds 2,730 metric tons (3,000 tons) of gross cane per day.

Cost and Reduction Benefits of Alternative Treatment and Control Technologies for Subcategory I

In developing the costs of the various control and treatment alternatives for Subcategory I, the following specific assumptions were made:

1. There are 70 grinding days per year.
2. Increasing evaporator vessels body height will not require reinforcing rings.
3. Pumping costs for a flow-through cane wash system are the same as for a recirculation system.
4. Contract labor is assumed at $12.25/hr.
5. Plant labor is assumed at $4.00/hr.
6. Excavation costs are assumed to be $1.67/cu.m ($1.26/cu.yd).
7. Clearing and grubbing are assumed to be $2,070/ha ($840/acre).
8. Grading costs are assumed to be $3,110/ha ($1,260/acre).
9. Embankment costs are assumed to be $1.67/cu.m ($1.26/cu.yd).
10. Dredging costs are assumed to be $0.67/cu.m ($0.51/cu.yd).
11. Truck loading costs are assumed to be $0.78/cu.m ($0.59/cu.yd).
12. Truck hauling is done on a contract basis and therefore no capital investment is required for trucks.
13. Truck hauling costs are assumed to be $0.40/cu.m - kilometer ($0.49/cu.yd - mile).
14. Truck hauling distances of from 2.41 to 16.1 kilometers (1.5 to 10 miles) per round trip are assumed.
15. Electrical costs are assumed to be $0.023 per kilowatt-hr.

Alternative A - This alternative assumes no added treatment and therefore no reduction in the waste loading. It is estimated that the effluent from a 2,730 metric tons (3000 tons) of gross cane per day factory is 45,800 cubic meters (12.1 million gallons) per day. The BOD_5 waste loading is 2.08 kilograms per metric ton (4.16 pounds per ton) of gross cane and the suspended solids loading is 17.56 kilograms per metric ton (35.1 pounds per ton) of gross cane.

Costs: 0
Reduction Benefits: None

Alternative B - This alternative consists of adding those in-plant modifications which may or may not be practiced at the individual factories which would enable a factory to attain the level of technology typified by the model factory. These procedures include the dry hauling or impoundage of filter mud, the dry hauling or impoundage of boiler ash, and the addition of entrainment controls for evaporators and vacuum pans. The following measures are taken to achieve a reduction in sucrose entrainment into barometric condenser cooling water:

- proper operation and good maintenance of entrainment controls
- improved baffling in evaporators and pans
- monitoring of barometric condenser cooling water
- increase vapor height in evaporators and pans
- addition of centrifugal separators to evaporators and pans
- addition of external separators for the last effect evaporators

Not all factories which experience high loses of sucrose into barometric condenser cooling water would have to employ all of the techniques listed above, but would in all probability utilize certain of these procedures.

The resulting BOD5 waste loading is 2.08 kilograms per metric ton (4.16 pounds per ton) of gross cane and the suspended solids loading is 17.56 kilograms per metric ton (35.1 pounds per ton) of gross cane.

Alternative B-1: Reduction of Entrainment into Barometric Condenser Cooling Water.

Costs: Incremental Investment Cost: $120,000
Incremental Yearly Cost: 27,800
Sugar and Molasses Savings: 41,200

Alternative B-2: Dry Hauling of Filter Cake.

Costs: Incremental Investment Cost: $37,800
Incremental Yearly Cost: 16,400

Alternative B-3: Impoundage of Filter Mud Slurry.

Costs: Incremental Investment Cost: $50,200
Incremental Yearly Cost: 8,900

Alternative B-4: Dry Hauling of Ash.

Costs: Incremental Investment Cost: $31,100
Incremental Yearly Cost: 8,600

Alternative B-5: Impoundage of Ash Slurry.

Costs:	Incremental Investment Cost:	$44,500
	Incremental Yearly Cost:	7,800

Itemized cost breakdowns for Alternatives B-1 through B-5 are presented in Tables 64 through 68.

Reduction Benefits: The reduction benefits for Alternative B involve BOD5 and suspended solids reductions to the levels typified by the model plant.

Alternative C - This alternative involves the use of sedimentation ponds to settle all of the waste water discharge streams except barometric condenser cooling water and excess condensate. The resulting BOD5 waste loading is 2.08 kilograms per metric ton (4.16 pounds per ton) of gross cane and the suspended solids loading is 2.51 kilograms per metric ton (5.02 pounds per ton) of gross cane.

Costs:	Incremental Investment Cost:	$ 75,700
	Incremental Yearly Cost:	26,200 - 64,600
	Total Investment Cost:	$75,700
	Total Yearly Cost:	26,200 - 64,600

An itemized cost breakdown for Alternative C is presented in Table 69.

Reduction Benefits: The reduction benefits for Alternative C involve a suspended solids reduction of 85.7 percent. The incremental reductions due to Alternative C are assumed to be 0.0 percent for BOD5 and 85.7 percent for suspended solids.

Alternative D - This alternative involves the treatment of the effluent from the settling pond, discussed in Alternative C, in an oxidation pond designed for total detention of the waste stream for the entire grinding season. The resulting BOD5 loading is expected to be less than 0.63 kilograms per metric ton (1.26 pounds per ton) of gross cane and the suspended solids loading is expected to be less than 0.47 kilograms per metric ton (0.94 pounds per ton) of gross cane.

Costs:	Incremental Investment Cost:	$383,000
	Incremental Yearly Cost:	47,200
	Total Investment Cost:	$459,000
	Total Yearly Cost	73,400 - 112,000

TABLE 64

ITEMIZED COST SUMMARY OF ALTERNATIVE B-1 FOR SUBCATEGORY I

Investment Costs

Items:	1.	Improved Baffling	$ 6,000
	2.	Monitoring Equipment	3,600
	3.	Increase Vapor Height	16,000
	4.	Centrifugal Separators For Evaporators	30,000
	5.	Centrifugal Separators For Pans	23,000
	6.	External Separators	20,000
	7.	Engineering	11,000
	8.	Contingencies	10,000
		Total Cost	$119,600

Operating Costs

Items:	1.	Operating and Maintenance	$ 17,000
		Total Cost	$ 17,000

Yearly Costs

Items:	1.	Operating Cost	$ 17,000
	2.	Investment Cost	4,780
	3.	Depreciation Cost	5,980
	4.	Annual Sugar and Molasses Savings	(41,200)
		Total Cost	$(13,400)

TABLE 65

ITEMIZED COST SUMMARY OF ALTERNATIVE B-2 FOR SUBCATEGORY I

Investment Costs			
Items:	1.	Mud Storage Bin	$ 26,900
	2.	Conveyor	10,900
		Total Cost	$ 37,800
Operating Costs			
Items:	1.	Operating & Maintenance	$ 13,000
		Total Cost	$ 13,000
Yearly Costs			
Items:	1.	Operating Cost	$ 13,000
	2.	Investment Cost	1,500
	3.	Depreciation Cost	1,900
		Total Cost	$ 16,400

TABLE 66

ITEMIZED COST SUMMARY OF ALTERNATIVE B-3 FOR SUBCATEGORY I

Investment Costs

Items:	1.	Pump, pipes, electrical	$ 12,000
	2.	Pond (Installed)	29,500
	3.	Contingencies	4,150
	4.	Engineering	4,570
		Total Cost	$ 50,200

Operating Costs

Items:	1.	Operating & Maintenance	$ 4,180
	2.	Power	180
		Total Cost	$ 4,360

Yearly Costs

Items:	1.	Operating Cost	$ 4,360
	2.	Investment Cost	2,000
	3.	Depreciation Cost	2,500
		Total Cost	$ 8,860

Land:	1.46 hectares

TABLE 67

ITEMIZED COST SUMMARY OF ALTERNATIVE B-4 FOR SUBCATEGORY I

Investment Costs			
Items:	1.	Ash Storage Bin	$ 20,200
	2.	Conveyor	10,900
		Total Cost	$ 31,100
Operating Costs			
Items:	1.	Operating & Maintenance	$ 5,800
		Total Cost	$ 5,800
Yearly Costs			
Items:	1.	Operating Cost	$ 5,800
	2.	Investment Cost	1,240
	3.	Depreciation Cost	1,560
		Total Cost	$ 8,600

TABLE 68

ITEMIZED COST SUMMARY OF ALTERNATIVE B-5 FOR SUBCATEGORY I

Investment Costs			
Items:	1.	Pump, pipes, electrical	$ 12,000
	2.	Pond (Installed)	24,800
	3.	Contingencies	3,680
	4.	Engineering	4,050
		Total Cost	$ 44,500
Operating Costs			
Items:	1.	Operating & Maintenance	$ 3,580
	2.	Power	180
		Total Cost	$ 3,760
Yearly Costs			
Items:	1.	Operating Cost	$ 3,760
	2.	Investment Cost	1,780
	3.	Depreciation Cost	2,230
		Total Cost	$ 7,770
Land:			1.22 hectares

TABLE 69

ITEMIZED COST SUMMARY OF ALTERNATIVE C FOR SUBCATEGORY I

Investment Costs			
Items:	1.	Ponds	$ 62,500
	2.	Contingencies	6,250
	3.	Engineering	6,900
		Total Cost	$ 75,650
Operating Costs			
Items:	1.	Maintenance	$ 840
	2.	Solids Handling	18,600 - 57,000
		Total Cost	$ 19,400 - 57,800
Yearly Costs			
Items:	1.	Operating Cost	$ 19,400 - 57,800
	2.	Investment Cost	3,030
	3.	Depreciation Cost	3,780
		Total Cost	$ 26,200 - 64,600
Land:			1.62 hectares

An itemized cost breakdown for Alternative D is presented in Table 70.

Reduction Benefits: The reduction benefits for Alternative D involve a BOD_5 reduction of greater than 69.7 percent and a suspended solids reduction of greater than 97.3 percent. The incremental reductions due to Alternative D are 69.7 percent for BOD_5 and 11.6 percent for suspended solids.

Alternative E - This alternative involves the treatment of the effluent from the settling pond, discussed in Alternative C, in an aerated lagoon designed with a quiescent zone and a total detention time of 9.5 days. The resulting BOD_5 loading is 0.63 kilograms per metric ton (1.26 pounds per ton) of gross cane and the suspended solids loading is 0.47 kilograms per metric ton (0.94 pounds per ton) of gross cane.

Costs:	Incremental Investment Cost:	$393,000
	Incremental Yearly Cost:	56,700
	Total Investment Cost:	$469,000
	Total Yearly Cost:	82,900 - 121,000

An itemized cost breakdown for Alternative E is presented in Table 71.

Reduction Benefits: The reduction benefits for Alternative E involve a BOD_5 reduction of 69.7 percent and a suspended solids reduction of 97.3 percent. The incremental reductions due to Alternative D are 69.7 percent for BOD_5 and 11.6 percent for suspended solids.

Alternative F - This alternative involves the use of a settling pond to settle and recycle the cane wash water. The blowdown from the recycle system is contained in an oxidation pond for the entire season and discharged after the season to assure waste stabilization. The resulting BOD_5 waste loading is 0.53 kilograms per metric ton (1.06 pounds per ton) of gross cane and the suspended solids loading is 0.080 kilograms per metric ton (0.16 pounds per ton) of gross cane.

Costs:	Incremental Investment Cost:	$199,000
	Incremental Yearly Cost:	58,500 - 104,000
	Total Investment Cost:	$199,000
	Total Yearly Cost:	58,500 - 104,000

An itemized cost breakdown for Alternative F is presented in Table 72.

