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DEVELOPMENT DOCUMENT FOR PROPOSED EFFLUENT LIMITATIONS GUIDELINES AND NEW SOURCE PERFORMANCE STANDARDS FOR THE

CANE SUGAR REFINING

SEGMENT OF THE SUGAR PROCESSING POINT SOURCE CATEGORY

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

DECEMBER 1973

Publication Notice

This is a development document for proposed effluent limitations guidelines and new source performance standards. As such, this report is subject to changes resulting from comments received during the period of public comments of the proposed regulations. This document in its final form will be published at the time the regulations for this industry are promulgated.

DEVELOPMENT DOCUMENT

for

PROPOSED EFFLUENT LIMITATIONS GUIDELINES

and

NEW SOURCE PERFORMANCE STANDARDS

CANE SUGAR REFINING SEGMENT
OF THE
SUGAR PROCESSING INDUSTRY

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ABSTRACT

This document presents the findings of an extensive study of the cane sugar refining industry for the purpose of recommending Effluent Limitations Guidelines, Federal Standards of Performance, and Pretreatment Standards for the Industry for the purpose of implementing Sections 304, 306, and 307 of the "Act."

Effluent Limitations Guidelines contained herein set forth 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 set forth 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 cane sugar refining segment of the sugar processing industry has been divided into two subcategories: liquid cane sugar refineries and crystalline cane sugar refineries. The proposed limitations for all three levels of technology as set forth above establish the requirements for discharge to navigable waters (see Table 1).

Supportive data and rationale for development of the proposed Effluent Limitations Guidelines and Standards of Performance are contained in this document. The remaining segments of the sugar processing industry not contained within this report are raw cane sugar processing and beet sugar processing. Raw cane sugar processing is being studied at this time and is to be presented at a later date. Beet sugar processing has been previously studied and is the subject of a separate report entitled - Beet Sugar Processing Segment of the Sugar Processing Industry.

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SECTION I

CONCLUSIONS

For the purpose of developing Effluent Limitations Guidelines and New Source Performance Standards, the cane sugar refining segment of the sugar processing industry has been divided into two subcategories: (1) liquid cane sugar refineries, and (2) crystalline cane sugar refineries. The main criterea for subcategorization of the cane sugar refining segment include differences in the manufacturing process employed which result in different waste water loadings.

Factors such as age and size of facilities, nature of water supply, raw material quality, and waste treatability were considered and found to further substantiate the subcategorization as stated.

It was determined that three refineries are currently achieving no discharge of pollutants to navigable waters by means of land retention. Two refineries discharge all process wastes to municipal treatment systems, and ten other refineries discharge all wastes except condenser cooling water to municipal systems. The majority of the remaining fourteen refineries partially treat their wastes.

It is estimated that the total industry cost of achieving the Best Practicable Control Technology Currently Available (BPCTCA) and the Best Available Technology Economically Achievable (BATEA) are $5,000,000 and $15,000,000 respectively.

The remainder of the cane sugar processing industry, namely the raw cane sugar processing segment, will be studied in a separate effort and a report is to be presented at a later date.

SECTION II
RECOMMENDATIONS

It is recommended that the following effluent limitations 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):

TABLE 1

RECOMMENDED EFFLUENT LIMITATIONS AND STANDARDS OF PERFORMANCE

MONTHLY AVERAGES

	Limitations-kg/kkg (lb/ton) of melt					
	BPCTCA		BATEA		NSPS	
	BOD5	TSS	BOD5	TSS	BOD5	TSS
Liquid Cane Sugar Refineries	0.24 (0.48)	0.10 (0.20)	0.06 (0.12)	0.03 (0.06)	0.06 (0.12)	0.03 (0.06)
Crystalline Cane Sugar Refineries	0.38 (0.76)	0.06 (0.12)	0.04 (0.08)	0.03 (0.06)	0.04 (0.08)	0.03 (0.06)

DAILY AVERAGES

	Limitations-kg/kkg (lb/ton) of melt					
	BPCTCA		BATEA		NSPS	
	BOD5	TSS	BOD5	TSS	BOD5	TSS
Liquid Cane Sugar Refineries	0.85 (1.70)	0.45 (0.90)	0.21 (C.42)	0.14 (0.28)	0.21 (0.42)	0.14 (0.28)
Crystalline Cane Sugar Refineries	1.14 (2.28)	0.24 (0.48)	0.12 (0.24)	0.12 (0.24)	0.12 (0.24)	0.12 (0.24)

In addition to the above limitations, the pH shall be maintained within the range of 6.0 to 9.0.

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 within one year of the enactment of the Act 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 proposed herein set forth effluent limitations guidelines pursuant to Section 304(b) of the Act for the cane sugar refining segment of the sugar processing 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 performances 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 cane sugar refining segment of the sugar processing source which was included within the list published January 16, 1973.

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

The effluent limitations and standards of performance recommended in this report were developed in the following manner.

General information was obtained on all plants and detailed information was collected for 28 (97%) of the 29 domestic cane sugar refineries identified as currently in operation (see Table 2). The sources and types of information consisted of:

a) Applications to the Corps of Engineers for Permits to Discharge under the Refuse Act Permit Program (RAPP) which were obtained for 24 refineries provided data on the characteristics of intake and effluent waters, water usages, wastewater treatment and control practices employed, daily production, and raw materials used.

b) A questionnaire previously submitted to segments of the industry (17 refineries) by the United States Cane Sugar Refiners' Association.

c) On-site inspections of 19 refineries which provided information on process diagrams and related water usage, water management practices, and control and treatment practices.

d) A sampling of four refineries to verify the accumulated data.

e) Other sources of information including personal and telephone interviews and meetings with regional EPA personnel, industry personnel, and consultants; State Permit Applications; internal data supplied by industry; and a review and evaluation of the available literature.

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

a) An identification of distinguishing features that could potentially provide a basis for subcategorization of the industry. These features included raw material quality, age and size of the refinery, nature of water supply, process employed, and others, discussed in detail in Section IV of this report.

b) A determination of the water usage and waste water characteristics for each subcategory, discussed in Section V, including the volume of water used, the sources of pollution in the plant, and the type and quantity of constituents in the waste waters.

c) An identification of those waste water constituents, discussed

TABLE 2

SOURCE OF DATA

Refinery	Type	Location	Size-kkg/day (Average Melt)	Visit	Sample	Data
Amstar	C	Baltimore, Md.	2350	No	No	1,2,4
Amstar	C	Boston, Mass.	900	Yes	No	1,2,3,4
Amstar	C	Brooklyn, N.Y.	1900	Yes	Yes	1,2,3,4,5
Amstar	C	Chalmette, La.	2800	No	No	1,2,4
Amstar	C	Philadelphia, Pa.	1900	No	No	1,2,4
J. Aron	C	Supreme, La.	680	No	No	1,4
C&H	C	Aiea, Hawaii	170	No	No	1,4
C&H	C	Crockett, Ca.	3175	Yes	No	1,3,4
Colonial	C	Gramercy, La.	1350	No	No	1,4
Evercane	C	Clewiston, Fla.	360	Yes	No	3
Glades County	C	Moore Haven, Fla.	420	No	No	3
Godchaux	C	Reserve, La.	1540	No	No	--
Guanica	C	Ensenada, P.R.	200	Yes	No	1,3
Iqualdad	C	Mayaguez, P.R.	630	No	No	1
Imperial	C	Sugarland, Texas	1350	Yes	No	1,2,3,4
Mercedita	C	Ponce, P.R.	545	Yes	No	1,3
National	C	Philadelphia	1900	No	No	1,3,4
Revere	C	Charlestown, Mass.	1090	Yes	No	3
Roig	C	Yabucoa, P.R.	360	Yes	No	1,3
Savannah Foods	C	Port Wentworth, Ga.	1700	Yes	Yes	1,2,3,4,5
South Coast	C	Mathews, La.	635	No	No	1,4
Southdown	C	Houma, La.	635	Yes	No	1,2,3,4
CPC	C-L	Yonkers, N.Y.	1650	No	No	1,2,3,4
SuCrest	C-L	Brooklyn, N.Y.	750	Yes	No	1,2,3
Florida Sugar	L	Belle Glade, Fla.	350	Yes	No	1,3,4
Industrial	L	St. Louis, Mo.	275	Yes	No	1,3,4
Pepsico	L	Long Island, N.Y.	725	Yes	Yes	1,3,5
Ponce Candy	L	Ponce, P.R.	55	Yes	No	1,3
SuCrest	L	Chicago, Ill.	775	Yes	Yes	3,5

C—Crystalline Refinery
L—Liquid Refinery
C-L—Combination Crystalline-Liquid Refinery
1 Corps of Engineers Application
2 Prior Analyses
3 Interview of Plant Personnel
4 Questionnaire
5 Verification Sampling

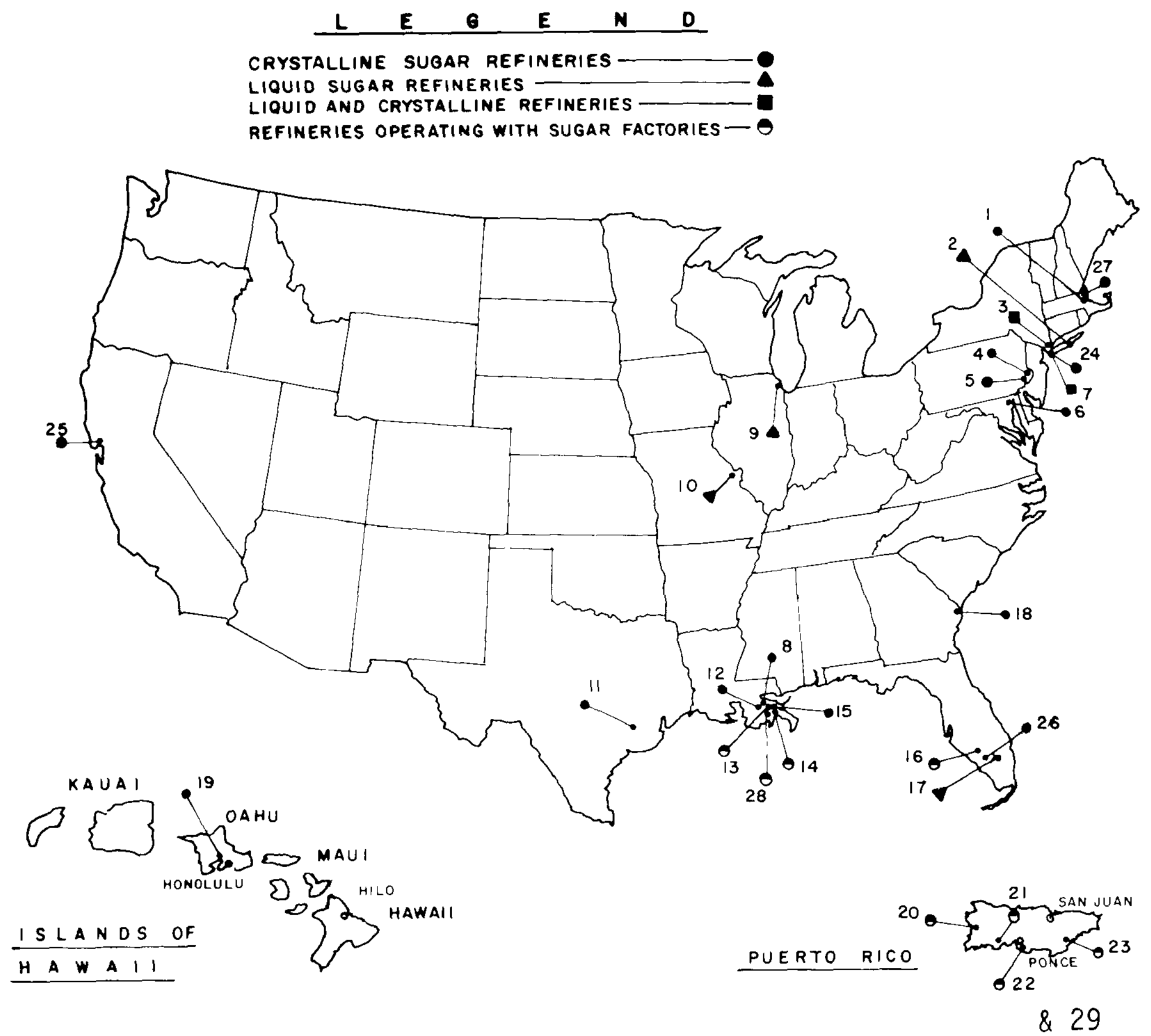


FIGURE 1

AMERICAN CANE
SUGAR REFINERIES

in Section VI, which are characteristic of the industry and were determined to be pollutants subject to effluent limitations guidelines and standards of performance.

d) An identification of the control and treatment technologies presently employed or capable of being employed by the refining industry, discussed in Section VII, including the effluent level attainable and associated treatment efficiency related to each technology.

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

The results of this analysis indicated that three refineries are currently achieving no discharge of pollutants to navigable waters by means of land retention, two refineries discharge all process wastes to municipal treatment systems, and ten other refineries discharge all wastes except condenser water to municipal systems. The majority of the remaining fourteen refineries partially treat or partially retain waste waters.

BACKGROUND OF THE CANE SUGAR INDUSTRY

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. Commercial cane sugar production began in the United States in the late eighteenth and early nineteenth centuries. The growth of the industry experienced considerable instability until the Federal Sugar Act of 1936 (amended in 1971) provided protective tariffs, a quota system, and price control.

DEFINITION OF THE INDUSTRY

Cane sugar refineries produce either a white crystalline or a clear liquid sugar from unrefined raw sugar which is purchased from domestic or foreign factories. Molasses is produced as a by-product and is sold as animal feed, for the making of alcohol, as a source of certain organic chemicals (ethyl and butyl alcoholols, and acetic and citric acids), and for other uses.

Due to the fact that raw sugar is more economically transported than is refined sugar (raw sugar is not considered to be a foodstuff and thus can be shipped in bulk without extensive sanitary safeguards), refineries are generally located in urbanized retail market areas as

TABLE 3

AMERICAN CANE SUGAR REFINERIES

Refinery	Location	Normal Melt kkg/day)	Map No.
[Crystalline Refineries (14)]			
Amstar	Baltimore, Md.	2350	6
Amstar	Boston, Mass.	900	1
Amstar	Brooklyn, N.Y.	1900	24
Amstar	Chalmette, La.	2800	15
Amstar	Philadelphia, Penn.	1900	4
California & Hawaiian	Crockett, Calif.	3175	25
California & Hawaiian	Aiea, Hawaii	170	19
Colonial (Borden)	Gramercy, La.	1350	12
Evercane (Savannah Foods)	Clewiston, Fla.	360	26
Godchaux	Reserve, La.	1540	8
Imperial	Sugarland, Texas	1350	11
National	Philadelphia, Penn.	1900	5
Revere	Charlestown, Mass.	1090	27
Savannah Foods	Port Wentworth, Ga.	1700	18
[Liquid Sugar Refineries (5)]			
Florida Sugar (Borden)	Belle Glade, Fla.	350	17
Industrial (Borden)	St. Louis, Mo.	275	10
Pepsico	Long Island, N.Y.	725	2
Ponce Candy	Ponce, P.R.	55	29
SuCrest	Chicago, Ill.	775	9

TABLE 3 (Continued)

AMERICAN CANE SUGAR REFINERIES

Refinery	Location	Normal Melt (kkg/day)	Map No.
[Liquid-Crystalline Refineries (2)]			
CPC	Yonkers, N.Y.	1650	3
SuCrest	Brooklyn, N.Y.	750	7
[Refineries Operating with Sugar Factories (8)]			
Glades County	Moore Haven, Fla.	420	16
Guanica	Ensenada, P.R.	200	21
Igualdad	Mayaguez, P.R.	630	20
J. Aron & Company	Supreme, La.	680	13
Mercedita	Ponce, P.R.	545	22
Roig	Yabucoa, P.R.	360	23
South Coast	Mathews, La.	635	14
Southdown	Houma, La.	635	28

shown in Figure 1 and Table 3. The refinery located in Aiea, Hawaii, produces sugar primarily for island consumption. The refinery at Crockett, California, services the West Coast market and receives its raw material primarily from the Hawaiian sugar factories.

In some cases, refineries can be located near both factories and retail markets as can be observed in south Florida, New Orleans, and Hawaii. The refineries in Puerto Rico, all of which operate in conjunction with raw sugar factories, serve the Puerto Rican domestic market.

The 24 refineries in the continental United States and Hawaii are owned by fifteen private corporations or cooperatives. Four of the refineries in Puerto Rico are operated by the Puerto Rican government. Those organizations operating more than one refinery are listed in Table 4.

TABLE 4

MULTIPLE OWNERSHIP OF SUGAR REFINERIES

Owner	Headquarters	Number of Refineries
Amstar	New York, N.Y.	5
California & Hawaiian	San Francisco, California	2
Borden	Columbus, Ohio	3
Savannah Foods	Savannah, Georgia	2
SuCrest	New York, New York	2

PROCESS DESCRIPTION - CANE SUGAR REFINERIES

The raw material for cane sugar refining is the raw, crystalline sugar produced by the cane sugar factories. Raw sugar consists primarily of crystals of sucrose ($C_{12}H_{22}O_{11}$) with small percentages of dextrose (glucose) and levulose (fructose), both with formulas of ($C_6H_{12}O_6$), as shown in Figure 2, and various impurities which may include bagasse particles, organics, inorganic salts, and microorganisms. Raw sugar crystals contain a film of molasses, the thickness of which varies with the purity of sugar, and in which the non-sucrose components are concentrated.

The raw sugar processed by the American refineries may be of domestic or foreign origin, and the production as well as the importation of raw sugar is closely governed by U.S.D.A. quota. From a refining process

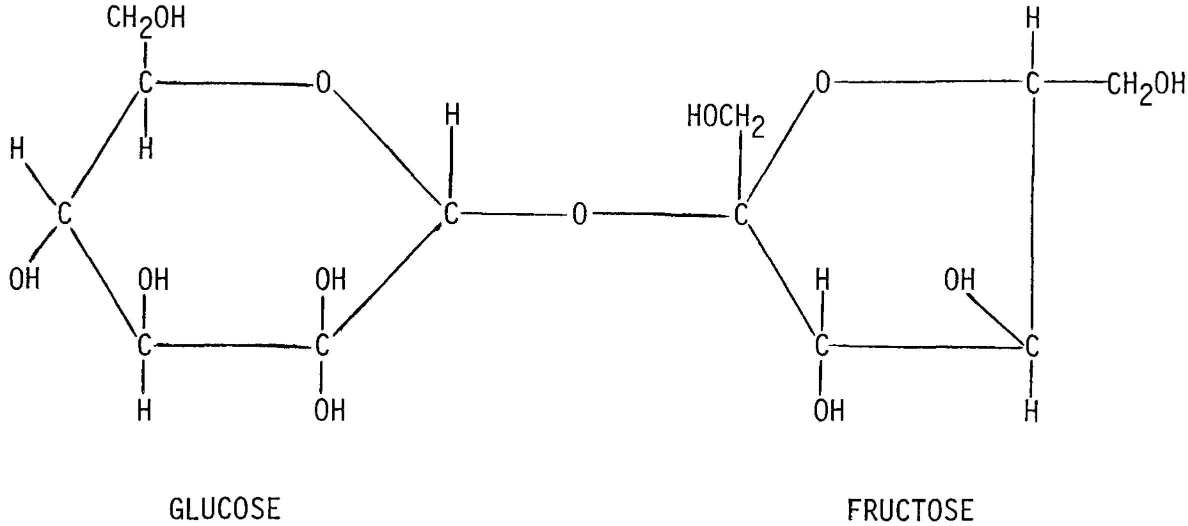


FIGURE 2

SUCROSE OR α-D-GLUCOPYRANOSYL--β-D-FRUCTOFURANOSIDE viewpoint, there is little difference in raw sugar related to its source other than the amount of impurities present.

A cane sugar refinery receives raw sugar in bulk form by truck, rail, barge, and/or ship, and stores it for periods up to several months in large warehouses. As required by the refining process, the raw sugar is conveyed from storage through continuous weighing to the magma mingler, the first step in sugar refining. Figure 3 presents a simplified process diagram of cane sugar refining.

Sugar refining may be broadly defined as the removal of most of the molasses film and associated impurities from the surface of the raw sugar crystals. The crystalline raw sugar is washed to remove part of the molasses film, then placed into solution, taken through various purification steps, and finally recrystallized. While the process is simple in scope, a detailed discussion could fill many volumes. This discussion will be necessarily of a limited nature. Furthermore, processes may vary in detail considerably from refinery to refinery, particularly in decolorization methods where the media may be bone char, granular activated carbon, powdered activated carbon, vegetable carbon, ion-exchange or other materials. The predominate media in the United States, however, is bone char. Figure 4 presents a process flow diagram of bone char refining and Figure 5 is a schematic of carbon refining.

Affination and Melting

The first step in the refining process is affination which begins with mingling, or placing the raw crystals into a syrup solution. The main source of the mingling syrup is the affination centrifugals. Either the recycled syrup is heated in order to aid in loosening the molasses film, or the resulting magma is heated in a revolving mixer. The magma is fed into centrifugals, which separate the syrup and molasses from the sugar. Hot water is then added to provide a washing action. The washed sugar is discharged into a melter which also contains about one-half of the sugar's weight in water. High- test sweet waters and remelt syrups may also be added. Steam heat and mechanical mixing are supplied to the melter. Melt liquor leaves the melter at a constant density of about 65° Brix and a temperature of about 66° Centigrade (150° Fahrenheit).

The liquor is subjected to coarse screening and, in many cases, fine screening to remove coarse materials such as sand and scale. These relatively small amounts of impurities are normally discarded as solid waste.

Clarification (Defecation)

The screened melt liquor still contains fine suspended and colloidal matter which are removed in clarification. Clarification may involve coagulation and either flotation clarifiers or pressure filtration. The most common chemical defecants are phosphoric acid, carbon dioxide, and

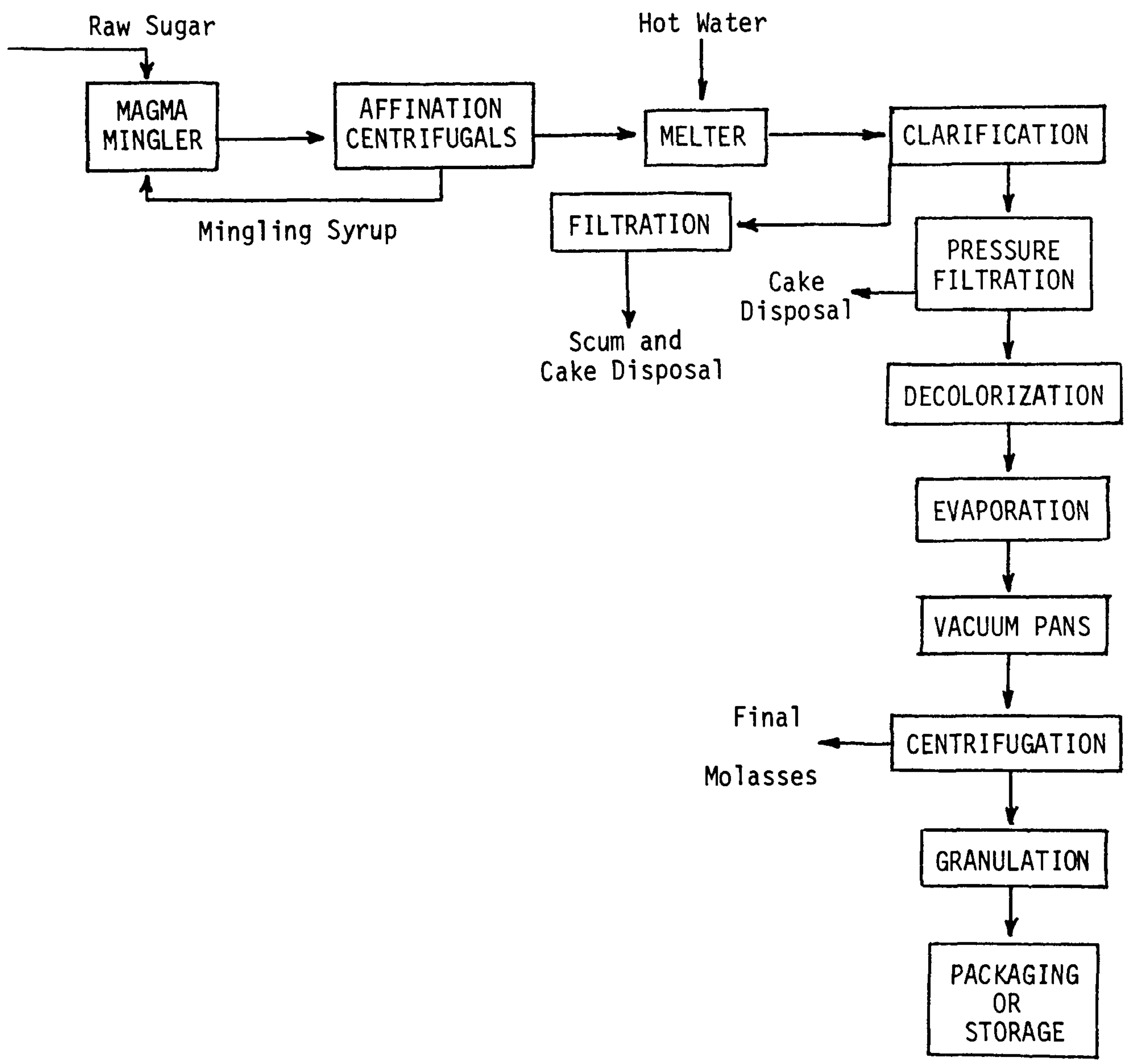


FIGURE 3

SIMPLIFIED PROCESS DIAGRAM FOR CANE SUGAR REFINING

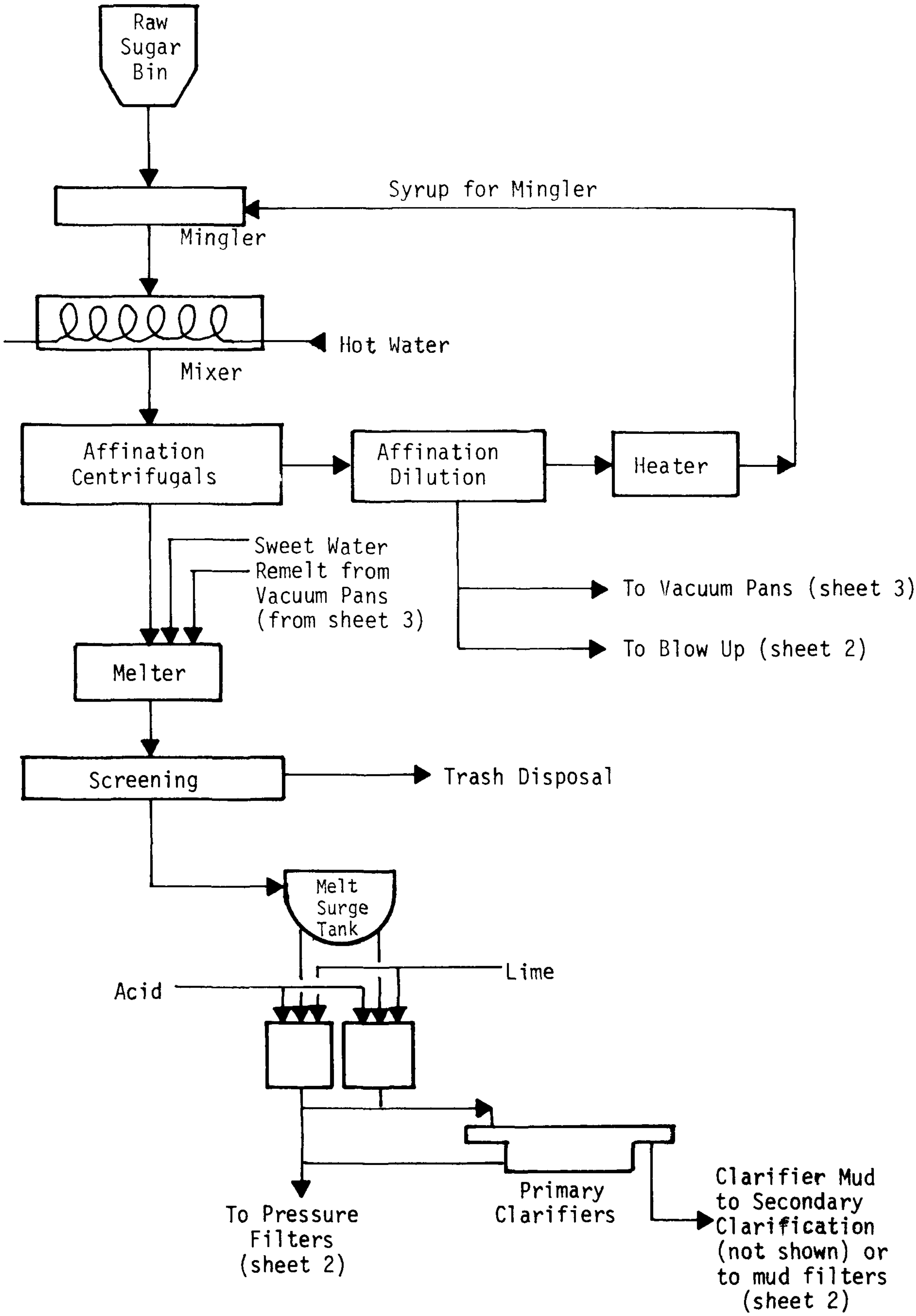


FIGURE 4

TYPICAL BONE CHAR REFINERY **Sheet 1 of 3**

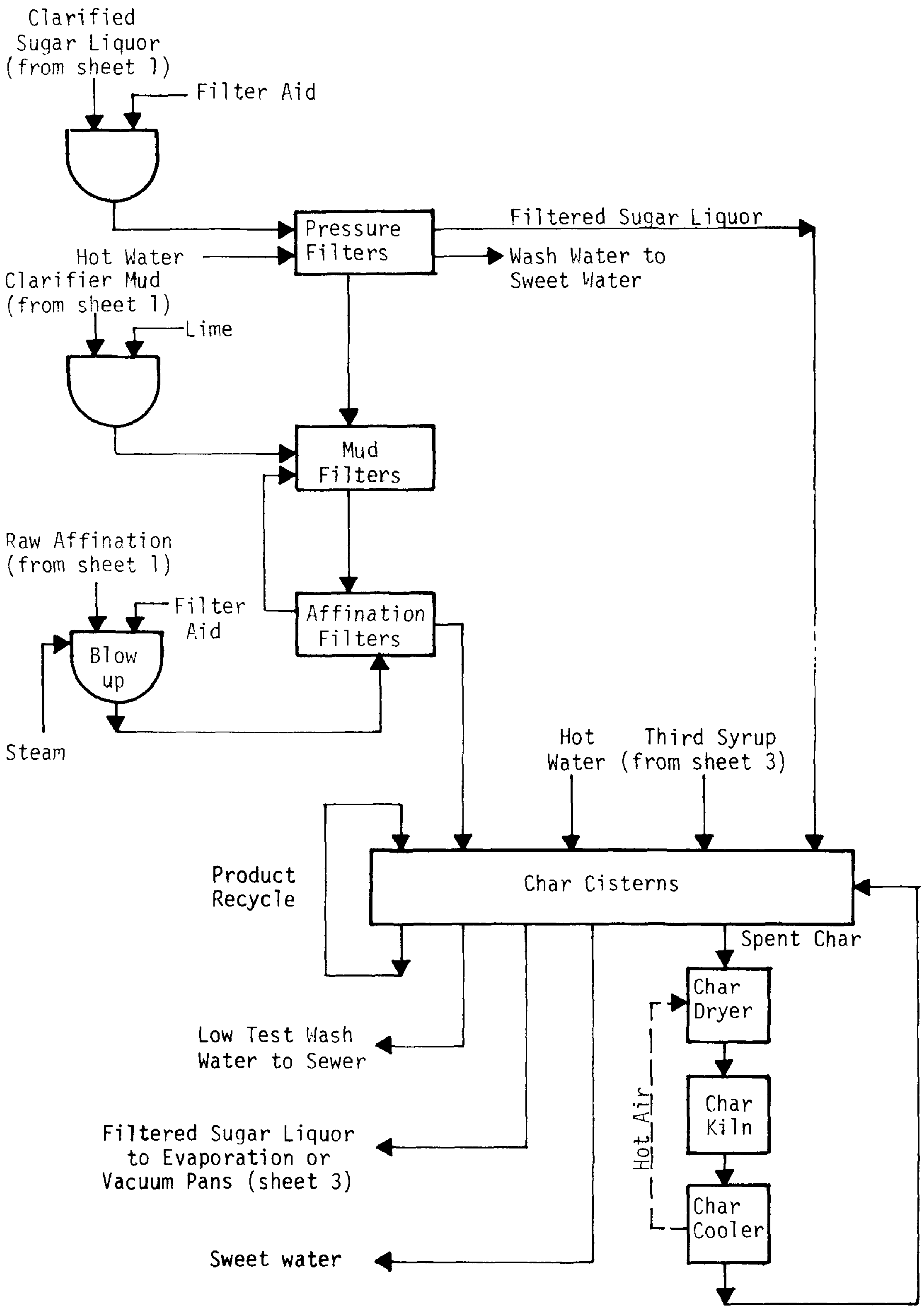


FIGURE 4 (CONTINUED)

