EPA-440/1-73-002

Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards

BEET SUGAR

Segment of the Sugar Processing Point Source Category

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

AUGUST, 1973

DEVELOPMENT DOCUMENT

for

EFFLUENT LIMITATIONS GUIDELINES

and

NEW SOURCE PERFORMANCE STANDARDS

BEET SUGAR PROCESSING SEGMENT OF THE SUGAR PROCESSING INDUSTRY

John Quarles
Acting Administrator

Robert L. Sansom
Assistant Administrator for Air & Water Programs

Allen Cywin
Director, Effluent Guidelines Division

Richard V. Watkins
Project Officer

August, 1973

Effluent Guidelines Division
Office of Air and Water Programs
U.S. Environmental Protection Agency
Washington, D.C. 20460

ERRATA

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

BEET SUGAR PROCESSING POINT SOURCE CATEGORY

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

AUGUST, 1973

The following changes should be made in the subject document:

a) The total of 12 plants as reported in the development document as accomplishing no discharge of process waste water pollutants to navigable waters should be changed to 11 plants. As recently reported by industry personnel one of the previously considered no discharge plants (Brawley, California) has an occasional discharge to navigable waters. The plant is being further investigated by EPA personnel and the state pollution control agency to substantiate these preliminary findings. No discharge permit is reported to have been received for this plant.

b) The total number of beet sugar plants of 53 indicated in the development document should be changed to 52. The Mason City, Iowa plant closed during the 1972-1973 season. The closing of the plant resulted primarily from profit and production considerations not due to factors directly attributable to pollution control.

It is planned that the above changes will be incorporated into the final printing of the development document.

ABSTRACT

This document presents the findings of an extensive study of the beet sugar processing industry by the Environmental Protection Agency for the purpose of developing effluent limitations guidelines of performance, and pretreatment standards for the industry to implement Sections 304(b) and 306 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 and the degree of effluent reduction attainable through the application of the best available technology economically achievable which must be achieved by existing point sources by July 1, 1977 and July 1, 1983, respectively. The standards of performance for new sources 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 proposed regulations for all three levels of technology set forth above establish the requirement of no discharge of process waste water pollutants to navigable waters.

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

CONTENTS

TABLES

FIGURES

SECTION I

CONCLUSIONS

Notice

> This document is a preliminary draft. It has not been formally released by EPA and should not at this stage be construed to represent Agency policy. It is being circulated for comment on its technical accuracy and policy implications.

For the purpose of establishing effluent limitations guidelines and standards of performance, the beet sugar segment of the sugar processing industry as a whole serves as a single logical category. Factors such as age, size of plant, process employed, climate, and waste control measures do not justify the segmentation of the industry into any subcategories. Similarities in waste loads, waste water characteristics and available treatment and control measures substantiate this conclusion.

Presently, 12 of the 53 operating plants are achieving zero discharge of waste waters to navigable waters. It is further concluded that the remainder of the beet sugar processing segment of the sugar processing industry can achieve the requirements as set forth herein by July 1, 1983. It is estimated that the capital costs of achieving such limitations and standards by all plants within the segment is less than $36 million. These costs would result in an increase in capital investment by an estimated 1.5 and 2.3 percent. As a result, the increased costs of the sale of bulk refined sugar to compensate for water pollution control requirements range from less than 2.6 to 3.7 percent under present conditions. The above costs data reflect conditions where no pollution control abatement measures are assumed to presently exist within the industry. In consideration of present in-place pollution control facilities within the segment, total capital costs are estimated at approximately $9 to $16 million. Increased capital costs of 0.6 to 1.0 percent would result with an estimated increase in cost of bulk refined sugar of 0.9 to 1.6 percent to compensate for pollution control measures.

SECTION II

RECOMMENDATIONS

No discharge of process waste water pollutants to navigable waters is recommended as the effluent limitations guidelines and standard of performance for the beet sugar processing industry. This represents the degree of effluent reduction obtainable by existing point sources through the application of the best practicable control technology currently available, and the best available technology economically achievable. This also represents, for new sources, a standard of performance providing for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction achievable through application of the best available demonstrated control technology, processes, operating methods or other alternatives. The technologies for achieving the limitations and standards as set forth are based on maximum water re-use and recycling within the process to minimize net waste water production and controlled land disposal of excess waste water without discharge of such waste waters to navigable waters. Disposal of waste water by controlled filtration on land or use for crop irrigation or other beneficial purposes is in conformance with no discharge of waste waters to navigable waters. The effluent limitation of no discharge of process waste water pollutants to navigable waters is based upon the availability of suitable land for controlled disposal of the excess process waste water. If suitable land is not available for controlled disposal through filtration the effluent limitation may be varied to allow the discharge of barometric condenser water derived from sugar evaporation and crystallization or equivalent within the pollutant limitations set forth in the following table:

Effluent Characteristic	Limitation
BOD_5	Maximum for any one day 3.3 kg/kkg lb refined sugar (3.3 lb/1000 lb) Maximum average of daily values for any period of 30 consecutive days 2.2 kg/kkg refined sugar (2.2 lb/1000 lb)
Temperature*	
pH	6.0 to 9.0 units

*No discharge of heated waste waters to navigable waters at a temperature greater than that of cooled water suitable for return to the heat producing process.