TABLE 70

ITEMIZED COST SUMMARY OF ALTERNATIVE D FOR SUBCATEGORY I

Investment Costs

Items:	1.	Pond	$ 308,000
	2.	Pump, Sump and Piping	8,600
	3.	Contingencies	31,700
	4.	Engineering	34,800
		Total Cost	$ 383,100

Operating Costs

Items:	1.	Operation & Maintenance	$ 8,900
	2.	Chemical Cost	2,900
	3.	Power Cost	870
		Total Cost	$ 12,700

Yearly Costs

Items:	1.	Operating Cost	$ 12,700
	2.	Investment Cost	15,300
	3.	Depreciation Cost	19,200
		Total Cost	$ 47,200

Land:	83 hectares

TABLE 71

ITEMIZED COST SUMMARY OF ALTERNATIVE E FOR SUBCATEGORY I

Investment Costs

Items:	1.	Aerated Lagoon	$316,000
	2.	Pump, Sump and Piping	8,600
	3.	Contingencies	32,500
	4.	Engineering	35,700
		Total Cost	$393,000

Operating Costs

Items:	1.	Operation & Maintenance	$ 11,700
	2.	Chemical Cost	2,900
	3.	Power Cost	6,700
		Total Cost	$ 21,300

Yearly Costs

Items:	1.	Operating Cost	$ 21,300
	2.	Investment Cost	15,700
	3.	Depreciation Cost	19,700
		Total Cost	$ 56,700

Land:	5.3 hectares

TABLE 72

ITEMIZED COST SUMMARY OF ALTERNATIVE F FOR SUBCATEGORY I

Investment Costs		
Items:	1. Settling Ponds	$ 62,500
	2. Cane Wash Recycle System	60,700
	3. Oxidation Pond	41,600
	4. Contingencies	16,500
	5. Engineering	18,100
	Total Cost	$199,400
Operating Costs		
Items:	1. Settling Pond Maintenance	$ 22,900 - 68,600
	2. Cane Wash Recycle Maintenance	13,500
	3. Oxidation Pond Maintenance	3,400
	4. Power Cost	730
	Total Cost	$ 40,500 - 86,200
Yearly Costs		
Items:	1. Operating Cost	$ 40,500 - 86,200
	2. Investment Cost	8,000
	3. Depreciation Cost	10,000
	Total Cost	$ 58,500 -104,200
Land:		6.7 hectares

Reduction Benefits: The reduction benefits for Alternative F involve a BOD_5 reduction of 74.5 percent and a suspended solids reduction of 99.5 percent. The incremental reductions due to Alternative F are 74.5 percent for BOD_5 and 99.5 percent for suspended solids.

Alternative G - This alternative involves the recycle of barometric condenser cooling water and cane wash water. The blowdown from the barometric condenser cooling water recycle system is assumed to be the makeup to the cane wash recirculation system. The blowdown from the cane wash recirculation system and the miscellaneous waste streams are treated in an oxidation pond, designed with a detention time equivalent to the entire season, and discharged after stabilization. The resulting BOD_5 waste loading is 0.050 kilograms per metric ton (0.10 pounds per ton) of gross cane and the suspended solids loading is 0.080 kilograms per metric ton (0.16 pounds per ton) of gross cane.

Costs:	Incremental Investment Cost:	$389,000
	Incremental Yearly Cost:	92,200 - 138,000
	Total Investment Cost:	$389,000
	Total Yearly Cost:	92,200 - 138,000

An itemized cost breakdown for Alternative G is presented in Table 73.

Reduction Benefits: The reduction benefits for Alternative G involve a BOD_5 reduction of 97.6 percent and a suspended solids reduction of 99.5 percent. The incremental reductions due to Alternative G are 97.6 percent for BOD_5 and 99.5 percent for suspended solids.

Alternative H - This alternative involves the recycle of barometric condenser cooling water and cane wash water. The blowdown from the barometric condenser cooling water recirculation system is assumed to be the makeup to the cane wash recirculation system. The blowdown from the cane wash recirculation system and the miscellaneous waste streams are treated in two aerated lagoons operated in series, designed with a total detention time of 28 days and with a quiescent zone. The resulting BOD_5 waste loading is 0.050 kilograms per metric ton (0.10 pounds per ton) of gross cane and the suspended solids loading is 0.080 kilograms per metric ton (0.16 pounds per ton) of gross cane.

Costs:	Incremental Investment Cost:	$525,000
	Incremental Yearly Cost:	126,000 - 171,000
	Total Investment Cost:	$525,000
	Total Yearly Cost:	126,000 - 171,000

TABLE 73

ITEMIZED COST SUMMARY OF
ALTERNATIVE G FOR SUBCATEGORY I

Investment Costs

Items:	1.	Settling Ponds	$ 62,500
	2.	Cane Wash Recycle System	60,700
	3.	Barometric Condenser Cooling Water Recirculation System	155,000
	4.	Oxidation Pond	43,200
	5.	Contingencies	32,100
	6.	Engineering	35,400
		Total Cost	$388,900

Operating Costs

Items:	1.	Settling Pond Maintenance	$ 22,900 - 68,600
	2.	Cane Wash Recycle Maintenance	13,500
	3.	Condenser Recirculation Maintenance & Operation	10,700
	4.	Oxidation Pond Maintenance	3,400
	5.	Power Cost	6,700
		Total Cost	$ 57,200 - 102,900

Yearly Costs

Items:	1.	Operating Cost	$ 57,200 - 102,900
	2.	Investment Cost	15,600
	3.	Depreciation Cost	19,400
		Total Cost	$ 92,200 - 137,900

Land:	7.1 hectares

An itemized cost breakdown for Alternative H is presented in Table 74.

Reduction Benefits: The reduction benefits for Alternative H involve a BOD_5 reduction of 97.6 percent and a suspended solids reduction of 99.5 percent. The incremental reductions due to Alternative H are 97.6 percent for BOD_5 and 99.5 percent for suspended solids.

A summary of the costs for all of the alternatives is presented in Table 75.

Related Energy Requirements of Alternative Treatment and Control Technologies for Subcategory I

Table 76 illustrates the estimated energy requirements for the application of the various treatment alternatives to the Subcategory I model factory. Energy requirements in the form of electrical energy needed for the operation of pumps, aerators, and spray nozzels, and the energy required for the disposal of solid wastes is compared to the overall energy requirements of the model factory. In order to place the energy requirements of the various alternatives in proper perspective, it should be noted that a typical 2,730 metric tons (3,000 tons) of gross cane per day factory consumes 3.15 million kilowatt-hours of electricity per year and requires 110 million kilograms (242 million pounds) of steam per year. In the estimate of total factory energy requirements, no allowance was made for usage of fuel associated with the harvesting and transportation of sugarcane. Therefore, the percentage increases in energy requirements presented in Table 76 are considered to be the maximum requirements for the application of the various treatment alternatives at the model factory.

As shown in Table 76, the two major uses of energy resulting from the application of the various treatment alternatives by Subcategory I factories are the recirculation of barometric condenser cooling water and the use of aerated lagoons as a treatment method. Alternatives E, G, and H require substantially greater energy usage than the other alternatives. Of these alternatives, Alternative H employs both a barometric condenser cooling water recirculation system and an aerated lagoon and would be the largest user of energy.

SUBCATEGORY II

A model factory representative of Subcategory II factories was developed in Section V and existing control and treatment was established and considered as part of the model plant because of its universal practice. As a result, it was concluded in Section VII that

TABLE 74

ITEMIZED COST SUMMARY OF ALTERNATIVE H FOR SUBCATEGORY I

Investment Costs

Items:	1.	Settling Ponds	$ 62,500
	2.	Cane Wash Recycle System	60,700
	3.	Barometric Condenser Cooling Water Recirculation System	155,000
	4.	Aerated Lagoon	155,700
	5.	Contingencies	43,400
	6.	Engineering	47,700
		Total Cost	$525,000

Operating Costs

Items:	1.	Settling Pond Maintenance	$ 22,900 - 68,600
	2.	Cane Wash Recycle Maintenance	13,500
	3.	Condenser Recirculation Maintenance & Operation	10,700
	4.	Aerated Lagoon Maintenance & Operation	12,700
	5.	Power Requirements	18,600
		Total Cost	$ 78,400 - 124,100

Yearly Costs

Items:	1.	Operating Cost	$ 78,400 - 124,100
	2.	Investment Cost	21,000
	3.	Depreciation Cost	26,300
		Total Cost	$125,700 - 171,400

Land: 2.8 hectares

TABLE 75

SUMMARY OF ALTERNATIVE COSTS
MODEL PLANT -- SUBCATEGORY I

Alternative	BOD5 Loading* (kg/kkg)	TSS Loading* (kg/kkg)	Total Investment Cost	Total Yearly Cost
A	2.08	17.56	$ 0	$0
B	2.08	17.56	189,000	11,600
C	2.08	2.51	75,700	26,200- 64,600
D	0.63	0.47	459,000	73,400-112,000
E	0.63	0.47	469,000	82,900-121,000
F	0.53	0.080	199,000	58,500-104,000
G	0.050	0.080	389,000	92,200-138,000
H	0.050	0.080	525,000	126,000-171,000

*Gross Cane Basis.

TABLE 76

YEARLY ENERGY USAGE FOR MODEL FACTORY SUBCATEGORY I

Alternative	Power Usage (kw-hr/yr)	Gasoline Usage (liters/yr)	Percent of Total Energy Requirement
A	0	0	0%
B-1	0	0	0
B-2	0	3,310	0.035
B-3	7,830	0	0.021
B-4	0	1,060	0.011
B-5	7,830	0	0.021
C	0	3,310-22,100	0.035-0.23
D	37,800	3,310-22,100	0.14 -0.33
E	291,000	3,310-22,100	0.84 -1.06
F	31,700	3,970-26,500	0.13 -0.36
G	291,000	3,970-26,500	0.84 -1.07
H	809,000	3,970-26,500	2.24 -2.47

the model factory attains a certain level of treatment and that no significant reduction benefits can be achieved by the application of control and treatment schemes.

Cost and Reduction Benefits of Alternative Treatment and Control Alternatives for Subcategory II

For the model factory developed as representative of Subcategory II, it is concluded that no further control and treatment is required to achieve a zero discharge limitation and therefore no additional costs of control and treatment are incurred.

Related Energy Requirements of Alternative Treatment and Control Technologies for Subcategory II

Since no further control and treatment is required, no added energy requirements are incurred.

SUBCATEGORY III

A model factory representative of Subcategory III factories was developed in Section V for the purpose of applying various control and treatment alternatives which are available to reduce the resulting waste loadings from the model factory. Eight alternatives were selected in Section VII as being applicable engineering alternatives. These alternatives provide for various levels of waste reductions for the model factory, which grinds 3,340 metric tons (3,675 tons) of net cane per day or 6,680 metric tons (7,350 tons) of gross cane per day.

Cost and Reduction Benefits of Alternative Treatment and Control Technologies for Subcategory III

In developing the costs of the various control and treatment alternatives for Subcategory III, the following specific assumptions were made:

1. There are 250 grinding days per year.

2. Plant labor is assumed to be $5.88/hr.

3. Excavation and the costs associated with construction of impoundments is assumed to be $3.30/cu.m ($2.52/cu.yd).

4. Truck hauling is done in-house.

5. The cost of operating trucks is assumed to be $0.13/kilometer ($0.21/mi).

6. A truck hauling distance of 16.1 kilometers (10 miles) is assumed.

7. Disposal of muds and ash on land is to a depth of 1.22 meters (four feet) and, if cane fields are employed for this purpose, it puts land out of service for three years.

8. Disposal of trash on land is to a depth of 1.5 meters (5 feet) and, if cane fields are used for this purpose, it puts land out of service for five years.

9. Cane fields used for disposal of solid waste are leased at $622/ha ($252/acre).

10. Electrical costs are assumed to be $0.023 per kilowatt-hr.

11. All investment costs include engineering and contingencies.

Alternative A - This alternative assumes no treatment and therefore no reduction in the waste loadings. It is estimated that the effluent from a 3,340 metric ton (3,675 tons) of net cane per day factory is 42,300 cubic meters (11.2 million gallons) per day. The BOD$_5$ raw waste loading is 12.3 kilograms per metric ton (24.6 pounds per ton) of net cane and the suspended solids raw waste loading is 194 kilograms per metric ton (388 pounds per ton) of net cane.

Costs: 0
Reduction Benefits: 0

Should an individual factory not attain that degree of control of entrainment of sucrose into barometric condenser cooling water which is exhibited by the model factory, a reduction of BOD$_5$ entrainment into barometric condenser cooling water is necessary. This can be accomplished by the following procedures:

- Good maintenance and proper operation
- Monitoring of barometric condenser cooling water
- Addition of centrifugal separators to the evaporators and vacuum pans
- Addition of external separators to the evaporators

The addition of these control measures allows for a reduction in the amount of BOD$_5$ discharged to those levels typified by the model factory. The reduction of BOD$_5$ into the barometric condenser cooling water increases sucrose and molasses production.

Alternative A-1: Reduction of Entrainment into Barometric Condenser Cooling Water.