TYPICAL BONE CHAR REFINERY Sheet 2 of 3

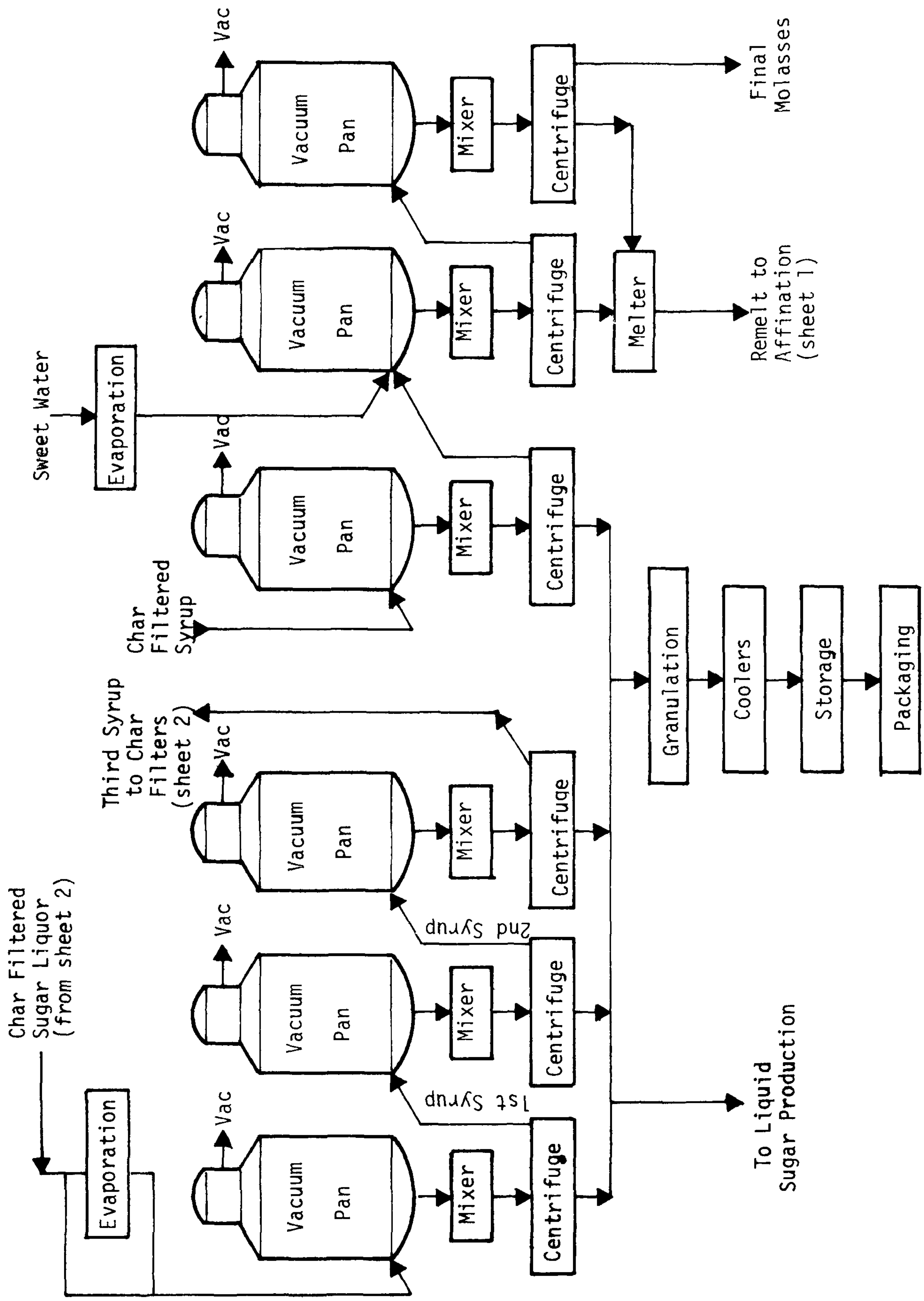


FIGURE 4 (CONTINUED)

TYPICAL BONE CHAR REFINERY

Sheet 3 of 3

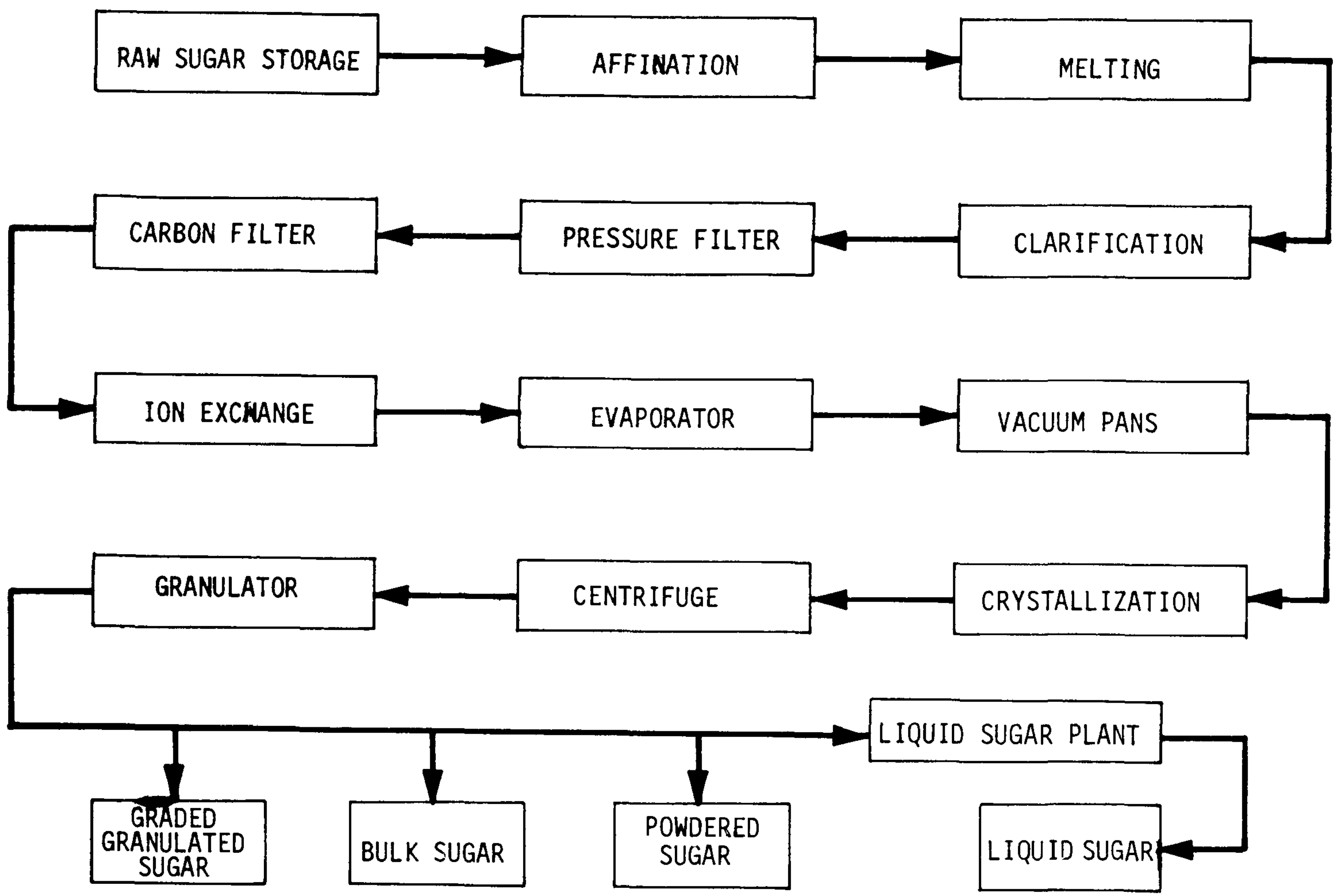


FIGURE 5

TYPICAL CARBON REFINERY

lime. The result of this treatment is neutralization of organic acids and formation of a tri-calcium phosphate precipitate which entrains much of the colloidal and other suspended matter in the liquor. Carbonation produces a calcium carbonate precipitate. Inert filter aids, most commonly diatomaceous earth, may be used alone or in conjunction with phosphoric acid.

Clarification systems that remove the colloidal and suspended precipitate by air flotation are called frothing clarifiers and are based simply on the principle of rising air bubbles trapping the precipitate and forming a scum on the liquid surface. Pressure filtration commonly takes place in a cloth or leaf-type filter with cake removal by means of high pressure sprays.

The muds, scums, and filter muds produced in clarification contain significant sugar concentrations which must be recovered. Frothing clarifier scums, particularly tri-calcium phosphate scums, are often sent to a second clarifier and the resulting scum is filtered on rotary vacuum drums with the addition of filter aid. The press cake is usually handled in a dry form and taken to landfill but may be slurried. High-test sluicings may be dewatered in rotary vacuum filters and the resulting sweetwater added to affination syrups and the dewatered cake used as filter aid for filtration.

Decolorization

After affination and clarification, the sugar liquor still contains impurities and color that require physical adsorption for removal. As previously stated, most large crystalline refineries use fixed bed bone char cisterns (also called filters), although in more than 50 years there have been no new refineries equipped with them. An individual cistern is commonly three meters (ten feet) in diameter and six meters (20 feet) deep and holds approximately 36 metric tons (40 tons) of bone char and 20,800 liters (5,500 gallons) of sugar liquor. There are generally 30 cisterns per million kilograms of daily melt.

Sugar liquor passes in parallel through each cistern in a downward direction and undergoes adsorption of the color bodies and ions. From 90 to 99 percent of color is removed, with the higher removal occurring at the beginning of the cycle. Divalent cations and anions and polyvalent organic ions are effectively removed, as are phosphate and bicarbonate. Monovalent ions are not removed.

After some period of operation, the decoloration ability of the char decreases to an unacceptable level and the char must be washed and regenerated by heat in kilns or char house furnaces. The sugar liquor in the cistern is displaced with a piston effect by hot water. The water effluent is a low purity sweet water and is taken to evaporation for sugar recovery. The total amount of sweet water produced is usually about one-half of the cistern's volume.

After the purity of the water effluent has degraded to a point where further sugar recovery is considered uneconomical, it is released as a waste water stream. The amount of wash water used may be governed either by time or by ash content.

After the last of the wash water has drained from the char cistern, the char is discharged from the cisterns, dried by hot air, and regenerated in kilns. The kilns provide a temperature of about 550° Centigrade and a controlled amount of air. Under these conditions any organic residue is destroyed and the buffering and decolorizing capacity of the char is renewed.

The operation of a granular carbon refinery is in many ways similar to that of a char refinery, but there are at the same time significant differences. Granular carbon adsorbs minimal ash and produces considerably more sweet water. The only waste water normally associated with the decolorization step in the process is water used for transporting the carbon. Transport water can be reused as transport water, but must be discharged periodically due to bacterial growth. Most granular carbon refineries discharge transport water once or twice a week.

Powdered activated carbon is used for decolorization in small refineries and in liquid sugar production. Regeneration of powdered carbon is difficult and it is normally discarded after one or two cycles. However, in 1972, one company announced the successful and economical regeneration of powdered activated carbon.

The clarified liquor is contacted and agitated for about 15 to 20 minutes with a slurry of carbon prepared with water or sugar solution. After that period of time, carbon will not adsorb more coloring matter, but coloring matter already adsorbed can be washed back into the sugar solution. The temperature of treatment is about 82° Centigrade (180° Fahrenheit). After the treatment is completed, about five kilograms (10 pounds) of filter aid per 3,800 liters (1,000 gallons) of sugar liquor is admixed and thoroughly dispersed in the liquor before filtration. The filtration is accomplished in filter aid precoat-type leaf filters. The cycle of each filter unit varies from five to twenty four hours, depending on the filterability and color of the sugar liquor that is being filtered. The decolorized filtrate is checked in a precoat-type leaf filter and then sent to the double-effect evaporators for concentration prior to crystallization. The total filter aid consumption is about 0.4 to 0.5 percent based on refined sugar output. The filter cake containing the filter aid, carbon, and impurities is sent in slurry form to the clarification scum tank, and all this mixture is filtered in a dry discharge type pressure filter (either plate and frame or leaf type); all solids are discarded, after sweetening off, in dry cake or slurry form in a suitable disposal area.

Ion-exchange resins are used to a limited extent in sugar refining for demineralization (deashing) or further color removal. They are used most extensively in carbon and liquid sugar refineries. Refinery liquors are percolated through a cation-exchanger which adsorbs alkaline salts from the liquor and leaves it highly acidic. Then the liquor is percolated through an anion-exchanger which removes the free acid and converts the sugar liquor to a neutral state. This double percolation can be avoided by using cationic and anionic resins mixed together in a single-bed cistern. The operation of ion-exchange beds in refineries is not unlike that of many industrial applications in that they are regenerated in place with sodium chloride, sulfuric acid, or other chemicals depending on the type of resin. The cost and disposal of chemicals needed for regeneration of ion-exchangers has precluded its application for the entire refining process.

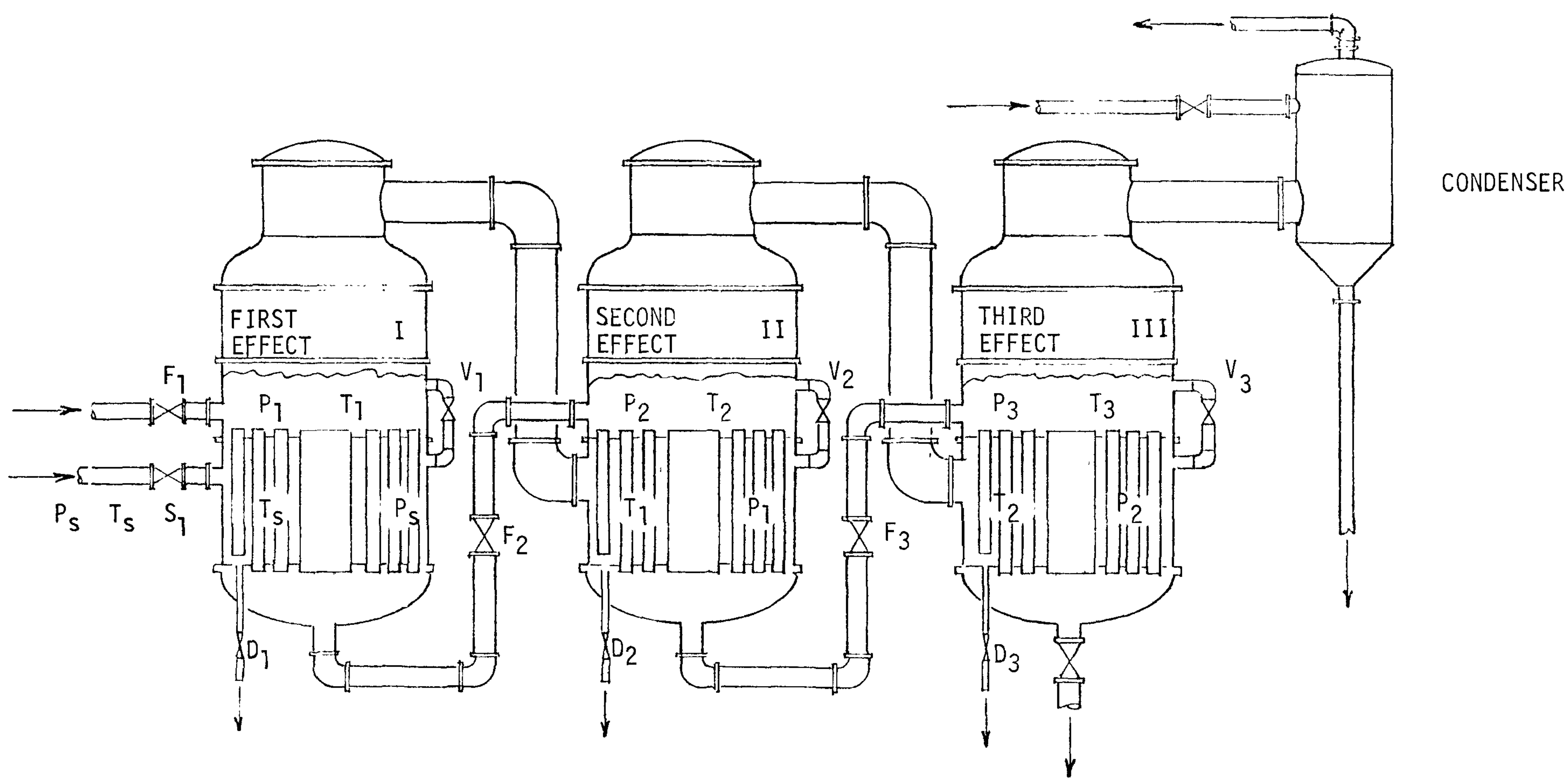
Evaporation

No matter what method of decolorization is used, the final steps of re-crystallizing and granulating are essentially the same in all refineries. The first step in recrystallization is the concentration of the decolorized sugar liquor and sweet waters in continuous-type evaporators.

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 flash evaporation and the principle allows evaporators to be operated in a series of several units. This practice is called multiple-effect evaporation, with each evaporator being an "effect", and is illustrated in Figure 6. 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 live steam or exhaust steam resulting from power production 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 is, therefore, lower than the preceding effect.

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

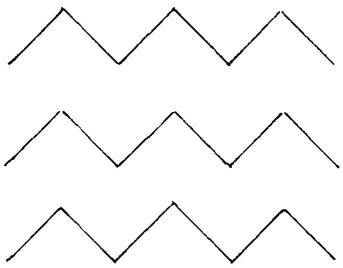
Condensation of the last effect vapors may be provided by one of several condenser designs, but all operate on the principle of relatively cold water passing through a cylindrical vessel, contacting the hot vapors, and condensing them. The resulting hot water leaves through a long vertical pipe called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



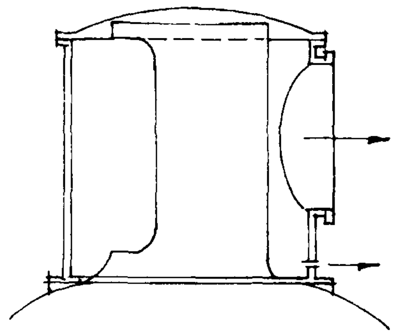
D_1, D_2, D_3, CONDENSATE VALVES
F_1, F_2, F_3, FEED VALVES
S_1, STEAM VALVE
V_1, V_2, V_3, VENT VALVES
P_s, P_1, P_2, P_3, PRESSURES
T_s, T_1, T_2, T_3, TEMPERATURES

FIGURE 6

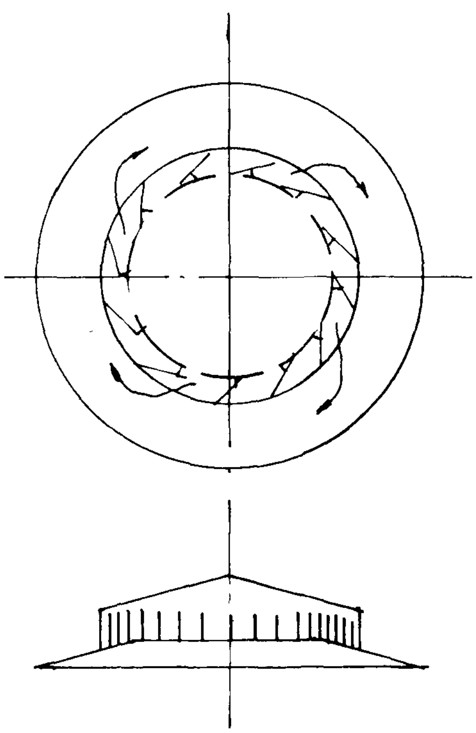
TRIPLE EFFECT EVAPORATION



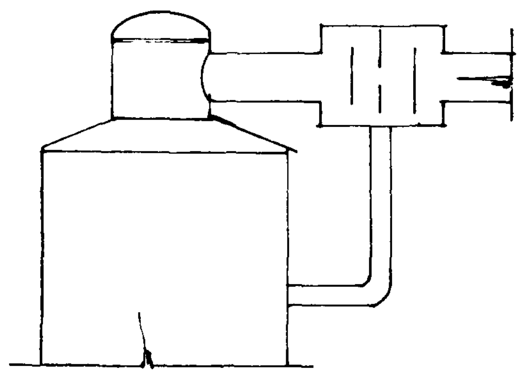
(A) Zig-Zag Baffle



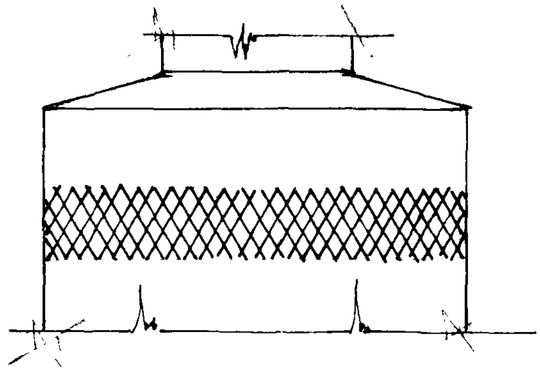
(B) Catch All



(C) Cyclone Separator



(D) In-Line Baffle Box



(E) Demister

FIGURE 7

DEVICES TO REDUCE ENTRAINMENT

by a vacuum pump or steam ejector. The condenser cooling water, or barometric leg water, at a flow rate of perhaps 76,000 cubic meters per day (20 million gallons) in a large refinery, is the largest volume of water used in a cane sugar refinery. It is often untreated river or sea water and is unsuitable for reuse in other processes in sugar refining although some refineries use better quality water which is recycled after cooling in a cooling tower or spray pond, and then reused in other processes.

A problem common to the sugar refiner in his attempt to prevent sugar loss and to the environmentalist in his attempt to prevent pollution is the entrainment of sugar in the vapors from the evaporators and vacuum pans. The condensed steam from the first effect has not come into direct contact with the sugar solution and is essentially pure water. It is usually used as feed water for the steam boilers as is the condensate from the second effect. The condensates from the other effects experience relatively little sugar entrainment and are used as process water; however, in some cases "excess" condensate may be discharged as a waste stream. The major problem, then, is with the vapor from the last effect which tends to have greater entrainment than the other effects. Due to its mixing with the condenser water, the resultant volume is too large for reuse in the process. However, condenser water may be recirculated. If recirculated, the warm water from the condensers of evaporators and vacuum pans is cooled in cooling towers or spray ponds and recycled. Only a fraction of the volume goes to the stabilization ponds as blowdown from the cooling tower or spray pond. This volume is a function of the dissolved solids content of the water being used as barometric condenser cooling water. One would not recycle brackish water because of the high concentration of dissolved solids. With good quality water, this blowdown can amount to as little as one percent.

Various methods of reducing entrainment are used in the industry, but most are based on either the principle of centrifugal action or that of direct impact; i.e., 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 allowing the vapor to come into direct contact with a wet surface. Schematics of various methods commonly used are shown in Figure 7.

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 has a great effect on the degree of entrainment because the further the vapor has to rise the greater the opportunity for liquid droplets to fall out. Most evaporator vapor belts in refineries range from 3.7 to 4.9 meters (12 to 16 feet) or about 2.0 to 2.5 times the length of the tubes.

Refineries monitor sucrose concentrations in condensate and condenser water in order to avoid sugar contamination in boiler feed waters and sugar loss in condenser water. The frequency of monitoring may vary from continuous (auto analyzers) to hourly, daily, or weekly. The methods of analysis for sucrose most commonly used are the alphanaphthol and resorcinol tests. Both methods are based on color change resulting from the reaction of the test reagent with sucrose.

Crystallization

After concentration in evaporators, in the case of crystalline refineries, the sugar liquor and sweet waters are crystallized in single-effect, batch type evaporators called vacuum pans. Several pans are used exclusively for commercial granulated sugar and the resulting syrups are boiled in other pans, as shown in Figure 4. Calandria pans are commonly used and are similar to the calandria evaporator described above except that the pans have larger diameters and shorter tubes in order to handle the more concentrated liquid.

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 new crystals do 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 the metastable phase and allows the growth of seed crystals. Automatic controls such as level, pressure, and viscosity instrumentation for pan operation are used extensively in sugar refining.

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 catchalls, centrifugal separators, or baffle arrangements are used along with sucrose monitoring (see Figure 7). In some cases a small surface condenser is inserted between the pan and the barometric condenser to act as a heat exchanger in order to heat process water. This also serves to reduce sucrose entrainment.

After the formation of crystals in the pans, the massecuite content of the pan--called a strike--is discharged into a mixer where it is gently agitated, and then into high speed centrifugals where the crystals are separated from the syrup. The crystals remaining in the centrifugals are washed with hot water to remove remaining syrup, and the crystalline sugar is discharged and sent to a combined dryer-cooler or to a dryer followed by a cooler.

There are normally four straight refinery massecuites boiled in the vacuum pans: filtered and evaporated first liquor and three remelt strikes derived from affination syrup, refinery run-off, soft sugar run-offs, and excess sweet water. The first refinery strike is boiled from first liquor, the second is boiled from first strike run-off, the third refinery strike is boiled from second run-off and the fourth strike from third run-off. The procedure of boiling second, third, and fourth refinery massecuites is the same as for the first one. In a refinery where only white sugar is produced, the last refinery strike run-off (fourth) can be used in affination as a mingling syrup. Some refineries use it to produce "soft sugars". It can be diluted and filtered through bone char or granulated adsorbents, or treated with powdered activated carbon and used again in boiling. The sugar recovered from the remelt strikes is used for the production of additional refined sugar and well exhausted refinery blackstrap molasses. From 10 to 15 percent of the original solids in the melt are recycled through the remelt (or recovery) stations.

Finishing

The dryer or granulator is usually a horizontal, rotating drum 1.5 to 2.4 meters (five to eight feet) in diameter and 7.6 to 11 meters (25 to 35 feet) long which receives steam heated air along with the sugar crystals. It may consist of one or more drums in parallel. The granulators remove most of the one percent moisture content to 0.02 percent or less. In addition, the dryers serve to separate the crystals from one another. After drying, the sugar goes to coolers, which are similar drums without the heating elements.

Any lumps remaining in the sugar are then removed by fine screening. Screening also accomplishes crystal size grading.

Both the granulating and screening processes produce considerable amounts of dust. Wet dust collectors are commonly used to collect this dust and the resulting sugar solution is collected as sweet water.

The finished crystalline sugar is transported to conditioning silos and then ultimately to packaging or bulk shipment. In the larger granulated sugar refineries it is not uncommon to produce liquid sugar by melting granulated sugars and then decolorizing the solution with powdered activated carbon; the resulting solution is then filtered and cooled before being sent to storage as liquid sucrose. It may also be inverted to either 100 percent, 50 percent or any other degree of inversion and stored separately from liquid sucrose in stainless steel clad tanks provided with ultra-violet lamps and air circulation filters for sterilization purposes.