"Availability of suitable land" shall mean that amount of land as determined by the formula set forth below which is adjacent to the point source, under the ownership or control of the point source discharger, his agents or representatives. The amount of land required for controlled filtration of process waste waters is determined by the application of the following formula:

$$A = 14.26(CL/S) \times 10^{-5} + 5.36C \times 10^{-2} \quad \text{(for metric system units)}$$

where A = land area requirements for controlled waste water disposal, hectares

C = processing capacity of plant, kkgs of refined sugar production/day

L = length of sugar production campaign of plant (including extended use campaign), days

S = actual soil filtration rate for waste water to be disposed of on land, cm/day not to exceed 0.635 cm/day

$$A = 6.31(CL/S) \times 10^{-4} + 6.01C \times 10^{-2} \quad \text{(for English system units)}$$

where A = land area requirements for controlled waste water disposal, ac

C = processing capacity of plant, ton of refined sugar production per day

L = length of sugar production campaign of plant (including extended use campaign), days

S = actual soil filtration rate for waste water to be disposed of on land, in. per day not to exceed 1/4 in/day

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 toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to Section 304(b) to the Act. Section 306 of the Act requires the achievement by new sources of a Federal standard of performance providing for the control of the discharge of pollutants which reflects 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 waste water process pollutants to navigable waters.

Section 304(b) of the Act requires the Administrator to publish within one year of 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 beet sugar processing segment of the sugar processing industry.

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 beet sugar processing segment of the sugar processing industry, 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 guidelines and standards of performance proposed herein were developed in the following manner. The point source category was first studied for the purpose of determining whether separate limitations and standards are appropriate for different segments within a point source subcategory. This analysis included a determination of whether differences in raw material used, product produced, manufacturing process employed, as well as factors which require the development of separate effluent limitations and standards for different segments. Raw waste characteristics for each subcategory were then identified and quantified. This included an analyses of (1) the source and volume of water used in the process employed and the sources of waste and waste waters in various plants; and (2) the constituents (including possible thermal) of all waste waters including other constituents which result in taste, odor, and color in water. The constitutents of waste waters which should be subject to effluent limitations guidelines and standards of performance were identified.

The full range of control and treatment technologies existing within the segment was identified. This included an identification of each distinct control and treatment technology, including both inplant and end-of-process technologies, which are existent or capable of being designed for each subcategory. It also included an identification in terms of the amount of constituents (including thermal) and the chemical, physical, and biological characteristics of pollutants associated with of the effluent levels achievable by the application of each of the treatment and control technologies. The problems, limitations and reliability of each treatment and control technology and the required implementation time were also identified. In addition, the non-water quality environmental impact, such as the effects of the application of such technologies upon other pollution problems, including air, solid waste, noise and radiation were also identified and evaluated. The energy requirements of each of the control and treatment technologies were identified as well as the cost of the application of such technologies.

The information, as outlined above, was then evaluated in order to determine the levels of technology constituting the "best practicable control technology currently available," "best available technology economically achievable" and the "best available demonstrated control technology, processes, operating methods, or other alternatives." In identifying such technologies, various factors were considered. These included the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application, the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques, required process changes, non-water quality environmental impact (including energy requirements) and other factors.

The data for identification and analyses were derived from a number of sources. These sources included EPA research information, published literature, a voluntary questionnaire survey of the industry conducted by the Beet Sugar Development Foundation, previous EPA technical guidance for beet sugar processing, qualified technical consultation, and on-site visits and interviews at better beet sugar processing plants throughout the United States. Each of these general sources provided information relating to the evaluation factors (cost, non-water quality impact effluent reduction benefits, etc). All references used in developing the guidelines for effluent limitations and standards of performance for new sources reported herein are included in Section XIV of this document.

General Description of the Beet Sugar Processing Segment

Although the culture of sugar beets is reported in early history, extraction of sugar from the beet was first begun on a commercial scale in Germany and France in the early nineteenth century. The earliest beet sugar enterprises in the United States were established in the 1830's in Pennsylvania, Massachussetts, and Michigan, but these plants and many others that followed, failed in a few years because of low sugar yield from then known processing methods. In 1879, the Alvarado, California beet sugar processing plant became the first successful operation in the U.S. because of higher sugar yields and production efficiency. The basic sugar extraction process for sugar beets has not changed since 1880. However, improved production equipment and increased processing rates, have progressively increased production efficiency particularly over the last twenty years.

There are a total of 53 beet sugar processing plants owned by 11 companies in the United States, (see Figure I and Table I), with a combined daily processing capacity of 164,000 kkgs (181,000t) of beets. Capacity of these plants ranges from 1270 to 8200 kkgs (1400 to 9000t) of sugar beets per day with annual production of 3 million kkgs (3.3 milliont) of refined sugar (Table II and III). A plant of average size handles approximately 3265 kkgs (3600t) of sliced beets per day during "campaign." For a plant of average size, the waste waters if discharged without treatment would be equivalent in terms of organic polluting effect as the sewage load to be expected from a population of about 823,000 people.

With consideration of in-place pollution control measures which have been constructed or installed by the beet sugar processing industry, the total potential pollution load from the average sized plant has been substantially reduced to approximate an equivalent pollution load of a population of 15,000 to 110,000. Pollution load is estimated in terms of present waste water discharged to surface waters as BOD_5.