Costs: Incremental Investment Cost: $117,900
Incremental Yearly Cost: 37,500
Sugar and Molasses Savings: 24,700

An itemized cost breakdown for Alternative A-1 is presented in Table 77.

Reduction Benefits: The reduction benefits for Alternative A involve reductions in the raw waste loadings to that level typified by the model factory.

Alternative B: This alternative involves the use of in-plant modifications to allow for the filter cake, boiler ashes, and trash to be dry-hauled. This alternative consists of the following in-plant modifications: (a) B-1: dry hauling of filter cake, (b) B-2: dry hauling of boiler ash, and (c) B-3: screening and hauling of trash.

The resulting BOD5 waste loading is 10.0 kilograms per metric ton (20.0 pounds per ton) of net cane and the suspended solids loading is 170 kilograms per metric ton (340 pounds per ton) of net cane.

Alternative B-1: Dry Hauling of Filter Cake.

Costs: Incremental Investment Cost: $112,000
Incremental Yearly Cost: 41,800

Alternative B-2: Dry Hauling of Boiler Ash.

Costs: Incremental Investment Cost: $112,000
Incremental Yearly Cost: 41,800

Alternative B-3: Screening and Hauling of Trash.

Costs: Incremental Investment Cost: $386,000
Incremental Yearly Cost: 196,000

An itemized cost breakdown for Alternative B is presented in Tables 78 through 80.

Reduction Benefits: The reduction benefits for Alternative B involve a BOD5 reduction of 18.7% and a suspended solids reduction of 12.4%.

Alternative C - This alternative involves clarification of the cane wash water and miscellaneous waste streams, employing polymer addition. No BOD5 removal is assumed although removals on the order of ten to twenty percent would be expected to occur. The resulting BOD5 waste loading is 10.0 kilograms per metric ton (20.0 pounds per ton) of net cane and the suspended solids loading is 2.1 kilograms per metric ton (4.2 pounds per ton) of net cane.

Costs: Incremental Investment Cost: $1,594,000
Incremental Yearly Cost: 555,000

TABLE 77

ITEMIZED COST SUMMARY OF ALTERNATIVE A-1 FOR SUBCATEGORY III

Investment Costs			
Items:	1.	Monitoring Equipment	$ 5,540
	2.	Centrifugal Separators for Evaporators	45,800
	3.	Centrifugal Separators for Pans	35,100
	4.	External Separators	30,500
		TOTAL COST	$116,900
Operating Costs			
Items:	1.	Operating & Maintenance	$ 27,000
		TOTAL COST	$ 27,000
Yearly Costs			
Items:	1.	Operating Cost	$ 27,000
	2.	Investment Cost	4,680
	3.	Depreciation Cost	5,850
	4.	Annual Sugar & Molasses	(24,700)
		TOTAL COST	$ 12,800

TABLE 78

ITEMIZED COST SUMMARY OF ALTERNATIVE B-1 FOR SUBCATEGORY III

Investment Costs		
Items:	1. Mud Storage Bin	$ 50,400
	2. Conveyor	10,900
	3. Truck (1)	50,400
	Total Cost	$111,700
Operating Costs		
Items:	1. Labor	$ 23,500
	2. Operation & Maintenance	7,400
	Total Cost	$ 30,900
Yearly Costs		
Items:	1. Operating Cost	$ 30,900
	2. Investment Cost	2,790
	3. Depreciation Cost	8,110
	Total Cost	$ 41,800
Land:		$0-7,400/yr.

TABLE 79

ITEMIZED COST SUMMARY OF ALTERNATIVE B-2 FOR SUBCATEGORY III

Investment Costs

Items:	1.	Mud Storage Bin	$ 50,400
	2.	Conveyor	10,900
	3.	Truck (1)	50,400
		Total Cost	$111,700

Operating Costs

Items:	1.	Labor	$ 23,500
	2.	Operation & Maintenance	7,400
		Total Cost	$ 30,900

Yearly Costs

Items:	1.	Operating Cost	$ 30,900
	2.	Investment Cost	2,790
	3.	Depreciation Cost	8,110
		Total Cost	$ 41,800

Land: $0-7,400/yr.

TABLE 80

ITEMIZED COST SUMMARY OF ALTERNATIVE B-3 FOR SUBCATEGORY III

Investment Costs

Items:	1.	Screens	$ 42,000
	2.	Tractors & Trailers (3)	277,000
	3.	Bulldozer	67,200
		Total Cost	$386,000

Operating Costs

Items:	1.	Labor	$118,000
	2.	Operation & Maintenance	32,200
		Total Cost	$150,000

Yearly Costs

Items:	1.	Operating Cost	$150,000
	2.	Investment Cost	9,700
	3.	Depreciation Cost	36,300
		Total Cost	$196,000

Land:	$0-88,500/yr.

Total Investment Cost:	$2,200,000
Total Yearly Cost:	835,000

An itemized cost breakdown for Alternative C is presented in Table 81.

Reduction Benefits: The reduction benefits for Alternative C involve a BOD$_5$ reduction of 18.7 percent and a suspended solids reduction of 98.9 percent. The incremental reductions due to Alternative C are 0.0 percent for BOD$_5$ and 86.5 percent for suspended solids.

Alternative D - This alternative involves the treatment of the settled wastes in an aerated lagoon. The resulting BOD$_5$ waste loading is 0.83 kilograms per metric ton (1.63 pounds per ton) of net cane and the suspended solids loading is 1.1 kilograms per metric ton (2.2 pounds per ton) of net cane.

Costs:	Incremental Investment Cost:	$1,180,000
	Incremental Yearly Cost:	336,000
	Total Investment Cost:	$3,380,000
	Total Yearly Cost:	1,170,000

An itemized cost breakdown for Alternative D is presented in Table 82.

Reduction Benefits: The reduction benefits for Alternative D involve a BOD$_5$ reduction of 93.3 percent and a suspended solids reduction of 99.4 percent. The incremental reductions due to Alternative D are 74.6 percent for BOD$_5$ and 0.5 percent for suspended solids.

Alternative E - This alternative involves the treatment of the settled effluent in an activated sludge system. The resulting BOD$_5$ waste loading is 0.57 kilograms per metric ton (1.14 pounds per ton) of net cane, and the suspended solids loading is 0.61 kilograms per metric ton (1.22 pounds per ton) of net cane.

Costs:	Incremental Investment Cost:	$2,760,000
	Incremental Yearly Cost:	686,000
	Total Investment Cost:	$4,960,000
	Total Yearly Cost:	1,520,000

An itemized cost breakdown for Alternative E is presented in Table 83.

Reduction Benefits: The reduction benefits for Alternative E involve a BOD$_5$ reduction of 95.4 percent and a

TABLE 81

ITEMIZED COST SUMMARY OF ALTERNATIVE C FOR SUBCATEGORY III

Investment Costs			
Items:	1.	Grit Removal	$ 42,000
	2.	Raw Water Pumps & Wet Wells	44,000
	3.	Polymer Feeding System	37,000
	4.	Heavy Duty Thickener	328,000
	5.	Vacuum Filters (8)	941,000
	6.	Trucks (4)	202,000
		Total Cost	$1,594,000
Operating Costs			
Items:	1.	Secondary Screen Maintenance	$ 840
	2.	Raw Waste Pumps	22,000
	3.	Polymer & Polymer Feed System	54,600
	4.	Thickener Maintenance	3,300
	5.	Vacuum Filters	
		Maintenance	47,000
		Labor	70,600
	6.	Trucks	
		Operation & Maintenance	37,600
		Truck Labor	129,400
	7.	Plant Labor	35,300
		Total Cost	$401,000
Yearly Cost			
Items:	1.	Operating Cost	$401,000
	2.	Investment Cost	63,800
	3.	Depreciation	89,800
		Total Cost	$555,000
Land:			$0-41,700/yr.

TABLE 82

ITEMIZED COST SUMMARY OF ALTERNATIVE D FOR SUBCATEGORY III

Investment Costs

Items:	1.	Aerated Lagoons	$ 941,000
	2.	Pump, Sump, Piping	31,600
	3.	Contingencies	97,300
	4.	Engineering	107,000
		Total Cost	$1,177,000

Operating Costs

Items:	1.	Operating & Maintenance	$ 53,900
	2.	Chemical Cost	60,800
	3.	Power Cost	115,600
		Total Cost	$ 230,000

Yearly Costs

Items:	1.	Operating Cost	$ 230,000
	2.	Investment Cost	47,100
	3.	Depreciation	58,900
		Total Cost	$ 336,000

Land:	$0-6,600/yr.

TABLE 83

ITEMIZED COST SUMMARY OF ALTERNATIVE E FOR SUBCATEGORY III

Investment Costs			
Items:	1.	Activated Sludge System	$2,520,000
	2.	Miscellaneous Costs	244,000
		Total Cost	$2,760,000
Operating Costs			
Items:	1.	Operation & Maintenance of Activated Sludge System	$ 249,000
	2.	Power Costs	189,000
		Total Cost	$ 438,000
Yearly Costs			
Items:	1.	Operating Cost	$ 438,000
	2.	Investment Cost	110,000
	3.	Depreciation	138,000
		Total Cost	$ 686,000
Land:			$0-1,500/yr.

suspended solids reduction of 99.7 percent. The incremental reductions due to Alternative E are 76.7 percent for BOD5 and 0.8 percent for suspended solids.

Consideration of the Use of Advanced Harvesting Systems

As discussed in Section VII, considerable research and development are being accomplished at the present time with regard to the usage of advanced harvesting systems capable of delivering sugarcane to the factory mills which can be processed without the necessity of a washing step. It is expected that such a system will be employed at the Subcategory III factories between 1977 and 1983, and will enable an individual factory to eliminate the portion of the cane wash water stream currently associated with that fraction (x) of the net sugarcane which would be harvested by the advanced systems. A further assumption is that the same unit waste loadings as developed for the cane wash water discharge stream from the model factory are applicable to that portion of the net sugarcane which is not harvested by the advanced systems.

The following treatment alternatives include the aforementioned assumption that a fraction (x) of the net sugarcane processed at a factory is harvested by the advanced harvesting systems. The following cost analysis assumes that 70% of the net sugarcane harvested is harvested by the advanced harvesting systems.

Alternative F - This alternative involves the assumption that Subcategory III factories will have employed the currently developed technology cf improved cane harvesting systems. For the purpose of developing costs considered to be representative of this subcategory, it has been assumed that 70% of the net sugarcane is harvested with the advanced systems. Alternative F involves the biological treatment of the settled discharge stream in an aerated lagoon. The resulting BOD5 waste loading is 0.50 kilograms per metric ton (1.0 pounds per ton) of net cane and the suspended solids loading is 0.31 kilograms per metric ton (0.62 pounds per ton) of net cane.

Costs:	Incremental Investment Cost:	$447,000
	Incremental Yearly Cost:	119,000

An itemized cost breakdown for Alternative F is presented in Table 84.

Reduction Benefits: The reduction benefits for Alternative F involve a BOD5 reduction of 95.9 percent and a suspended solids reduction of 99.8 percent.

Alternative G - This alternative involves similar assumptions with regard to the model plant as Alternative F. Alternative G involves a

TABLE 84

ITEMIZED COST SUMMARY OF ALTERNATIVE F FOR SUBCATEGORY III

Investment Costs

Items:	1.	Aerated Lagoons	$ 349,000
	2.	Pump, Sump, and Piping	20,200
	3.	Contingencies	36,900
	4.	Engineering	40,600
		Total Cost	$ 446,700

Operating Costs

Items:	1.	Operation & Maintenance	$ 23,900
	2.	Chemical Costs	18,500
	3.	Power Costs	35,900
		Total Cost	$ 78,300

Yearly Costs

Items:	1.	Operating Cost	$ 78,300
	2.	Investment Cost	17,900
	3.	Depreciation	22,300
		Total Cost	$ 118,500

Land: $0-1,760/yr.

cane wash water recirculation system with discharge of the settled twenty percent blowdown and miscellaneous waste water discharge stream to an aerated lagoon. The resulting BOD_5 waste loading is 0.39 kilograms per metric ton (0.78 pounds per ton) of net cane and the suspended solids loading is 0.071 kilograms per metric ton (0.142 pounds per ton) of net cane.

Costs:	Incremental Investment Cost:	$473,000
	Incremental Yearly Cost:	205,000

An itemized cost breakdown for Alternative G is presented in Table 85.