Liquid Sugar Production

As noted in Table 3, there are four refineries in the United States that produce liquid sugar exclusively as a final product and two that produce large portions of liquid as well as crystalline sugar. Most of the remaining twenty-two produce some liquid sugar by melting granulated sugar.

As shown in Figure 8, the initial refining steps of affination, decolorization, and even evaporation in a liquid sugar refinery are essentially the same as in a crystalline sugar refinery. The primary difference occurs in the fact that liquid sugar refineries do not recrystallize their primary product. While this preempts the necessity of using vacuum pans to effect crystal formation and growth in the case of the primary product, nevertheless, all but two liquid refineries use vacuum pans for the crystallization of remelt sugars, producing molasses as a by-product. The two liquid refineries that do not remelt use a highly pure raw material. The production of liquid sugar is essentially a concentration and decolorization of the melted raw sugar solution. Because crystal formation is not a part of primary liquid sugar production, considerably less condenser water and process steam is required. This results in substantially less water usage to process the same quantity of raw cane sugar into liquid sugar than that required to process it into crystalline sugar. This is further discussed in Section V. After evaporation, the sugar solution is filtered and cooled and then sent to storage as liquid sugar. It may also be inverted to a specific degree and stored separately in stainless steel clad tanks equipped with ultra-violet lamps and air circulation filters to insure sterilization. The processes of filtration and inversion are the same as those used in the formulation of liquid sugar by the melting of crystalline sugar.

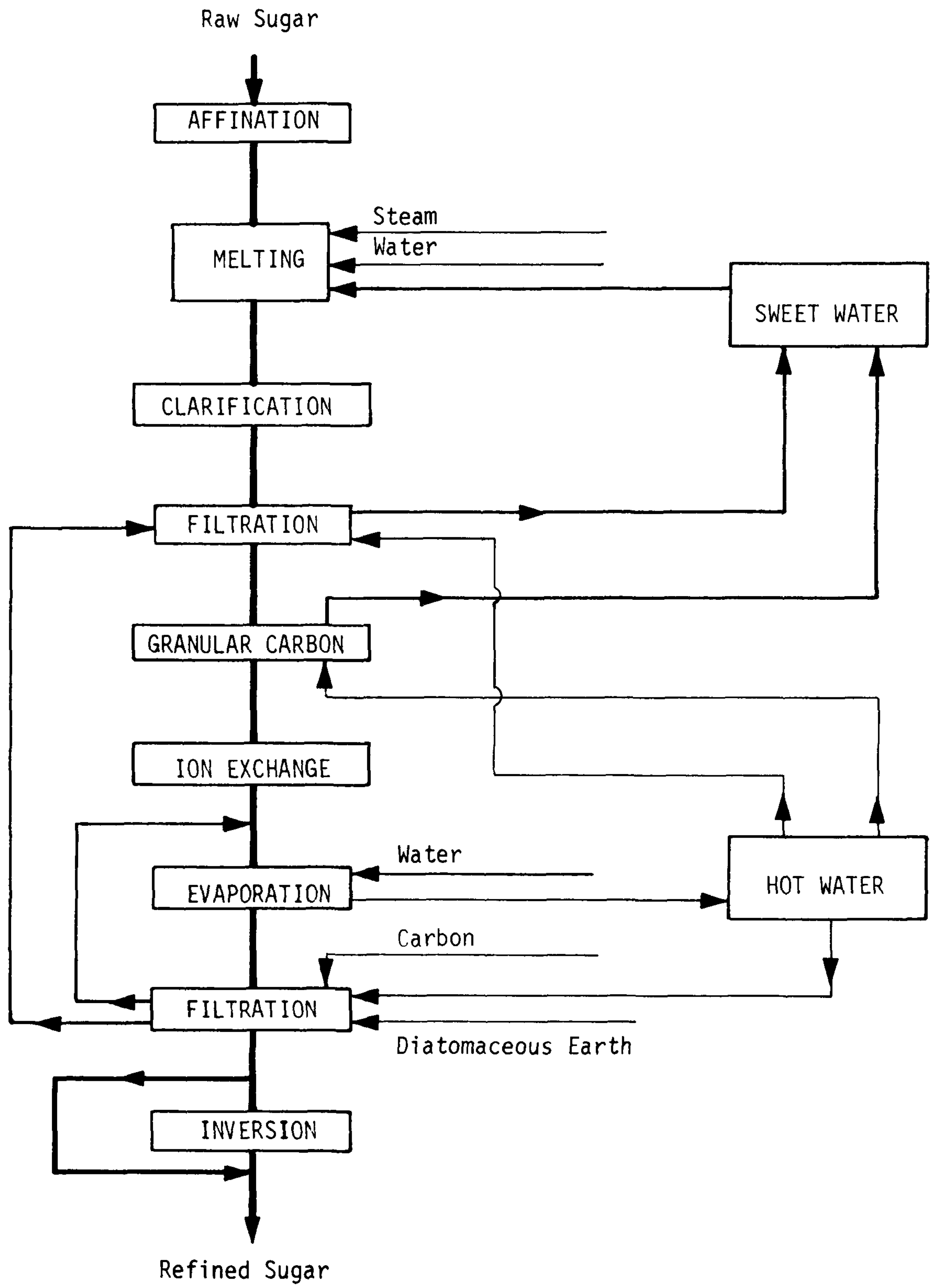


FIGURE 8

LIQUID SUGAR REFINING

SECTION IV

INDUSTRY CATEGORIZATION

In the development of effluent limitation guidelines and standards of performance for the cane sugar refining industry, it was necessary to determine whether significant differences exist which form a basis for subcategorization of the industry. The objective of industry subcategorization is to subdivide the industry in order that separate effluent limitations and standards be established for such subcategories. Several factors were considered significant with regard to identifying potential subcategories in the cane sugar refining industry. These factors included:

1) Raw material quality
2) Refinery size
3) Refinery age
4) Nature of water supply
5) Land availability
6) Process variation

After consideration of the above factors, the cane sugar refining industry has been divided into two subcategories: liquid cane sugar refining and crystalline cane sugar refining. The justification for this subcategorization is presented below.

Raw Material Quality

All cane sugar refineries process raw sugar as produced by raw sugar factories. An obvious point of inquiry in this regard is the source of raw sugar--namely, imported versus domestic raw sugar. A significant portion of raw sugar refined in the United States is imported from Africa, Latin America, the Phillipine Islands, and Southeast Asia. Depending upon the operation of the factory, and to some extent upon the conditions under which raw sugar is shipped and stored, raw sugar could vary in impurity and moisture content. Investigations revealed that no significant variation in raw sugar quality exists because of specifications imposed by individual refineries.

The exceptions are two liquid refineries which impose higher than normal standards for raw sugar purchases. One refinery purchases raw sugar from selected Louisiana and Central America factories, while the other purchases from selected Florida factories. The high quality of raw sugar allows these two refineries to avoid remelting and preempts the use of vacuum pans (as previously discussed in Section III, Introduction). Neither of these refineries discharges waste water directly to surface waters. One is located in an urban area and discharges all waste to a municipal sewer; the other has a rural siting and has geographical conditions which allow for total impoundage of all waste waters.

For the purpose of establishing national effluent limitations and standards, these two refineries are considered to be exceptions to general practices. They are therefore not applicable as examples of best practicable or best available technologies because of the nonavailability of this high-purity raw sugar to the refining industry in general. For this reason, separate subcategorization based on raw material quality is not required.

Refinery Size

As indicated in Section III, cane sugar refineries vary considerably in size. The smallest operation is the Ponce Candy refinery, with a refining capacity of 55 metric tons (60 tons) per day. The California & Hawaiian refinery at Crockett, California, with a refining capacity of 3175 metric tons (3500 tons) per day, claims the distinction of being the world's largest sugar refinery. Other large refineries are located in the urbanized Northeast, in Savannah, Georgia, and in the New Orleans area. The smaller refineries are generally those associated with sugar factories.

It might be expected that larger refineries would have better operation than smaller ones; however, in actual practice this is not always the case. While data are more variable for small refineries, no evidence is available which shows significant differences in process water usage (See Section V). For the above reasons size is not regarded as a technical element for subcategorization. Size is considered to be a factor to be further studied for possible economic impact; for this reason, cost estimates for control and treatment pertaining to typical large and small refineries are included in Section VIII, Cost, Energy, and Non-Water Quality Aspects.

Refinery Age

Cane sugar refineries vary considerably in age of structure; several of the larger refineries currently operating were originally constructed in the decades following the American Civil War, while others were constructed after the Second World War. On a basis of unit operations employed, all refineries have undergone a process of continuous modernization. The age of the walls of a refinery is no indication of the age of the processing equipment within the walls. No definitive subcategorization on the basis of age can be established. This conclusion is further substantiated in that one of the oldest refineries has been determined to be exemplary in terms of inplant controls and practices and raw waste characteristics.

Nature of Water Supply

The quantity and quality of fresh water supplies utilized by refineries were originally considered to be possible elements for industry subcategorization because of potential prohibitive factors that could be encountered in control and treatment. Water used for process or boiler water must be of highest quality; if a high quality source of water is unavailable, a refinery must provide treatment. However, the quality of water used as condenser cooling water is unimportant; it was observed to vary from municipal water to sea water. Typically, refineries use a low quality surface water as barometric condenser cooling water.

The major importance of the gross characteristics of condenser water is that with a high quality intake, the discharge (which essentially has no net pollution except for temperature and entrained sucrose) can be reused in the refining process. Thus a major waste water stream, condenser cooling water, can be significantly reduced or, depending on the relative volumes, virtually eliminated. One refinery accomplishes this by utilizing municipal water as the source for condenser cooling water. It is a liquid refinery which does not use vacuum pans, for reasons discussed above and in Section III, and thus has a relatively low volume of condenser water. More typically, due to the volumes required and based on present practices, refineries utilize available surface waters as condenser cooling water, regardless of quality.

Land Availability

Land availability was originally considered as a possible element for subcategorization because of the potential economic advantages and technical feasibility of waste water treatment and retention by lagooning, land disposal, and impoundage (see Section VII, Control and Treatment Technology). Land availability has been defined as the ownership or potential ownership of land, or the use or potential use of land owned by others with the owner's permission, with such land being of sufficient quantity to provide treatment of waste water by lagooning, land disposal, or impoundage, and with the stipulation that the economic value of the land does not prohibit its use in such manner. For a number of large refineries in urban areas, the nonavailability of land must further be defined as the lack of sufficient space for industrial waste water treatment facilities. However, these refineries presently have access to municipal treatment systems, to which they discharge their process waste water.

It was determined that relatively little of the sugar refining industry has available land. Forty-five percent of the refinery installations may be considered to be rurally located, but these represent only about 25 percent of the industry on a production basis. Land and excavation costs for total impoundage of waste waters make this treatment alternative prohibitive for the industry as a whole. The option exists, however, with a proper choice of site location based on a careful consideration of geographical and climatic conditions, for new sources to utilize the availability of land in eliminating discharge to navigable waters. For the purpose of establishing uniform national effluent limitations guidelines and standards land availability is not regarded as a technical element necessitating subcategorization.

Process Variation

While the production of refined sugar from raw sugar involves similar operational principles in any refinery, in practice considerable process variation can occur. These variations may be caused by the end product desired or by the attitude of refinery management.

The only process variation which produces significant differences with regard to waste water generation is that which produces liquid versus crystalline sugar (discussed previously in Section III). Due to the reduced amount of recrystallization necessary in liquid refining, crystalline refineries discharge almost twice as much water (on a unit basis) as liquid refineries. In terms of BOD_5 loading, liquid refineries produce approximately two times as much BOD_5 (on a unit basis) as crystalline refineries. This will be further discussed in Section V, Water Use and Waste Characterization.

Another process difference which has to be considered as a potential element for subcategorization is the type of decolorization medium used in the production of crystalline sugar--activated carbon versus bone char. As is shown in Section V, no significant differences occur in process water use as a result of utilization of bone char versus activated carbon as the decolorization medium.

Because of significant differences in water usage and waste loadings the cane sugar refining industry has been divided into two subcategories: liquid cane sugar refining and crystalline cane sugar refining. Within the liquid sugar subcategory there are four refineries which produce exclusively liquid sugar and two refineries which produce liquid in addition to crystalline sugar. These refineries account for over twenty percent of total sugar production. The remainder of the twenty-eight refineries produce crystalline sugar as their primary product.

SECTION V

WATER USE AND WASTE CHARACTERIZATION

SPECIFIC WATER USES - CANE SUGAR REFINERIES

Figure 9 shows a schematic diagram of water usage and waste water flows in a typical liquid sugar refinery and Figure 10 presents one for a typical crystalline refinery. The major inplant water uses include:

Barometric condenser cooling water
Filter cake slurry
Char wash
Floor wash water
Carbon slurries
Boiler makeup
Truck and car wash
Affination water
Ion-exchange regeneration

Water use varies widely among cane sugar refineries due to variations in process, water reuse, and conservation techniques. As shown in Table 5, the amount of fresh water used in refineries varies from 10.5 to 64.2 cubic meters per metric ton (2,520 to 15,400 gallons per ton) of raw melted. The average water usage in liquid sugar refineries is approximately 18.1 cubic meters per metric ton (4,350 gallons per ton), while the average for crystalline refineries is appxoximately 38.2 cubic meters per metric ton (9,160 gallons per ton). Combination crystalline-liquid cane sugar refineries use approximately 35.2 cubic meters per metric ton (8,450 gallons per ton).

Water balances for a liquid and a crystalline refinery are shown in Figures 11 and 12, respectively. Negligible water enters a sugar refinery from raw material. High quality fresh water enters the liquid refinery illustrated at a rate of 1.67 cubic meters per metric ton of raw sugar (400 gallons per ton) and is used for all process purposes other than cooling water. Cooling water is used for the barometric condensers at a rate of 20.9 cubic meters per metric ton (5,000 gallons per ton) of raw sugar melted, and the source of this water is typically the nearest body of surface water. Raw water in the crystalline refinery shown is used at a rate of 45.1 cubic meters per metric ton (10,800 gallons per ton) of raw sugar melted; 3.38 cubic meters (810 gallons) of this is high quality water used for various purposes while 41.7 cubic meters (10,000 gallons) is low quality surface water used as barometric condenser cooling water.

In general, cane sugar refineries are more sophisticated in waste water control techniques than are sugar factories (and more conscious of sugar losses); however, current practices for water reuse are generally

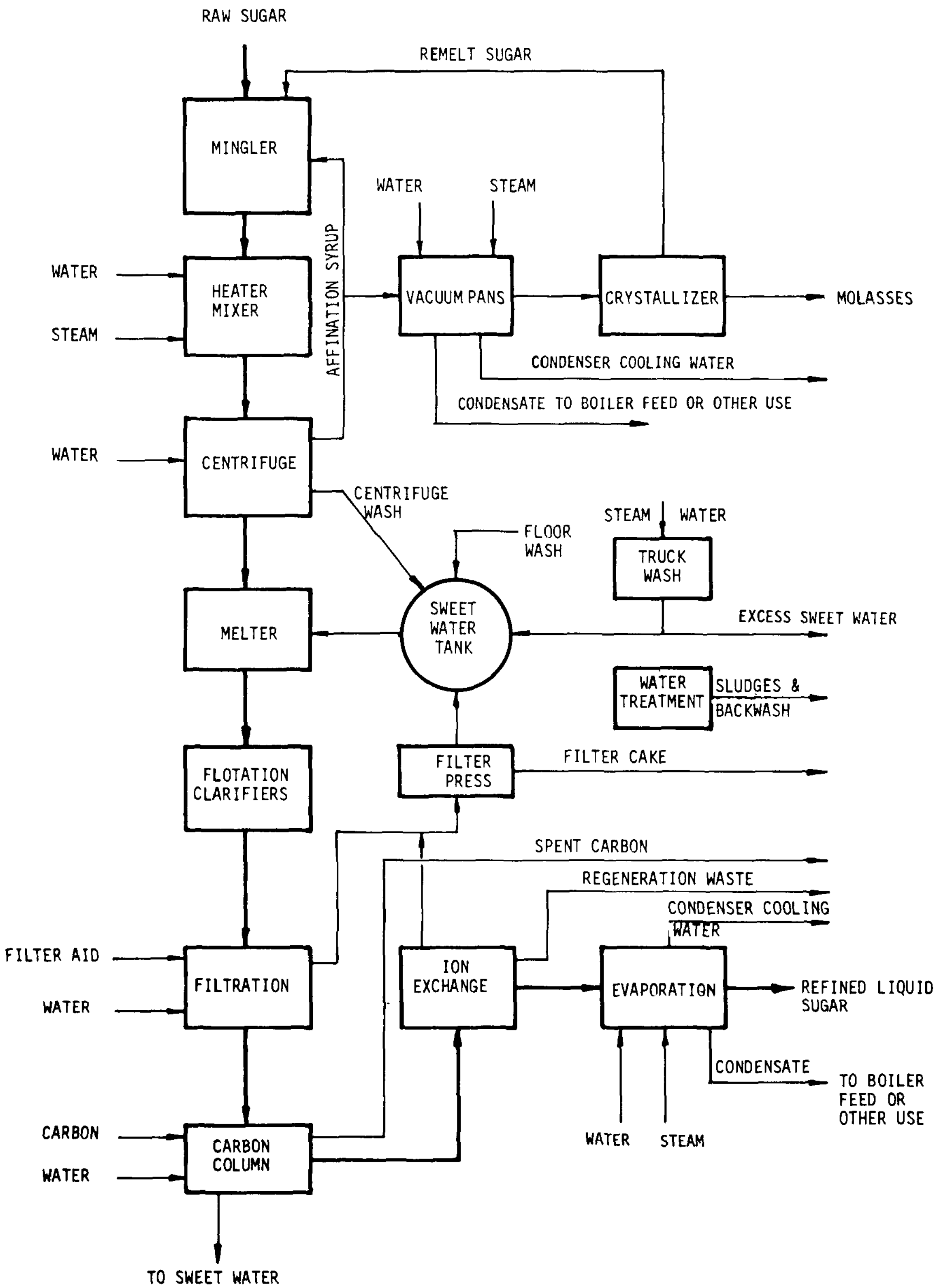


FIGURE 9

WASTEWATER FLOW DIAGRAM FOR A LIQUID SUGAR REFINERY

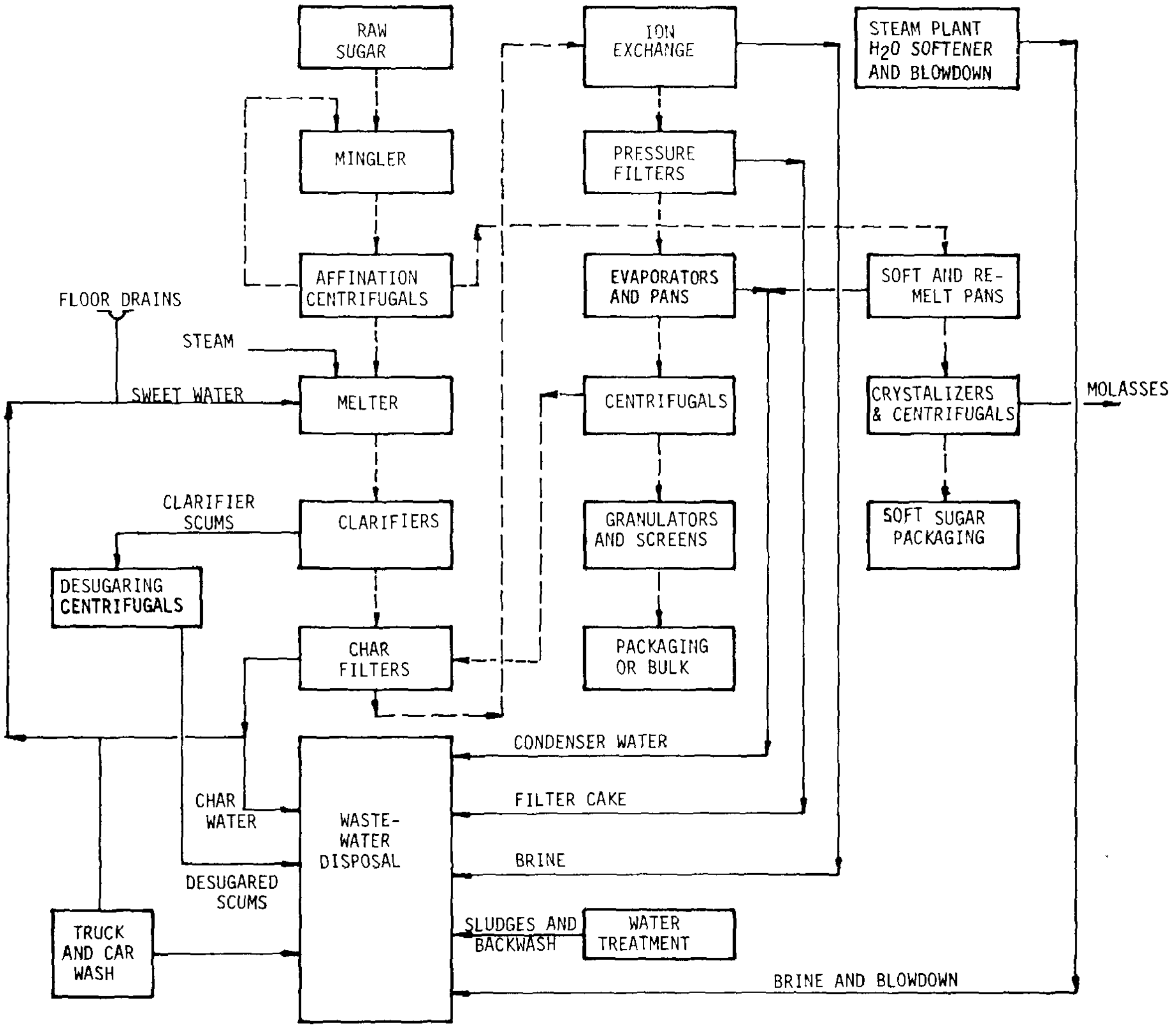


FIGURE 10

WASTEWATER FLOW DIAGRAM FOR A CRYSTALLINE REFINERY

TABLE 5

UNIT WATER* INTAKE AND WASTE WATER DISCHARGES
CANE SUGAR REFINERIES

Refinery	Intake	Discharge	Condenser Water	Process Water	Decolorization Wash
C-1	48.5	48.5	44.9	3.6	
C-2	16.8	16.8	16.1	0.7	0.66
C-3		42.9			
C-4		44.6	43.2	1.4	
C-5	45.2	43.8	42.5	1.3	
C-6		42.4	40.6	1.8	
C-7	25.8	25.8	24.4	1.4	0.54
C-8		64.2	62.8	1.4	0.84
C-9		38.1	34.1	4.0	
C-11		25.0	24.4	0.6	
C-12		63.1	61.7[1]	1.4	
C-14		3.32[2]	23.5	2.7	0.22
L-1	10.5	10.5	8.0		
L-2	16.0	16.0	16.0		
L-3		16.0	14.1	1.9	
L-4		30.0	26.9	3.1	

* All values expressed as cubic meters per kkg of melt.
1 Based on pump capacity, not on actual measured flows.
2 Has a recycle system for barometric condenser cooling water resulting in a reduction in water discharged.

TABLE 5
(CONTINUED)

UNIT WATER* INTAKE AND WASTE WATER DISCHARGES
CANE SUGAR REFINERIES

Refinery	Intake	Discharge	Condenser Water	Process Water	Decolorization Wash
CL-1		22.5	21.3	1.2	
CL-2	47.9	47.9	47.1	0.8	
CF-1			91.3[3]	1.0	
CF-2			45.0	8.6[4]	
CF-3			68.6[5]	2.2	
CF-4			72.0[6]	1.4	

* All values expressed as cubic meters per kkg of melt.
3 Based on vacuum pan capacity, not on actual measured flows.
4 Includes substantial water usage as a result of factory operations (i.e. continuous water spray of bagasse pile). Maximum discharge as a result of refinery operation alone approximated at 3.0 m^3/kkg of melt.
5 Based on pump capacity, not on actual measured flows.
6 Based on maximum barometric condenser capacity; a greater than 50% overflow occurs over pumping capacity of 86.9 m^3/kkg of melt making 43.5 m^3/kkg of melt the upper limit of actual barometric condenser cooling water flow.

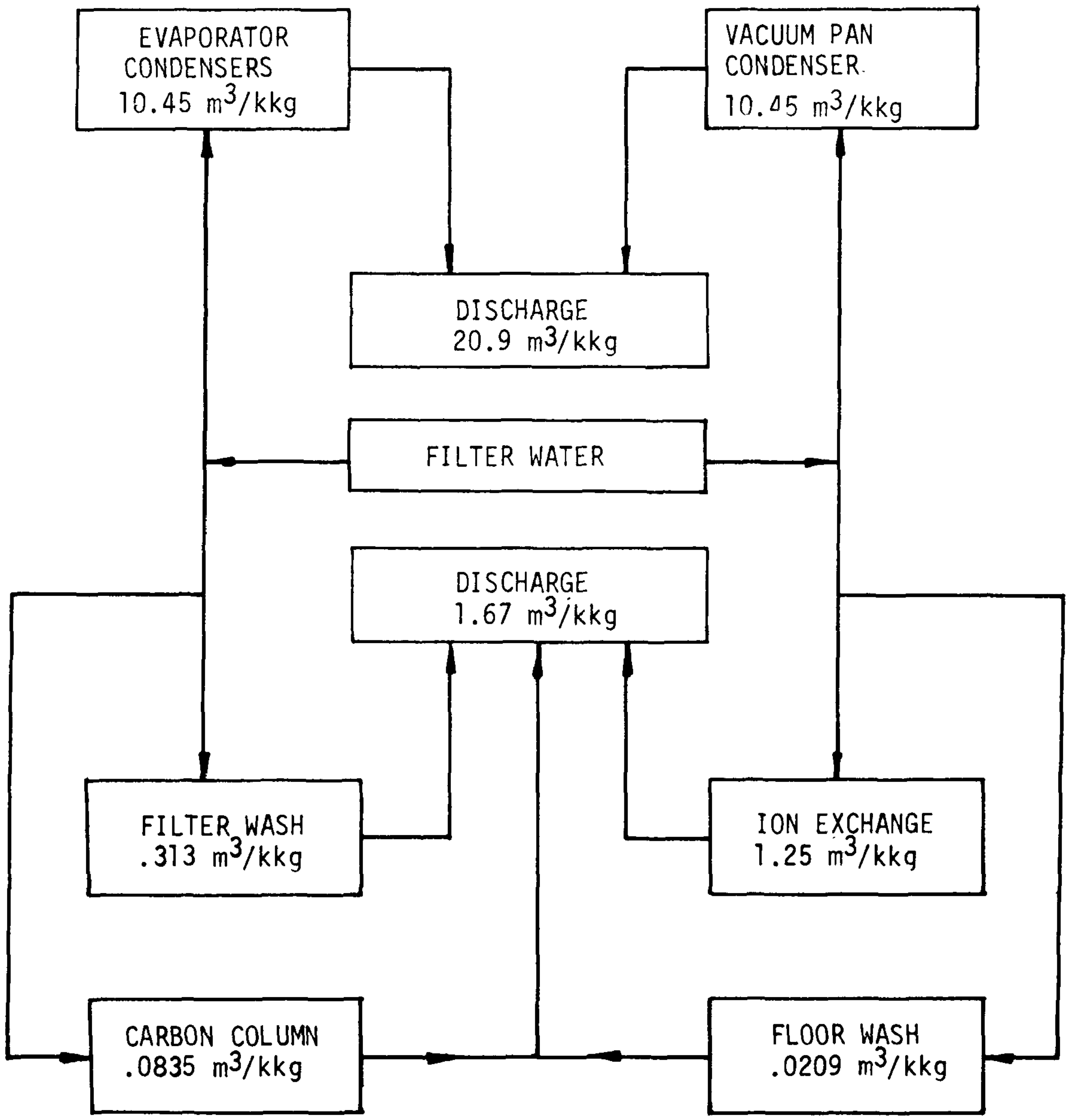


FIGURE 11

WATER BALANCE IN A LIQUID SUGAR REFINERY

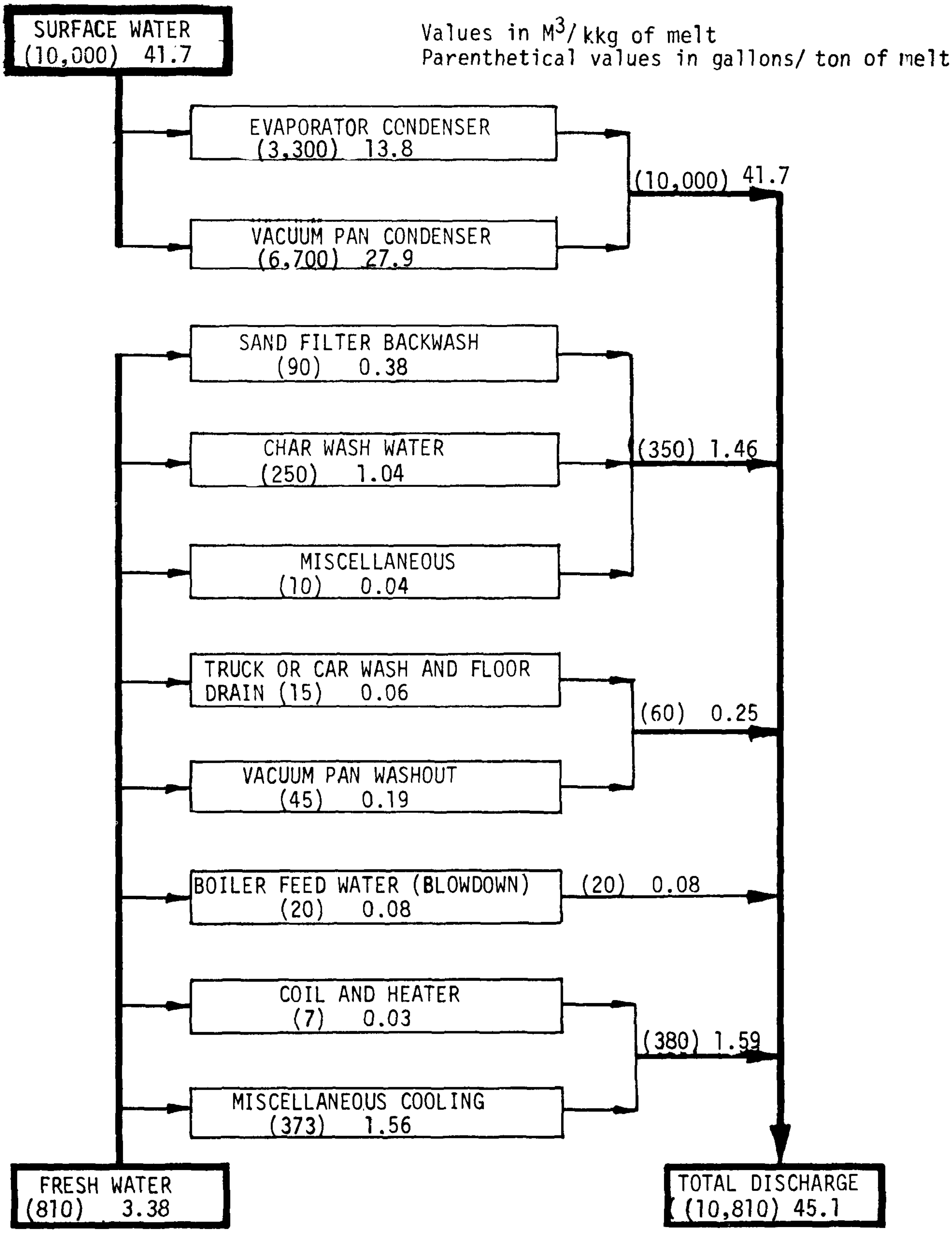


FIGURE 12

WATER BALANCE FOR A CRYSTALLINE SUGAR REFINERY limited to recovery of high purity sweetwaters for their sucrose content and reuse of condensates for boiler feed water and other purposes.