Within the U.S., beet sugar processing plants are located from the warmer areas of Southern California and Arizona to the cool temperature regions of Montana, Minnesota, and North Dakota. Sugar beets are also processed in modern plants in Canada, Great Britain, Western Europe, Poland, the Soviet Union, and other countries. There are some 800 beet sugar plants in Europe and in North America and all use the same basic technology for processing. About 15% of the U.S. beet sugar processing is obtained individually from each of the states of California, Idaho and Colorado. The states of Minnesota, Michigan and Washington each process about six percent while the remaining 37 percent of the sugar beets are about equally distributed from the other eleven states. The South Platte River Basin is one of the most important beet sugar processing areas in the country. The industry not only forms an important part of the regional economy but also has a significant pollution impact on water quality.

Figure I

LOCATION OF BEET SUGAR PROCESSING PLANTS WITHIN THE U.S., 1972

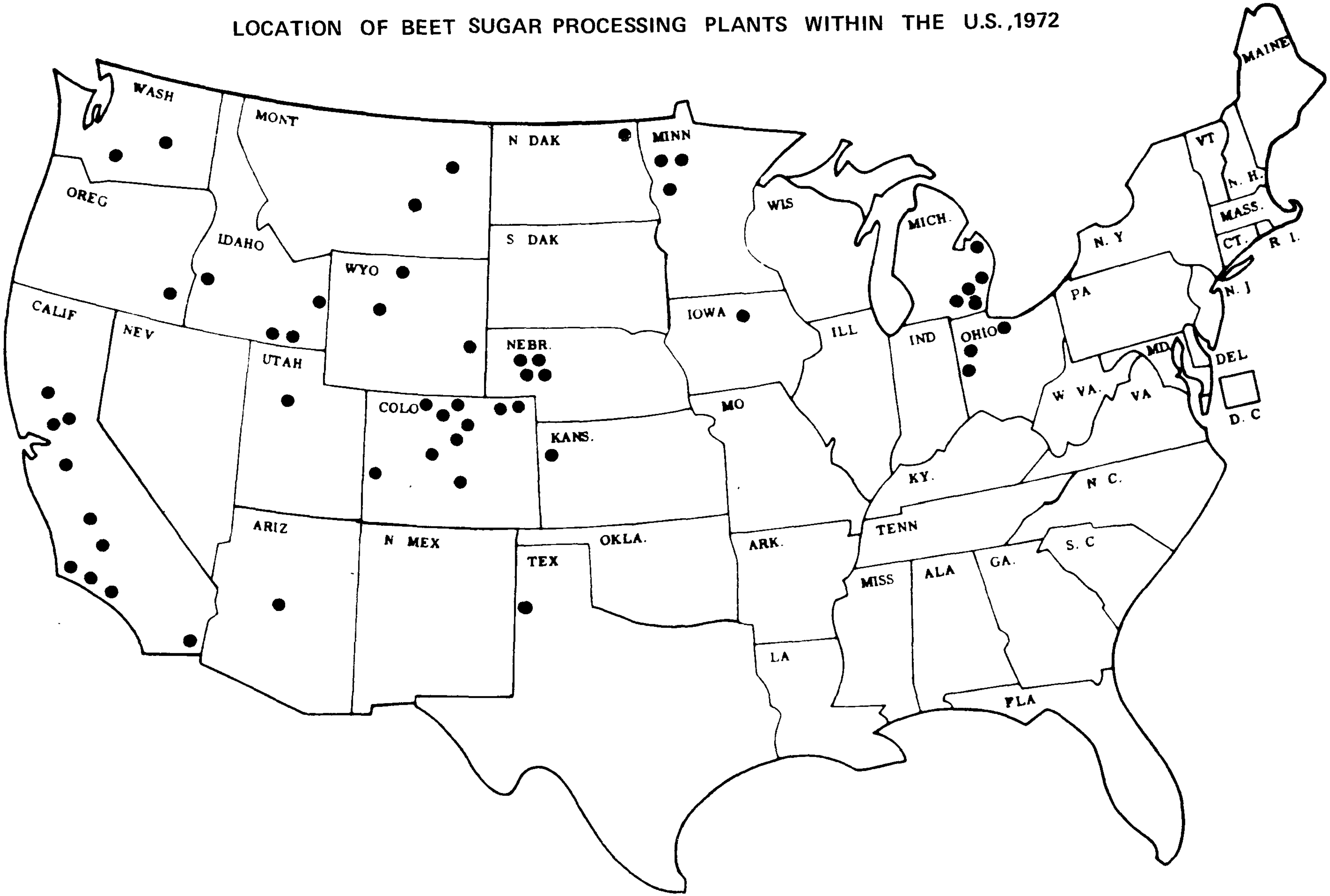


TABLE I

Operating Beet Sugar Processing Plants in the United States (35)

Company	Plants
Amalgamated Sugar Company, Ogden, Utah	4
American Crystal Sugar Company, Fargo, North Dakota	7
Buckeye Sugar, Inc., Ottawa, Ohio	1
Holly Sugar Corp., Colorado Springs, Colorado	9
Michigan Sugar Company, Saginaw, Michigan	4
Monitor Sugar Company, Bay City, Michigan	1
The Great Western Sugar Company, Denver, Colorado	15
Northern Ohio Sugar Company, a wholly-owned subsidiary of The Great Western Sugar Company	2
Spreckels Sugar Division, Amstar Corporation San Francisco, California	5
Union Sugar Division, Consolidated Foods Corporation, San Francisco, California	1
Utah-Idaho Sugar Company, Salt Lake City, Utah	4
TOTAL	53