Reduction Benefits: The reduction benefits for Alternative G involve a BOD_5 reduction of 96.8 percent and a suspended solids reduction of 99.9 percent.

Alternative H - This alternative involves similar assumptions with regard to the model plant as Alternative F. Alternative H incorporates the addition of a barometric condenser cooling water recirculation system with discharge of the blowdown to the cane wash water system, and the addition of a biological system in the form of an aerated lagoon to treat the settled cane wash water and other discharge streams. The resulting BOD_5 waste loading is 0.23 kilograms per metric ton (0.47 pounds per ton) of net cane and the suspended solids loading is 0.31 kilograms per metric ton (0.62 pounds per ton) of net cane.

Costs:	Incremental Investment Cost:	$582,000
	Incremental Yearly Cost:	157,000

An itemized cost breakdown for Alternative H is presented in Table 86.

Reduction Benefits: The reduction benefits for Alternative H involve a BOD_5 reduction of 98.1 percent and a suspended solids reduction of 99.8 percent.

An assumption which significantly affects the calculation of the costs of pollution abatement to Subcategory III factories involves the choice of a method of disposing of solid wastes on the land. Information presented in Tables 77 through 86 includes a range of costs associated with land usage. At least three distinct alternatives exist. One alternative would be to assume that existing cane fields are taken out of production for varying periods of time for the purpose of pollution abatement facilities or for the application of solid wastes. The upper range of values presented in Tables 77 through 86 assumes that cropland is taken out of production (based on the assumptions presented previously in this section) and assigns a cost for the leasing of this land.

TABLE 85

ITEMIZED COST SUMMARY OF ALTERNATIVE G FOR SUBCATEGORY III

Investment Costs

Items:	1.	Aerated Lagoons	$ 246,000
	2.	Pump, Sump, and Piping	20,200
	3.	Cane Wash Recirculation System	53,000
	4.	Lime Feed & Storage	71,400
	5.	Contingencies	39,100
	6.	Engineering	43,000
		Total Cost	$ 472,700

Operating Costs

Items:	1.	Aerated Lagoons O&M	$ 18,800
	2.	Cane Wash Recirculation System O&M	23,400
	3.	Chemical Costs	84,300
	4.	Power Costs	35,900
		Total Cost	$ 162,000

Yearly Costs

Items:	1.	Operating Cost	$ 162,000
	2.	Investment Cost	18,900
	3.	Depreciation	23,600
		Total Cost	$ 205,000

Land: $0-1,010/yr.

TABLE 86

ITEMIZED COST SUMMARY OF ALTERNATIVE H FOR SUBCATEGORY III

Investment Costs			
Items:	1.	Aerated Lagoons	$ 362,000
	2.	Pump, Sump, and Piping	20,200
	3.	Barometric Condenser Cooling Water Recirculation System	98,300
	4.	Contingencies	48,100
	5.	Engineering	52,900
		Total Cost	$ 582,000
Operating Costs			
Items:	1.	Aerated Lagoons O&M	$ 24,600
	2.	B.C.C.W. Recirculation System O&M	7,980
	3.	Chemical Costs	24,100
	4.	Power Costs	47,800
		Total Cost	$ 104,500
Yearly Costs			
Items:	1.	Operating Cost	$ 104,500
	2.	Investment Cost	23,300
	3.	Depreciation	29,100
		Total Cost	$ 157,000
Land:			$0-2,270/yr.

The lower range of costs corresponds to a second alternative that, either: (1) land exists for pollution abatement purposes; (2) solid wastes are disposed on land which is not suitable for growing cane, such as rocky ground, dry gulches, or other unsuitable areas; or (3) solid waste at low application rates is disposed on fields which are to be plowed for new planting. This alternative would not involve the incapacitation of cultivated cane growing areas and therefore, would involve no cost associated with the leasing of land. It is possible that with the proper planning and management, this alternative could result in the reclamation of otherwise unsuitable land areas for use as cropland. No credit has been given in this section for added value associated with the reclamation of land.

The third alternative would include a combination of the above two alternatives with some cropland being taken out of production. Based on the assumptions presented previously in this section, the costs associated with this alternative would lie within the range of values presented in Tables 77 through 86.

A summary of the costs for all of the various alternatives is presented in Table 87.

Related Energy Requirements of Alternative Treatment and Control Technologies for Subcategory III

Table 88 illustrates the estimated energy requirements for the application of the various treatment alternatives to the Subcategory III model factory. Energy requirements in the form of electrical energy needed for the operation of pumps, aerators, and spray nozzels, and the energy required for the disposal of solid wastes is compared to the overall energy requirements of the model factory. In order to place the energy requirements of the various alternatives in proper perspective, it should be noted that a typical 3,340 metric tons (3,675 tons) of net cane per day factory consumes 3.6 million kilowatt-hours of electricity per year and requires 393 million kilograms (864 million pounds) of steam per year. In the estimate of total factory energy requirements, no allowance was made for usage of fuel associated with the harvesting and transportation of sugarcane. Therefore, the percentage increases in energy requirements presented in Table 88 are considered to be the maximum requirements for the application of the various treatment alternatives at the model factory.

As shown in Table 88, the major uses of energy resulting from the application of the various alternatives by Subcategory III factories are aerated lagoons, activated sludge systems, and barometric condenser cooling water recirculation systems. The highest energy use alternatives are Alternatives D, E, F, G, and H which employ at least one of these three higher energy demanding treatment techniques.

TABLE 87

SUMMARY OF ALTERNATIVE COSTS
MODEL FACTORY -- SUBCATEGORY III

Alternative	BOD5 Loading* (kg/kkg)	TSS Loading* (kg/kkg)	Total Investment Cost	Total Yearly Cost
A	12.3	194	$ 118,000	$ 12,800
B	10.0	170	610,000	280,000
C	10.0	2.1	2,200,000	835,000
D	0.83	1.1	3,380,000	1,170,000
E	0.57	0.61	4,960,000	1,520,000
F	0.50	0.31	447,000**	119,000**
G	0.39	0.071	473,000**	205,000**
H	0.23	0.31	582,000**	157,000**

*Net Cane Basis.
**Incremental, rather than total costs.

TABLE 88

YEARLY ENERGY USAGE FOR MODEL FACTORY SUBCATEGORY III

Alternative	Power Usage (kw-hr/yr)	Gasoline Usage (liters/yr)	Percent of Total Energy Requirement
A	0	0	0%
A-1	0	0	0
B-1	0	40,900	0.125
B-2	0	40,900	0.125
B-3	0	189,000	0.58
C	787,000	498,000	2.16
D	5,030,000	498,000	5.63
E	8,220,000	521,000	8.23
F	1,560,000	339,000	2.28
G	1,560,000	339,000	2.28
H	2,080,000	339,000	2.75

SUBCATEGORY IV

A model factory representative of Subcategory IV factories was developed in Section V and existing control and treatment was established and considered as part of the model plant because of its universal practice. As a result it was concluded in Section VII that the model factory attains a certain level of treatment and that no significant reduction benefits can be achieved by the application of control and treatment schemes.

Cost and Reduction Benefits of Alternative Treatment and Control Alternatives for Subcategory IV

For the model factory developed as representative of Subcategory IV, it is concluded that no further control and treatment is required to achieve a zero discharge limitation and therefore no additional costs of control and treatment are incurred.

Related Energy Requirements of Alternative Treatment and Control Technologies for Subcategory IV

Since no further control and treatment is required, no added energy requirements are incurred.

SUBCATEGORY V

The model factory representative of Subcategory V factories was developed in Section V and is similar in nature to the model factory representative of Subcategory I factories. The same eight control and treatment alternatives selected to be applied to the Subcategory I model factory are selected as being applicable engineering alternatives and are selected to be applied to the Subcategory V model factory.

Cost and Reduction Benefits of Alternative Treatment and Control Technologies

In developing the costs of the various control and treatment alternatives for Subcategory V, the following specific assumptions were made:

1. All costs are based on those developed for Subcategory I with changes listed below.

2. There are 120 grinding days per year.

Alternative A - This alternative assumes no added treatment and therefore no reduction in the waste load. It is estimated that the effluent from a 2,730 metric tons (3,000 tons) of gross cane per day factory is 45,800 cubic meters (12.1 million gallons) per day. The BOD5 waste loading is 2.08 kilograms per metric ton (4.16 pounds per ton) of gross cane and the suspended solids loading is 17.56 kilograms per metric ton (35.1 pounds per ton) of gross cane.

Costs: 0
Reduction Benefits: None

Alternative B - This alternative consists of adding those in-plant modifications which may or may not be practiced at the individual factories which would enable a factory to attain the level of technology typified by the model factory. These procedures include the dry hauling or impoundage of filter mud, the dry hauling or impoundage of ash, and the addition of entrainment controls for evaporators and vacuum pans. The following measures are taken to achieve a reduction in sucrose entrainment into barometric condenser cooling water:

- proper operation and good maintenance of entrainment controls
- improved baffling in evaporators and pans
- monitoring of barometric condenser cooling water
- increase vapor height in evaporators and pans
- addition of centrifugal separators to evaporators and pans
- addition of external separators for the last effect evaporators

Not all factories which experience high loses of sucrose into barometric condenser cooling water would have to employ all of the techniques listed above, but would in all probability utilize certain of these procedures. The resulting BOD5 waste loading is 2.08 kilograms per metric ton (4.16 pounds per ton) of gross cane and the suspended solids loading is 17.56 kilograms per metric ton (35.1 pounds per ton) of gross cane.

Alternative B-1: Reduction of Entrainment into Barometric Condenser Cooling Water.

Costs:	Incremental Investment Cost:	$120,000
	Incremental Yearly Cost:	28,200
	Sugar and Molasses Savings:	70,700

Alternative B-2: Dry Hauling of Filter Cake.

Costs:	Incremental Investment Cost:	$37,800
	Incremental Yearly Cost:	26,100

Alternative B-3: Impoundage of Filter Mud Slurry.

Costs:	Incremental Investment Cost:	$65,700
	Incremental Yearly Cost:	13,400

Alternative B-4: Dry Hauling of Ash.

Costs:	Incremental Investment Cost:	$31,100
	Incremental Yearly Cost:	12,500

Alternative B-5: Impoundage of Ash Slurry.

Costs:	Incremental Investment Cost:	$57,500
	Incremental Yearly Cost:	11,600

Itemized cost breakdowns for Alternatives B-1 through B-5 are presented in Tables 89 through 93.

Reduction Benefits: The reduction benefits for Alternative B involve BOD$_5$ and suspended solids reductions to the levels typified by the model plant.

Alternative C - This alternative involves the use of sedimentation ponds to settle all of the waste water streams except barometric condenser cooling water and excess condensate. The resulting BOD$_5$ waste loading is 2.08 kilograms per metric ton (4.16 pounds per ton) of gross cane and the suspended solids loading is 2.51 kilograms per metric ton (5.02 pounds per ton) of gross cane.

Costs:	Incremental Investment Cost		$ 75,700
	Incremental Yearly Cost	40,000 -	106,000
	Total Investment Cost		$75,700
	Total Yearly Cost	40,000 -	106,000

An itemized cost breakdown for Alternative C is presented in Table 94.

Reduction Benefits: The reduction benefits for Alternative C involve a suspended solids reduction of 85.7 percent. The incremental reductions due to Alternative C are assumed to be 0.0 percent for BOD$_5$ and 85.7 percent for suspended solids.

Alternative D - This alternative involves the treatment of the effluent from the settling pond, discussed in Alternative C, in an oxidation pond designed for total detention of the waste stream for the entire grinding season. The resulting BOD$_5$ loading is expected to be less than 0.63 kilograms per metric ton (1.26 pounds per ton) of gross cane and the suspended solids loading is expected to be less than 0.47 kilograms per metric ton (0.94 pounds per ton) of gross cane.