Obviously, the factor most affecting total water usage is process variation. As indicated above, crystalline refineries with their requirements for large volumes of barometric condenser cooling water use 60 percent more raw water than liquid refineries. The extremes of this situation may be illustrated by Refinery L-1 which employs no recrystallization in its manufacture of liquid sugar as compared to Refinery C-8 which produces strictly crystalline sugar. The crystalline refinery in this case uses over 600 percent more raw water.

Of all factors affecting water use, one of the most influential is the availability of land for disposal, or conversely, the cost of sewer surcharges. For example, Refineries C-1, C-2, C-4, C-5, C-9, and C-14 discharge process wastes to municipal sewers and average 36.6 cubic meters of water usage per metric ton (8,600 gallons per ton) of melt, while Refinery C-3 which does not discharge to municipal sewers, averages 42.9 cubic meters per metric ton (10,300 gallons per ton) of melt. Refineries L-1 and L-4 employ very similar processes but the former discharges all waste waters to municipal sewers, while the latter uses total impoundage. The difference in water usage is a factor of one to three.

Char Wash

Forty-eight percent of all refineries use bone char for decolorization, and these refineries include all of the largest refineries. Tables 6 and 7 give a breakdown of the type of decolorization medium used by each of the 29 refineries currently in operation. The waste water produced by the washing of char is a major waste stream in bone char refineries.

The amount of water used for char washing appears to be more dependent on the opinion of the operator than on any other factor. This is dictated by the fact that in almost all aspects, the use of bone char is more art than science.

The unit flow of char wash water varies from about 0.22 to approximately 0.84 cubic meters per metric ton (53 to 200 gallons per ton) of raw sugar melted. The typical flow would appear to be about 0.6 cubic meters per metric ton (144 gallons per ton).

Other Process Wastes

A non-char refinery, whether crystalline or liquid, uses granular or powdered activated carbon and possibly a combination of carbon and ion-exchange to effect color removal. The major process wastes in a carbon refinery consist of carbon wash water (and in some cases carbon slurry), and possibly ion-exchange regeneration. For liquid refineries, the total process water discharge (total waste water discharge less

TABLE 6

DECOLORIZATION MEDIA USED BY EACH CANE SUGAR REFINERY CURRENTLY OPERATING

	Decolorization Media			
Refinery	Bone Char	Activated Carbon	Activated Carbon plus Ion-Exchange	Bone Char, Carbon, and Ion-Exchange
C-1	X			
C-2	X			
C-3	X			
C-4	X			
C-5		X		
C-6	X			
C-7	X			
C-8	X			
C-9	X			
C-10	X			
C-11	X			
C-12	X			
C-13	X			
C-14	X			
L-1			X	
L-2			X	
L-3			X	
L-4			X	
L-5			X	
CL-1				X
CL-2			X	
CF-1		X		
CF-2			X	
CF-3		X		
CF-4		X		
CF-5		X		
CF-6		X		
CF-7		X		
CF-8		X		

TABLE 7

SUMMARY OF TYPES OF DECOLORIZATION MEDIA
USED BY CANE SUGAR REFINERS

Refinery Type	Decolorization Media			
	Bone Char	Activated Carbon	Activated Carbon plus Ion-Exchange	Bone Char, Carbon, and Ion-Exchange
Crystalline	13	8	1	0
Liquid	0	0	5	0
Crystalline-Liquid	0	0	1	1
Total	13	8	7	1

barometric condenser cooling water) averages approximately 2.5 cubic meters per metric ton (600 gallons per ton) of raw sugar melted.

A major factor considered in the subcategorization of the cane sugar refining segment is the potential difference in process water discharge due to the use of activated carbon versus bone char as the decolorization medium in the production of crystalline cane sugar. A substantial difference in discharge flow would mean a substantial cost difference associated with the treatment of this waste water stream. The average process water discharge for all crystalline refineries is 1.86 cubic meters per metric ton (450 gallons per ton) of melt. The average process water discharge for all crystalline refineries utilizing bone char as the decolorization medium is 1.90 cubic meters per metric ton (455 gallons per ton) of melt, while for those using activated carbon is 1.78 cubic meters per metric ton (430 gallons per ton) of melt. This amounts to a difference of 6.5% more process water discharged by crystalline bone char refineries. The average process water discharge by the better crystalline refineries is 1.18 cubic meters per metric ton (283 gallons per ton) of melt. The average process water discharge by the better crystalline bone char refineries is 1.15 cubic meters per metric ton (276 gallons per ton) of melt, while for the better refineries using activated carbon is 1.23 cubic meters per metric ton (295 gallons per ton) of melt. This amounts to a difference of 6.8% more process water discharged by the better crystalline activated carbon refineries. (See Tables 8 and 9). It has been determined from this analysis that no significant difference exists in the process water discharge of crystalline bone char versus activated carbon refineries.

Another factor considered was the difference in process water discharge versus size for crystalline cane sugar refineries. As shown in Figure 13, no correlation exists between process water discharge and size of the refinery.

Miscellaneous Water Uses and Waste Streams

Water is used for a number of purposes in a cane sugar refinery in addition to those previously discussed. Fortunately, most of the waste streams produced can be recovered as low purity sweet water. In a well operated refinery essentially all floor drainage is recovered. Condensates produced by the condensation of vapors in all but the last effect of multiple-effect evaporators are used for boiler feed water and other purposes in the refinery.

Sludges, scums, and filter cakes have in some past instances been slurried and discharged to streams. Current practice is to either impound these slurries after desweetening or to handle them dry and provide land disposal.

TABLE 8

PROCESS WATER DISCHARGE FOR CRYSTALLINE CANE SUGAR REFINING (ALL REFINERIES)

Type of Refinery	Number in Study	Average Process Water Discharge (m^3/kkg of melt)	Range (m^3/kkg of melt)
Crystalline (All)	15	1.86	0.6 - 4.0
Bone Char	10	1.90	0.6 - 4.0
Activated Carbon	5	1.78	1.0 - 3.0

$$\text{Difference} = \frac{1.90 - 1.78}{1.86} = 6.5\%$$

TABLE 9

PROCESS WATER DISCHARGE FOR CRYSTALLINE CANE SUGAR REFINING (AVERAGE OF THE BEST)

Type of Refinery	Number in Study	Average Process Water Discharge (m^3/kkg of melt)	Range (m^3/kkg of melt)
Crystalline (Best)	9	1.18	0.6 - 1.4
Bone Char	6	1.15	0.6 - 1.4
Activated Carbon	3	1.23	1.0 - 1.4

$$\text{Difference} = \frac{1.23 - 1.15}{1.18} = 6.8\%$$

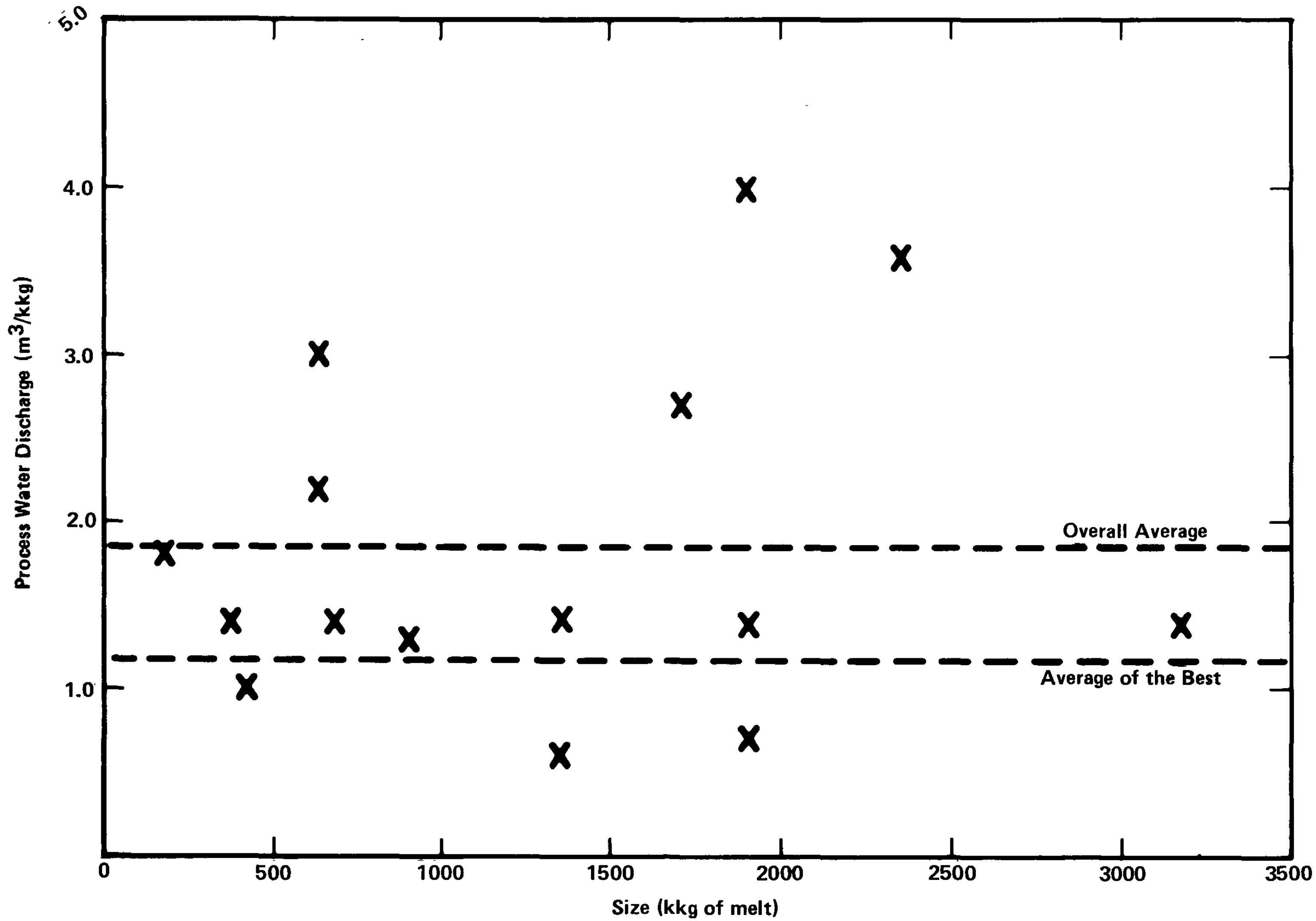


Figure 13
PROCESS WATER DISCHARGE VERSUS SIZE FOR CRYSTALLINE CANE SUGAR REFINING

Minor waste streams may include boiler blowdown, cooling tower blowdcwn, water treatment sludges, and various wash waters. These are highly variable and minor in individual volume, but may be significant in terms of total pollution load, particularly in a poorly operated refinery.

Barometric Condenser Cooling Water

The major waste water stream in any refinery, in terms of volume, is barometric condenser cooling water produced by contact condensation of vapors from the last effect of multiple-effect evaporators and from vacuum pans. The amount of condenser water used on a unit basis in a refinery varies with the availability of water, the extent of automation in the control of operations, and the thermodynamic relationship between the intake water and the vapors to be condensed; i.e., the higher the temperature of condenser water influent, the larger the volume of cooling water required for vapor condensation.

From the most reliable of data available, the average once-through flow of condenser water for refineries of all categories is nearly 31.5 cubic meters per metric ton (7,550 gallons per ton) of raw sugar melted. For liquid sugar refineries the average is nearer 16.3 cubic meters per metric ton (3,900 gallons per ton) of raw sugar melted, while for crystalline refineries the average is nearly 36.5 cubic meters per metric ton (8,750 gallons per ton) of melt.

Recirculation of barometric condenser cooling water is practiced by several refineries; this technique of reduction of the discharge waste water stream is further discussed in Section VII, Control and Treatment Technology.

WASTE WATER CHARACTERISTICS--CANE SUGAR REFINERIES

The characteristics of the total waste water effluent from a cane sugar refinery vary widely, depending upon the characteristics of the individual waste stream as described below. However, the following major total raw waste streams can be identified:

1. The waste water produced by a crystalline sugar refinery using bone char for decolorization. The majority of waste stream components are char wash water which is a part of the process water stream, condenser cooling water.

2. The waste water produced by a crystalline sugar refinery using carbon for decolorization. The major waste streams from this type of refinery are barometric condenser cooling water and process water, including ion-exchange regeneratin solutions and carbon slurries.

3. The waste water produced by a liquid sugar refinery em-

ploying affination and remelt and, therefore, using vacuum pans. The discharge from this refinery is similar to that from the carbon crystalline refinery except that the flow of condenser water is less.

4. The waste waters produced by a liquid refinery which does not use affination, does not remelt, and therefore, does not use vacuum pans. The discharge from this refinery is similar to the discharge from number three except that the barometric condenser flow is less.

5. The waste waters produced by a refinery which produces both liquid and crystalline sugar by separate processes. The discharge is a combination of numbers two and three.

Barometric Condenser Cooling Water

Theoretically, barometric condenser cooling water should carry net values of only two constituents--sucrose and heat. The sucrose is obtained from entrainment in last-effect evaporators and vacuum pans and heat is a result of heat-exchange between the barometric condenser cooling water and vapors. In terms of waste water characteristics, sucrose appears in condenser water as BOD_5, COD, and dissolved solids. In practice, as indicated in Tables 10 and 11, relatively small concentrations of other constituents appear. In some cases these probably appear as a result of analytical error and in other cases because of contamination of the condenser water by unknown waste streams.

The chemical composition of barometric condenser cooling water from a particular refinery is highly variable because of variable operational parameters as well as factors in the design of evaporators and vacuum pans. The characteristics are similar to those from a raw sugar factory and do not significantly vary according to process differences. The BOD_5 concentrations vary from 4 mg/l to 39 mg/l and the BOD_5 loadings from 0.07 to 1.8 kilograms per metric ton (0.13 to 3.6 pounds per ton) of melt.

Tables 10 and 11 indicate that the volume of barometric condenser cooling water from liquid refineries is less than that from crystalline; however, the BOD_5 concentrations are higher. It is estimated that the average crystalline refinery discharges barometric condenser cooling water with a BOD_5 concentration of about 12 mg/l and a flow of 36.5 cubic meters per metric ton (8,750 gallons per ton) of melt, while that from a liquid refinery has a BOD_5 concentration of approximately 19 mg/l and a flow of 16.3 cubic meters per metric ton (3,900 gallons per ton). The BOD_5 loadings for all refineries are generally between 0.15 and 1.0 kilograms per metric ton (0.3 and 2.0 pounds per ton) of melt.

TABLE 10

CONDENSER WATER SUMMARY: LOADINGS*

Refinery	Source	Melt kkg/day	Flow m^3/kkg	BOD5	COD	TSS	DS	NH_3-N	Kjel-N	NO_3-N	TP
C-1	4	2,350	44.9	0.40	1.1	0.81	44.5	0.02	0.07	0.20	0.13
C-2	3	1,900	16.1	0.07	0.64	0.29			0.0		0.0
C-4	4	1,900	43.2	0.60	1.1	0.43	8.8	0.06	0.29	0.41	0.11
C-5	2	900	42.5	0.21	16.6	0.38					
C-8	2	1,350	62.8	0.94	1.9						
C-9	2	1,900	34.1	0.38	0.75	0.0					
C-11	2	1,350	24.4	0.52	0.83						
L-3	3	775	14.1	0.44	1.4	0.11	0.42	0.0	0.0		0.0
L-4	2	350	26.9	0.16	2.7	0.24					
CL-1	2	1,630	21.4	0.17	0.04	0.02					
CL-2	4	750	47.1	1.8	6.6	1.8					

Data Source: 1) RAPP Data 3) ESE Data
2) USCSRA Data 4) Internal Data

*All values reported in kg/kkg of melt unless otherwise specified

TABLE 11

CONDENSER WATER SUMMARY: CONCENTRATIONS*

Refinery	Source	Melt kkg/day	Flow m^3/day	BOD5	COD	TSS	DS	NH_3-N	Kjel-N	NO_3-N	TP
C-1	4	2,350	105,600	9	25	18	990	0.4	1.5	4.4	2.9
C-2	3	1,900	30,500	4	40	18			0		0
C-4	4	1,900	82,300	14	25	10	203	1.5	6.8	9.5	2.6
C-5	2	900	38,250	5	391	9					
C-8	2	1,350	84,800	15	30						
C-9	2	1,900	64,700	11	22	0					
C-11	2	1,350	33,000	21	34						
L-3	3	775	10,900	31	99	8	30	0.01	0		0
L-4	4	350	9,400	6	100	9					
CL-1	2	1,630	34,700	8	2	1					
CL-2	4	750	35,300	39	141	38					

Data Source: 1) RAPP Data 3) ESE Data
2) USCSRA Data 4) Internal Data

* All values reported in mg/l except where otherwise noted

Adsorbents

Commercial adsorbents play an important role in the sugar refining process. While a large portion of the original impurities in the raw sugar is removed during defecation and clarification, there are considerable amounts of colloidal and dissolved impurities that yield only to adsorbent action.

Impurities that are removed by adsorbents may be classified (2) into three types: (1) colloidal material, (2) color-forming compounds, and (3) inorganic constituents.

Although a large number of adsorbents could theoretically be used in sugar refining, only a few are in current use. These include:

1) Bone char
2) Ion-exchange resins, mixed media
3) Ion-exchange resins, specific media
4) Granular activated carbon
5) Powdered activated carbon

Bone char is used in most of the larger sugar refineries in the United States and accounts for approximately 69 percent of all American sugar refining. Bone char is effective in the removal of both inorganic materials (ash) and organic impurities (colorants), and the resulting char wash waters have high concentrations of both ash and colorants. Since the subsequent char kiln does not affect the ash content in the char, and since ash buildup in the char leads to decreased char efficiency, considerable attention is given by refiners to the char washing operation. The basic philosophy is that it is better to use too much water than not enough.

As mentioned in Section III, the first portion of the char wash water is recycled for sucrose recovery. The limiting factors on the amount of char wash recycled are: (1) Sucrose concentrations in the wash water decrease with washing time and eventually reach the point where recovery is impractical; and (2) Ash concentrations in the wash water increase as the sucrose concentrations decrease.

The spent char wash waters have BOD_5 concentrations ranging from 500 to 2,000 mg/l and dissolved solids concentrations ranging from 1,000 to 3,000 mg/l (see Tables 12 and 13). The BOD_5 loading from bone char washing is between 0.15 and 1.7 kilograms per metric ton (0.3 and 3.4 pounds per ton) of raw sugar melted.

Ion-exchange is an effective remover of color as well as ash and is utilized as the decolorization medium in liquid and combination liquid-crystalline refineries. The waste characteristics resulting from the regeneration of an ion-exchange bed are greatly dependent on the particular use of that bed. Ion-exchange is often used in combination with carbon columns, and in these cases the usual practice is to remove organics with the carbon column and then use ion-exchange as a final

TABLE 12

CHAR WASH WATER SUMMARY: LOADINGS*

Refinery	Source	Melt kkg/day	Flow m^3/kkg	BOD5	COD	TSS	DS	NH_3-N	Kjel-N	NO_3-N	TP
C-2	3	1,900	0.66	0.79	1.27	0.03	1.90		0.01		0.0
C-8	4	1,350	0.84	1.65	2.21	0.05					
C-14	3	1,700	0.22	0.17	0.45	0.01	0.37	0.0	0.0		0.0

Data Source: 1) RAPP Data 2) USCSRA Data 3) ESE Data 4) Internal Data

*All values reported in kg/kkg except where otherwise noted

TABLE 13

CHAR WASH WATER SUMMARY: CONCENTRATIONS*

Refinery	Source	Melt kkg/day	Flow m^3/day	BOD5	COD	TSS	DS	NH_3-N	Kjel-N	NO_3-N	TP
C-2	3	1,900	1,250	1,200	1,930	46	2,880		9.8		0.15
C-8	4	1,350	1,130	1,960	2,630	57					
C-14	3	1,700	380	750	2,040	59	1,690	2.02	12.2		0.89

Data Source: 1) RAPP Data 2) USCSRA Data 3) ESE Data 4) Internal Data

*All values reported in mg/l except where otherwise noted polishing to remove inorganics. The inorganics of concern include anions as well as cations; for such removal, a "monobed" consisting of both cationic and anionic exchangers is often used. The cation-exchanger can also be used as a polishing step. Most of the organic material found in the sugar liquor is anionic, so that a strongly acidic anion-exchanger (cationic resin) can be used to remove color.

Regeneration of ion-exchange beds usually results in a higher volume of non-recoverable water than those from carbon columns and bone char. If the ion-exchange bed is used primarily as an organic color remover rather than as a final polishing and inorganic remover, the wash waters have higher concentrations of organic carbon and correspondingly higher BOD_5 concentrations. The BOD_5 loading from a liquid refinery using carbon columns for organic color removal as well as for inorganic removal is approximately 2.9 kilograms per metric ton (5.8 pounds per ton) of melt. No analyses from ion-exchange beds used only for inorganic removal have been made, but it appears that the BOD_5 loading is higher than from bone char and granular carbon and considerably lower than from ion-exchange used for organic carbon removal.

Granular carbon is strictly an organic carbon remover and is, therefore, a color remover. The regeneration of granular carbon requires sweetening off with water and heating of the carbon to volatilize organic material, thereby reactivating the surface. Most of the wash water which results from sweetening off a carbon column can be recovered for process because of its sucrose content. A certain amount of water is usually wasted because of low purity. While very little information on the characteristics of this water is available, samples were collected from one liquid sugar refinery. In this refinery a flow of 0.08 cubic meters per metric ton (19.2 gallons per ton) of melt was wasted and the resulting BOD_5 loading was approximately 0.1 kilograms per metric ton (0.2 pounds per ton) of melt.

Miscellaneous Waste Streams

In addition to the waste water resulting from condensers and adsorbent regeneration, there are a number of minor waste streams generated in a cane sugar refinery. These include: floor washings, filter washings, truck and car washings, and boiler blowdown.

The flows associated with these waste streams are highly variable and in some cases can be eliminated by reducing the volume of water used. This results in a waste stream of higher sucrose concentration which can be recycled back into the process. Table 14 indicates characteristics of some of the filter wash waters.

Tables 15 and 16 list waste water characteristics in terms of concentrations and loadings from crystalline, liquid, and combination crystalline-liquid refineries. It is apparent that in terms of unit

TABLE 14

WASTE WATER CHARACTERISTICS OF LIQUID SUGAR REFINERIES

Characteristic	Filter Cake Slurry	Truck & Car Wash	Boiler Blowdown
BOD_5, mg/l	735(3	17,250(1,3	0(1
COD, mg/l	2,120(3	40,300(1,3	0(1
TS, mg/l	3,880(3	6,530(1,3	2,110(1
DS, mg/l	1,430(3	6,480(1,3	2,020(1
TSS, mg/l	2,360(3	50(1,3	90(1
pH	6.3(3	7.2(1,3	5.7(1
NH_3 -N, mg/l	0.32(3	3.04(1,3	0(1
KN, mg/l	12.2 (3	0.49(1,3	0(1
NO_3 -N, mg/l	75.8 (3	1.80(1	0(1
TP, mg/l		0.60(3	2(3
Total Coliform per 100 ml		240(1	0(1
Fecal Coliform per 100 ml		240(1	0(1

(1 RAPP data
(2 USCSRA questionnaire
(3 Internal data

Figures 14 and 15 are illustrations of the estimated flow and loadings for the process water and barometric condenser cooling water, and total discharge streams for the average crystalline and liquid cane sugar refineries, respectively.

TABLE 15

TOTAL WASTE LOADING SUMMARY*

Refinery	Source	Melt kkg/day	Flow m^3/kkg	BOD5	COD	TSS	DS	NH_3-N	Kjel-N	NO_3-N	TP
C-1	4	2,350	48.5	0.63	1.9	0.92	46.9	0.02	0.08	0.21	0.14
C-2	3	1,900	16.7	1.0	1.9	0.34			0.01		0.00
C-3	2	2,800	42.9	1.8	5.0	3.6					
C-4	2	1,900	44.6	1.7	3.1	1.4					
C-5	2	900	43.8	1.1	17.1	12.5					
C-6	2	170	42.4	1.9	1.5	0.08					
C-7	2	3,175	25.8	2.4	6.6						
C-8	2	1,350	64.2	1.7	3.4	0.06					
C-9	2	1,900	38.1	1.7	3.5	0.34					
C-11	2	1,350	25.0	2.1	3.4	1.2					
C-14	2	1,700	3.32	0.87	1.5	1.3					
L-1	2	275	10.5	5.1	6.1	8.4					
L-3	3	775	16.0	3.7	6.6	0.94	16.2	0.00	0.01		0.03
L-4	2	350	30.0	2.2	5.7	7.4					
CL-1	2	1,650	22.5	2.3	5.6	1.1					
CL-2	1	750	47.9	1.1				0.00	0.00	0.00	0.00

Data Source: 1) RAPP Data 2) USCSRA Data 3) ESE Data 4) Internal Data

*All value reported in kg/kkg of melt unless otherwise specified.

TABLE 16

TOTAL FLOW SUMMARY*

Refinery	Source	Melt kkg/day	Flow m^3/day	BOD5	COD	TSS	DS	NH_3-N	Kjel-N	NO_3-N	TP
C-1	4	2,350	114,000	13	39	19	966	0.46	1.66	4.33	2.80
C-2	3	1,900	31,900	60	115	20			0.60		0.00
C-3	2	2,800	120,000	43	116	85					
C-4	2	1,900	84,800	39	70	30					
C-5	2	900	39,400	24	391	286					
C-6	2	170	7,200	46	36	2					
C-7	2	3,175	82,000	92	255						
C-8	2	1,350	86,700	26	53	1					
C-9	2	1,900	72,300	45	91	9					
C-11	2	1,350	33,800	85	136	46					
C-14	3	1,700	5,650	263	460	397					
L-1	2	275	2,900	487	579	796					
L-3	3	775	12,400	230	415	59	1,014	0.03	0.51		1.61
L-4	2	350	10,500	72	190	247					
CL-1	2	1,650	37,200	104	247	51					
CL-2	1	750	35,900	22				0.0	0.02	0.0	0.0

Data Source: 1) RAPP Data 2) USCSRA Data 3) ESE Data 4) Internal Data

*All values reported in mg/l except where otherwise noted organic loadings, liquid sugar refineries have higher loadings than do crystalline refineries. This is apparently due to the high organic levels produced in the waste waters resulting from ion-exchange regeneration (all of the liquid sugar installations listed use ion-exchange as an integral part of their process) and to the extent of recrystallization and subsequent remelt practiced by these refineries. An extreme example of this is Refinery L-1, which has the highest waste loading of all refineries listed. It is important to note that this refinery does not remelt sugar (i.e., produces no molasses) and some impurities that would otherwise be contained in molasses must leave the refinery in its waste water. This principle is true to a lesser extent for other liquid and liquid-crystalline refineries that remelt to varying degrees. Refinery L-3, for example, does not remelt sugar in its primary product line but must recrystallize in a side product line (refer to Figure 9) to effect recovery of additional sugar and molasses by-product. This refinery still produces a BOD_5 loading of 3.70 kilograms per metric ton (7.40 pounds per ton) of raw sugar melted. The impact of ion-exchange on the BOD_5 loading from a refinery is illustrated by the fact that 77 percent of the total BOD_5 loading at the latter refinery is due to ion-exchange regeneration waste water.

Figures 14 and 15 are illustrations of the estimated flow and loadings for the process water and barometric condenser cooling water, and total discharge streams for the average crystalline and liquid cane sugar refineries, respectively.