TABLE II

Consumption and Processing for the Beet Sugar Processing Industry

Production of Sugar Beets

Domestic production (1970)	25.9 million kkg (28.6 million tons)
Percent sucrose (1969)	12.59
Sugar yield per harvested land area (1970)	5.21 kkg/ha (2.33 ton/ac)
Number of beet sugar farms (1969)	18,424
Domestic land area harvested (1969)	624,100 ha (1,542,000 ac)
Planted land area harvested (1969)	35.7 ha (88.2 ac)
Average land area harvested (1969)	33.9 ha (82.5 ac)
Sugar beet yield per unit land area	41.5 kkg/ha (18.5 ton/ac)

Raw Sugar Production (1969)

Total continental sugar production	4.17 million kkg	(4.6 million tons)
Cane sugar production	1.17 million kkg	(1.3 million tons)
Beet sugar production	3.00 million kkg	(3.3 million tons)
Other U.S. cane sugar production (Hawaii, Puerto Rico, and Virgin Islands)	1.45 million kkg	(1.6 million tons)
Total U.S. sugar production	5.62 million kkg	(6.2 million tons)
Total world sugar production	71.1 million kkg	(78.4 million tons)

Sugar Beets Processed (1969)

Total sliced	24.6 million kkg	(27.1 million tons)
Sucrose in cossettes, percent		14.36

Domestic (U.S.) Refined Beet Sugar Production (1969)

Refined sugar per unit weight of beets received	113 kg/kkg	(226 lb/ton)
Refined sugar per unit weight of beets sliced	116 kg/kkg	(231 lb/ton)
Extraction rate based on weight of beets sliced	80.43 percent	

Sugar Consumption (1969) - Raw Value

Total U.S. sugar consumption	9.61 million kkg	(10.6 million tons)
Per capita U.S. consumption (refined value)	44.7 kg	(98.6 lb)

Miscellaneous Information (based on weight of beets sliced)

Typical sugar content of beets	15%
Typical sugar recovery, non-Steffen plant	70 - 85%
Typical sugar recovery, Steffen plant	80 - 95%
Typical dried pulp production	4.5%
Typical molasses production, non-Steffen plant	4.5%

TABLE III

Present and Projected Processing Capacity of Beet Sugar Processing Plants by States

State	Number of Plants	Rated 1973 Capacity Wt. of Beets Sliced/Day, kkg (tons)		Projected Capacity 1980 Wt. of Beets Sliced/Day kkg (ton)	
California	10	28,400	(1,300)	36,300	(40,000)
Colorado	10	24,500	(27,000)	26,600	(29,300)
Michigan	5	10,200	(11,250)	10,700	(11,800)
Idaho	4	22,600	(24,920)	22,600	(24,950)
Minnesota	3	10,400	(11,500)	13,500	(14,750)
Nebraska	4	9,000	(9,900)	9,100	(10,000)
Montana	2	7,000	(7,700)	10,400	(11,450)
Ohio	3	6,000	(6,650)	5,000	(5,130)
Utah	1	2,200	(2,430)	5,800	(6,350)
Wyoming	3	6,500	(7,200)	6,800	(7,500)
Washington	2	11,200	(12,325)	12,500	(13,800)
Arizona	1	3,800	(4,200)	3,800	(4,200)
Iowa	1	2,200	(2,400)	2,200	(2,400)
Kansas	1	2,900	(3,200)	3,300	(3,600)
North Dakota	1	4,700	(5,200)	4,500	(5,000)
Oregon	1	6,000	(6,600)	6,500	(7,200)
Texas	1	6,000	(6,600)	5,900	(6,500)
	53	163,600	(190,800)	185,500	(204,500)

Processing and Refining Operations

General

The raw materials entering beet sugar processing operations are sugar beets, limestone, small quantities of sulfur, fuel, and water. The products are refined sugar, dried beet pulp, and molasses. The average raw material requirements and end products produced per unit weight of clean beets processed are given below for non-Steffen and Steffen processes (30).

NON-STEFFEN PLANTS

Raw Material or End-Product	Per Unit Weight of Sliced Beets
Limestone	40.0 kg/kkg (80 lb/t)
Fuel, gas or coal	6.9×10^5 kg cal (2.5×10^6 BTU/t)
Avg. water intake	9150 l (2200 gal/t)
Dry Beet pulp	50.1 kg/kkg (100 lb/t)
Sugar product	130 kg/kkg (260 lb/t)
Molasses produced	50.0 kg/kkg (100 lb/t)
Avg. waste water flow	8780 l/kkg (2100 gal/t)