Costs:	Incremental Investment Cost:	$ 590,000
	Incremental Yearly Cost:	74,600

TABLE 89

ITEMIZED COST SUMMARY OF ALTERNATIVE B-1 FOR SUBCATEGORY V

Investment Costs			
Items:	1.	Improved Baffling	$ 7,300
	2.	Monitoring Equipment	4,400
	3.	Increase Vapor Height	19,400
	4.	Centrifugal Separators For Evaporators	36,300
	5.	Centrifugal Separators For Pans	28,000
	6.	External Separators	24,200
		Total Cost	$119,600
Operating Costs			
Items:	1.	Operating and Maintenance	$ 17,400
		Total Cost	$ 17,400
Yearly Costs			
Items:	1.	Operating Cost	$ 17,400
	2.	Investment Cost	4,780
	3.	Depreciation Cost	5,980
	4.	Annual Sugar and Molasses Savings	(70,700)
		Total Cost	$(42,500)

TABLE 90

ITEMIZED COST SUMMARY OF ALTERNATIVE B-2 FOR SUBCATEGORY V

Investment Costs			
Items:	1.	Mud Storage Bin	$ 26,900
	2.	Conveyor	10,900
		Total Cost	$ 37,800
Operating Costs			
Items:	1.	Operating & Maintenance	$ 22,700
		Total Cost	$ 22,700
Yearly Costs			
Items:	1.	Operating Cost	$ 22,700
	2.	Investment Cost	1,500
	3.	Depreciation Cost	1,900
		Total Cost	$ 26,100

TABLE 91

ITEMIZED COST SUMMARY OF ALTERNATIVE B-3 FOR SUBCATEGORY V

Investment Costs

Items:	1. Pump, pipes, electrical	$ 12,000
	2. Pond (Installed)	42,300
	3. Contingencies	5,430
	4. Engineering	5,970
	Total Cost	$ 65,700

Operating Costs

Items:	1. Operating & Maintenance	$ 7,170
	2. Power	300
	Total Cost	$ 7,470

Yearly Costs

Items:	1. Operating Cost	$ 7,470
	2. Investment Cost	2,630
	3. Depreciation Cost	3,290
	Total Cost	$ 13,400

Land:	2.51 hectares

TABLE 92

ITEMIZED COST SUMMARY OF ALTERNATIVE B-4 FOR SUBCATEGORY V

Investment Costs			
Items:	1.	Ash Storage Bin	$ 20,200
	2.	Conveyor	10,900
		Total Cost	$ 31,100
Operating Costs			
Items:	1.	Operating & Maintenance	$ 9,720
		Total Cost	$ 9,720
Yearly Costs			
Items:	1.	Operating Cost	$ 9,720
	2.	Investment Cost	1,240
	3.	Depreciation Cost	1,560
		Total Cost	$ 12,500

TABLE 93

ITEMIZED COST SUMMARY OF ALTERNATIVE B-5 FOR SUBCATEGORY V

Investment Costs			
Items:	1.	Pump, pipes, electrical	$ 12,000
	2.	Pond (Installed)	35,500
	3.	Contingencies	4,750
	4.	Engineering	5,230
		Total Cost	$ 57,500
Operating Costs			
Items:	1.	Operating & Maintenance	$ 6,100
	2.	Power	300
		Total Cost	$ 6,400
Yearly Costs			
Items:	1.	Operating Cost	$ 6,400
	2.	Investment Cost	2,300
	3.	Depreciation Cost	2,900
		Total Cost	$ 11,600
Land:			2.07 hectares

TABLE 94

ITEMIZED COST SUMMARY OF ALTERNATIVE C FOR SUBCATEGORY V

Investment Costs		
Items:	1. Ponds	$ 62,500
	2. Contingencies	6,250
	3. Engineering	6,900
	Total Cost	$ 75,700
Operating Costs		
Items:	1. Maintenance	$ 1,400
	2. Solids Handling	31,800 - 97,600
	Total Cost	$ 33,200 - 99,000
Yearly Costs		
Items:	1. Operating Cost	$ 33,200 - 99,000
	2. Investment Cost	3,030
	3. Depreciation Cost	3,790
	Total Cost	$ 40,000 -105,800
Land:		1.62 hectares

Total Investment Cost: $666,000
Total Yearly Cost: 115,000 - 181,000

An itemized cost breakdown for Alternative D is presented in Table 95.

Reduction Benefits: The reduction benefits for Alternative D involve a BOD5 reduction of greater than 69.7 percent and a suspended solids reduction of greater than 97.3 percent. The incremental reductions due to Alternative D are 69.7 percent for BOD5 and 11.6 percent for suspended solids.

Alternative E - This alternative involves the treatment of the effluent from the settling pond, discussed in Alternative C, in an aerated lagoon designed with a quiescent zone and a total detention time of 9.5 days. The resulting BOD5 loading is 0.63 kilograms per metric ton (1.26 pounds per ton) of gross cane and the suspended solids loading is 0.47 kilograms per metric ton (0.94 pounds per ton) of gross cane.

Costs: Incremental Investment Cost: $393,000
Incremental Yearly Cost 65,000

Total Investment Cost: $469,000
Total Yearly Cost: 105,000 - 171,000

An itemized cost breakdown for Alternative E is presented in Table 96.

Reduction Benefits: The reduction benefits for Alternative E involve a BOD5 reduction of 69.7 percent and a suspended solids reduction of 97.3 percent. The incremental reductions due to Alternative E are 69.7 percent for BOD5 and 11.6 percent for suspended solids.

Alternative F - This alternative involves the use of a settling pond to settle and recycle the cane wash water. The blowdown from the recycle system is contained in an oxidation pond for the entire season and discharged after the season to assure waste stabilization. The resulting BOD5 waste loading is 0.53 kilograms per metric ton (1.06 pounds per ton) of gross cane and the suspended solids loading is 0.080 kilograms per metric ton (0.16 pounds per ton) of gross cane.

Costs: Incremental Investment Cost: $221,000
Incremental Yearly Cost: 86,300 - 165,000

Total Investment Cost: $221,000
Total Yearly Cost: 86,300 - 165,000

TABLE 95

ITEMIZED COST SUMMARY OF ALTERNATIVE D FOR SUBCATEGORY V

Investment Costs			
Items:	1.	Pond	$ 479,000
	2.	Pump, Sump and Piping	8,600
	3.	Contingencies	48,800
	4.	Engineering	53,600
		Total Cost	$ 590,000
Operating Costs			
Items:	1.	Operation & Maintenance	$ 15,000
	2.	Chemical Cost	5,040
	3.	Power Cost	1,480
		Total Cost	$ 21,500
Yearly Costs			
Items:	1.	Operating Cost	$ 21,500
	2.	Investment Cost	23,600
	3.	Depreciation Cost	29,500
		Total Cost	$ 74,600
Land:			142 hectares

TABLE 96

ITEMIZED COST SUMMARY OF ALTERNATIVE E FOR SUBCATEGORY V

Investment Costs

Items:	1.	Aerated Lagoon	$316,000
	2.	Pump, Sump and Piping	8,600
	3.	Contingencies	32,500
	4.	Engineering	35,700
		Total Cost	$393,000

Operating Costs

Items:	1.	Operation & Maintenance	$ 13,100
	2.	Chemical Cost	5,040
	3.	Power Cost	11,500
		Total Cost	$ 29,600

Yearly Costs

Items:	1.	Operating Cost	$ 29,600
	2.	Investment Cost	15,700
	3.	Depreciation Cost	19,700
		Total Cost	$ 65,000

Land: 5.3 hectares

An itemized cost breakdown for Alternative F is presented in Table 97.

Reduction Benefits: The reduction benefits for Alternative F involve a BOD5 reduction of 74.5 percent and a suspended solids reduction of 99.5 percent. The incremental reductions due to Alternative F are 74.5 percent for BOD5 and 99.5 percent for suspended solids.

Alternative G - This alternative involves the recycle of barometric condenser cooling water and cane wash water. The blowdown from the barometric condenser cooling water recycle system is assumed to be the makeup to the cane wash recirculation system. The blowdown from the cane wash recirculation system and the miscellaneous waste streams are treated in an oxidation pond, designed with a detention time equivalent to the entire season, and discharged after stabilization. The resulting BOD5 waste loading is 0.050 kilograms per metric ton (0.10 pounds per ton) of gross cane and the suspended solids loading is 0.080 kilograms per metric ton (0.16 pounds per ton) of gross cane.

Costs:	Incremental Investment Cost:	$ 410,000
	Incremental Yearly Cost:	126,000 - 205,000
	Total Investment Cost:	$410,000
	Total Yearly Cost:	126,000 - 205,000

An itemized cost breakdown for Alternative G is presented in Table 98.

Reduction Benefits: The reduction benefits for Alternative G involve a BOD5 reduction of 97.6 percent and a suspended solids reduction of 99.5 percent. The incremental reductions due to Alternative G are 97.6 percent for BOD5 and 99.5 percent for suspended solids.

Alternative H - This alternative involves the recycle of barometric condenser cooling and cane wash water. The blowdown from the barometric condenser cooling water water recirculation system is assumed to be the makeup to the cane wash recycle system. The blowdown from the cane wash recirculation system and the miscellaneous waste streams are treated in two aerated lagoons operated in series, designed with a total detention time of 28 days and with a quiescent zone. The resulting BOD5 waste loading is 0.050 kilograms per metric ton (0.10 pounds per ton) of gross cane and the suspended solids loading is 0.080 kilograms per metric ton (0.16 pounds per ton) of gross cane.

Costs:	Incremental Investment Cost:	$525,000
	Incremental Yearly Cost:	167,000 - 246,000

TABLE 97

ITEMIZED COST SUMMARY OF ALTERNATIVE F FOR SUBCATEGORY V

Investment Costs

Items:	1.	Settling Ponds	$ 62,500
	2.	Cane Wash Recycle System	60,700
	3.	Oxidation Pond	59,100
	4.	Contingencies	18,200
	5.	Engineering	20,100
		Total Cost	$221,000

Operating Costs

Items:	1.	Settling Pond Maintenance	$ 39,500 - 118,000
	2.	Cane Wash Recycle Maintenance	19,900
	3.	Oxidation Pond Maintenance	5,700
	4.	Power Cost	1,250
		Total Cost	$ 66,400 - 144,900

Yearly Costs

Items:	1.	Operating Cost	$ 66,400 - 144,900
	2.	Investment Cost	8,800
	3.	Depreciation Cost	11,100
		Total Cost	$ 86,300 - 164,800

Land: 9.8 hectares

TABLE 98

ITEMIZED COST SUMMARY OF ALTERNATIVE G FOR SUBCATEGORY V

Investment Costs

Items:	1.	Settling Ponds	$ 62,500
	2.	Cane Wash Recycle System	60,700
	3.	Barometric Condenser Cooling Water Recirculation System	155,000
	4.	Oxidation Pond	60,300
	5.	Contingencies	33,900
	6.	Engineering	37,200
		Total Cost	$410,000

Operating Costs

Items:	1.	Settling Pond Maintenance	$ 39,500 - 118,000
	2.	Cane Wash Recycle Maintenance	19,900
	3.	Condenser Recirculation Maintenance & Operation	12,800
	4.	Oxidation Pond Maintenance	5,700
	5.	Power Cost	11,400
		Total Cost	$ 89,300 - 168,000

Yearly Costs

Items:	1.	Operating Cost	$ 89,300 - 168,000
	2.	Investment Cost	16,400
	3.	Depreciation Cost	20,500
		Total Cost	$126,000 - 205,000

Land:	10.3 hectares

Total Investment Cost:	$525,000
Total Yearly Cost:	167,000 - 246,000

An itemized cost breakdown for Alternative H is presented in Table 99.

Reduction Benefits: The reduction benefits for Alternative H involve a BOD5 reduction of 97.6 percent and a suspended solids reduction of 99.5 percent. The incremental reductions due to Alternative H are 97.6 percent for BOD5 and 99.5 percent for suspended solids.

A summary of the costs for all of the alternatives is presented in Table 100.

Related Energy Requirements of Alternative Treatment and Control Technologies for Subcategory V

Table 101 illustrates the estimated energy requirements for the application of the various treatment alternatives to the Subcategory V model factory. Energy requirements in the form of electrical energy needed for the operation of pumps, aerators, and spray nozzels, and the energy required for the disposal of solid wastes is compared to the overall energy requirements of the model factory. In order to place the energy requirements of the various alternatives in proper perspective, it should be noted that a typical 2,730 metric tons (3,000 tons) of gross cane per day factory consumes 5.4 million kilowatt-hours of electricity per year and requires 189 million kilograms (415 million pounds) of steam per year. In the estimate of total factory energy requirements, no allowance was made for usage of fuel associated with the harvesting and transportation of sugarcane. Therefore, the percentage increases in energy requirements presented in Table 101 are considered to be the maximum requirements for the application of the various treatment alternatives at the model factory.