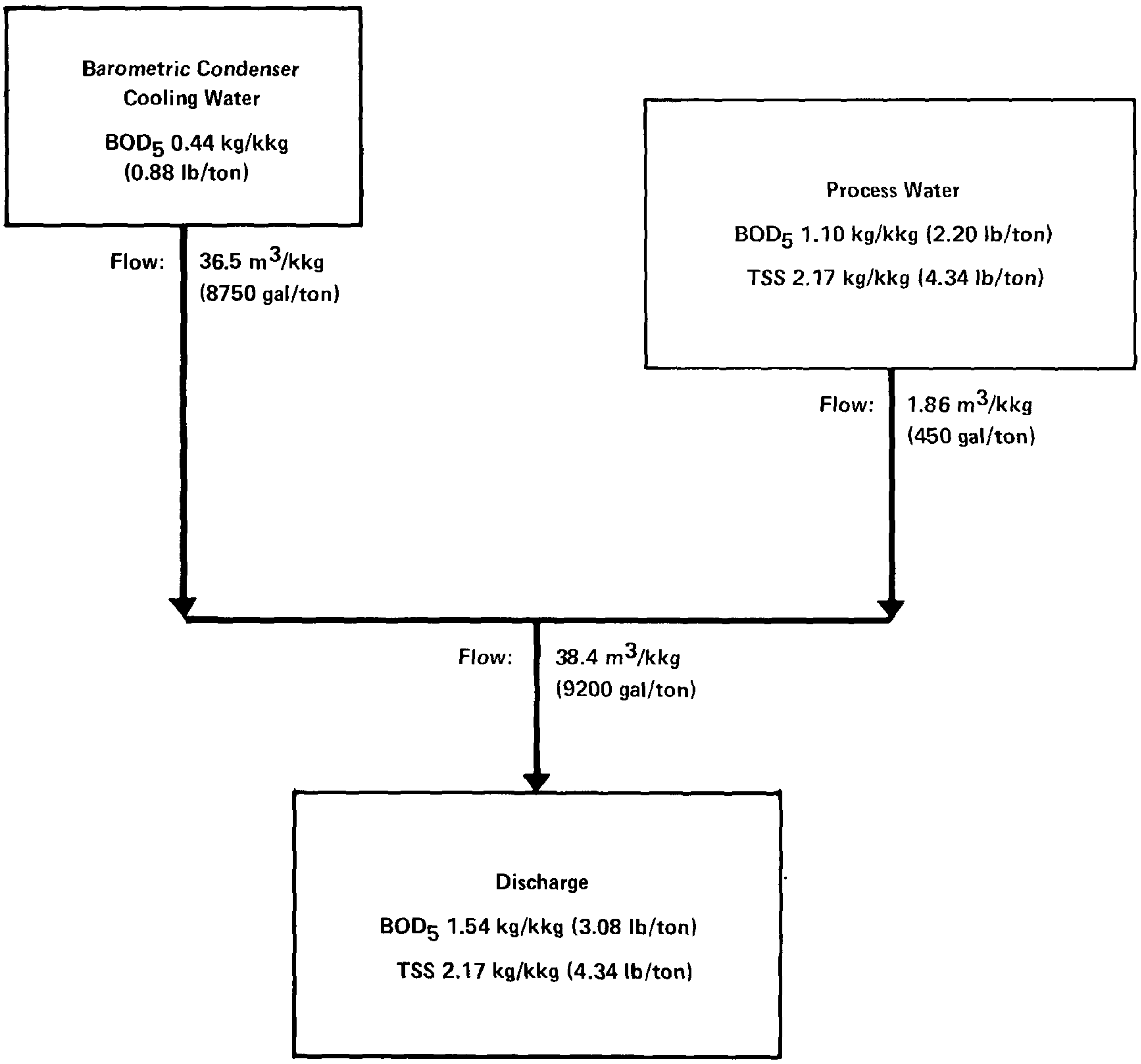


Figure 14
RAW WASTE LOADINGS AND WATER USAGE FOR THE AVERAGE CRYSTALLINE CANE SUGAR REFINERY

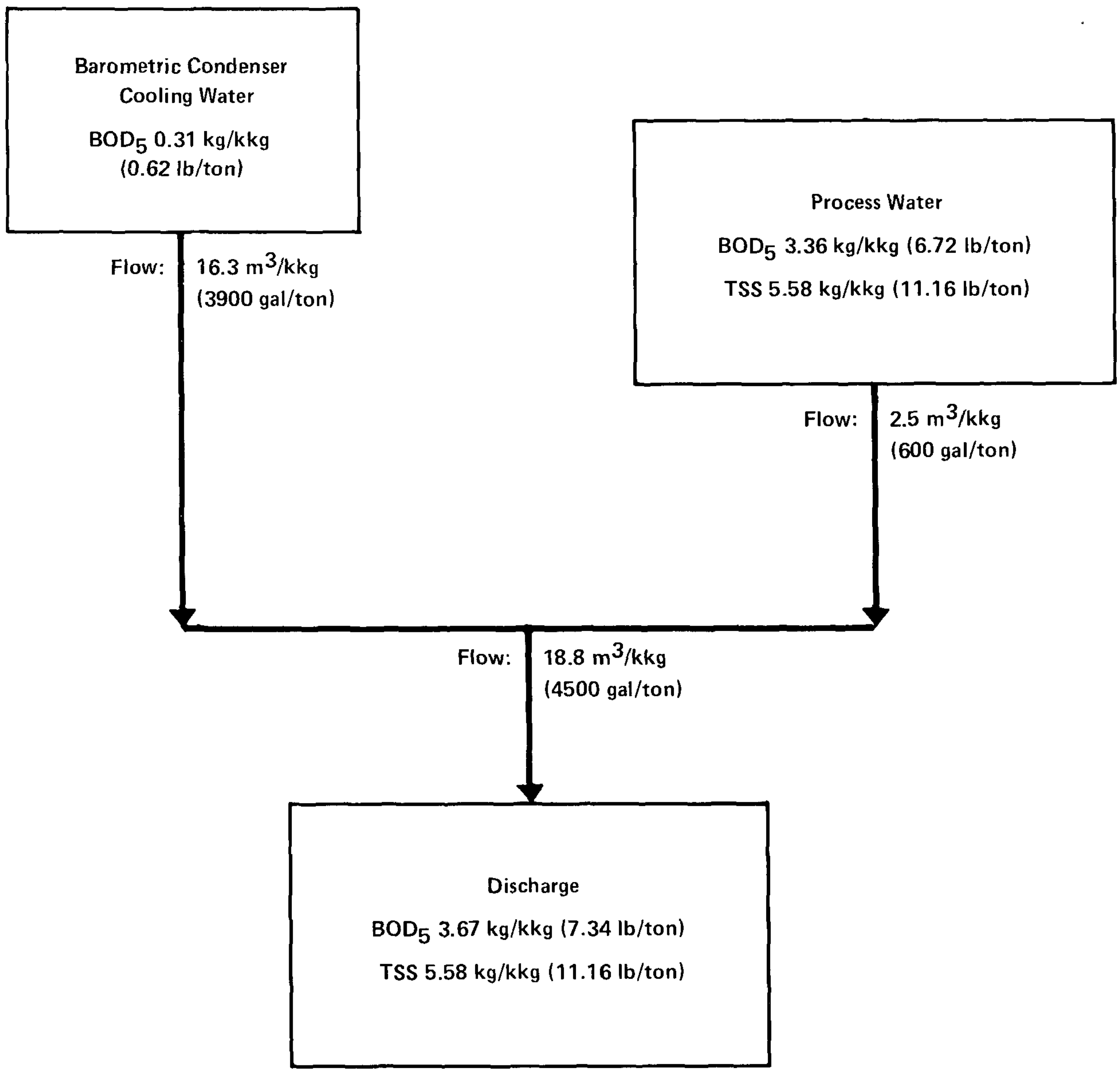


Figure 15
RAW WASTE LOADINGS AND WATER USAGE FOR THE AVERAGE LIQUID CANE SUGAR REFINERY

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

Major waste water parameters of pollutional significance for the cane sugar refining segment include BOD (5-day, 20° Centigrade), suspended solids, and pH. Additional parameters of significance include COD, temperature, sucrose, alkalinity, total coliforms, fecal coliforms, total dissolved solids, and nutrients (forms of nitrogen and phosphorus). On the basis of all evidence reviewed, there do not exist any purely hazardous or toxic pollutants (e.g., heavy metals, pesticides) in wastes discharged from cane sugar refineries.

When land disposal of waste water is practiced, contribution to ground pollution must be prevented. If deep well injection is used, all practices must be in accordance with the Environmental Protection Agency's "Policy on Subsurface Emplacement of Fluids by Well Injection" with accompanying "Recommended Data Requirements for Environmental Evaluation of Subsurface Emplacement of Fluids by Well Injection"(6).

MAJOR WASTE WATER CONTROL PARAMETERS

The following selected parameters are determined to be the most important characteristics of cane sugar refining wastes. Data collected during the preparation of this document was limited in most cases to these parameters. Nevertheless, the use of these parameters adequately describes the waste water characteristics of the refining industry. BOD (5-day), suspended solids, and pH are the parameters selected for effluent limitations guidelines and standards of performance for new sources.

Biochemical Oxygen Demand (5-day BOD)

Biochemical oxygen demand (BOD) is a semi-quantitative measure of the biologically degradable organic matter in a waste water. For this reason, in waste water treatment, it is commonly used as a measure of treatment efficiency. It is a particularly applicable parameter for the sugar industry since 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.

The primary disadvantage of the BOD test is the time period required for analysis (five days is normal) and the considerable amount of care that must be taken to obtain valid results.

Typical BOD_5 levels in both crystalline and liquid cane sugar refining are quite high, ranging from several hundred to several thousand mg/l for certain waste streams. Discharge of such wastes to surface waters can result in oxygen depletion and damage to aquatic life.

Suspended Solids

Suspended solids serve as a parameter for measuring the efficiency of waste water treatment facilities and for the design of such facilities. In sugar waste waters, most suspended solids are inorganic in nature, originating from process flows such as char wash and carbon slurries in refineries. Condenser water is essentially free of net suspended solids.

pH

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.

ADDITONAL PARAMETERS

Chemical Oxygen Demand

Under the proper conditions, the chemical oxygen demand (COD) test can be used as an alternative to the BOD test. The COD test is widely used as a means of measuring the total amount of oxygen required for oxidation of organics to carbon dioxide and water by the action of a strong oxidizing agent under acid conditions. It differs from the BOD test in that it is independent of biological assimilability. The major disadvantage of the COD test is that it does not distinguish between biologically active and inert organics. The major advantage is that it can be conducted in a short period of time, or continuously in automatic analyzers. In many instances, COD data can be correlated to BOD data and the COD test can then be used as a substitute for the BOD test.

Considerable difficulties occur with the COD test in the presence of chlorides, and it must be noted that condenser cooling water in a number of refineries consists of brackish water.

No definitive relationship between BOD (5-day) and COD can be established at the present time. Therefore, it was concluded that effluent limitations guidelines and standards of performance could not be established for COD.

Bacteriological Characteristics

No bacteriological problems are present in the refined sugar product from a cane sugar refinery due to the fact that any bacteria present in the product prior to evaporation are destroyed in the evaporation process. There is no introduction of microorganisms in the refining process.

Temperature

The temperatures of waste waters discharged from cane sugar refineries can 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, may result in serious consequences to aquatic environments.

Alkalinity

Alkalinity in water is a measure of hydroxide, carbonate and bicarbonate ions. Its primary significance in water chemistry is its indication of a water's capacity to neutralize acidic solutions. In high concentrations, alkalinity can cause problems in water treatment facilities.

Nutrients

Forms of nitrogen and phosphorus act as nutrients for ... growth of aquatic organisms and can lead to advanced eutrophication in surface water bodies. In water supplies, nitrate nitrogen in excessive concentrations can cause methemoglobinemia in human infants and for this reason has been limited by the United States Public Health Service to ten milligrams per liter, as nitrogen, in public water supplies (7).

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

Total Dissolved Solids

Total dissolved solids may reach levels of 1,000 milligrams per liter in refinery waste waters. In refinery condenser water, where entrained sucrose causes dissolved solids, the concentration is typically 20 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 sugar refinery effluents, dissolved solids are more often organic in nature, originating from sucrose.

Sugar Analysis

Analysis for sucrose content is important in process control as an indicator of sugar loss. The two common tests used are the alphanapthol and resorcinol methods. Neither of these methods provides high accuracy at low sucrose concentrations, but they do 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. Due to its inaccuracy at low levels and to the fact that sugar content is measured by BOD, the sugar analysis is not an adequate parameter for guidelines establishment.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

Current technology for the control and treatment of cane sugar refinery waste waters consists primarily of process control (recycling and reuse of water, prevention of sucrose entrainment in barometric condenser cooling water, recovery of sweet waters), impoundage (land retention), and disposal of process wastes to municipal sewer systems.

The general scope of current technology, and the attitude of refiners, is that the volume of process water is sufficiently low that it can be handled by end-of-line treatment and disposal systems whereas the much higher volume of barometric condenser cooling water makes it impractical to treat. This position is illustrated by the fact that few refineries release substantial amounts of process waters to receiving streams while all but five refineries discharge barometric condenser cooling water to surface water bodies.

<u>In-Plant Control Measures and Techniques in the Cane Sugar Refining Industry</u> In-plant control measures are essential in the total effort for pollution control in cane sugar refineries. In-plant control refers to the operational and design characteristics of the refinery and their impact on total waste management. Specific elements are water utilization and conservation, housekeeping techniques, and any operational or design factors that affect waste water quantity and/or quality. A primary portion of in-plant control is for the prevention of sugar loss and thus is an extension of historical efforts. To the refiner the loss of sugar in waste water represents lost money; to the environmentalist it is an organic pollutant. Other measures of in-plant control include the facilitation of dry-handling techniques for sludges and filter cakes, maximum recovery and reuse of various process streams, and improved housekeeping practices.

<u>Raw Sugar Handling</u>. Raw sugar is normally delivered to refineries by truck, rail car, barge, or ship. The unloading of the raw sugar at the receiving area offers an opportunity for sugar spillage, and the periodic washdown of the receiving area produces a variable waste stream with a high sugar content. In one refinery visited, raw sugar conveyor belts were routinely washed down and the resulting sugar solutions were allowed to flow into a surface water body, carrying with them an indeterminable amount of BOD_5.

Most refineries recover floor washings in the receiving area to some extent--some refineries almost in total. The practice in some refineries is to recover as much spilled sugar as possible by sweeping, then discharge subsequent rinse water to waste. A minimal effort at sugar loss prevention through equipment modification and improved housekeeping can essentially prevent the loss of sugar and its resulting pollutant load from the raw sugar receiving area.

Truck and Car Wash. The tank trucks and rail tank cars that transport liquid sugar and edible syrups must be maintained under sanitary conditions. This normally involves cleaning of the tanks with steam and water after each use. The first few minutes of washing produces a sweet water that is of sufficient sucrose concentration to allow economical recovery for processing. The sucrose concentration in the wash water effluent after the first few minutes is considered by most refiners to be too low for recovery and is wasted. This stream can be minimized by maximizing recovery, but in any event the stream is small in volume and a minor contribution to total process waste water flow.

Floor Wash. Since any bacteriological contamination to the raw sugar syrup prior to evaporation is eliminated by evaporation, the recovery of essentially all floor wash drains as sweet water is possible and is practiced in some refineries.

Barometric Condenser Cooling Water. The development of calandria-type vacuum pans and evaporators in the sugar industry has afforded increased boiling rates, but at the same time the possibility of sucrose entrainment in the barometric condenser water has increased. Sucrose entrainment represents an economic loss to the refiners as well as an organic pollutant load to the environment in the condenser water effluent. All sugar refineries employ some means to reduce entrainment, with the motive in the past being primarily an economic one.

Entrainment is a result of liquid droplets being carried out with water vapors in evaporators and vacuum pans. There are three important factors which affect the efficiency of entrainment control:

(1) Height of the vapor belt (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 height of the vapor belt is of sufficient magnitude, most liquid droplets will fall back into the boiling liquor due to gravity and be removed from the vapor before exiting the evaporator or vacuum pan. 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. Vapor heights in the cane sugar refining industry have been generally found to be more adequate than those in raw sugar factories. However, when existing vapor heights are insufficient, they can be increased by installing a spacer in existing equipment. This has been done in several cases for the purpose of increasing evaporation capacity, but entrainment reduction has been a secondary result.

In addition to proper design, proper operation of the evaporators and vacuum pans is essential in minimizing sucrose entrainment. It is

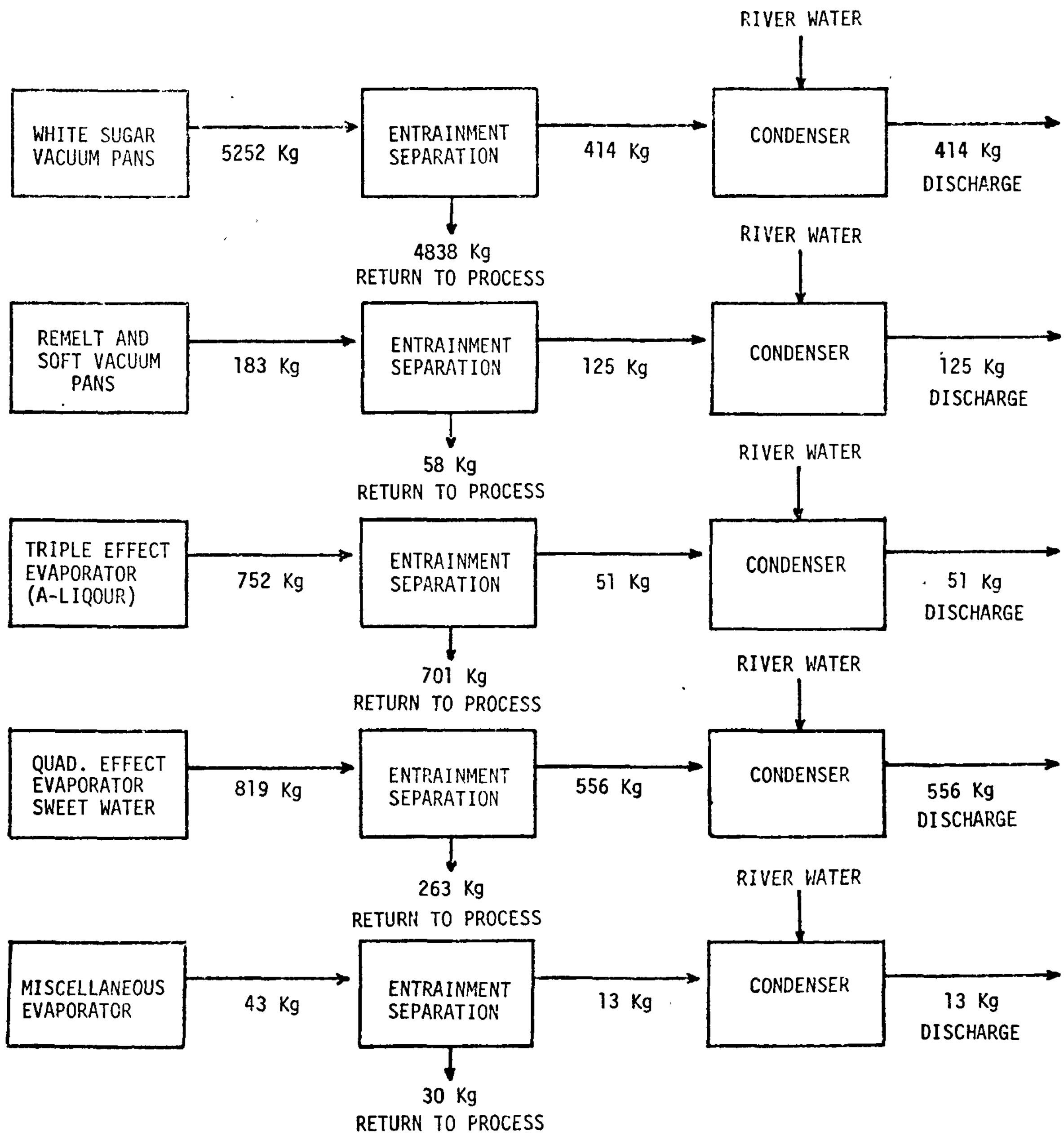


FIGURE 16

ENTRAINMENT REDUCTION

important to maintain the liquid level in evaporators and vacuum pans near the design level; in essence, if the liquid level is increased, the vapor height is decreased. An important variable which must be carefully controlled is the pressure inside the vessel. If the pressure is suddenly decreased, flash evaporation is likely to occur resulting in an increase in boiling rate and liquid carryover. Automatic controls are available for the operation of evaporators and pans and these have been installed in a number of refineries. The typical refinery has liquid level controllers on all evaporator bodies and absolute pressure control on last bodies of multiple effects 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 principles are commonly used. The Serner separator (7), a type of baffle arrangement, is used in several refineries. Figure 16 shows the effectiveness of Serner separators, used in conjunction with other baffles and direction reversals, based on experience in a particular installation. The total BOD_5 reduction in this case is 84 percent. Higher reductions are considered possible with careful design coupled with proper operation.

Demisters have been found to be applicable to entrainment reduction in certain cases. These devices, which consist basically of a wire mesh screen serving the dual purpose of impingement and direction change, were used to a large extent in the Cuban sugar industry before 1960 and have been used to a limited extent in the United States. One refinery, upon the installation of demisters in most of its evaporators and vacuum pans experienced a 50 percent reduction in barometric condenser cooling water COD. However, during the same maintenance program, changes were made in the baffles and other control equipment, and the amount of reduction due solely to the demisters remained unclear.

At least two major refineries use partial surface condensers as heat exchangers in the exhaust ducts prior to barometric condensation. These units not only affect liquid-vapor separation but also capture heat from the vapors, and have been installed for the latter purpose.

Total surface condensers have also been considered but in general they have been rejected, primarily due to the costs associated with installation, but also for a number of other reasons including operational problems and the questionable benefits associated with their use. A total surface condenser condenses vapors by indirect (non-contact) cooling resulting in no sucrose loss in condenser water and a stream of hot condensate that must be discharged because of its low sucrose content.

One potential problem with surface condensers is fouling. Most refineries use low quality surface (river or estuarine) water for condenser cooling. While total surface condensers have not been used in refineries, a comparison can be made with surface heat exchangers used for air and oil coolers of turbine generators. The general experience of the sugar industry has been that raw river water is unacceptable for such applications because of fouling (13).

A second 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 inch mercury) must be maintained. Adjustments to the absolute pressure, made necessarily 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; however, the lag time associated with a surface condenser makes absolute pressure control considerably more difficult and can actually increase sugar entrainment.

The physical installation of surface condensers would be a problem in many refineries, and in some cases an almost insurmountable one. Vertical height when unavailable can often be obtained by raising the roof of a refinery, but horizontal space can be achieved only with considerable difficulty. The weight of surface condensers could cause severe structural problems in older refineries. The units would have to be installed on the fourth or fifth floor of a building that might be a century old. The structural analysis required to insure the feasibility of doing so would be extremely difficult.

USCSRA has estimated (13) that in a typical 1900 metric ton (2100 ton) refinery, surface condensers would approximately double required pumping energy, increase electrical requirements by about 1000 kilowatts, and require 11,350 to 13,620 kilograms per hour (25,000 to 30,000 pounds per hour) additional steam capacity.

Recirculation of barometric condenser cooling water through a cooling tower is feasible and is practiced at three refineries. Spray ponds have proved to be feasible for the cooling and recirculation of condenser water for two small rural refineries, for several cane sugar factories, and for a number of beet sugar plants. However, the land required for these facilities generally prohibits their use for urban refineries.

One large urban refinery recycles barometric condenser cooling water through a cooling tower and discharges on the average about two to three percent of the flow as blowdown. Cooling towers, while expensive, might be applicable to other refineries and offer a means of reducing waste water volume; however, in northern climates winter temperatures would interfere with operation, and in dense urban areas wind blown sprays and odors can present problems. These problems can be reduced by proper design and operation, and probably eliminated for most wind conditions.

Filter Cake. Most refineries use pressure filters such as the Valley or Industrial type for removing impurities from sugar liquors. Filter aid, usually diatomaceous earth, is used with the filters. When the pressure drop across the filter increases to an unacceptable value or when the filter efficiency drops, the filter cake is removed. The desweetened cake is semi-dry (about 50 percent moisture) and may be handled in that form or it may be slurried for pumping. In the dry form it is normally conveyed to trucks which in turn transport the material to landfill or other land disposal. In the slurried form it may be pumped to impoundage or municipal sewage. A major portion of the cake can be recovered in a kiln by revivification of the filter aid. An existing system for filter cake recycle and land disposal is illustrated in Figure 17. In this system approximately 80 percent of the cake is conveyed to a multiple hearth kiln where the cake is heated to about 816°C (1,500°F). Revivified filter aid is discharged from the kiln, pulverized, and returned to the filtration step of the refining process. Makeup filter aid is added to the system as required. The installation of a continuous carbonation process for lime mud slurry, to make it suitable for vacuum filtration and removal of sugar by washing, is reported by one refinery to have reduced total settleable solids by 96 percent and BOD_5 by 20 percent.

Adsorbant Regeneration. In-plant modifications for the reduction of waste waters resulting from the regeneration of bone char, carbon columns, and ion-exchange resins are practically non-existent, although there are some minor, mainly operational, modifications to reduce waste water loads which include:

(1) Recovery of waste waters with lower sucrose concentrations, i.e., recovery of a greater portion of spent char wash water,

(2) Reduction in the volume of wash water used to sweeten off bone char and carbon columns, and greater dependence on volatilization of organics,

(3) Elimination or reduction in the use of ion-exchange as an organic color remover.

These modifications are merely proposals and the implications of their adaptation are not fully known; research on this subject is needed. At present, control and treatment of these wastes is restricted to end-of-line treatment.

Treatment and Disposal Technology Currently Available to the Cane Sugar Refining Industry

Waste water treatment and disposal in the cane sugar refining industry ranges from essentially no treatment to complete land retention with no discharge to surface waters. Since the early 1950's most large urban refineries have discharged major process waste streams, such as char

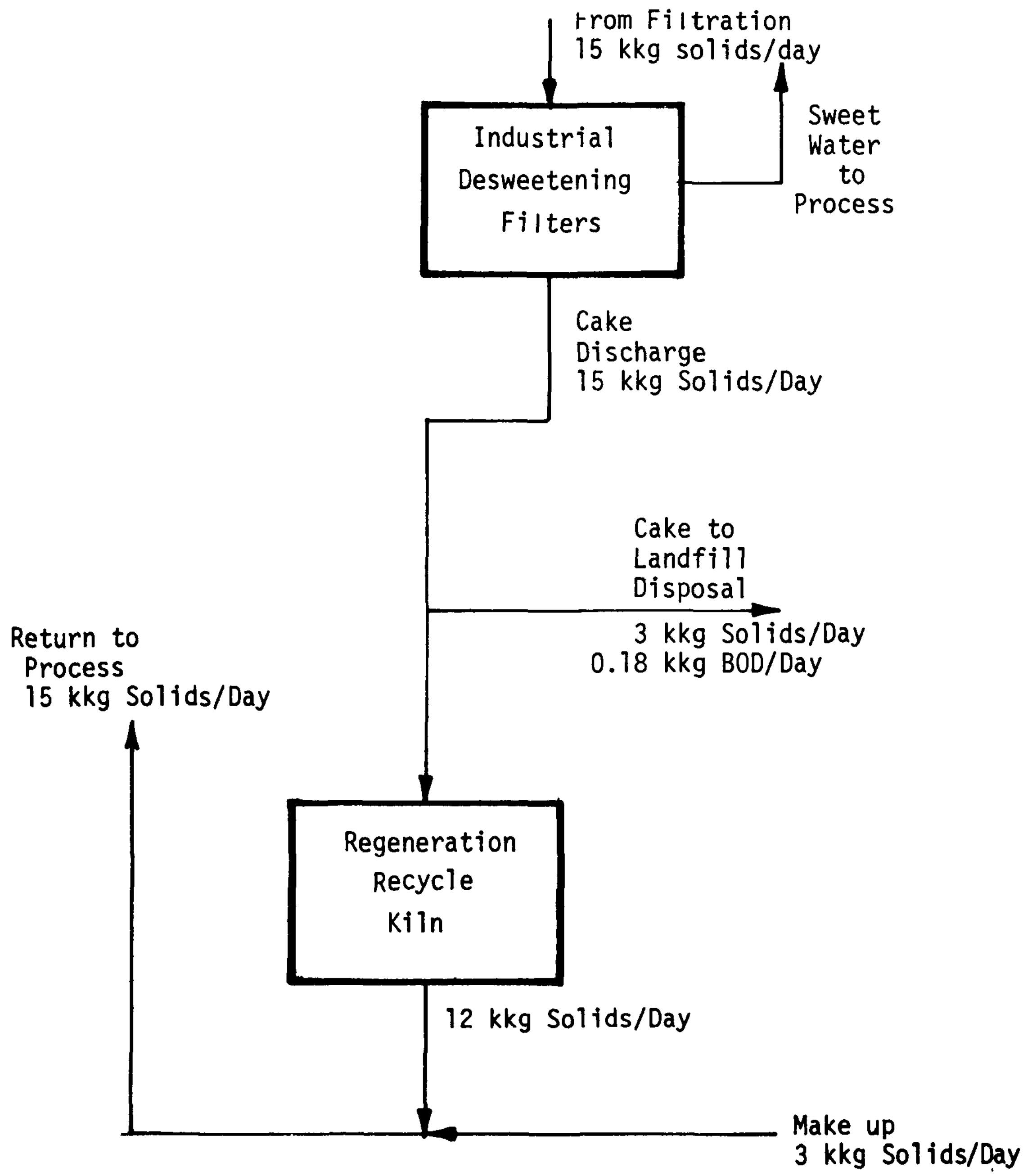


FIGURE 17

FILTER CAKE RECYCLE SYSTEM

wash, to municipal sewers. The current standard practice for urban refineries, which represent approximately two-thirds of American refined cane sugar production, is to discharge all waste streams other than condenser water to municipal sewage treatment plants. Rural refineries, representing the remaining one-third of total sugar production, generally have available land for impoundment, and the standard practice in these refineries is either total or partial waste water retention. A summary of disposal methods currently employed in the industry is presented in Table 17.

There are two notable exceptions to the practice of urban refineries discharging process wastes to municipal sewers and barometric condenser cooling water to surface water bodies. One large crystalline refinery, which uses a cooling tower for recirculation of condenser water, discharges all waste water except uncontaminated cooling water to municipal treatment. This is made possible by the use of a cooling tower recycle system which reduces condenser water discharge by 98 percent.