STEFFEN PLANTS

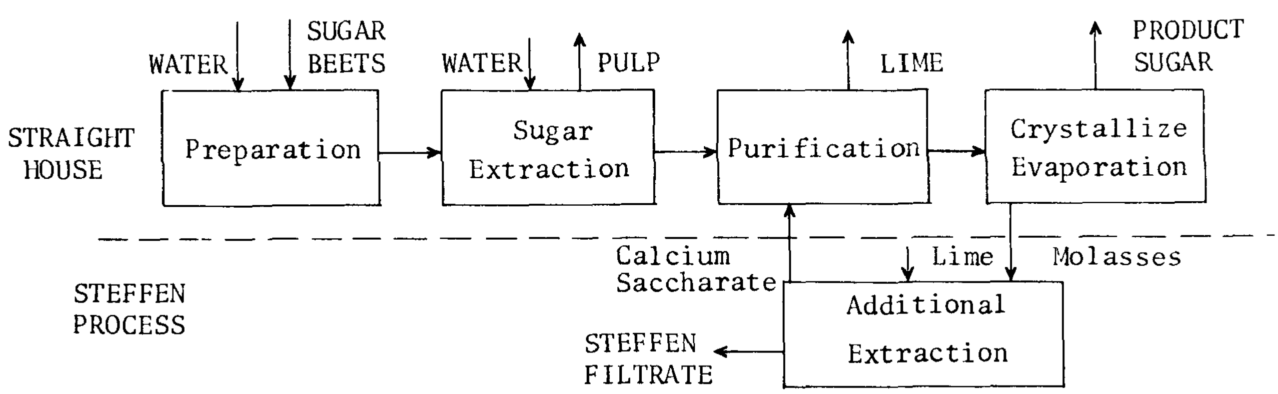
Molasses worked	50.1 kg/kkg (100 lb/t)
Additional limestone	20.0 kg/kkg (40 lb/t)
Additional sugar produced	15.0 kg/kkg (30 lb/t)
Steffen filtrate	376 l/kkg (90 gal/t)

The various unit operations required for converting sugar beets into refined sugar are many and complex, but they are essentially the same in all plants in this country. The basic processes consist of slicing, diffusion, juice purification, evaporation, crystallization and recovery of sugar.

The sugar beet harvesting, piling and processing periods vary in different sections of the country. The processing season or "campaign" extends from early October to late February or early March in Ohio, Michigan, North Dakota, Minnesota, and the Rocky Mountain Region. However, the length of the processing season is variable and sometimes intermittent, being highly dependent upon climatic conditions. In the warmer areas, the beet processing season may extend from April to late December. The sugar beet processing campaign is a seasonal activity operating on a 24-hour per day basis, 7 days per week during the campaign and from 40 to more than 400 seasonal workers are employed at a single plant.

Incoming sugar beets contain between 10 to 16 percent sugar, about 5 percent non-soluble matter (called "marc") and water. The initial process for the extraction of purified sugar and the formation of byproduct molasses (the "straight house") is identical throughout the industry. Some plants also have an additional operation, the "Steffen process," for the extraction of additional sugar from molasses. Whether a plant is a "straight house" or a "Steffen process" operation, the end product of the beet sugar processing plant is refined sugar. In the straight house or non-Steffen processes the byproduct molasses containing approximately 85 percent solids and 15 percent water results. The total molasses produced accounts for approximately 4.5 percent of the weight of beets sliced. Sugar extraction efficiency in the straight house or non-Steffen process is approximately 75 percent. The Steffens process operation enables the plant to extract additional sugar from the molasses produced in a straight house operation and, with this addition, the production may be 85 percent efficient in total extraction of the sugar from raw beets. Of the total of 53 beet sugar processing plants in the U.S. at present 20 of these plants utilize the Steffen process.

In recent years, there has been a trend toward using a lower "purity" beet, i.e. lower sugar content. The lower purity of beets is attributed to their harvest prior to maturity in order to maintain uniform processing rates and therefore a longer processing season. Higher nitrogen content of soils through wide-spread fertilizer use, and increased



emphasis on sugar beet plant breeding for disease resistence also may be factors in reduced beet purity. With lower purity of beets, the sugar extraction efficiency in a straight house operation decreases substantially, approaching 70 percent, the sugar which is not extracted is retained in the byproduct molasses.

Production Classification

The U. S. Bureau of the Census, Census of Manufacturers classifies the beet sugar processing segment of the sugar processing industry as Standard Industrial Classification (SIC) Group Code Number 2063 under the more general category of Sugar and Confectionery Products, Food and Kindred Products (Major Group 10). The four-digit classification code (2063) comprises industrial establishments primarily engaged in manufacturing sugar and sugar products from sugar beets. A detailed list of product codes within the broad beet sugar processing industry classification code (2063) is included in Table IV.

Regulations and Future Growth

Federal Sugar Act

Until the late 1940's the economic stability of both the beet sugar and cane sugar processing industry fluctuated widely. Tariff reductions on imported sugar seriously depressed the domestic sugar economy throughout its growth. The sugar industry is now protected and operates on a quota system established by the Federal Sugar Act of 1948 which was amended in July, 1962. Quotas are established on both domestic and foreign sugar. Under the Federal Sugar Act, the price of sugar is controlled by the Secretary of Agriculture. Annually, the total national sugar requirement is projected and sales quotas to domestic producers are adjusted accordingly.

Anticipated Industry Growth

Under the present Federal Sugar Act, the beet sugar processing industry is permitted to increase its production at a rate of 3 percent annually. The growth and development of beet production areas and processing facilities may be in new areas as well as in present beet-growing areas. Some companies anticipate very large increases at certain plants and little or no growth at others. Additional beet sugar processing plants are presently being considered for construction in the United States. One such plant is being considered at Renville, Minnesota, to replace a former plant at Chasca, Minnesota, which was closed in 1970. This plant reportedly may employ an ion exchange process for extracting sugar from molasses rather than the convetional Steffen process. A plant is also proposed at Wappenton, North Dakota. Another plant at Hillsboro, North Dakota is presently under construction, with completion scheduled for 1974.