As shown in Table 101, the two major uses of energy resulting from the application of the various treatment alternatives by Subcategory I factories are the recirculation of barcmetric condenser cooling water and the use of aerated lagoons as a treatment method. Alternatives E, G, and H require substantially greater energy usage than the other alternatives. Of these alternatives, Alternative H employs both a barometric condenser cooling water recirculation system and an aerated lagoon and would be the largest user of energy.

TABLE 99

ITEMIZED COST SUMMARY OF ALTERNATIVE H FOR SUBCATEGORY V

Investment Costs

Items:	1.	Settling Ponds	$ 62,500
	2.	Cane Wash Recycle System	60,700
	3.	Barometric Condenser Cooling Water Recirculated System	155,000
	4.	Aerated Lagoon	155,700
	5.	Contingencies	43,400
	6.	Engineering	47,700
		Total Cost	$525,000

Operating Costs

Items:	1.	Settling Pond Maintenance	$ 39,500 - 118,000
	2.	Cane Wash Recycle Maintenance	19,900
	3.	Condenser Recirculation Maintenance & Operation	12,800
	4.	Aerated Lagoon Maintenance & Operation	16,200
	5.	Power Requirements	31,800
		Total Cost	$120,000 - 199,000

Yearly Costs

Items:	1.	Operating Cost	$120,000 - 199,000
	2.	Investment Cost	21,000
	3.	Depreciation Cost	26,300
		Total Cost	$167,000 - 246,000

Land: 2.8 hectares

TABLE 100

SUMMARY OF ALTERNATIVE COSTS
MODEL FACTORY -- SUBCATEGORY V

Alternative	BOD5 Loading* (kg/kkg)	TSS Loading* (kg/kkg)	Total Investment Cost	Total Yearly Cost
A	2.08	17.56	$ 0	$ 0
B	2.08	17.56	189,000	(3,900)
C	2.08	2.51	75,700	40,000-106,000
D	0.63	0.47	666,000	115,000-181,000
E	0.63	0.47	469,000	105,000-171,000
F	0.53	0.080	221,000	86,300-165,000
G	0.050	0.080	410,000	126,000-205,000
H	0.050	0.080	525,000	167,000-246,000

*Gross Cane Basis.

TABLE 101

YEARLY ENERGY USAGE FOR MODEL FACTORY SUBCATEGORY V

Alternative	Power Usage (kw-hr/yr)	Gasoline Usage (liters/yr)	Percent of Total Energy Requirement
A	0	0	0%
B-1	0	0	0
B-2	0	5,680	0.035
B-3	13,000	0	0.021
B-4	0	1,820	0.011
B-5	13,000	0	0.021
C	0	5,680-37,900	0.035-0.23
D	64,300	5,680-37,900	0.14 -0.33
E	500,000	5,680-37,900	0.84 -1.06
F	54,300	6,810-45,400	0.13 -0.36
G	496,000	6,810-45,400	0.84 -1.07
H	1,380,000	6,810-45,400	2.24 -2.47

NON-WATER QUALITY ASPECTS OF ALTERNATIVE TREATMENT AND CONTROL TECHNOLOGY

The non-water quality aspects associated with the application of the various alternative control and treatment technologies are considered below. In general, the impact of aesthetic considerations, including the sight of treatment facilities as well as odor and noise effects, are minimized by the typical location of cane sugar factories away from urban areas.

Air Pollution

Waste water lagooning, particularly under anaerobic conditions, can promote the growth of sulfur reducing organisms and associated noxious gasses. Aerobic conditions can be maintained by the design of shallow ponds, by the use of aerators, by pH adjustment, or by other means.

Spray drift from cooling ponds can cause problems in congested areas. Proper location of cooling devices, with regard to prevailing winds and to the uses of surrounding land, can be employed to minimize the effects of drift. The use of warm water for cane washing could cause fogging problems during certain weather conditions and could possibly contribute to unsafe working conditions. Recirculation systems could be employed which would minimize potential fogging problems.

Noise

There is little if any noise pollution associated with the control and treatment technologies discussed in this document.

Solid Waste

The removal of solids from waste water produces a solid waste disposal problem in the form of sludges. In those cases where sludge is to be impounded, previously discussed measures for protection of groundwater should be observed. Sanitary landfills, when available, usually offer an economic solution if hauling distances are reasonable. Land is usually available for land spreading of sludges, and in the case of some areas in Hawaii and particularly in Florida, the rapid loss of top soil makes the return of organics to the soil a highly desirable practice.

In any event, the additional solid wastes produced by the various control and treatment alternatives are not expected to be a serious problem. The costs associated with their handling and disposal have been taken into account in Section VIII, and technology is available to prevent harmful effects to the environment as a result of land disposal of sludge.

For those waste materials considered to be non-hazardous where land disposal is the choice for disposal, practices similar to proper sanitary landfill technology may be followed. The principles set forth in the EPA's Land Disposal of Solid Wastes Guidelines (CFR Title 40, Chapter 1; Part 241) may be used as guidance for acceptable land disposal techniques.

For those waste materials considered to be hazardous, disposal will require special precautions. In order to ensure long-term protection of public health and the environment, special preparation and pretreatment may be required prior to disposal. If land disposal is to be practiced, these sites must not allow movement of pollutants such as fluoride and radium-226 to either ground or surface water. Sites should be selected that have natural soil and geological conditions to prevent such contamination or, if such conditions do not exist, artificial means (e.g., liners) must be provided to ensure long-term protection of the environment from hazardous materials. Where appropriate, the location of solid hazardous materials disposal sites should be permanently recorded in the appropriate office of the legal jurisdiction in which the site is located. It should be noted that there is no evidence that hazardous materials are present in the slurries, sludges, muds, ashes, and cakes which result from the processing of sugarcane into a raw sugar product.

SECTION IX

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE EFFLUENT LIMITATIONS GUIDELINES

INTRODUCTION

The effluent limitations which must be achieved by July 1, 1977, are to specify the degree of effluent reduction attainable through the application of the best practicable control technology currently available. Best practicable control technology currently available is generally based upon the average of best existing performance by plants of various sizes, ages and unit processes within the industrial category and/or subcategory.

Consideration must also be given to:

a. The total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application;

b. The size and age of equipment and facilities involved;

c. The process employed;

d. The engineering aspects of the application of various types of control techniques;

e. Process changes;

f. Non-water quality environmental impact (including energy requirements).

Best practicable control technology currently available emphasizes treatment facilities at the end of a manufacturing process but includes the control technologies within the process itself when these are considered to be normal practice within the industry.

A further consideration is the degree of economic and engineering reliability which must be established for the technology to be "currently available." As a result of demonstration projects, pilot plants, and general use, there must exist a high degree of confidence in the engineering and economic practicability of the technology at the time of construction or installation of the control facilities.

EFFLUENT REDUCTIONS ATTAINABLE THROUGH THE APPLICATION OF BEST PRACTICABLE CCNTROL TECHNOLOGY CURRENTLY AVAILABLE FOR THE RAW CANE SUGAR SEGMENT OF THE SUGAR PROCESSING PCINT SOURCE CATEGORY

Based upon the information contained in Sections III through VIII of this document it has been determined that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is as follows:

	30-Day Average		Daily Average	
	BOD5	TSS	BOD5	TSS
I (Subpart D)	0.63	0.47	1.14	1.41
II (Subpart E)	0	0	0	0
III (Subpart F)	-	2.1	-	4.2
IV (Subpart G)	0	0	0	0
V (Subpart H)	0.63	0.47	1.14	1.41

The above recommendations are expressed in terms of kilograms of pollutant per metric ton of gross cane, except for Subcategory III which are expressed in terms of kilograms of pollutant per metric ton of net cane, and are subject to the following qualifications:

It is recommended that the factories of Subcategory II (those factories located in Florida and Texas) and Subcategory IV (those factories located in Hawaii but not on the Hilo-Hamakua coast of the island of Hawaii) be required to attain the level of no discharge of polluted waste water to navigable waters in that under normal operating conditions this limitation is readily attainable and is in fact being achieved by the factories which form these subcategories. It is further recommended that discharge of factory waste waters to navigable waters be allowed during the occurrence of rainfall events that cause an overflow of process waste water from a facility designed, constructed, and operated to contain all process generated waste waters.

It is also recommended that for all cases for which a discharge of waste waters is allowed, the pH of the waste waters be required to be maintained in the range of 6.0 to 9.0.

EFFLUENT LIMITATIONS GUIDELINES DEVELOPMENT

For the purpose of establishing uniform national effluent limitations and guidelines, model factories were hypothesized which represent the various subcategories of the raw cane sugar processing segment of the sugar processing category. Treatment technologies were considered which are applicable to all factories within each of the various subcategories. These technologies can be applied to treat the unit raw waste loadings of the various waste water discharge streams existent at raw cane sugar factories. An average rather than an exemplary plant approach has been taken in the determination of unit water usages and effluent raw waste loadings on which to base attainable effluent reductions and costs associated with the application of the various control and treatment technologies.

It is felt that the effluent limitations and guidelines presented in this section are reasonable and technically achievable through the application of improved in-plant controls and the addition of an appropriate treatment system to treat the process generated waste water discharge streams.

Establishment of Daily Average Effluent Limitations. The ratios of the daily maximum to 30-day average limitations are based upon statistical analyses of available data and analyses of the results of treatment systems operating on wastes similar in nature to those associated with the production of raw cane sugar.

Production Basis. The average permitted effluent level should be the recommended level, expressed as kg/kkg (lb/ton), multiplied by the present daily processing rate, expressed as kkg (ton) per day. It is recommended that the processing rate be based on the highest processing rate attained over five (5) consecutive days (not necessarily continuous) of full normal production. It is recommended that the processing rate on which the effluent limitations are based should be one-fifth (1/5) of the maximum five day total production rate.

IDENTIFICATION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

The technology identified as the best practicable control technology currently available is defined as follows for each subcategory:

Subcategory I

The best practicable control technology currently available for Subcategory I is identified as the use of in-plant controls to the extent typified by general operating practice (such as the use of entrainment prevention devices to reduce the degree of entrainment of sucrose into barometric condenser cooling water and the elimination of the discharge of filter cake and boiler ash), the use of settling ponds to remove solids from cane wash water, and the use of a biological treatment system to treat the effluent from the settling ponds and all other waste streams except barometric condenser cooling water and excess condensate.

Subcategories II and IV

The best practicable control technology currently available for Subcategories II and IV is identified as the containment of all waste waters except when rainfall events cause an overflow of process waste water from a facility designed, constructed, and operated to contain all process generated waste waters.

Subcategory III

The best practicable control technology currently available for Subcategory III is identified as the use of in-plant controls and clarification of the entire waste stream (except barometric condenser cooling water and excess condensate) with polymer addition.

Subcategory V

That portion of the industry segment comprising Subcategory V is in a state of flux between the hand harvesting of sugarcane and an increased reliance on mechanical harvesting techniques. However, since available data indicate raw waste loadings on the order of those exhibited by Subcategory I factories it is concluded that the technology described above for Subcategory I is directly applicable to Subcategory V.

ENGINEERING ASPECTS OF CONTROL TECHNOLOGY APPLICATIONS

With the exception of polymer addition, all technology discussed in this section is existing technology within the industry segment. Polymer addition, as discussed in Section VII, Control and Treatment Technology, has been well demonstrated by the Hawaiian cane sugar industry to be a practical and available technique. In general, then, the concepts discussed herein are proven, available for implementation prior to July 1, 1977, and may be readily utilized by the industry.

COSTS OF APPLICATION

The costs of attaining the effluent reductions set forth herein are summarized in Section VIII, Cost, Energy, and Non-Water Quality Aspects.

The capital and total yearly costs (August-1971 dollars) to the raw cane sugar processing segment of the sugar processing category to achieve the best practicable control technology currently available effluent limitations are estimated to range from between $9.52 and $10.41 million, and $2.98 and $4.06 million, respectively. These total costs are based on an estimation of those control and treatment techniques which must be applied at each of the seventy-six individual cane sugar factories to achieve the effluent limitations. These costs do not include expenses already incurred as a result of pollution abatement facilities already existent at the individual factories.