The second exception is a small liquid refinery which uses municipal water for barometric condenser cooling water intake. Unlike other refineries that use low quality surface water for condenser water, this refinery is able to extensively use the condenser water effluent in-plant and discharges all waste water to municipal treatment. It must be noted, however, that the refinery does not use affination, does not have vacuum pans, and, therefore, uses an atypically small flow of barometric condenser cooling water.

The following table, Table 17, is a summary of the existing waste treatment practices of the refineries currently operating. All cane sugar refineries are represented and the most reliable and current information presented.

Biological treatment of sugar wastes has been demonstrated to a limited extent in the raw cane sugar industry and more extensively outside of the industry. Sucrose is well known to be highly biodegradable, and substantial BOD_5 reductions have been observed in impoundage lagoons for both factories and refineries. In the beet sugar industry, anaerobic and aerobic fermentation processes have been successfully used (17). The applicability of biological treatment to refinery waste waters has also been well demonstrated by the 12 refineries that discharge process wastes to municipal biological treatment systems. While no refineries currently employ biological treatment in the form of activated sludge or aerated lagoons, these systems are considered to be currently available technology for the industry. With proper design and with nutrient addition to the nutrient deficient wastes, these systems can achieve 90 to 95 percent and higher treatment efficiencies for highly organic wastes such as process waste water from cane sugar refining.

TABLE 17

SUMMARY OF WASTE WATER TREATMENT AND DISPOSAL TECHNIQUES OF UNITED STATES CANE SUGAR REFINERIES

Refinery	Disposal of Waste Waters
C-1	All process water to municipal sewers; barometric condenser cooling water to river. Filter slurry to sewer.
C-2	All process water to municipal sewers; barometric condenser cooling water to river. Dry haul filter cake after regeneration and recycle of filter aid.
C-3	All liquid wastes to river. Filter slurry to river.
C-4	All process water to municipal sewers; barometric condenser cooling water to river. Dry haul filter cake after regeneration and recycle of filter aid.
C-5	All process water to municipal sewers; barometric condenser cooling water to river. Dry haul filter cake.
C-6	All liquid wastes to river. Dry haul cake after regeneration and recycle of filter aid.
C-7	Primary settling of process water; overflow discharges to river.
C-8	All liquid wastes to river. Future use of municipal system is probable (sewer hook-up is in-place). Dry haul filter cake.
C-9	Most process water to municipal sewers; barometric condenser cooling water to river. Dry haul filter cake.
C-10	Most process water to municipal sewers; barometric condenser cooling water to river. Dry haul filter cake.

C-11	Discharge into a swamp after traveling through a two and a half mile canal. Have recently constructed a spray pond. Recycle of barometric condenser cooling water is a possibility.
C-12	Total impoundment of waste water resulting in no discharge to navigable waters. Have two cooling towers for recycle of barometric condenser cooling waters; blowdowns are .3 and .7 percent.
C-13	Discharges into a swamp.
C-14	All process wastes to municipal sewers; recycle of barometric condenser cooling water through a cooling tower and discharge of blowdown to municipal sewers. Dry haul filter cake.
L-1	All liquid wastes to municipal sewers. Filter slurry to municipal sewer.
L-2	All process water to municipal sewer; barometric condenser cooling water to river. Filter slurry to settling, dewatering, and dry haul.
L-3	All process water to municipal sewer: barometric condenser cooling water to river. Filter slurry to sewer.
L-4	Total impoundment of waste waters resulting in no discharge to navigable waters. Barometric condenser cooling water recycled through a spray canal. Filter slurry to total impoundage.
L-5	Barometric condenser cooling water recycled through a cooling tower. Process water and filter slurry discharged with no treatment.
CL-1	Most process water to municipal sewers; barometric condenser cooling water to river. Filter slurry dewatered and dry hauled.
CL-2	Most of process wastes to municipal sewers; barometric condenser cooling water to river. Dry haul filter cake.

CF-1	Closed system of canals and holding ponds resulting in no discharge to navigable waters. Filter slurry to total impoundage. Barometric condenser cooling water recycled through a spray pond.
CF-2	Total impoundment of acid/caustic wastes and filter cake slurry; impoundment with overflow of all other waste waters, 700 acres of lagoons.
CF-3	Barometric condenser cooling water passed through spray pond (partial recycle, 75-90%, possible) before discharge; all process waters discharge to total impoundage. Filter slurry to total impoundage.
CF-4	Barometric condenser cooling impounded, then discharged; all other waters impounded completely in ponds; cooling tower recently built (50% of condenser water); recycle possible. Filter slurry to total impoundage.
CF-5	Partial impoundment.
CF-6	Partial reuse of waste waters in raw sugar factory for cane washing during grinding season.
CF-7	Partial impoundment.
CF-8	Partial impoundment.

Waste holding lagoons have widespread use in the raw cane sugar industry and are employed by several cane sugar refineries in rural areas. One small liquid refinery was at one time operated in conjunction with a raw sugar factory, and a lagoon system was designed to contain all wastes from both operations. The subsequent closing of the factory left the refinery with more than adequate pond area for total waste water impoundage. Several factory-refinery combinations in Louisiana and Puerto Rico use impoundage to various extents; two refineries discharge to large, swampy private land holdings with a resulting undefined eventual discharge.

Those refineries which utilize waste holding ponds to achieve impoundage with an overflow are those operating in conjunction with raw cane sugar factories. Wastes from both the refinery and the factory are discharged to the same holding ponds, making it impossible to determine the treatment efficiency associated with this technology.

In the construction and operation of holding ponds, sealing of pond bottoms to control percolation may be necessary (although expensive), but self sealing may occur as a result of organic mat formation. No contamination of groundwater should be allowed.

Land irrigation is practiced at only one refinery - a small refinery in Puerto Rico which is located on the dry south coast of the island. Other refineries are prohibited from using this technology by either (1) being located in urban areas, or (2) being located in areas of high rainfall.

Deep-well injection is not practiced in cane sugar refining nor in beet sugar processing; one raw sugar factory in Florida practices this method of disposal. Deep-well injection may exist as a disposal alternative; however, the effects of subsurface injection are usually difficult to determine. This method of disposal can only be recommended with the stipulation that extensive studies be conducted to insure environmental protection beyond any reasonable doubt.

Effluent Limitations Guidelines Development

For the purposes of establishing effluent limitations guidelines, model refineries were hypothesized to represent the crystalline and liquid cane sugar refining industry subcategories. These model refineries were derived from a basis of good water usage and conservation, but poor in-plant controls to limit BOD_5 and suspended solids loadings. These model refineries are illustrated in Figures 18 and 19. The following treatment alternatives have been applied to these model refineries to determine the best practicable control technology currently available (BPCTCA), the best available technology economically achievable (BATEA), and the standards of performance for new sources (NSPS):

Alternative A: This Alternative represents the baseline

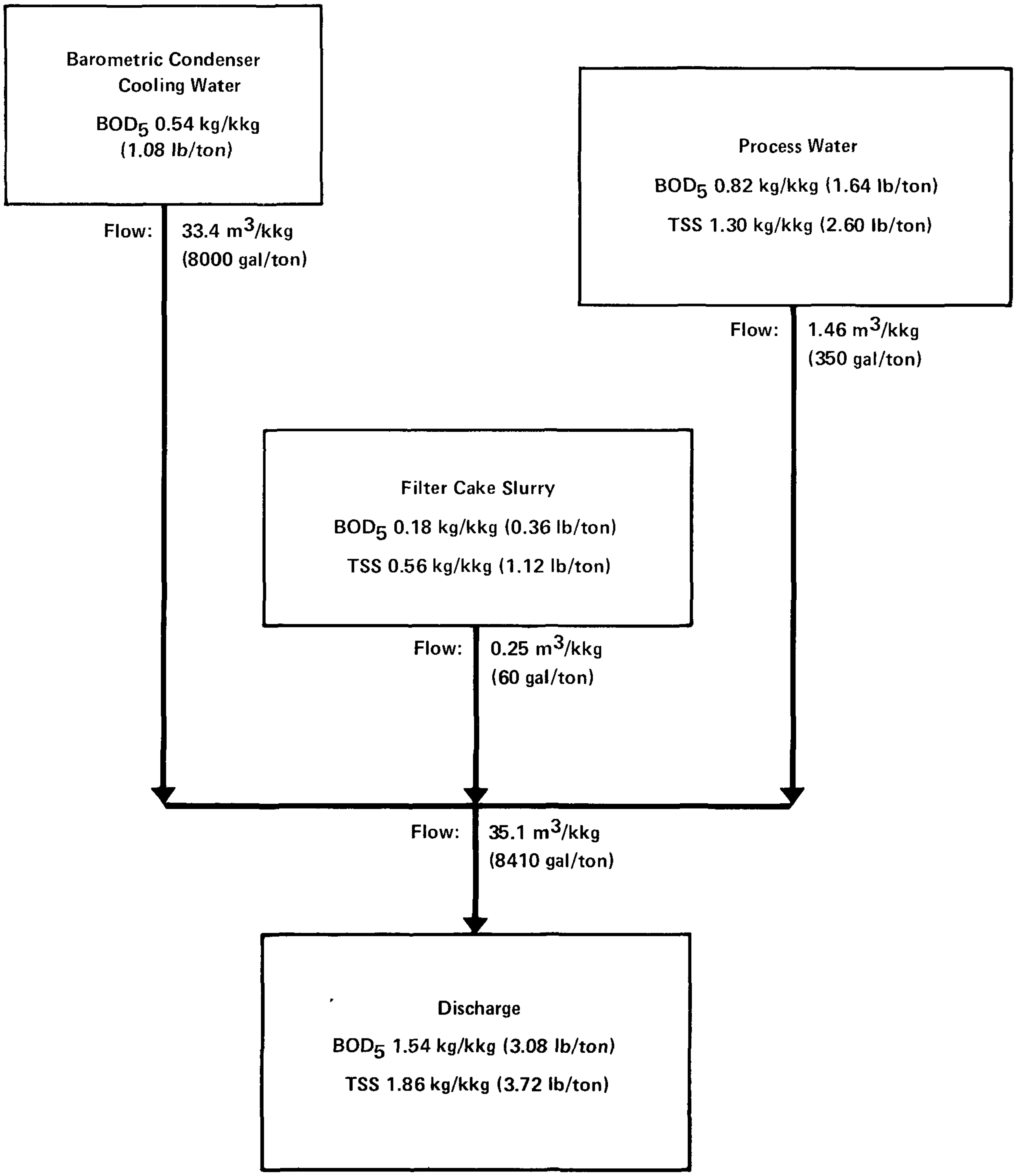


Figure 18
RAW WASTE LOADINGS AND WATER USAGE FOR THE MODEL CRYSTALLINE CANE SUGAR REFINERY

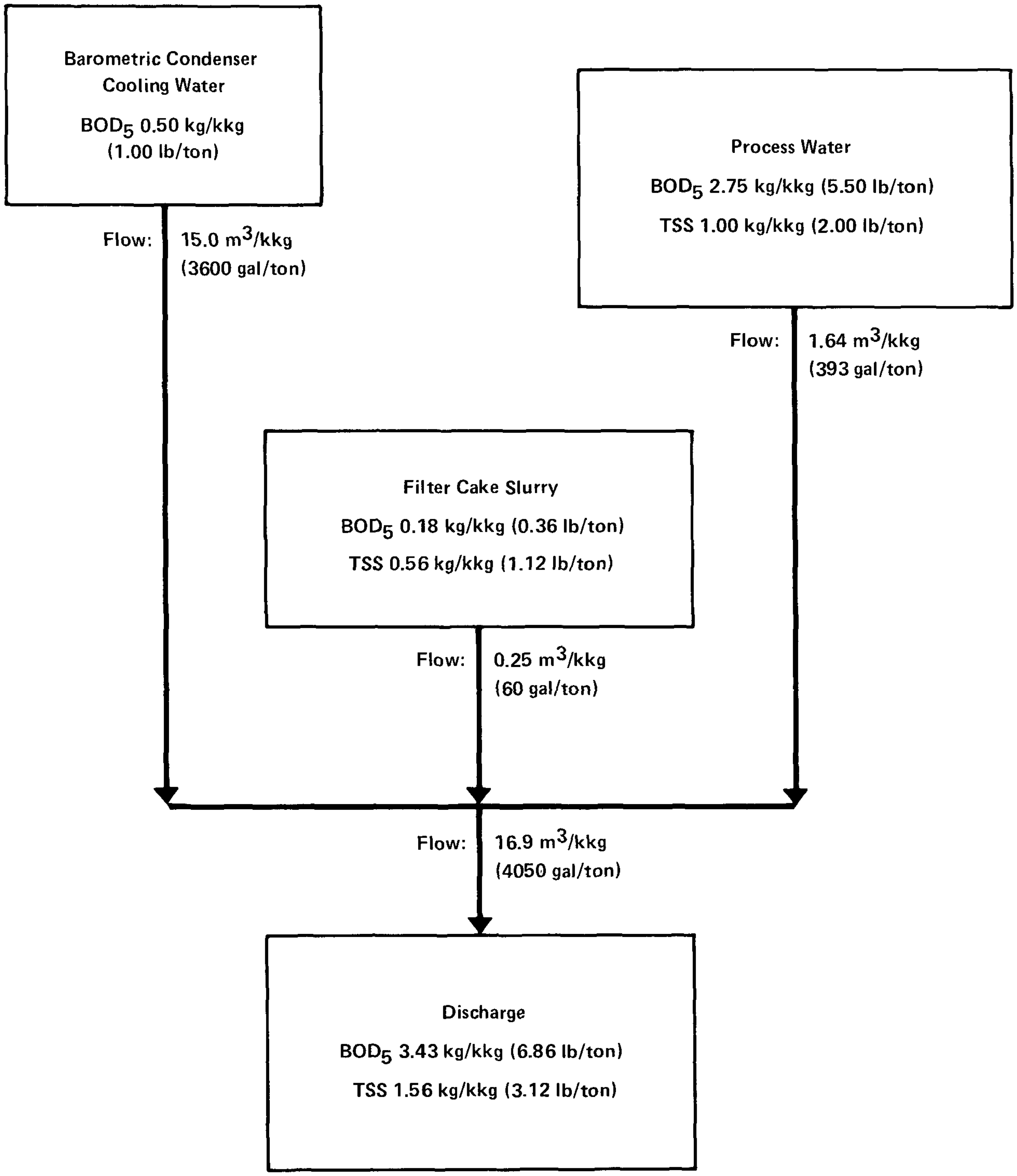


Figure 19
RAW WASTE LOADINGS AND WATER USAGE FOR THE
MODEL LIQUID CANE SUGAR REFINERY

and includes good water usage but poor in-plant controls. This Alternative also assumes no treatment, and represents the model raw waste loadings.

Alternative B: This Alternative involves the elimination of a discharge of filter cake, which results from the clarification of melt liquor. Filter cake can be disposed of without discharge to navigable waters by controlled impoundage of the filter slurry (Alternative B-1) or by dry handling of the filter cake (Alternative B-2). A decrease in water usage of 0.25 cubic meters per metric ton (60 gallons per tons) of melt is evidenced over Alternative A if dry handling of filter cake is incorporated.

Alternative C: This Alternative involves, in addition to Alternative B, the addition of demisters and external separators to reduce entrainment of sucrose into barometric condenser cooling water. This technology is illustrated for both liquid and crystalline refineries in Figures 20 and 21. For the barometric condenser cooling water flows developed for both the crystalline and liquid cane sugar refining subcategories, BOD_5 entrainment can be reduced to below 10 mg/l.

Alternative D: This Alternative involves, in addition to Alternative C, the addition of an activated sludge system to treat process waters.

Alternative E: This Alternative involves, in addition to Alternative D, the recycle of barometric condenser cooling water through a cooling device with biological treatment of the assumed two percent blowdown and incorporates sand filteration of the effluent from the activated sludge system to further effect solids removal. This results in reductions in water usages of 88 percent for liquid refineries and 94 percent for crystalline refineries, over Alternative D.

Alternative F: This Alternative includes, in addition to Alternative C, the elimination of a discharge of process waters by total impoundage of this waste stream. This technology requires that large quantities of land be available and is not judged to be available technology for urban refineries. It is a current practice of many rural refineries, however.

Alternative G: This Alternative involves in addition to Alternative F, a recycling of barometric condenser cooling water through a cooling device and total re-

CRYSTALLINE REFINERIES

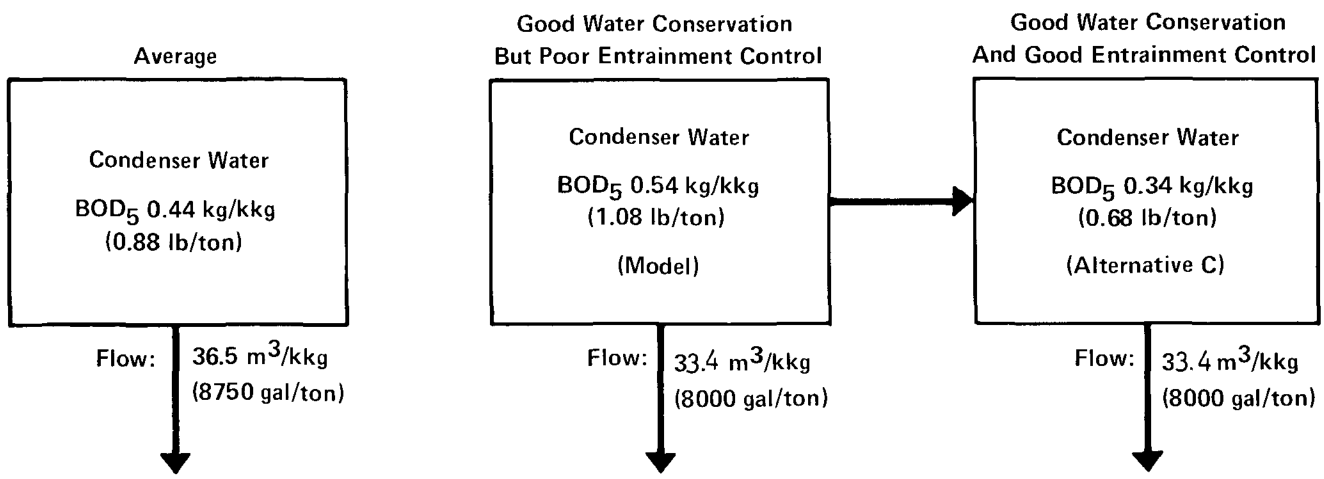


Figure 20
CONDENSER WATER LOADINGS AND WATER USAGE FOR
CRYSTALLINE CANE SUGAR REFINERIES

LIQUID REFINERIES

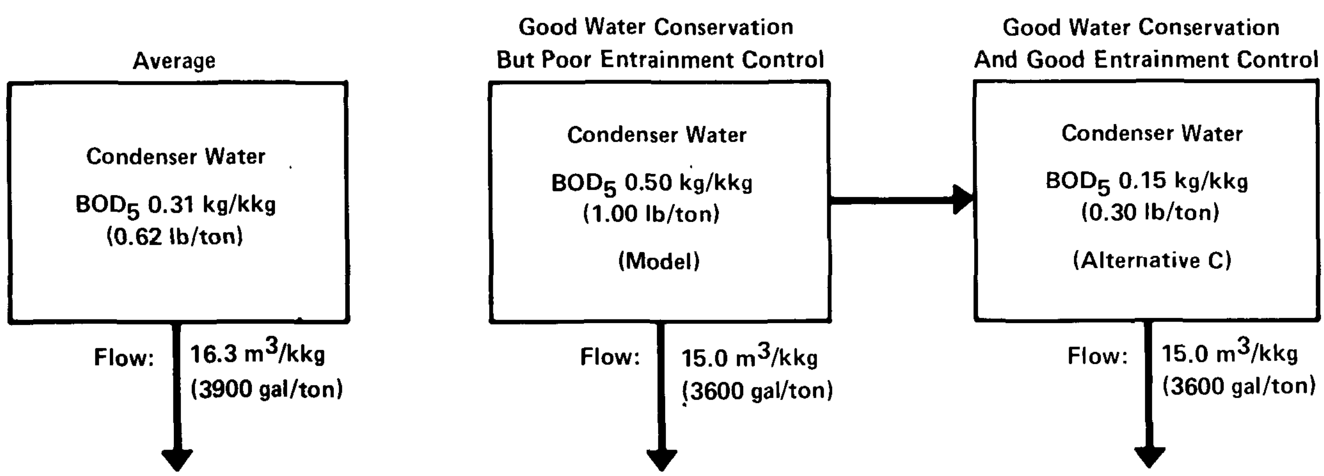


Figure 21
CONDENSER WATER LOADINGS AND WATER USAGE FOR
LIQUID CANE SUGAR REFINERIES

tention of the assumed two percent blowdown. This technology requires that large quantities of land be available and is not judged to be available technology for urban refineries. It is a current practice of three refineries, all rurally located. Reduction in water usages of 88 percent for liquid refineries and 94 percent for crystalline refineries results, over Alternative F.

Specific features of the recommended best practicable control technology currently available (BPCTCA) for the two subcategories are:

--Containment of filter mud slurry or dry handling of filter cake with land disposal.

--Prevention of spillage during raw sugar handling, unloading and storage.

--Entrainment prevention in evaporators and pans through baffling, centrifugal separators, dimisters, and utilization of the proper height of the vapor belt.

--Maximum reuse of all general waste streams. i.e. - floor and equipment washes, filter screen washes. (At present some refineries recycle essentially all floor and equipment washes back to the process.)

--Biological treatment of process waters by activated sludge or equivalent biological treatment system.

These features are the equivalent of Alternative D as discussed previously.

The effluent limitations guidelines were established on the following bases. It has been determined that sucrose entrainment in the barometric condenser cooling water, at the flows chosen for the model refineries, can be reduced to the equivalent of 10 mg/l BOD_5 for both crystalline and liquid refineries. It has also been determined that process water can be treated to the extent that the resulting effluent monthly average waste loadings from the activated sludge system are 30 mg/l BOD_5 and 40 mg/l TSS for the crystalline cane sugar refinery, and 50 mg/l BOD_5 and 60 mg/l TSS for the liquid cane sugar refinery. The addition of the BOD_5 attributed to the barometric condenser cooling water to that of the process water results in the limitation guideline. The TSS limitation guidelines is that amount attributable to the process water.

Specific features of the recommended best available technology economically achievable (BATEA) for the two subcategories are:

--Those features considered to be best practicable control technology currently available.

--Recycle of barometric condenser cooling water for condenser or other in-plant uses with recycle of the blowdown stream to biological treatment. Cooling devices (canals, ponds, or towers) are in integral part of a barometric condenser cooling water recycle system.

--The additon of sand filtration of the effluent from the activated sludge or equivalent biological treatment system.

These features are the equivalent of Alternative E as discussed previously.

The effluent limitations guidelines were established on the following bases. The activated sludge system which treats the process water of the model refineries has been expanded to handle the blowdown stream from the cocling device utilized in recycling barometric condenser cooling water. The effluent levels from the activated sludge system are the same as those designed for in the treatment of process water (BPCTCA). The Effluent limitations guidelines reflect the level of treatment attributed to the further solids removal as a result of sand filtration. It has been determined that at the effluent waste loading entering the sand filtration units from the activated sludge system, a resulting monthly average waste loading from the sand filtration units of 15 mg/l TSS can be easily achieved. The effluent limitations guidelines are established to reflect a value of 15 mg/l TSS and that amount of BOD_5 removed with the solids. These effluent levels are determined to be 28 mg/l BOD_5 for the liquid refinery and 18 mg/l BOD_5 for the crystalline refinery.

Specific features of the reccmmended best available demonstrated control technology, processes, operating methods or other alternatives (NSPS) are:

--Those features considered to be best available technology economically achievable.

These features are the equivalent of Alternative E as discussed previously.

The effluent limitations guidelines are further developed and the ccsts of application of the various treatment alternatives are presented in Section VIII, Cost, Energy, and Non-Water Quality Aspects.

Establishment of Daily Average Effluent Limitations Guidelines

Based on engineering judgement and an evaluation of what can be achieved by the application of activated sludge for the treatment of cane sugar refining waste waters, daily average limitations have been established.

It is felt that the daily average limitations cannot be as strict as those variances above the monthly average typical of a well-designed and well-operated municipal treatment system. This is due to the greater variation in waste loadings typical of industrial waste waters and for other unknown factors. No cane sugar refinery currently utilizes an activated sludge system to treat its waste waters. However, the activated sludge system is currently available well-demonstrated technology for wastes similar in nature to those associated with cane sugar refining.

For the crystalline cane sugar refining subcategory, daily average effluent limitations guidelines have been established based on three times the monthly average limitations for BOD_5 and four times the monthly average limitations for TSS. Because of a higher BOD_5 raw waste loading and the potential for a correspondingly higher variability, daily average effluent limitations guidelines have been established for the liquid cane sugar refining subcategory based on three and one-half times the monthly average limitations for BOD_5 and four and one-half times the monthly average limitations for TSS.

SECTION VIII

COST, ENERGY, AND NON-WATER QUALITY ASPECTS

COST AND REDUCTION BENEFITS OF ALTERNATIVE TREATMENT AND CONTROL TECHNOLOGIES FOR CANE SUGAR REFINERIES

The Model Refineries

The cost estimates contained in this document are based on two crystalline refineries with melts of 545 metric tons (600 tons) per day and 1900 metric tons (2100 tons) per day, respectively, and a liquid refinery with a melt of 508 metric tons (560 tons) per day. These refineries are considered to be generally representative of both large and small crystalline operations and of liquid operations. Obviously, any given existing installation may vary considerably from the models presented; each sugar refinery has unique characteristics and unique problems that must be taken into consideration. The following are assumed features of the representative refineries:

1. The present level of barometric condenser cooling water BOD_5 entrainment is 16 ppm in crystalline refineries and 33 ppm in liquid refineries.
2. Both liquid and crystalline refineries employ liquid level controls on evaporators and absolute pressure controls on the last evaporator body.
3. Both crystalline refineries employ triple-effect evaporators; the liquid refinery uses double-effect evaporators.
4. Total mud slurry equals 114 cubic meters (30,000 gallons) per day for the liquid refinery, 135 cubic meters (35,700 gallons) per day for the 545 metric ton (600 ton) per day crystalline refinery, and 455 cubic meters (120,000 gallons) per day for the 1900 metric ton (2100 ton) per day crystalline refinery.
5. The operating year consists of 250 days.
6. Ninety-eight percent of condenser water BOD_5 is due to sucrose.
7. Both liquid and crystalline refineries discharge diatomaceous earth filter slurries.
8. The liquid and crystalline refineries do not recycle condenser water.
9. There is presently a discharge of process water with no treatment in the case of both liquid and crystalline refineries.

Basis of Cost Analysis

The following are the basic assumptions made in presentation of cost information:

1. Investment costs are based on actual engineering cost estimates.
2. 0.454 kg (one lb.) of sugar is equivalent to .511 kg (1.125 lb.) of BOD_5.
3. 3.79 liters (one gallon) of 80° Brix final molasses sells for $.042 per liter ($.16 per gallon).
4. All costs are August 1971 dollars.
5. Equipment depreciation is based on an 18 year straight-line method, except for rolling stock which is depreciated over 6 years by the straight-line method.
6. Excavation of filter mud pits costs $0.53 per cubic meter ($.40 per cubic yard); annual excavation and disposal costs $0.79 per cubic meter ($0.60 per cubic yard).
7. Annual interest rate for capital cost equals 8 percent.
8. Salvage value for all facilities depreciated over 18 years is zero.
9. Only sugar losses in the barometric condenser cooling water can be recovered.
10. Liquid sugar sells for $254.00 per metric ton ($230.50 per ton); crystalline sugar sells for $260.00 per metric ton ($236.40 per ton).
11. Contingency is taken at 10 percent of installed cost.
12. Engineering and expediting costs are taken at 10 percent of installed cost plus contingency.
13. Total yearly cost equals:
    (Investment cost) . (Yearly depreciation percentage) + Yearly operating cost + (Investment cost /2) (.08)
14. Hook-up charges associated with disposal to municipal systems are assumed to be zero.

<u>Qualifying Statements</u>. The following cost analyses include in some cases considerable costs for excavation and dyke construction. In some instances these costs may be minimized or nullified by topographic conditions. In other instances they may be reduced by utilizing in-house equipment and labor.

Land costs vary widely. The figures used herein are considered to be representative of non-urban areas where the use of land would be expected. In urban areas land is often not available; when it is used, the cost can be expected to be substantially higher than reported in this document.

The investment cost associated with hook-up to a municipal waste system is assumed herein to be nil. In actuality this cost can vary from zero to considerable sums of money; for purposes of economic impact, it is necessary to assess the cost on an individual basis. However, for the purposes of presenting cost information for the entire industry, it must be noted that thirteen refineries already have municipal hook-up. Therefore, for these thirteen refineries, the assumption of zero additional cost is valid because they already have municipal hook-up.

Crystalline Refinery

Two representative crystalline refineries were chosen as a basis for cost estimates: a small refinery with a melt of 545 metric tons (600 tons) per day and a large refinery with a melt of 1900 metric tons (2100 tons) per day. The following treatment alternatives may be applied to both refineries.

Alternative A: No Waste Treatment or Control. The effluent from a 545 metric ton (600 ton) per day crystalline refinery is 19,100 cubic meters (5.05 million gallons) per day and from a 1900 metric ton (2100 tons) per day crystalline refinery is 66,700 cubic meters (17.7 million gallons) per day. The resulting BOD5 and suspended solids loads are 1.54 kilograms per metric ton (3.08 pounds per ton) and 1.86 kilograms per metric ton (3.72 pounds per ton) respectively, for both refineries. Since no waste treatment is involved, no cost associated with waste treatment or control can be attributed to this Alternative.

COSTS: 0
REDUCTION BENEFITS: None

Alternative B: Elimination of Discharge from Filters. This Alternative can be achieved either by impounding the mud resulting from slurrying filter cake with water or by dry hauling the desweetened filter cake to landfill. The resulting effluent waste loads for BOD5 and suspended solids are 1.36 kilograms per metric ton (2.72 pounds per ton) of melt and 1.30 kilograms per metric ton (2.60 pounds per ton) of melt respectively, at this control level.