Large population growth, urban encroachment due to land development and increased land values are likely to result in decreased growth of the beet sugar processing industry in Colorado. Industry experts predict that the areas of future growth of the beet sugar processing industry will be the Red River of the North (Minnesota and North Dakota), and the Columbia River Basin. Expansion of the industry may be expected in Kansas and Nebraska due to proximity to sugar beet growing areas and land availability for future beet sugar processing plant sites and land disposal of waste waters.

TABLE IV

Product Classification by SIC Code for the Beet Sugar Processing Industry[3]

SIC Product Code			Product
20630			Refined beet sugar and byproducts
			Granulated beet sugar:
		20630-09	Shipped in individual services (small packets)
		20630-11	Shipped in consumer units (cartons & sacks of 25 lbs. or less)
		20630-13	Shipped in commercial units (bags & other containers more than 25 lbs.)
		20630-15	Shipped in bulk (railcars, trucks, or bins)
	20630-21		Cube and tablet sugar:
			Confectioners powdered sugar:
		20630-31	Shipped in consumer units (containers of 10 lbs. or less)
		20630-35	Shipped in commercial units (containers of more than 10 lbs.)
			Liquid sugar or sugar syrup:
		20630-51	Sucrose type
		20630-55	Inert and partially inert type
			Other beet sugar factory products and byproducts
			Whole or straight house molasses:
		20630-71	Shipped for desugarization
		20630-79	Shipped for other uses
	20630-81		Discard molasses
	20630-83		Molasses beet pulp
	20630-85		Dried beet pulp, plain
	20630-87		Wet beet pulp (estimated dry weight basis)

SECTION IV

INDUSTRY CATEGORIZATION

Profile of Production Processes

Beginning at the point from which sugar beets arrive at a given plant to the production of refined sugar, the production processes, beet handling methods, and associated plant management are all considered part of the total plant system. Detailed narrative descriptions of processes and methods associated with beet sugar processing are given below. The description serves as an introduction to the rationale for categorizing the beet sugar processing segment of the sugar processing industry.

Delivery and Storage of Beets

Beets are delivered to the plant by trucks or railroad cars and stored in large piles or dumped directly into flumes for transport into the processing plant. Beets must generally be stored for periods ranging from 20 to 60 days or more, since the processing period takes considerably longer than the harvest. In areas benefited by low ambient temperatures, beets can be stored in large piles until processing begins. However, during the storage period, considerable deterioration of beets may occur. Loss of recoverable sugar from beets through inversion in storage occurs even under the best of storage conditions. Therefore, great effort is made to reduce the time in storage by maintaining maximum slicing rates in the processing plants to the possible detriment of sugar extraction efficiency. Storage of beets in piles is not practiced in California and other areas where the prevailing warmer winter temperatures would encourage rapid beet deterioration. The harvest is carefully regulated in these regions so that beets may be processed soon after removal from the field. If harvesting is interrupted by winter rains, the plants are closed until harvesting can resume.

Transporting, Washing, Slicing and Weighing

Sugar beets are transported from the delivery point or storage piles to the process by water flumes. The beet transport flumes are provided with rock catchers which trap and remove stones and other heavy foreign material from flume flow. Trash catchers remove light material including weeds and loose beet tops. The sugar beets are lifted from the flume to a beet washer by a beet wheel and are discharged from the washer to a roller conveyor where they receive a final washing by high pressure sprays of clean water. Water from the beet washer and sprays is discharged into the flume system. The washed beets are sliced into thin ribbon-like strips called "cossettes," and fed into a continuous diffuser. A scale mechanism is usually installed in a section of the belt feeding the diffuser to weigh the sliced beets entering this portion of the process.

Sugar Extraction by Diffusers

The diffuser extracts sugar and other soluble substances from the "cossettes" under a counter-current flow of water. The liquor or "raw juice" containing the sugar and other soluble substances is pumped to purification stations. This raw juice contains between 10 and 15 percent sugar.

Disposal of Exhausted Cossettes

The exhausted beet pulp or "cossettes" are conveyed to pulp presses where the water content is reduced from about 95 percent to approximately 80 percent before the pulp is fed into a pulp drier where the pressed pulp is further dried to a moisture content of 5 to 10 percent. The pulp press water is usually returned to the diffuser as part of the diffuser supply. The dried pulp is utilized as a base for livestock feed. Only one plant in the industry now stores wet beet pulp in a silo. This silo is scheduled for replacement with a pulp drier by October, 1973.

Carbonation of Raw Juice, Clarification, Concentration and Separation

The raw juice from the diffuser containing most of the sugar from the beets as well as soluble and collodial impurities is pumped to the first carbonation station. Lime (calcium oxide), slaked lime or calcium saccharate (from the Steffen process) is added to the raw juice and, the juice is then saturated with carbon dioxide gas to precipitate calcium carbonate. The calcium carbonate sludge thus formed carries with it suspended impurities in the juice and is separated from the mixture by vacuum filters. The "thin juice," after further treatment with carbon dioxide, filtration and treatment with sulfur dioxide to reduce the pH to about 8, is concentrated in multiple-effect evaporators to a "thick juice" (65 percent solids) and then boiled in a vacuum pan crystallizer to obtain the crystallized sugar. The sugar is separated by centrifugation from the adhering syrup and dried. The remaining syrup is further concentrated to yield additional crystalline sugar and molasses. The molasses may be added to the exhausted beet pulp and sold for animal feed or may be further desugarized by the Steffen process.