NON-WATER QUALITY ENVIRONMENTAL IMPACT

The primary non-water quality environmental impacts are summarized in Section VIII, Cost, Energy, and Non-Water Quality Aspects. A major concern is that in those cases where a strong reliance is placed upon the land for ultimate disposal of wastes, no resulting ground-water pollution should be allowed. Technology is available to ensure that land disposal systems are maintained commensurate with soil tolerances and to prevent groundwater contamination.

Of additional concern is the generation of solid wastes in the form of sludges and muds and the possibility of odors resulting from impoundage lagoons. In both cases, responsible operation and maintenance procedures coupled with sound environmental planning have been shown to obviate the problems.

FACTORS TO BE CONSIDERED IN APPLYING EFFLUENT LIMITATIONS

The above assessment of what constitutes the best practicable control technology currently available is predicated on the assumption of a degree of uniformity among factories within each subcategory that strictly speaking, does not exist. The control technologies described herein have been formulated partly as a function of general land availability within each subcategory. In many cases, the degree of land availability may dictate that an individual factory employ one treatment alternative over another.

A second factor that must be considered, particularly with regard to Subcategories I and V, is the impact of the discharge from stabilization ponds; i.e., the allowable rate of discharge from the ponds at the time they are drained.

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SECTION X

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE EFFLUENT LIMITATIONS GUIDELINES

INTRODUCTION

The effluent limitations which must be achieved by July 1, 1983, are to specify the degree of effluent reduction attainable through the application of the best available technology economically achievable. The best available technology economically achievable is not based upon an average of the best performance within an industrial category, but is to be determined by identifying the very best control and treatment technology employed by a specific point source within the industrial category or subcategory, or where it is readily transferable from one industrial process to another. A specific finding must be made as to the availability of control measures and practices to eliminate the discharge of pollutants, taking into account the cost of such elimination.

Consideration must also be given to:

a. The age of equipment and facilities involved;

b. The process employed;

c. The engineering aspects of the application of various types of control techniques;

d. Process change;

e. Cost of achieving the effluent reduction resulting from application of the best economically achievable technology;

f. Non-water quality environmental impact (including energy requirements).

In contrast to the best practicable control technology currently available, the best economically achievable technology assesses the availability in all cases of in-process controls as well as control or additional treatment techniques employed at the end of a production process.

Those plant processes and control technologies which at the pilot plant semi-works, or other level, have demonstrated both technological performances and economic viability at a level sufficient to reasonably justify investing in such facilities may be considered in assessing the best available economically achievable technology. The best available technology economically achievable is the highest degree of control technology that has been achieved or has been demonstrated to be capable of being designed for plant scale operation up to and including "no discharge" of pollutants. Although economic factors are considered in this development, the costs for this level of control are intended to be the top-of-the-line of current technology subject to limitations imposed by economic and engineering feasibility. However, the best available technology economically achievable may be characterized by some technical risk with respect to performance and with respect to certainty of costs. Therefore, the best available technology economically achievable may necessitate some industrially sponsored development work prior to its application.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE -- EFFLUENT LIMITATIONS GUIDELINES

Based upon the information contained in Sections III through VIII of this document, it has been determined that the degree of effluent reduction attainable through the application of the best available technology economically achievable is as follows:

	30-Day Average		Daily Average	
Subcategory	BOD5	TSS	BOD5	TSS
I(Subpart D)	0.050	0.080	0.10	0.24
II(Subpart E)	0	0	0	0
III(Subpart F)	The greater of: 0.11 or 0.76(1-x)+0.0060	The greater of: 0.13 or 1.01(1-x)+0.0080	The greater of: 0.22 or 1.52(1-x)+0.012	The greater of: 0.39 or 3.03(1-x)+0.024
IV(Subpart G)	0	0	0	0
V(Subpart H)	0.050	0.080	0.10	0.24

The above recommendations are expressed in terms of kilograms of pollutant per metric ton of field cane processed, except for Subcategory III which are expressed as kilograms of pollutant per metric ton of net cane processed, and are subject to the same qualifications listed in Section IX.

It is also recommended that for all cases for which a discharge of waste waters is allowed, the pH of the waste waters be required to be maintained in the range of 6.0 to 9.0.

IDENTIFICATION OF THE BEST AVAILABLE CONTROL TECHNOLOGY ECONOMICALLY ACHIEVABLE

The technology identified as the best available technology economically achievable is defined as follows for each subcategory:

Subcategory I

The best available technology economically achievable for Subcategory I is identified as the recycle of barometric condenser cooling water and cane wash water with biological treatment of the blowdown and miscellaneous waste streams.

Subcategories II and IV

The best available technology economically achievable for Subcategories II and IV is identified as being equivalent to the best practicable control technology currently available.

Subcategory III

The best available technology economically achievable for Subcategory III is identified as the addition of a barometric condenser cooling water recirculation system, the blowdown used as makeup to the cane wash system. The entire clarified stream would then be treated in a biological treatment system.

Subcategory V

The best available technology economically achievable for Subcategory V is the same as that identified in this section for Subcategory I.

ENGINEERING ASPECTS OF CONTROL TECHNOLOGY APPLICATIONS

The engineering aspects of this level of control and treatment technology are the same as discussed in Section IX, and also include the assumption that for Subcategory III factories, a fraction of the net sugarcane harvested will be harvested by the advanced harvesting systems. These systems are available at the present time and are expected to be the general operating procedure at Subcategory III factories between 1977 and 1983.

COSTS OF APPLICATION

The additional capital and total yearly costs (August-1971 dollars) to the raw cane sugar processing segment of the sugar processing category to achieve the best available technology economically achievable effluent limitations are estimated to range from between $6.05 and $7.53 million, and $1.02 and $1.33 million, respectively. This estimate of total costs does not include those costs associated with attainment of the best practicable control technology currently available and is based on an estimation of those control and treatment techniques which must be applied at each individual factory in order that the effluent limitations be attained. These costs do not include those expenses already incurred as a result of pollution abatement facilities already existent at the individual factories.

NON-WATER QUALITY ENVIRONMENTAL IMPACT

The non-water quality environmental impact of this level of technology is the same as that discussed in Section IX.

FACTORS TO BE CONSIDERED IN APPLYING EFFLUENT LIMITATIONS

The factors to be considered in applying effluent limitations are the same as those discussed in Section IX.

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

INTRODUCTION

In addition to effluent limitations and guidelines reflecting the best practicable control technology currently available and the best available technology economically achievable, applicable to existing point source discharges on July 1, 1977, and July 1, 1983, respectively, the Act requires that performance standards be established for new sources. The term "new source" is defined in the Act to mean "any source, the construction of which is commenced after the publication of proposed regulations prescribing a standard of performance." New source technology shall be evaluated by adding to the consideration underlying the identification of best available technology economically achievable a determination of what higher levels of pollution control are available through the use of improved production processes and/or treatment techniques.

New source performance standards may be based on the best in-plant and end-of-process control technology identified. Additional considerations applicable to new source performance standards take into account techniques for reducing the level of effluent by changing the production process itself or adopting alternative processes, operating methods, or other alternatives. The end result of the analysis will be the identification of effluent standards which reflect levels of control achievable through the use of improved production processes (as well as control technology), rather than prescribing a particular type of process or technology which must be employed. A further determination which must be made for new source technology is whether a standard permitting no discharge of pollutants is practicable.

At least the following factors should be considered with respect to production processes which are to be analyzed in assessing technology applied to new sources:

a. The type of process employed and process changes;

b. Operating methods;

c. Batch as opposed to continuous operations;

d. Use of alternative raw materials and mixes of raw materials;

e. Use of dry rather than wet processes (including substitution of recoverable solvents for water); and

f. Recovery of pollutants as by-products.

NEW SOURCE PERFORMANCE STANDARDS

Based upon the information contained in Sections III through VIII of this document, it has been determined that the degree of effluent reduction attainable for new sources in Subcategories I, II, III, IV, and V is the same as that identified as attainable by the application of the best available technology economically achievable.

PRETREATMENT CONSIDERATIONS

Effluents from cane sugar factories contain no constituents that are known to be incompatible with a well-designed and operated municipal waste water treatment plant nor any that would pass through such a system. In general, municipal treatment facilities are not available because cane sugar factories are located in rural areas. In the event that municipal sewers do become available to factories, introduction of factory waste waters should result in no treatability problems.

Contributions of solids attributable to waste waters discharged by a cane sugar factory could be substantial. A judgment should be made on an individual basis as to the amount of solids which should be allowed to enter a particular municipal treatment system. Consideration should be given to the existing municipal load and total capacity. If it is determined that pretreatment for solids removal is necessary, primary settling should be provided at the cane sugar factory.

Where acid and caustic wastes are discharged, these should be held and discharged in such a way as to maintain the pH of the discharge to municipal sewers between 6 and 9.

SECTION XII

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SECTION XIII

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GLOSSARY

1. "Act" - The Federal Water Pollution Act as amended.

2. Activated Sludge Process - A biological waste water treatment process in which a mixture of waste water and activated sludge is agitated and aerated. The sludge is subsequently separated from the treated waste water (mixed liquor) by sedimentation and wasted or returned to the process as needed.

3. Aerated Lagoon - A natural or artificial waste water treatment pond in which mechanical or diffused air aeration is used to supplement the oxygen supply.

4. Aerobic - This refers to life or processes that can occur only in the presence of oxygen.

5. Alkalinity - Alkalinity is a measure of the capacity of water to neutralize an acid.

6. Alphanaphthol Test - A test for sucrose concentration in condensate and condenser water. The method is based on a color change which occurs in the reaction of alphanaphthol with sucrose.

7. Anaerobic - This refers to life or processes that occur in the absence of oxygen.

8. Ash Content - In analysis of sugar products, sulfuric acid is added to the sample, and this residue, as "sulfated ash" heated to 800°C is taken to be a measure of the inorganic constituents.

9. Bagacillo - Fine bagasse particles.

10. Bagasse - Solid material remaining after the milling process has removed the juice from sugar cane. It is generally used as boiler fuel and, in some cases, in the manufacture of various by-products.

11. Barometric Condenser - See Condenser, Barometric.

12. Barometric Leg - A long vertical pipe through which spent condenser water leaves the barometric condenser. Serves as a source of vacuum.

13. Barometric Leg Water - Condenser cooling water.

14. Biological Waste Water Treatment - Forms of waste water treatment in which bacterial or biochemical action is intensified to stabilize, oxidize, and nitrify the unstable organic matter present. Intermittent sand filters, contact beds, trickling filters, and activated sludge processes are examples.

15. Blackstrap Molasses - Molasses produced by the final vacuum pan, and from which sugar is unrecoverable by ordinary means. Blackstrap is usually sold for various uses.

16. BOD - Biochemical Oxygen Demand is a semiquantitative measure of biological decomposition of organic matter in a water sample. It is determined by measuring the oxygen required by micro-organisms to oxidize the contaminants of a water sample under standard laboratory conditions. The standard conditions include incubation for five days at 20°C.

17. Boiler Ash - The solid residue remaining from combustion of fuel in a boiler furnace.

18. Boiler Feedwater - Water used to generate steam in a boiler. This water is usually condensate, except during boiler startup, when treated fresh water is normally used.

19. Boiler Blowdown - Discharge from a boiler system designed to prevent a buildup of dissolved solids.

20. Calandria - The steam belt or heating element in an evaporator or vacuum pan, consisting of vertical tube sheets constituting the heating surface.

21. Calandria Evaporator - An evaporator using a calandria; the standard evaporator in current use in the sugar industry.

22. Calandria Vacuum Pan - A vacuum pan using a calandria; the standard vacuum pan in current use in the sugar industry.

23. Cane - Gross Cane: Crop material by weight as harvested, including field trash and other extraneous material.

    Net Cane: Gross cane less the weight of extraneous material.

24. Cane Milling - The process whereby raw sugarcane is chopped and crushed in order to separate the sugar-containing juice from the solid pulp.

25. Cane Washing - Washing of sugarcane with water to remove soil, mud, rocks, and other foreign matter preparatory to milling.

26. Centrifugation - A procedure used to separate materials of differing densities by subjecting them to high speed revolutions. In sugar processing, centrifugation is used to remove sugar crystals from massecuite.

27. Clarification - Removing undissolved materials (largely insoluble lime salts) from cane juice by settling, filtration, or flotation.