B-1: Impound Filter Slurry

COSTS: 545 metric tons (600 tons) per day crystalline refinery

Incremental Investment Cost:	$33,000
Total Investment Cost:	$33,000
Total Yearly Cost:	$ 8,600

1900 metric tons (2100 tons) per day crystalline refiner

Incremental Investment Cost:	$66,000
Total Investment Cost:	$66,000
Total Yearly Cost:	$20,000

B-2: Dry Disposal of Filter Cake

COSTS: 545 metric tons (600 tons) per day crystalline refinery

Incremental Investment Cost:	$61,000
Total Investment Cost:	$61,000
Total Yearly Cost:	$45,000

1900 metric tons (2100 tons) per day crystalline refinei

Incremental Investment Cost: $61,000
Total Investment Cost: $61,000
Total Yearly Cost: $71,000

REDUCTION BENEFITS: An incremental reduction in BOD_5 of approximately 0.18 kilograms per metric ton (0.36 pounds per ton) of melt and in suspended solids of approximately 0.56 kilograms per metric ton (1.12 pounds per ton) of melt is evidenced over Alternative A. Total plant reductions of 11.7 percent for BOD_5 and 30.5 percent for suspended solids would be achieved.

For the purpose of accruing total costs in this section of the report, the use of dry disposal of filter cake (B-2) will be considered representative of Alternative B.

Alternative C: In plant Modifications to Reduce Entrainment of Sucrose into Condenser Water. This Alternative includes, in addition to Alternative B, the installaticn of demisters and external separators in crder to reduce entrainment of sucrose in barometric condenser cocling water. It is assumed that, in addition, both refineries have good baffling and operational controls in the evaporators and vacuum pans, as well as good vapor height. This technology is currently widely practiced in the industry. The resulting effluent waste loads for BOD_5 and suspended solids are 1.16 kilograms per metric ton (2.32 pounds per ton) of melt and 1.30 kilcgrams per metric ton (2.60 pounds per ton) of melt respectively, for the selected refineries at this control level.

COSTS: 545 metric tons (600 tons) per day crystalline refinery

Incremental Investment Cost: $ 52,000
Total Investment Cost: $113,000
Total Yearly Cost: $ 62,000

1900 metric tons (2100 tons) per day crystalline refinery

Incremental Investment Cost: $ 73,000
Total Investment Cost: $134,000
Total Yearly Cost: $ 75,000

REDUCTION BENEFITS: An incremental reduction in BOD_5 of 0.20 kilograms per metric ton (0.42 pounds per ton) of melt is evidenced over Alternative B. The total reducticn in BOD_5 is 24.7 percent. No further reduction in suspended solids is achieved.

Alternative D: Biological Treatment of Process Water. This Alternative assumes the addition of an activated sludge plant to Alternative C to treat process water. Presently there are no refineries which have their own biological treatment systems, but refinery wastes are commonly treated in municipal biological treatment plants. As discussed in Section VII, Control and Treatment Technology, refinery waste water is highly biodegradable and thus well suited for biological treatment.

A schematic of the activated sludge system is shown in Figure 22. Waste water is pumped through a primary clarifier to an aerated lagoon, with biological sludge being returned to the aerated lagoon from a secondary clarifier. Excess sludge is pumped to a sludge digester; the sludge from the digester is pumped to a holding lagoon. The total effluent waste loadings as a result of the addition of this Alternative are estimated to be 0.38 kilograms per metric ton (0.76 pounds per ton) of melt for BOD_5 and 0.06 kilograms per metric ton (0.12 pounds per ton) of melt for suspended solids.

COSTS: 545 metric tons (600 tons) per day crystalline refinery

Incremental Investment Cost:	$255,000
Total Investment Cost:	$368,000
Total Yearly Cost:	$205,000

1900 metric tons (2100 tons) per day crystalline refinery

Incremental Investment Cost:	$662,000
Total Investment Cost:	$796,000
Total Yearly Cost:	$296,000

REDUCTION BENEFITS: An incremental reduction in BOD_5 of approximately 0.78 kilograms per metric ton (1.56 pounds per ton) of melt and in suspended solids of approximately 1.24 kilograms per metric ton (2.48 pounds per ton) of melt is evidenced over Alternative C. Total reductions of 75.3 percent for BOD_5 and 96.8 percent for suspended solids would be achieved.

Alternative E: Recycle of Condenser Water and Biological Treatment of Blowdown. This Alternative includes, in addition to Alternative D, the recycle of barometric condenser cooling water followed by biological treatment of a blowdown in an activated sludge unit and the addition of sand filtration to further treat the effluent from the activated sludge unit. The blowdown is assumed to be approximately two percent of the condenser flow. Presently, there are three refineries using cooling towers and two which utilize a spray pond for the purpose of recycling barometric condenser cooling water. Recycle of condenser water accomplishes two important things; (1) it cools the water, thereby removing the heat normally discharged and (2) it concentrates the waste loadings into the smaller blowdown stream, making biological treatment

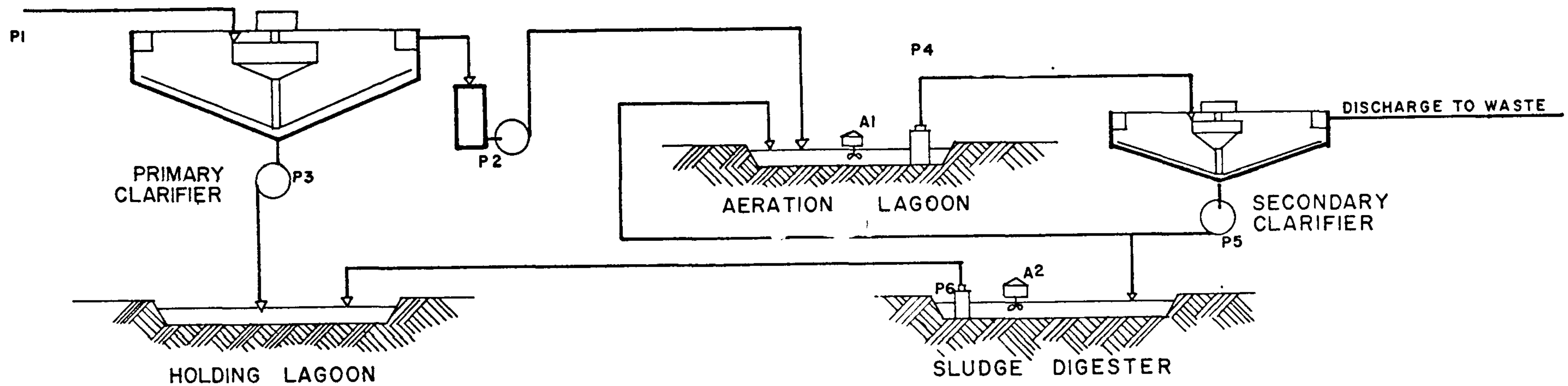


FIGURE 22

SCHEMATIC OF ACTIVATED SLUDGE SYSTEM

of this waste stream feasible. The total effluent waste loadings as a result of the addition of this Alternative are estimated to be 0.04 kilograms per metric ton (0.08 pounds per ton) of melt for BOD5 and 0.03 kilograms per metric ton (0.06 pounds per ton) of melt for suspended solids. In addition, 665,000 kilogram calories per metric ton (2.4 million BTU per ton) of melt are effectively removed from condenser water.

There are a number of methods of recycling condenser water; for the purposes of this document, the following are considered: cooling towers and spray ponds.

E-1: Alternative E with a Cooling Tower

COSTS: 545 metric tons (600 tons) per day crystalline refinery

Incremental Investment Cost:	$346,000
Total Investment Cost:	$714,000
Total Yearly Cost:	$283,000

1900 metric tons (2100 tons) per day crystalline refiner

Incremental Investment Cost:	$ 714,000
Total Investment Cost:	$1,510,000
Total Yearly Cost:	$ 470,000

E-2: Alternative E with a Spray Pond

COSTS: 545 metric tons (600 tons) per day crystalline refinery

Incremental Investment Cost:	$ 282,000
Total Investment Cost:	$ 650,000
Total Yearly Cost:	$ 271,000

1900 metric tons (2100 tons) per day crystalline refine

Incremental Investment Cost:	$ 596,000
Total Investment Cost:	$1,392,000
Total Yearly Cost:	$ 438,000

REDUCTION BENEFITS: An incremental reduction in BOD5 of approximately 0.34 kilograms per metric ton (0.68 pounds per ton) of melt and in suspended solids of 0.03 kilograms per metric ton (0.06 pounds per ton) of melt is evidenced by addition of this Alternative to Alternative D. Total reductions of 97.5 percent for BOD5 and 98.4 percent for suspended solids would be achieved.

Alternative F: Elimination of Discharge of Process Water. This Alternative assumes that, in addition to Alternative C, all process waters are eliminated by controlled retention and total impoundage. The resulting effluent waste loading for BOD_5 associated with this control level is estimated at 0.34 kilograms per metric ton (0.68 pounds per ton) of melt, that amount attributable to barometric condenser cooling water. The suspended solids loading is zero as the only suspended solids-bearing waste stream has been eliminated.

F: Elimination of Discharge of Process Water by Containment

Total impoundment of process water is sucessfully practiced by five refineries; however, a considerable amount of land is required (see Tables 17 and 18, Path 13). Containment of process waters is, therefore, not considered to be practicable technology for urban crystalline refineries.

COSTS: 545 metric tons (600 tons) per day crystalline refinery.

Incremental Investment Cost:	$1,410,000
Total Investment Cost:	$1,530,000
Total Yearly Cost:	$ 211,000

1900 metric tons (2100 tons) per day crystalline refinery

Incremental Investment Cost:	$4,870,000
Total Investment Cost	$5,000,000
Total Yearly Cost:	$ 591,000

REDUCTION BENEFITS: An incremental reduction in plant BOD_5 of 0.82 kilograms per metric ton (1.64 pounds per ton) of melt and in suspended solids of 1.30 kilograms per metric ton (2.60 pounds per ton) of melt is evidenced in comparison to Alternative C. Total reductions in BOD_5 of 78.0 percent and in suspended solids of 100 percent are achieved.

.Alternative G: Elimination of Discharge of Barometric Condenser Cooling Water. This Alternative assumes that in addition to Alternative F, there is an elimination of discharge of barometric condenser cooling water. To achieve this level of treatment, it has been assumed that condenser water is recycled and the blowdown impounded. The blowdown of barometric condenser cooling water is assumed to be two percent of the total condenser flow. Effluent waste loads associated with this control level are zero kilograms per metric ton (zero pounds per ton) of melt.

G-1: Recycle of Condenser Water Through a Cooling Tower with an Assumed Two Percent Blowdown to Controlled Land Retention, in Addition to Alternative F.

TABLE 18

SUMMARY OF WASTE LOADS FROM TREATMENT ALTERNATIVES
FOR THE SELECTED CRYSTALLINE REFINERIES

Effluent Constituent Parameters	Raw Waste	A	B	C	D*	E**	F	G
BOD5 kg/kkg of melt	1.54	1.54	1.36	1.16	0.38	0.04	0.34	0
(lb/ton of melt)	(3.08)	(3.08)	(2.72)	(2.32)	(0.76)	(0.08)	(0.68)	(0)
TSS kg/kkg of melt	1.86	1.86	1.30	1.30	0.06	0.03	0	0
(lb/ton of melt)	(3.72)	(3.72)	(2.60)	(2.60)	(0.12)	(0.06)	(0)	(0)
FLOW (m^3/kkg)								
Barometric Condensers	33.4	33.4	33.4	33.4	33.4	0.67	33.4	0.67
Process Water	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46
Filter Slurry	0.25	0.25	0	0	0	0	0	0

* BPCTCA

** BATEA;NSPS

TABLE 19

SUMMARY OF ALTERNATIVE COSTS FOR A 545 METRIC TONS (600 TONS) PER DAY CRYSTALLINE SUGAR REFINERY

Alternative	BOD5 Load*	% BOD5 Removal	TSS Load*	% TSS Removal	Investment Cost	Total Yearly Operating Cost	Total Yearly Cost
A	1.54	0.0	1.86	0.0	0	0	0
B-1	1.36	11.7	1.30	30.5	33,000	5,400	8,600
B-2	1.36	11.7	1.30	30.5	61,000	36,700	45,000
C	1.16	24.7	1.30	30.5	113,000	55,600	62,000**
D	0.38	75.3	0.06	96.8	368,000	174,000	205,000
E-1	0.04	97.5	0.03	98.4	714,000	219,000	283,000
E-2	0.04	97.5	0.03	98.4	650,000	214,000	271,000
F	0.34	78.0	0.0	100	1,530,000	70,000	211,000
G-1	0.0	100	0.0	100	2,530,000	114,000	352,000
G-2	0.0	100	0.0	100	2,470,000	109,000	340,000

*Waste Loadings in Kilograms per Metric Ton of Melt

**Includes Sugar Savings of $7,400/yr. as a Result of Entrainment Prevention.

TABLE 20

SUMMARY OF ALTERNATIVE COSTS FOR A 1,900 METRIC TONS (2,100 TONS) PER DAY CRYSTALLINE SUGAR REFINERY

Alternative	BOD5 Load*	% BOD5 Removal	TSS Load*	% TSS Removal	Investment Cost	Total Yearly Operating Cost	Total Yearly Cost
A	1.54	0.0	1.86	0.0	0	0	0
B-1	1.36	11.7	1.30	30.5	66,000	14,000	20,000
B-2	1.36	11.7	1.30	30.5	61,000	64,000	71,000
C	1.16	24.7	1.30	30.5	134,000	87,000	75,000**
D	0.38	75.3	0.06	96.8	796,000	244,000	296,000
E-1	0.04	97.5	0.03	98.4	1,510,000	350,000	470,000
E-2	0.04	97.5	0.03	98.4	1,390,000	330,000	438,000
F	0.34	78.0	0.0	100	5,000,000	137,000	591,000
G-1	0.0	100	0.0	100	7,620,000	245,000	950,000
G-2	0.0	100	0.0	100	7,510,000	226,000	918,000

*Waste Loadings in Kilograms per Melt

**Includes Sugar Savings of $27,000/yr. as a Result of Entrainment Prevention.

TABLE 21

IMPLEMENTATION SCHEDULES FOR A SMALL CRYSTALLINE SUGAR REFINERY

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
1	Containment of filter muds, all process water, and blowdown from cooling tower	0	0	61	No	2,500,000	316,000
2	Containment of filter muds, all process water, and blowdown from spray pond	0	0	61	No	2,440,000	304,000
3	Containment of filter muds and discharge process water and blowdown from cooling tower to municipal treatment	0	0	0.7	Yes	297,000	113,000
4	Containment of filter muds and discharge of process water and blowdown from spray pond to municipal treatment	0	0	0.7	Yes	233,000	102,000
5	Dry disposal of filter cake and containment of all process waters and blowdown from cooling tower	0	0	60	No	2,530,000	352,000

TABLE 21

IMPLEMENTATION SCHEDULES FOR A SMALL CRYSTALLINE SUGAR REFINERY
(Continued)

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
6	Dry disposal of filter cake and containment of all process water and blowdown from spray pond	0	0	60	No	2,470,000	340,000
7	Dry disposal of filter cake with discharge of process waters and blowdown from cooling tower to municipal treatment	0	0	0.2	Yes	325,000	149,000
8	Dry disposal of filter cake and containment of all process water and blowdown from spray pond to municipal treatment	0	0	0.2	Yes	261,000	138,000
9	Containment of filter muds and biological treatment of process water and blowdown from cooling towers, fol-lowed by sand filtr.	0.4	0	0.8	No	686,000	247,000
10	Containment of filter muds and biological treatment of process water and blowdown from spray pond, fol-lowed by sand filtr.	0.04	0	0.9	No	622,000	235,000

TABLE 21

IMPLEMENTATION SCHEDULES FOR A SMALL CRYSTALLINE SUGAR REFINERY
(Continued)

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
11	Dry disposal of filter cake and biological treatment of process water and blowdown from cooling tower, followed by sand filtr.	0.04	0	0.3	No	714,000	283,000
12	Dry disposal of filter cake and biological treatment of process water and blowdown from spray pond, followed by sand filtr.	0.04	0	0.4	No	650,000	271,000
13	Containment of filter muds and process waters and discharge of condenser water without cooling or recycle	0.34	0.67	38	No	1,500,000	174,000
14	Containment of filter muds, municipal treatment of process waters, and discharge of condenser water without cooling or recycle	0.34	0.67	0.5	Yes	85,000	53,000
15	Dry disposal of filter cake, containment of process water and discharge of condenser water without cooling or recycle	0.34	0.67	38	No	1,530,000	211,000

TABLE 21

IMPLEMENTATION SCHEDULE FOR A SMALL CRYSTALLINE SUGAR REFINERY
(Continued)

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
16	Dry disposal of filter cake, municipal treatment of process water, and discharge of condenser water without cooling or recycle	0.34	0.67	0	Yes	113,000	89,000
17	Containment of filter muds, biological treatment of process water, and discharge of condenser water without cooling or recycle	0.38	0.67	0.7	No	340,000	169,000
18	Dry disposal of filter cake, biological treatment of process water, and discharge of condenser water without cooling or recycle	0.38	0.67	0.2	No	368,000	205,000

TABLE 22

IMPLEMENTATION SCHEDULES FOR A LARGE CRYSTALLINE SUGAR REFINERY

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
1	Containment of filter muds, all process waters, and blowdown from cooling tower	0	0	198	No	7,620,000	899,000
2	Containment of filter muds, all process water, and blowdown from spray pond	0	0	198	No	7,510,000	868,000
3	Containment of filter muds and discharge process water and blowdown from cooling tower to municipal treatment	0	0	1.8	Yes	539,000	252,000
4	Containment of filter muds and discharge of process water and blowdown from spray pond to municipal treatment	0	0	1.9	Yes	423,000	221,000
5	Dry disposal of filter cake and containment of all process waters and blowdown from cooling tower	0	0	196	No	7,620,000	950,000

TABLE 22

IMPLEMENTATION SCHEDULES FOR A LARGE CRYSTALLINE SUGAR REFINERY
(Continued)

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
6	Dry disposal of filter muds and containment of all process water and blowdown from spray pond	0	0	196	No	7,510,000	918,000
7	Dry disposal of filter mud with discharge of process waters and blowdown from cooling tower to municipal treatment	0	0	0.2	Yes	534,000	303,000
8	Dry disposal of filter cake, containment of all process water, and blowdown from spray pond to municipal treatment	0	0	0.2	Yes	418,000	272,000
9	Containment of filter muds and biological treatment of process water and blowdown from cooling tower, followed by sand filtr.	0.04	0	1.7	No	1,510,000	419,000
10	Containment of filter muds and biological treatment of process water and blowdown from spray pond followed by sand filtr.	0.04	0	1.9	No	1,400,000	387,000

TABLE 22

IMPLEMENTATION SCHEDULES FOR A LARGE CRYSTALLINE SUGAR REFINERY
(Continued)

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
11	Dry disposal of filter cake and biological treatment of process water and blowdown from cooling tower, followed by sand filtr.	0.04	0	0.3	No	1,510,000	470,000
12	Dry disposal of filter cake and secondary treatment of process water and blowdown from spray pond, followed by sand filtr.	0.04	0	0.4	No	1,390,000	438,000
13	Containment of filter muds and process waters and discharge of condenser water without cooling or recycle	0.34	0.67	136	No	5,010,000	540,000
14	Containment of filter muds, municipal treatment of process waters, and discharge of condenser water without cooling or recycle	0.34	0.67	1.6	Yes	139,000	120,000
15	Dry disposal of filter cake, containment of process water and discharge of condenser water without cooling or recycle	0.34	0.67	135	No	5,000,000	591,000

TABLE 22

IMPLEMENTATION SCHEDULES FOR A LARGE CRYSTALLINE SUGAR REFINERY
(Continued)

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
16	Dry disposal of filter cake, municipal treatment of process water, and discharge of condenser water without cooling or recycle	0.34	0.67	0	Yes	134,000	171,000
17	Containment of filter muds, biological treatment of process water, and discharge of condenser water without cooling or recycle	0.38	0.67	1.7	No	801,000	245,000
18	Dry disposal of filter cake, biological treatment of process water, and discharge of condenser water without cooling or recycle	0.38	0.67	0.2	No	796,000	296,000

COSTS: 545 metric tons (600 tons) per day crystalline refinery

Incremental Investment Cost: $1,000,000
Total Investment Cost: $2,530,000
Total Yearly Cost: $ 352,000

1900 metric tons (2100 tons) per day crystalline refinery

Incremental Investment Cost: $2,620,000
Total Investment Cost: $7,620,000
Total Yearly Cost: $ 950,000

G-2: Recycle of Condenser Water Through a Spray Pond with an Assumed Two Percent Blowdown to Controlled Land Retention, in Addition to Alternative F.

COSTS: 545 metric tons (600 tons) per day crystalline refinery

Incremental Investment Cost: $ 940,000
Total Investment Cost: $2,470,000
Total Yearly Cost: $ 340,000

1900 metric tons (2100 tons) per day crystalline refinery

Incremental Investment Cost: $2,510,000
Total Investment Cost: $7,510,000
Total Yearly Cost: $ 918,000

REDUCTION BENEFITS: An incremental reduction in plant BOD_5 of 0.34 kilograms per metric ton (0.68 pounds per ton) of melt is evidenced by addition of this Alternative to Altermative F. Total reduction of BOD_5 and suspended solids is 100 percent.

Discharge of Process Waste Streams to Municipal Treatment Systems. For the purpose of presenting cost information which is representative of the industry, it is necessary to determine costs associated with various schemes of discharge to municipal treatment systems. Twelve refineries currently discharge all or a portion of their wastes to municipal treatment systems. Seven of these are crystalline refineries with one other crystalline refinery having sewer hook-up and soon to practice this treatment technique. The following schemes are possible and the resulting costs presented.

M.T.#1: Discharge of Process Water to Municipal Treatment

This method of treatment of process water is practiced by twelve refineries, all urbanly located. This technology is not available to most rural refineries or to those refineries whose waste is not accepted by a municipal treatment system. It is however, a well demonstrated treatment method and practiced by 42 per cent of the nation's refineries. The costs presented here include the costs associated with Alternative C.

COSTS: 545 metric tons (600 tons) per day crystalline refinery

Incremental Investment Cost:	$0
Total Investment Cost:	$113,000
Total Operating Cost:	$ 83,000
Total Yearly Cost:	$ 90,000*

1900 metric tons (2100 tons) per day crystalline refinery

Incremental Investment Cost:	$0
Total Investment Cost:	$134,000
Total Operating Cost:	$183,000
Total Yearly Cost:	$171,000*

* Includes savings as a result of recovery of sugar which would normally be entrained in the barometric condenser cooling water.

M.T.#2: Recycle of Condenser Cooling Water Through a Cooling Tower with an Assumed Two Percent Blowdown to Municipal Treatment, in Addition to M.T.#1

COSTS: 545 metric tons (600 tons) per day crystalline refinery

Incremental Investment Cost:	$212,000
Total Investment Cost:	$325,000
Total Operating Cost:	$123,000
Total Yearly Cost:	$149,000

1900 metric (2100 tons) per day crystalline refinery

Incremental Investment Cost:	$400,000
Total Investment Cost:	$534,000
Total Operating Cost:	$276,000
Total Yearly Cost:	$303,000

M.T.#3: Recycle of Condenser Cooling Water Through a Spray Pond with an Assumed Two Percent Blowdown to Municipal Treatment, in Addition to M. T. # 1

COSTS:	545 metric (600 tons) per day crystalling refinery	
	Incremental Investment Cost:	$148,000
	Total Investment Cost:	$261,000
	Total Operating Cost:	$118,000
	Total Yearly Cost:	$138,000
	1900 metric tons (2100 tons) per day crystalline refinery	
	Incremental Investment Cost:	$284,000
	Total Investment Cost:	$418,000
	Total Operating Cost:	$256,000
	Total Yearly Cost:	$272,000

Liquid Refinery

A liquid refinery with an average melt of 508 metric tons (560 tons) of sugar per day was chosen as a basis for cost estimates. The following treatment alternatives may be applied to this refinery.

Alternative A: No Waste Treatment or Control. The effluent from a 508 metric ton (560 ton) per day liquid refinery is 8,590 cubic meters (2.23 million gallons) per day. The resulting BOD_5 and suspended solids loadings are 3.43 kilograms per metric ton (6.86 pounds per ton) and 1.56 kilograms per metric ton (3.12 pounds per ton) respectively. Because no waste treatment is involved, no cost can be attributed to this Alternative.

COSTS: 0
REDUCTION BENEFITS: None

Alternative B: Elimination of Discharge from Filters. This Alternative can be achieved either by impounding the mud resulting from slurrying filter cake with water or by dry hauling the desweetened filter cake to landfill. The resulting effluent waste loads for BOD_5 and suspended solids are estimated to be 3.25 kilograms per metric ton (6.50 pounds per ton) and 1.00 kilograms per metric ton (2.00 pounds per ton) of melt respectively, at this control level.

B-1: Impound Filter Slurry

COSTS:	Incremental Investment Cost:	$31,000
	Total Investment Cost:	$31,000
	Total Yearly Cost:	$12,000

B-2: Dry Disposal of Filter Cake

COSTS:	Incremental Investment Cost:	\$61,000
	Total Investment Cost:	\$61,000
	Total Yearly Cost:	\$45,000

REDUCTION BENEFITS: An incremental reduction in BOD_5 of approximately 0.18 kilograms per metric ton (0.36 pounds per ton) of melt and in suspended solids of approximately 0.56 kilograms per metric ton (1.12 pounds per ton) of melt is evidenced over Alternative A. Total plant reductions of 5.3 percent for BOD_5 and 35.9 percent for suspended solids would be achieved.

For the purpose of accruing total costs in this section of the report, the use of dry disposal of filter cake (B-2) will be considered representative of Alternative B.

Alternative C: Inplant Modifications to Reduce Entrainment of Sucrose into Condenser Water. This Alternative includes, in addition to Alternative B, the installation of demisters and external separators in order to reduce entrainment of sucrose in barometric condenser cooling water. It is assumed, in addition, that the refinery has good baffling and operational controls in the evaporators and vacuum pans, as well as good vapor height. The resulting effluent waste loads for BOD_5 and suspended solids are 2.90 kilograms per metric ton (5.80 pounds per ton) of melt and 1.00 kilograms per metric ton (2.00 pounds per ton) of melt respectively, at this control level.

COSTS:	Incremental Investment Cost:	\$ 54,000
	Total Investment Cost:	\$115,000
	Total Yearly Cost:	\$ 62,000

REDUCTION BENEFITS: An incremental reduction in BOD_5 of 0.35 kilograms per metric ton (0.70 pounds per ton) of melt is evidenced over Alternative B. The total reduction in BOD_5 is 15.4 percent and in suspended solids is 35.9 percent.

Alternative D: Biological Treatment of Process Water. This Alternative assumes the addition of an activated sludge plant to treat process water. Presently there are no refineries which have their own biological treatment systems, but refinery wastes are commonly treated in municipal biological treatment plants. As discussed in Section VII, refinery waste is highly biodegradable and thus well suited for biological treatment.

A schematic of the activated sludge system is shown in Figure 22. Waste water is pumped through a primary clarifier to an aerated lagoon with biological sludge being returned to the aerated lagoon from a secondary clarifier. Excess sludge is pumped to a sludge digester; the sludge from the digester is pumped to a holding lagoon. The total effluent waste loadings as a result of the addition of this Alternative are estimated to be 0.24 kilograms per metric ton (0.48 pounds per ton) of melt for BOD5 and 0.10 kilograms per metric ton (0.20 pounds per ton) of melt for suspended solids.

COSTS:	Incremental Investment Cost:	$337,000
	Total Investment Cost:	$452,000
	Total Yearly Cost:	$230,000

REDUCTION BENEFITS: An incremental reduction in BOD5 of approximately 2.66 kilograms per metric ton (5.32 pounds per ton) of melt and in suspended solids of 0.90 kilograms per metric ton (1.80 pounds per ton) of melt is evidenced over Alternative C. Total reductions of 93.0 percent for BOD5 and 93.6 percent for suspended solids would be achieved.

Alternative E: Recycle of Barometric Condenser Cooling Water and Biological Treatment of Blowdown. This Alternative includes, in addition to Alternative D, the recycle of barometric condenser cooling water followed by biological treatment of blowdown in an activated sludge unit and the addition of sand filtration to further treat the effluent from the activated sludge unit. The blowdown is assumed to be approximately two percent of the total flow. Presently there are three refineries using cooling towers and two which utilize a spray pond for the purpose of recycling condenser cooling water. Recycle of barometric condenser cooling water accomplishes two important things: (1) it cools the water, thereby removing the heat normally discharged and (2) it concentrates the waste loadings into the smaller blowdown stream, making biological treatment of this waste stream feasible. The total effluent waste loadings as a result of the addition of this Alternative are estimated to be 0.06 kilograms per metric ton (0.12 pounds per ton) of melt for BOD5 and 0.03 kilograms per metric ton (0.06 pounds per ton) of melt for suspended solids. In addition, 250,000 kilogram calories per metric ton (0.9 million BTU per ton) of melt are effectively removed from condenser water.

There are a number of methods of recycling condenser water; for the purposes of this document, the following are considered: cooling towers and spray ponds.

E-1: Alternative E with a Cooling Tower

COSTS:	Incremental Investment Cost:	$174,000
	Total Investment Cost:	$626,000
	Total Yearly Cost:	$265,000

E-2: Alternative E with a Spray Pond

COSTS:
Incremental Investment Cost: $152,000
Total Investment Cost: $604,000
Total Yearly Cost: $261,000

REDUCTION BENEFITS: An incremental reduction in BOD5 of 0.18 kilograms per metric ton (0.36 pounds per ton) of melt and in suspended solids of 0.07 kilograms per metric ton (0.14 pounds per ton) of melt is evidenced by addition of this Alternative to Alternative D. Total reductions of 98.3 percent for BOD5 and 98.1 percent for suspended solids are achieved.

Alternative F: Elimination of Discharge of Process Water. This Alternative assumes that, in addition to Alternative C, all process waters are eliminated by controlled retention and total impoundage. The resulting effluent waste loading for BOD5 associated with this control level is estimated at 0.15 kilograms per metric ton (0.30 pounds per ton) of melt, that amount attributable to barometric condenser cooling water. The suspended solids loading is zero as the only suspended solids-bearing waste stream has been eliminated.