The Steffen Process

In this process the molasses produced from the straight house operation is diluted, cooled and treated with calcium oxide to precipitate the sugar as a saccharate. The calcium saccharate, after separation by filtration from the remaining solution of impurities (Steffen filtrate) is returned to the first carbonation station in the straight house process. The Steffen filtrate may be discharged as a waste, used for raw juice clarification in the straight house process, or after precipitation and removal of calcium carbonate by addition of carbon dioxide (carbonation), evaporated to a thick liquor called concentrated Steffen filtrate. This filtrate may be dried in combination with beet pulp or used as a source for the production for such byproducts as monosodium glutamate, and potash fertilizer salts.

Categorization of the Beet Sugar Processing Segment

The beet sugar processing segment of the sugar processing industry is defined as the production of sugar utilizing sugar beets as a raw material.

Factors Considered

With respect to identifying any relevant, discrete categories for the beet sugar processing segment of the sugar processing industry, the following factors or elements were considered in determining whether the industry segment should be subdivided into subcategories for the purpose of the application of effluent limitations guidelines and standards of performance:

1. Waste water constituents
2. Treatability of wastes
3. Raw materials
4. Products produced
5. Production processes and methods
6. Size and age of production facilities
7. Land availability, climate, and soil conditions

After considering all of these factors, it is concluded that the beet sugar processing segment of the sugar processing industry comprises a single and coherent industry category which need not logically, on the basis of these factors, be further subcategorized. Accordingly, categorization is based on the entire industry, encompassing all plants, processes, wastes, and descriptive elements into a single category as defined above.

Raw Waste Water Constituents and Treatability

The nature and characteristics of raw waste components released for treatment or control from any beet sugar processing plant are similar. Moreover, all effluents respond to, and are treated by, the same or similar waste treatment systems. As with other factors considered, wastes and treatment systems, show some variations (e.g., increases in total waste loads as lime mud slurry from Steffen plants), however, the variations are not sufficient in magnitude to warrant subcategorization on this basis. Typical waste water constituents, waste loads, and flow data for the beet sugar processing segment of the sugar processing industry are included in Table VI.

The difference in waste load by comparison of a Steffen to a non-Steffen beet sugar processing plant results from additional lime use in clarification of sugar solution, the generation of Steffen filtrate, and the possibility of additional organic entrainment of barometric condenser water through the additional concentration process in the Steffen process. In practical terms, these additional waste sources present little impact on the total plant pollutional waste load volumes and effects under present waste disposal practices.. A Steffen house operation may contribute a lime mud slurry volume of 680 and BOD_5 of 9.5 kg/kkg (180 gal and 19 lb/ ton) of beets sliced in comparison to 340 l and 3.2 kg per kkg (90 gal and 6.5 lb/ton) of beets sliced for a non-Steffen process. Under present plant practices, the relatively small lime slurry volume generated at beet sugar processing plants (Steffen or non-Steffen) is disposed of on land without discharge to navigable waters. Steffen filtrate, resulting from extraction of sugar from molasses in the Steffen process, is universally concentrated for byproduct recovery or disposed of on land without discharge to navigable waters. The Steffen filtrate is a small volume waste of 510 l/kkg (120 gal/ton) of beets sliced of high pollutional load of (5.2 kg BOD_5/kkg (10.4 lbs/ton) of beets sliced. Additional sugar entrainment in the evaporation and crystallization process may be expected to result in an increase of .05 kg BOD_5/kkg (0.1 lb/ton) of beets sliced in a Steffen process as compared to .25 kg BOD_5/kkg (0.5 lbs/ton) of beets sliced commonly expected for a non-Steffen process. The additional waste load is not significant and may be reduced or eliminated by the identical technology judged applicable to a non-Steffen process.

Raw Materials and Final Products

Raw materials (e.g., sugar beets, water, limestone, and fuel) and final products do not provide a basis for subcategorization of the industry, as the essential characteristics of these materials are consistent throughout the industry. Unimportant variations in the composition of these materials may exist as exemplified by sugar beets themselves. The beets will vary slightly in quality and characteristics primarily in terms of the sugar content and amount of associated incoming "tare" and debris. These variations are not unique and are experienced throughout the industry and are influenced by cultural practices, care in harvesting of the beets, climatic conditions and handling procedures.

Water use is determined by the needs of the individual plant, and under existing practices is primarily influenced by the temperature and quality of available water supply sources and the degree of inplant water reuse. Water use by beet sugar processing plants varies markedly due to these variables.

The quality of product (refined sugar) is uniform throughout the industry. Differences arise in the various uses for which the final product is made or the method of packaging for the buyer. The latter factors are not environmental quality related insofar as their relationship to beet sugar processing. Lime used in the process for precipitation of impurities and pH control is disposed of by the same technique throughout the industry.

Energy requirements in a beet sugar processing plant are fairly uniform (1.2 Kw of electrical energy per ton of beets sliced per day). Small variations can be attributed to ancillary activities such as pollution abatement equipment. Sugar, molasses and beet pulp are the three major products produced in all plants and industry-wide product quality control effectively eliminates any significant differences in unit quantity of production or product characteristics.