28. Clarifier - A unit of which the primary purpose is to reduce the amount of suspended matter in a liquid.

29. Coagulation - The clumping of particles in order to settle out impurities; often induced by chemicals such as lime or alum.

30. COD - Chemical Oxygen Demand. Its determination provides a measure of the oxygen demand equivalent to that portion of matter in a sample which is susceptible to oxidation by a strong chemical oxidant.

31. Compound Imbibition - The most common type of imbibition which involves the addition and recirculation of water and juices to the bagasse at different points in a four mill network, in order to dissolve sucrose.

32. Condensate - Water resulting from the condensation of vapor.

33. Condenser - A heat exchange device used for condensation.

    Barometric: Condenser in which the cooling water and the vapors are in physical contact; the condensate is mixed in the cooling water.

    Surface: Condenser in which heat is transfered through a barrier that separates the cooling water and the vapor. The condensate can be recovered separately.

34. Condenser Water - Water used for cooling in a condenser.

35. Crystallization - The process through which sugar crystals separate from massecuite.

36. Cush-cush - The coarser particles of impurities present in cane juice after milling.

37. Decanting - Separation of liquid from solids by drawing off the upper layer after the heavier material has settled.

38. Demineralization - Removal of mineral impurities from sugar.

39. Dextrose - Glucose. A monosaccharide sugar with the formula $C_6H_{12}O_6$. Dextrose is a minor component of raw sugar.

40. Diatomaceous Earth - A viable earthy deposit composed of nearly pure silica and consisting essentially of the shells of the microscopic plants called diatoms. Diatomaceous earth is utilized by the cane sugar industry as a filter aid.

41. Disaccharides - A sugar such as sucrose composed of two monosaccharides.

42. D.O. - Dissolved Oxygen is a measure of the amount of free oxygen in a water sample. It is dependent on the physical, chemical, and biochemical activities of the water sample.

43. Drycleaning - Cleaning of raw cane without the use of water.

44. "Effect" - In systems where evaporators are operated in a series of several units, each evaporator is known as an effect.

45. Entrainment - The entrapment of liquid droplets containing sugar in the water vapor produced by evaporation of syrup.

46. Evaporator - A closed vessel heated by steam and placed under a vacuum. The basic principle is that syrup enters the evaporator at a temperature higher than its boiling point under the reduced pressure, or is heated to that temperature. The result is flash evaporation of a portion of the water in the syrup.

47. Extraction - Pol extracted from cane per 100 pol in cane.

48. False Crystals - New sugar crystals which form spontaneously without the presence of others. This event is undesirable and, therefore, vacuum pan conditions are maintained in a narrow range of sucrose concentration and temperature which precludes their formation.

49. Fiber - The dry water-insoluble fibrous material in cane products.

50. Filter Cake - The residue remaining after filtration of the sludge produced by the clarification process.

51. Filter Mud - A mud produced by slurrying filter cake. The resultant waste stream is the most significant source of solids and organics within a cane sugar factory.

52. Filter Press - In the past, the most common type of filter used to separate solids from sludge. It consists of a simple and efficient plate and frame filter which allows filtered juice to mix with clarified juice and be sent to the evaporators.

53. Fixed Beds - A filter or adsorption bed where the entire media is exhausted before any of the media is cleaned.

54. Flocculant - A substance that induces or promotes fine particles in a colloidal suspension to aggregate into small lumps, which are more easily removed.

55. Floorwash - Water used to wash factory floors and equipment.

56. Flotation - The raising of suspended matter to the surface of the liquid in a tank as scum (by aeration, the evolution of gas, chemicals,

electrolysis, heat, or bacterial decomposition) and the subsequent removal of the scum by skimming.

57. Fly Ash - Solid residue produced by combustion in a furnace.

58. Frothing Clarifiers - Flotation devices that separate tricalcium phosphate precipitate from the liquor.

59. Furfural - An aldehyde C_4H_3OCHO used in making Furaw and as a resin.

60. Glucose - Dextrose.

61. GPD - Gallons per day.

62. GPM - Gallons per minute.

63. Granulation - The process which removes remaining moisture from sugar, and thus also separates the crystals from one another.

64. Granulator - A rotary dryer used in sugar refineries to remove free moisture from sugar crystals prior to packaging or storing.

65. Gross Cane - A measure by weight of the entire harvested cane plant, before processing.

66. Hydrolization - The addition of H_2O to a molecule. In sugar production hydrolization of sucrose results in an inversion into glucose and fructose and represents lost production.

67. Imbibition - The use of water in the milling process to dissolve sucrose. Identical, in this connotation, to maceration and saturation.

68. Impoundment - A pond, lake, tank, basin, or other space which is used for storage of waste water.

69. Impurities - Fine particles of bagasse, fats, waxes, and gums contained in the cane juice after milling. These impurities are reduced by successive refining processes.

70. Invert Sugars - Glucose and fructose formed by the splitting of sucrose by the enzyme sucrase.

71. Ion-Exchange Resins - Resins consisting of three-dimensional hydrocarbon networks to which are attached ionizable groups.

72. Isomers - Two or more compounds containing the same elements and having the same molecular weights, but differing in structure and properties, e.g., glucose and fructose.

73. Lagoon - A pond containing raw or partially treated waste water in which aerobic or anaerobic stabilization occurs.

74. Land Spreading - The disposal of waste water on land to achieve degradation by soil bacteria.

75. Levulose - Fructose. A monosaccharide sugar composed of six carbon chains with the formula $C_6H_{12}O_6$. Levulose is a component of raw sugar.

76. Maceration - The use of water in the milling process to dissolve sucrose. Identical, in this connotation, with imbibition and saturation.

77. Maceration Water - Water applied to the bagasse during the milling process to dissolve sucrose, which is later reclaimed.

78. Massecuite - Mixture of sugar crystals and syrup which originates in the boiling of the sugar (literally, cooked mass).

79. Malt Liquor - Molten sugar to which has been added a small amount of water (half the weight of the sugar).

80. MGD - Million gallons per day.

81. mg/l - Milligrams per liter (equals parts per million (ppm) when the specific gravity is unity).

82. Mixed Media Filtration - A combination of different materials through which a waste water or other liquid is passed for the purpose of purification, treatment, or conditioning.

83. ml/l - Milliliters per liter.

84. Moisture - Loss in weight due to drying under specified conditions, expressed as percentage of total weight.

85. Molasses - A dark-colored syrup containing sucrose, dextrose, levulose, amino acids, organic acids, and minerals produced in processing cane and beet sugar.

86. Monosaccharides - A carbohydrate that does not hydrolyze, as glucose, fructose, ribose, or other simple sugars: occurring naturally or obtained by the hydrolysis of glycosides or polysaccharides.

87. Mud - The sludge resulting from the clarification process.

88. Multiple Effect Evaporation - The operation of evaporators in a series.

89. Non-contact Waste Waters - Those waste waters such as spent cooling water which are independent of the manufacturing process and contain no pollutants attributable to the process.

90. Nutrients - The nutrients in contaminated water are routinely analyzed to characterize the food available for micro-organisms to promote organic decomposition. They are:

Ammonia Nitrogen (NH_3), mg/l as N.
Kjeldahl Nitrogen (ON), mg/l as N.
Nitrate Nitrogen (NO_3), mg/l as N.
Total Phosphate (TP), mg/l as P.
Ortho Phosphate (OP), mg/l as P.

91. pH - pH is equal to the negative log of the hydrogen ion concentration.

92. Phase of Supersaturation - Metastable phase in which existing sugar crystals grow but new crystals do not form; the intermediate phase in which existing crystals grow and new crystals do form; and the labile phase in which new crystals form spontaneously without the presence of others.

93. Plate and Frame Filter - A filtering device consisting of a "screen" fastened inside a metal frame.

94. POL - The value determined by single polarization of the normal weight of a sugar product made up to a total volume of 100 milliliters at 20°C, clarified when necessary with dry lead subacetate, and read in a tube 200 milliliters long at 20°C, using the Bates-Jackson saccharimeter scale. The term is used in calculations as if it were a real substance.

95. Polluted Waste Waters - Those waste waters containing measurable quantities of substances that are judged to be detrimental to receiving waters and that are attributable to the process.

96. Polyelectrolytes - A coagulant aid consisting of long chained organic molecules.

97. Precoat Filter - A type of filter in which the media is applied to an existing surface prior to filtration.

98. Raw Sugar - An intermediate product consisting of crystals of high purity covered with a film of low quality syrup.

99. Recrystallization - Formation of new crystals from previously melted sugar liquor. Recrystallization is encouraged by evaporators and accomplished in vacuum pans.

100. Remelt - A solution of low grade sugar in clarified juice or water.

101. Resorcinol Test - A color indicator test used for the determination of the concentration of sucrose in condensate and condenser waters.

102. Ridge and Furrow Irrigation - A method of irrigation by which water is allowed to flow along the surface of fields.

103. **Rotary Vacuum Filter** - A rotating drum filter which utilizes suction to separate solids from the sludge produced by clarification.

104. **Saturation** - The use of water in the milling process to dissolve sucrose. Identical, in this connotation, with imbibition and maceration.

105. **Seed Sugar** - Small sucrose crystals which provide a surface for continued crystal growth.

106. **Setting Pond** - See Clarifier.

107. **Settlings** - The material which collects in the bottom portion of a clarifier.

108. **Sludge** - The separated precipitate from the clarification process. It consists largely of insoluble lime salts and includes calcium phosphates, coagulate albumin, fats, acids, gums, iron, alumina, and other material.

109. **Solids** - Various types of solids are commonly determined on water samples. These types of solids are:

Total Solids - (TS): The material left after evaporation and drying of a sample at 103° to 105°C.

Dissolved Solids - (DS): The difference between the total solids and the suspended solids.

Volatile Solids - (VS): Material which is lost when the total solids sample is heated to 550°C.

Seattleable Solids (STS): The materials which settle in an Immhoff cone in one hour.

Suspended Solids (SS): The material removed from a sample filtered through a standard glass fiber filter and dried at 103-105°C.

110. **Spray Evaporation** - A method of waste water disposal in which water is sprayed into the air to expedite evaporation.

111. **Spray Irrigation** - A method of irrigation by which water is sprayed from nozzles onto a crop. In order to avoid clogging of the nozzles, the water must be relatively low in suspended solids.

112. **Strike** - The massecuite content of a vacuum pan.

113. **Sucrose** - A disaccharide having the formula $C_{12}H_{22}O_{11}$. The terms

sucrose and sugar are generally interchangeable, and the common sugar of commerce is sucrose in varying degrees of purity. Refined cane sugar is essentially 100 percent sucrose.

114. Sugar - The sucrose crystals, including adhering mother liquor, remaining after centrifugation.

Commercial: Sugar from high grade massecuite, which enters into commerce.
Low Grade: Sugar from low grade massecuite, synonymous with remelt sugar.
96 DA: A value used for reporting commercial sugar on a common basis, calculated from an empirical formula issued by the United States Department of Agriculture.

115. Supersaturation - The condition of a solution when it contains more solute (sucrose) than that which would be dissolved under normal pressure and temperature.

116. Surface Condenser - See Condenser, Surface.

117. Suspended Solids - Solids found in waste water or in the stream which in most cases can be removed by filtration. The origin of suspended matter mav be man-made wastes or natural sources as from erosion.

118. Turbidity - A condition in a liquid caused by the presence of fine suspended matter and resulting in the scattering and absortion of light; an analytical quantity usually reported in arbitrary turbidity units determined by measurements of light diffraction.

119. Vapor - Steam liberated from boiling sugar liquor.

120. Vapor Belt - The distance between the liquid level in an evaporator or vacuum pan and the top of the cylindrical portion of the body.

121. Waste Streams - Any liquified waste material produced by a factory.

METRIC UNITS
CONVERSION TABLE

MULTIPLY (ENGLISH UNITS) by TO OBTAIN (METRIC UNITS)

ENGLISH UNIT	ABBREVIATION	CONVERSION	ABBREVIATION	METRIC UNIT
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram - calories
British Thermal Unit/pound	BTU/lb	0.555	kg cal/kg	kilogram calories/kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	°F	0.555(°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	0.7457	kw	killowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig +1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
ton (short)	ton	0.907	kkg	metric ton (1000 kilograms)
yard	yd	0.9144	m	meter

* Actual conversion, not a multiplier