F: Elimination of Discharge of Process Water by Containment

Total impoundment of process water is successfully practiced by five refineries; however, a considerable amount of land is required (see Table 21, Path 13). Containment of process water is, therefore, not considered to be practicable technology for urban liquid refineries.

COSTS:
Incremental Investment Cost: $1,455,000
Total Investment Cost: $1,570,000
Total Yearly Cost: $ 217,000

REDUCTION BENEFITS: An incremental reduction in plant BOD5 of 2.75 kilograms per metric ton (5.50 pounds per ton) of melt and in suspended solids of 1.00 kilograms per metric ton (2.00 pounds per ton) of melt is evidenced in comparison to Alternative C. Total reductions in BOD5 of 95.6 percent and in suspended solids of 100 percent are achieved.

Alternative G: Elimination of Barometric Discharge of Condenser Cooling Water. This Alternative assumes that in addition to Alternative F there is an elimination of discharge of barometric condenser cooling water. To achieve this level of treatment, it has been assumed that condenser

TABLE 23

SUMMARY OF WASTE LOADS FROM TREATMENT ALTERNATIVES
FOR THE SELECTED LIQUID REFINERY

Effluent Constituent Parameters	Raw Waste	A	B	C	D*	E**	F	G
BOD_5 kg/kkg of melt	3.43	3.43	3.25	2.90	0.24	0.06	0.15	(0)
(lb/ton of melt)	(6.86)	(6.86)	(6.50)	(5.80)	(0.48)	(0.12)	(0.30)	(0)
TSS kg/kkg of melt	1.56	1.56	1.00	1.00	0.10	0.03	0	0
(lb/ton of melt)	(3.12)	(3.12)	(2.00)	(2.00)	(0.20)	(0.06)	(0)	(0)
FLOW (m^3/kkg)								
Barometric Condensers	15.0	15.0	15.0	15.0	15.0	0.30	15.0	0.30
Process Water	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64
Filter Flurry	.25	.25	0	0	0	0	0	0

* BPCTCA
** BATEA:NSPS

TABLE 24

SUMMARY OF ALTERNATIVE COSTS FOR A 508 METRIC TON (560 TONS) PER DAY LIQUID SUGAR REFINERY

Alternative	BOD_5 Load*	% BOD_5 Removal	TSS Load*	% TSS Removal	Investment Cost	Total Yearly Operating Cost	Total Yearly Cost
A	3.43	0.0	1.56	0.0	0	0	0
B-1	3.25	5.3	1.00	35.9	31,000	5,800	12,000
B-2	3.25	5.3	1.00	35.9	61,000	37,000	45,000
C	2.90	15.4	1.00	35.9	115,000	59,000	62,000**
D	0.24	93.0	0.10	93.6	452,000	194,000	230,000
E-1	0.06	98.3	0.03	98.1	626,000	213,000	265,000
E-2	0.06	98.3	0.03	98.1	604,000	210,000	261,000
F	0.15	95.6	0.0	100	1,570,000	74,000	217,000
G-1	0.0	100	0.0	100	2,040,000	93,000	280,000
G-2	0.0	100	0.0	100	2,013,000	90,000	275,000

*Waste Loadings in Kilograms per Metric Ton of Melt

**Includes Sugar Savings of $10,000/yr. as a Result of Entrainment Prevention.

TABLE 25

IMPLEMENTATION SCHEDULES FOR A LIQUID SUGAR REFINERY

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
1	Containment of filter muds, all process water, and blowdown from cooling tower	0	0	51	No	2,010,000	247,000
2	Containment of filter muds, all process water, and blowdown from spray pond	0	0	51	No	1,980,000	242,000
3	Containment of filter muds and discharge process water and blowdown from cooling tower to municipal treatment	0	0	0.5	Yes	186,000	77,000
4	Containment of filter muds and discharge of process water and blowdown from spray pond to municipal treatment	0	0	0.5	Yes	164,000	72,000
5	Dry disposal of filter cake and containment of all process waters and blowdown from cooling tower	0	0	50	No	2,040,000	280,000

TABLE 25

IMPLEMENTATION SCHEDULES FOR A LIQUID SUGAR REFINERY
(Continued)

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
6	Dry disposal of filter cake and containment of all process water and blowdown from spray pond	0	0	50	No	2,010,000	275,000
7	Dry disposal of filter cake with discharge of process waters and blowdown from cooling tower to municipal treatment	0	0	0.1	Yes	216,000	110,000
8	Dry diposal of filter cake and containment of all process water and blowdown from spray pond to municipal treatment	0	0	0.1	Yes	194,000	105,000
9	Containment of filter muds and biological treatment of process water and blowdown from cooling tower, followed by sand filtr.	0.06	0	0.6	No	596,000	232,000
10	Containment of filter muds and biological treatment of process water and blowdown from spray pond, followed by sand filtr.	0.06	0	0.6	No	574,000	228,000

TABLE 25

IMPLEMENTATION SCHEDULES FOR A LIQUID SUGAR REFINERY
(Continued)

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
11	Dry disposal of filter cake and biological treatment of process water and blowdown from cooling tower, followed by sand filtr.	0.06	0	0.2	No	626,000	265,000
12	Dry disposal of filter cake and biological treatment of process water and blowdown from spray pond, followed by sand filtr.	0.06	0	0.3	No	604,000	261,000
13	Containment of filter muds and process waters and discharge of condenser water without cooling or recycle	0.15	0.25	41	No	1,540,000	184,000
14	Containment of filter muds, municipal treatment of process waters, and discharge of condenser water without cooling or recycle	0.15	0.25	0.4	Yes	85,000	51,000
15	Dry disposal of filter cake, containment of process water and discharge of condenser water without cooling or recycle	0.15	0.25	40	No	1,570,000	217,000

TABLE 25

IMPLEMENTATION SCHEDULES FOR A LIQUID SUGAR REFINERY
(Continued)

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
16	Dry disposal of filter cake, municipal treatment of process water, and discharge of condenser water without cooling or recycle	0.15	0.25	0	Yes	115,000	84,000
17	Containment of filter muds, biological treatment of process water, and discharge of condenser water without cooling or recycle	0.24	0.25	0.5	No	422,000	197,000
18	Dry disposal of filter cake, biological treatment of process water, and discharge of condenser water without cooling or recycle	0.24	0.25	0.2	No	452,000	230,000

water is recycled and the blowdown impounded or discharged to a municipal treatment system. The blowdown of barometric condenser cooling water is assumed to be two percent of the total condenser flow. Effluent waste loads associated with this control level are zero kilograms per metric ton (zero pounds per ton) of melt.

G-1: Recycle of Condenser Water Through a Cooling Tower with an Assumed Two Percent Blowdown to Controlled Land Retention, in Addition to Alternative F.

COSTS:	Incremental Investment Cost:	$ 470,000
	Total Investment Cost:	$2,040,000
	Total Yearly Cost:	$ 280,000

G-2: Recycle of Condenser Cooling Water Through a Spray Pond with an Assumed Two Percent Blowdown to Controlled Land Retention in Addition to Alternative F.

COSTS:	Incremental Investment Cost:	$ 443,000
	Total Investment Cost:	$2,013,000
	Total Yearly Cost:	$ 275,000

REDUCTION BENEFITS: An incremental reduction in plant BOD5 of 0.15 kilograms per metric ton (0.30 pounds per ton) of melt is evidenced by addition of this Alternative to Alternative F. Total reductions of BOD5 and suspended solids are 100 percent.

<u>Discharge of Process Waste Streams to Municipal Treatment System</u>. For the purpose of presenting cost information which is representative of the industry, it is necessary to determine costs associated with various schemes of discharge to municipal treatment systems. Twelve refineries currently discharge all or a portion of their wastes in municipal treatment systems. Three of these are liquid refineries and two are combination crystalline - liquid refineries. The following schemes are possible and the resulting costs presented.

M.T.#1: Discharge of Process Water to Municipal Treatment

This method of treatment of process water is practiced by three of the five liquid refineries and by both combination crystalline - liquid refineries, all urbanly located. This technology is not available to most rural refineries or to those refineries whose waste is not accepted by a municipal treatment system. It is however, a well demonstrated treatment method and practiced by 42 percent of the nation's refineries. The costs presented include those costs attributable to Alternative C.

COSTS:	Incremental Investment Cost:	$0
	Total Investment Cost:	$115,000
	Total Operating Cost:	$ 81,000
	Total Yearly Cost:	$ 84,000*

* Includes savings as a result of recovery of sugar which would normally be entrained in the barometric condenser cooling water.

M.T.#2: Recycle of Condenser Cooling Water Through a Cooling Tower with an Assumed Two Percent Blowdown to Municipal Treatment, in Addition to M.T. #1

COSTS:	Incremental Investment Cost:	$101,000
	Total Investment Cost:	$216,000
	Total Operating Cost:	$ 97,000
	Total Yearly Cost:	$110,000

M.T.#3: Recycle of Condenser Cooling Water Through a Spray Pond with an Assumed Two Percent Blowdown to Municipal Treatment, in Addition to M.T.#1

COSTS:	Incremental Investment Cost:	$ 79,000
	Total Investment Cost:	$194,000
	Total Operating Cost:	$ 94,000
	Total Yearly Cost:	$105,000

RELATED ENERGY REQUIREMENTS OF ALTERNATIVE TREATMENT AND CONTROL TECHNOLOGIES - CANE SUGAR REFINING

To process 0.9 metric tons (one ton) of raw sugar into refined sugar, it is estimated that 60 and 64 kilowatt-hours of electricity are required for crystalline and liquid sugar refineries, respectively. This electrical energy is affected by process variations, in-place pollution control devices, and amount of lighting.

At a cost of 2.3 cents per kilowatt-hour, a crystalline sugar refinery processing 136,250 metric tons (150,000 tons) of raw sugar per year, would have a yearly energy cost of $209,000. Associated with the control alternatives are additional annual energy costs. These are estimated to be:

Alternatives	Cost
A	$ -0-
B-1	300
B-2	1,200
C	1,200
D	8,140
E-1	27,000
E-2	27,000
F	1,460
G-1	19,700
G-2	14,000
M.T. #1	1,200
M.T. #2	19,300
M.T. #3	13,600

At a cost of 2.3 cents per kilowatt-hour, a crystalline cane sugar refinery processing 475,000 metric tons (525,000 tons) of raw sugar per year would have a yearly energy cost of $725,000. Associated with the control alternatives are additional annual energy costs. These are estimated to be:

Alternatives	Cost
A	$ -0-
B-1	500
B-2	1,200
C	1,200
D	28,000
E-1	83,000
E-2	71,000
F	1,600
G-1	51,800
G-2	40,400
M.T. #1	1,200
M.T. #2	51,200
M.T. #3	39,800

At a cost of 2.3 cents per kilowatt-hour, a liquid cane sugar refinery processing 127,000 metric tons (140,000 tons) of raw sugar per year would have a yearly energy cost of $206,000. Associated with the control alternatives are additional annual energy costs. These are estimated to be:

Alternatives	Cost
A	$ -0-
B-1	300
B-2	1,200
C	1,200
D	21,300
E-1	27,000

E-2	26,000
F	1,400
G-1	6,500
G-3	5,300
M.T. #1	1,200
M.T. #2	6,200
M.T. #3	5,100

NON-WATER QUALITY ASPECTS OF ALTERNATIVE TREATMENT AND CONTROL TECHNOLOGY

Air Pollution

Waste water lagooning, particularly under anaerobic conditions, can promote the growth of sulfur reducing organisms and associated noxious gases. The maintenance of aerobic conditions can be maintained by the design of shallow ponds (two feet or less), by the use of aerators (although these can increase an existing problem), by pH adjustment, or by other means.

As previously mentioned, spray drift from cooling towers and spray ponds can present a problem in urban areas. This can be reduced by proper design, and can probably be eliminated for most wind conditions.

Solid Wastes

The removal of solids from waste water produces a solid waste disposal problem in the form of sludges. In these cases, where the sludges are to be impounded, previously discussed measures for protection of ground water must be taken. Sanitary landfills, when available, usually offer an economical solution if hauling distances are reasonable. The additional solids waste produced by waste water treatment is not expected to be a significant problem. Technology and knowledge are available to prevent harmful effects to the environment as a result of land disposal of sludge.

SECTION IX

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE EFFLUENT LIMITATIONS GUIDELINES

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. This average is not based upon the broad range of plants within the cane sugar refining segment of the sugar processing categcry, but based upon performance levels achievable by exemplary plants.

Consideraticn 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 REDUCTION ATTAINABLE THROUGH THE APPLICATION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE FOR THE CANE SUGAR REFINING SEGMENT

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 that resulting from maximum sucrose entrainment prevention in barometric condenser cooling water, elimination of a discharge of filter cake, and biological treatment of all process water other than uncontaminated (non-contact) cooling water and barometric condenser cooling water. The effluent levels attainable for this degree of reduction are shown in Table 1.

BOD5

The final effluent BOD5 limits were derived by assuming the use of a biological treatment system to attain reductions in process water BOD5 loading to 30 and 50 mg/l for crystalline and liquid cane sugar refineries respectively, and attaining a BOD5 entrainment reduction in barometric condenser cooling water to 10 mg/l. This does not imply that plants must necessarily duplicate the assumed raw waste loadings, water usages, and treatment efficiencies. It is possible for plants to achieve the indicated final effluent waste loads operating at lower average treatment efficiencies but receiving lower raw waste loads and/or using less process or barometric condenser cooling water. In addition, an entirely different approach such as disposal by controlled irrigation or controlled land impoundage may be employed.

Suspended Solids

The final effluent TSS limits were derived by assuming process water TSS loading reductions to 40 and 60 mg/l for crystalline and liquid cane sugar refineries, respectively. No TSS limit has been established for barometric condenser cooling water because of the low TSS raw waste loading associated with this waste water stream.

Identification of Best Practicable Control Technology Currently Available

Best Practicable Control Technology Currently Available for the cane sugar refining segment of the sugar processing category is recycle and reuse of certain process waters of the sugar processing category within the refining process, minimization of sucrose entrainment in barometric condenser cooling water, elimination of a discharge of filter cake and biological treatment of excess process waters. Implementation of this requires the following:

a. Collection and recovery of all floor drainage.

b. Minimization of sucrose entrainment in barometric condenser cooling water by the use of improved baffling systems, demisters, and/or other control devices.

c. Dry handling of filter cakes after desweetening with disposal to sanitary landfills, or complete containment of filter cake slurries.

d. Biological treatment of all waste water discharges other than uncontaminated (non-contact) cooling water and barometric condenser cooling water.

Engineering Aspects of Control Technique Applications

The technology defined for this level is practicable. There are refineries which currently collect all floor drains. Most refineries currently achieve either dry handling or complete containment of filter cake. All of the control devices described for entrainment control have been demonstrated by various refineries. Biological treatability of refinery waste waters has been demonstrated by the twelve refineries that discharge into municipal biological treatment systems.

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 investment costs associated with this level of technology represent approximately 2% of the total investment needed to build the typical refinery. The total cost to the cane sugar refining segment is approximately $5,000,000.

Non-water Quality Environmental Impact

The primary non-water quality environmental impacts are summarized in Section VIII, Cost, Energy and Non-water Quality Aspects. The major concern is the strong reliance upon the land for ultimate disposal of wastes. However, the technology is available to assure that land disposal systems are maintained commensurate with soil tolerances.

A secondary 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 refineries that, strictly speaking, does not exist. Tables 21, 22, and 25 list various treatment control alternatives and summarize requirements and benefits associated with each. It is believed that the data in these tables can be a valuable aid in assessing problems and associated solutions for individual installations.

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 changes;
(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 levels, 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 economically achievable technology 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 this document, it has been determined that the degree of effluent reduction attainable through the application of the Best Available Technology Economically Achievable is that resulting from the technology of cooling and recycling barometric condenser cooling water with biological treatment of the blowdown and the addition of sand filtration to further treat the effluent from the biological treatment system. The effluent levels attainable for this degree of reduction are shown in Table 1.

Identification of Best Available Technology Economically Achievable

Best Available Technology Economically Achievable for the cane sugar refining segment is the technology described in Section IX of this document with the addition of a cooling and recycling system for barometric condenser cooling water, with the blowdown from the recycling system being discharged to the biological treatment system, and the addition of sand filtration to further treat the effluent from the biological treatment system. Alternatives to this system would be the futher reduction of sucrose entrainment in condenser waters to an acceptable level for discharge, controlled irrigation, and controlled land impoundage.

Engineering Aspects of Control Techniques Applications

The technclogy defined for this level is currently practiced by one major cane sugar refinery in the southern United States. The specific recycling method in this instance is a cooling tower.

Costs of Application

The costs of obtaining the effluent reductions set forth herein are summarized in Section VIII, Cost, Energy, and Non-Water Quality Aspects.

The investment costs associated with this level of technology represent approximately 3.5 percent of the total investment needed to build the typical refinery. The total investment cost to the cane sugar refining segment is approximately $15,000,000, or $10,000,000 above that required to achieve the best practicable control technology currently available.

Non-Water Quality Environmental Impact

The non-water quality environmental impact would be an intensification of those impacts described in Section IX.

Factors to be Considered in Applying Effluent Limitations

The same factors as discussed in Section IX should be considered for this level. For refineries in rural areas, spray ponds or irrigation canals may be more feasible for recycling barometric condenser cooling water than cooling towers. Tables 21, 22, and 25 list various treatment control alternatives and summarize requirements and benefits associated with each.

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

INTRODUCTION

In addition to guidelines reflecting the best practicable control technology currently available and the best available technology economically achievable, applicable to existing point source discharges 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. Thus, in addition to considering the best in-plant and end-of-process control technology, identified in best available technology economically achievable, new source technology is to be based upon an analysis of how the level of effluent may be reduced by changing the production process itself. Alternative processes, operating methods or other alternatives must be considered. However, the end result of the analysis will be to identify 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.

Specific Factors to be Taken into Consideration

At least the following factors should be considered with respect to production processes which are to be analyzed in assessing new source technology:

(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 FOR THE CANE SUGAR REFINING SEGMENT OF THE SUGAR PROCESSING INDUSTRY

Because of the large number of specific improvements in management practices, design of eqiupment, and processes and systems that have some potential of development, it is not possible to determine, within reasonable accuracy, the potential waste reductions achievable through their application in new sources. However, the implementation of those in-plant and end-of-pipe controls described in Section VII, Control and Treatment Technology, would enable new sources to achieve the effluent discharge levels defined in Section X.

The short lead time for application of new source performance standards (less than a year versus approximately four and ten years for other guidelines) affords little opportunity to engage in extensive development and testing of new procedures. The single justification for more restrictive limitations for new sources than for existing sources would be one of relative economics of installation in new plants versus modification of existing plants. There is no data to indicate that the economics of the application of in-plant and end-of-pipe technologies described in Section VII, Control and Treatment Technology, would be significantly weighted in favor of new sources.

The attainment of zero discharge of pollutants does not appear to be feasible for cane sugar refineries, other than those with sufficient and suitable land for irrigation or total impoundage.

In view of the aforegoing, it is recommended that the effluent limitations for new sources be the same as those determined to be best available control technology economically achievable, presented in Section X.

SECTION XII

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SECTION XIII

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SECTION XIV

GLOSSARY

Affination - Washing to remove the adhering film of molasses from the surface of the raw sugar crystal, the first step in the refining operation.

Affination Centrifugal - A high speed centrifugal which separates syrup and molasses from sugar. Syrup from this centrifugal is recycled to the mingling phase of refinement.

Alkalinity - Alkalinity is a measure of the capacity of water to neutralize an acid.

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 the inorganic constituents.

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.

Barometric Condenser - See Condenser, Barometric.

Barometric Leg - A long vertical pipe through which spent condenser water leaves the condenser. Serves as a source of vacuum.

Barometric Leg Water - Condenser cooling water.

Biological Wastewater Treatment - Forms of waste water treatment in which bacterial or biochemical action is intensified to stabilize, oxidize, and nitrify the unstable organic matter present. Trickling filters, and activated sludge processes are examples.

Blackstrap Molasses - Molasses produced by the final vacuum pans, and from which sugar is unrecoverable by ordinary means. Blackstrap is usually sold for various uses.

BOD5 - 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.

Boiler Ash - The solid residue remaining from combustion of fuel in a boiler furnace.

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.

Boiler Blowdown - Discharge from a boiler system designed to prevent a buildup of dissolved solids.

Bone Char - An adsorption material used in cane sugar refineries which is utilized in the removal of organic and inorganic impurities from sugar liquor.

Calandria - The steam belt or heating element in an evaporator or vacuum pan, consisting of vertical tube sheets constituting the heating surface.

Calandria Evaporator - An evaporator using a calandria; the standard evaporator in current use in the sugar industry.

Calandria Vacuum Pan - A vacuum pan using a calandria; the standard vacuum pan in current use in the sugar industry.

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.

Char cistern - Cylindrical vats, measuring approximately 10 feet in diameter by 20 feet deep, which contain approximately 40 tons of bone char.

Clarification - The process of removing undissolved materials (largely insoluble lime salts) from cane juice by settling, filtration, or flotation.

Coagulation - In water and waste water treatment, the destabilization and initial aggregation of colloidal and finely divided suspended matter by the addition of a floc-forming chemical or by biological process.

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.

Condensate - Water resulting from the condensation of vapor.

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 transferred through a barrier that separates the cooling water and the vapor. The condensate can be recovered separately.

Condenser Water - Water used for cooling in a condenser.

Crystallization - The process through which sugar crystals separate from massecuite.

Decanting - Separation of a liquid from solids by drawing off the upper layer after the heavier material has settled.

Decolorization - The refining process of removing color from sugar. The predominantly used methods involve the use of bone char, granular activated carbon, vegetable carbon, or powdered activated carbon.

Defecants - Chemicals which are added to melt liquor in order to remove remaining impurities. They include phosphoric acid (or carbon dioxide) and lime. The result of the treatment is the neutralization of organic acids and formation of a tri-calcium phosphate precipitate which entrains much of the colloidal and other suspended matter in the liquor.

Defecation Process - A method for purifying the cane juice involving lime, heat, and a small amount of phosphate. The result is the formation of an insoluble precipitate which is then removed in the clarification process.

Demineralization - Removal of mineral impurities from sugar.

Dextrose - Glucose. An invert sugar with the formula C6#H12O6. Dextrose is a minor component of raw sugar.

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.

Disaccharides - A sugar such as sucrose composed of two monosaccharides.

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.

Dry Cleaning - Cleaning of raw cane without the use of water.

"Effect" - In systems where evaporators are operated in series of several units, each evaporator is known as an effect.

Entrainment - The entrapment of liquid droplets containing sugar in the water vapor produced by evaporation of syrup.

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.

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.

Filter Cake - The residue remaining after filtration of the sludge produced by the clarification process.

Filter Mud - A mud produced by slurrying filter cake. The resultant waste stream is a significant source of solids and organics within a cane sugar refinery.

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.

Fixed Beds - A filter or adsorption bed where the entire media is exhausted before any of the media is cleaned.

Flocculant - A substance that induces or promotes fine particles in a colloidal suspension to aggregate into small lumps, which are more easily removed.

Floorwash - Water used to wash factory or refinery floors and equipment.

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.

Frothing Clarifiers - Flotation devices that separate tri-calcium phosphate precipitate from the liquor.

Furfural - An aldehyde C_4H_3OCHO used in making Furaw and as a resin.

Glucose - Dextrose.

GPD - Gallons per day.

GPM - Gallons per minute.

Granular Activated Carbon - Substance used for decolorization of sugar. It differs from bone char in that it produces more sweet water, adsorbs no ash, and is normally not washed. There is little waste water produced from this process.

Granulation - The process which removes remaining moisture from sugar, thus also separates the crystals from one another.

Granulator - A rotary dryer used in sugar refineries to remove free moisture from sugar crystals prior to packaging or storing.

Hydrolization - The addition of H2O to a molecule. In sugar production, hydrolization of sucrose results in an inversion into glucose and fructose and represents lost production.

Impoundment - A pond, lake, tank, basin, or other space which is used for storage of waste water.

Impurities - Fine particles of bagasse, fats, waxes, and gums contained in the cane juice after milling. These impurities are reduced by successive refining processes.

Invert Sugars - Glucose and fructose formed by the splitting of sucrose by the enzyme sucrase.

Ion exchange - Reversible exchange of ions contained in a crystal for different ions in solution without destruction of crystal structure or disturbance of electrical neutrality. Used in sugar refining for color removal or removal of impurities.

Ion Exchange Resins- Resins consisting of three-dimensional hydrocarbon networks to which are attached ionizable groups.

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.

Juices - Clarified: The juice obtained as a result of the clarification process, and synonymous with evaporator supply when the filtered juice is returned to the mixed juice.

Mixed: The juice sent from the extraction plant to the boiling house.

Levulose - Fructose. An invert sugar composed of six carbon chains with the formula C6H12O6. Levulose is a component of raw sugar.

Magma - A heated sugar syrup solution to which raw crystals have been added.

Magma mingler - A revolving coiled mixer in which magma is heated in order to facilitate loosening the molasses film from raw sugar crystals; the first step in the refinement process.

Massecuite - Mixture of sugar crystals and syrup which originates in the boiling of the sugar (literally cooked mass).

Malt Liquor - Molten sugar to which has been added a small amount of water (half the weight of the sugar).

MGD - Million gallons per day.

mg/l - Milligrams per liter (equals parts per million ±ppm1 when the specific gravity is unity).

Moisture - Loss in weight due to drying under specified conditions, expressed as percentage of total weight.

Molasses - A dark-colored syrup containing non-sugars produced in processing cane and beet sugar.

Monosaccharides - Simplified form of sugar.

Moving Beds - A filtration or adsorption bed where the media is constantly being removed and fresh media added.

Mud - The precipitated sludge resulting from the clarification process.

Multiple Effect Evaporation - The operation of evaporators in a series.

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 (NH3), mg/l as N
Kjeldahl Nitrogen (ON), mg/l as N
Nitrate Nitrogen (NO3), mg/l as N
Total Phosphate (TP), mg/l as P
Ortho Phosphate (OP), mg/l as P.

pH - pH is a measure of the negative log of hydrogen ion concentration.

Phases 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.

Plate and Frame Filter - A filtering device consisting of a "screen" fastened inside a metal frame.

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.

Polyelectrolytes - Coagulent aids consisting of long chained organic molecules.

Precoat Filter - A type of filter in which the media is applied to an existing surface prior to filtration.

Raw Sugar - An intermediate product consisting of crystals of high purity covered with a film of low quality syrup.

Recrystallization - Formation of new crystals from previously melted sugar liquor. Recrystallization is encouraged by evaporators and accomplished in vacuum pans.

Regeneration Kilns - Ovens which operate with a controlled amount of air, and in which bone char is placed for renewal of its capacities for buffering and decolorizing.

Regeneration of Char - After some sixty hours of operation, the decolorizing ability of bone char decreases to an unacceptable level, and the char must be washed and regenerated by heat in kilns or char house furnaces.

Remelt - A solution of low grade sugar in clarified juice or water.

Resorcinol Test - A color indicator test for determining the concentration of sucrose in condensate and condenser waters.

Rotary Vacuum Filter - A rotating drum filter which utilizes suction to separate solids from the sludge produced by clarification.

Saturation - The use of water in the milling process to dissolve sucrose. Identical, in this connotation, with imbibition and maceration.

Seed Sugar - Small sucrose crystals which provide a surface for continued crystal growth.

Settlings - The material which collects in the bottom portion of a clarifier.

Sludge - The separated precipitate from the clarification process. It consists largely of insoluble lime salts and includes calcium phosphates, coagulate albumin, fats, acids and gums, iron, alumina, and other material.

Slurry - A mixture of water and solids. Filter cakes, ash, or other solids may be slurried to facilitate handling.

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 and suspended solids.
Volatile Solids (VS):	Organic material which is lost when the sample is heated to 550°C.
Settleable Solids (STS):	The materials which settle in an Immhoff cone in one hour.

Stabilization Pond - A type of oxidation pond in which biological oxidation of organic matter is effected by natural or artificially accelerated transfer of oxygen to the water from air.

Strike - The massecuite content of a vacuum pan.

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.

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.

Supersaturation - The condition of a solution when it contains more solute (sucrose) than would be present under normal pressure and temperature. When equilibrium is established between the saturated solution and undissolved solute, crystal growth commences.

Surface Condenser - See Condenser, Surface.

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 may be man-made wastes or natural sources as from erosion.

Vapor - Steam liberated from boiling sugar liquor.

Vapor Belt - The distance between the liquid level in air evaporator or vacuum pan and the top of the cylindrical portion of the body.

Vegetable Carbon - A media for sugar decolorization.

Waste Streams - Any liquid waste material produced by a refinery.

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 per kilogram
cubic feet per minute	cfm	0.028	cu m/min	cubic meters per minute
cubic feet per second	cfs	1.7	cu m/min	cubic meters per 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 Farenheit	°F	0.555(°F-32)[1]	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liter
gallon per minute	gpm	0.0631	l/sec	liters per second
gallon per ton	gal/ton	4.173	l/kkg	liters per metric ton
horsepower	hp	0.7457	kw	kilowatts

[1] Actual conversion, not a multiplier

CONVERSION TABLE (CONTINUED)

Multiply (English Units)		by	To Obtain (Metric Units)	
English Unit	Abbreviation	Conversion	Abbreviation	Metric Unit
inches	in	2.54	cm	centimeters
inches of Mercury	in Hg	0.03342	atm	atmospheres (absolute)
pounds	lb	0.454	kg	kilograms
pounds per ton	lb/ton	0.5005	kg/kkg	kilograms per metric ton
million gallons per day	mgd	3,785	cu m/day	cubic meters per day
mile	mi	1.609	km	kilometer
pound per square inch (gauge)	psig	(0.0680 psig+1)[1]	atm	atmospheres (absolute)
square feet	sq ft	0.929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
tons (short)	t	0.907	kkg	metric tons (1000 kilograms)
yard	y	0.9144	m	meter

[1] Actual conversion, not a multiplier