Production Processes and Methods

As discussed in the previous section, there is little to differentiate in the essential operations conducted for beet sugar processing at all plants. Improved sugar recovery processes (e.g., Steffen Process) lead to enhanced inprocess recycle efficiencies but show no material effect upon overall production methods or raw waste loads. Other unit processes such as slicing, extraction, pulp pressing and carbonation perclarification are uniform in all plants.

Some plants within the beet sugar processing industry operate what is referred to as an "extended use" campaign. In such operations, the "thick juice" after purification and concentration is stored in part for processing through the sugar end of the plant during the intercampaign. The effect of such operations on raw waste loads from the plant is to extend the period of waste water generation over the thick juice processing period. The total waste load remains the same. However, the waste generated as a problem source in the processing of beets to thick juice is of primary consideration (flume, condenser and lime mud wastes). The processing of thick juice in the intercampaign in the sugar end of the process adds only a small waste load attributed primarily to contaminants in barometric condenser waters of the crystallization tank without adequate entrainment control devices.

In consideration of the relatively small waste load attributed only to barometric condenser water resulting from the extended use campaign, such procedures are not justification for categorization of the beet sugar processing segment. Waste disposal facilities designed and operated to adequately dispose of waste waters resulting during the beet processing season serve adequately during the "extended use" campaign operations, since these two activities are not conducted concurrently.

Land Availability, Climate and Soil Conditions

Land availability, climatic and soil conditions are principal factors that must be considered in the handling and disposal of beet sugar processing waste waters.

Climate, soil conditions, and land availability vary in various regions of the country and at individual plant sites. Very tight soil in terms of percolation characteristics exists in some geographical regions (e.g., glacial till soils of Michigan, Ohio and the Red River of the North in North Dakota and Minnesota) which necessitates greater reliance upon evaporation and increased land requirements as a mechanism for obtaining no discharge of process waste water pollutants to navigable waters. Land availability is particularly an important factor where because of climate and soil conditions increased reliance on pond surface evaporation is required. Based on mass water balance relationships developed in this document, land requirements for no discharge of process waste water pollutants to navigable waters with extensive recycling and controlled land disposal of waste waters (0.635 cm or 1/4 in per day allowable filtration rate) is approximately 50.6 ha (100 aç) for the average sized plant. Greater land requirements may result under adverse land disposal conditions. Present practice in much of the industry is the construction and use of much larger land disposal areas for waste disposal than actually required for this purpose. Necessary land is generally available under the prevailing climate and soil conditions throughout the industry for controlled land disposal of waste waters, and these factors do not serve for general subcategorization of the beet sugar processing segment of the sugar processing industry on this basis. The basis for controlled land disposal of waste water by reliance on maximum allowable soil filtration rates alone, effectively eliminates variable climatic factors such as rainfall and evaporation as a point of concern in the recommended land based waste water disposal and control technology. With the exception of the Michigan Ohio area (where lake evaporation nearly compensates for annual rainfall) additional waste water losses may be attributable to net evaporation as well as filtration. Factors related to land availability and soil characteristics need to be dully considered in application of effluent guidelines and limitations for a land based waste water control technology and such factors are considered for establishing applicable guidelines and standards for individual plants as the best practicable control technology currently achievable for this industry. (See Section II) This level of technology is to be achieved by all plants by July 1, 1977.

Size and Age of Production Facilities

As can be determined from Table V, size is not a significant factor because over seventy percent of both the number of plants and production capacity are in the range of 1800-4700 kkgs (2000 - 5200 ton) per day; with the balance of the plants characterized by the same order of magnitude. Similarly, age of equipment and facilities proves unimportant because the industry has been continually modernizing operations to enhance production efficiency. Size of plant bears a general relationship to land available -- the smaller plants being generally located in more urbanized areas with climatic and soil conditions less favorable than other areas for controlled land disposal. The relationship is only general in context; there are notable exceptions to the generalization The matter is more appropriately one of land availability as discussed in more detail in the following subject heading and Section IX of this document. Raw waste load characteristics and quantities for various waste water components is reliably related to unit production rates, thereby eliminating size as a possible factor in generation of disproportionate waste loads by capacity of plant.

TABLE V

SIZE DISTRIBUTION OF BEET SUGAR PROCESSING PLANTS IN THE UNITED STATES, DAILY SLICING CAPACITIES

Slicing Capacity in kkg/day (ton/day)	Number of Plants
1270 (1400) or less	1
1450 - 1810 (1600 - 2000)	7
2200 - 2180 (2001 - 2400)	12
2181 - 2630 (2401 - 2900)	4
2631 - 3080 (2901 - 3400)	7
3081 - 3450 (3401 - 3800)	6
3451 - 3990 (3801 - 4400)	6
3991 - 4710 (4401 - 5200)	3

5890 - 6350 (6500 - 7000)	5

6351 - 8610 (7000 - 9500)	1

More than 8610 (9500)	1
TOTAL	53

SECTION V

WATER USE AND WASTE CHARACTERIZATION

Specific Water Uses

Water is commonly used in a beet sugar processing plant for six principal purposes:

Transporting (fluming) of beets to the processing operation Washing beets Processing (extraction of sugar from the beets) Transporting beet pulp and lime mud cake waste Condensing vapors from evaporators and pans Cooling

The quantity of fresh water intake to plants ranges between 1,250 and 25,000 l/kkg (300 and 6,000 gal/ton) of beets sliced. Fresh water use is highly contingent upon in-plant water conservation practices and reuse techniques. Average water use in the industry approximates 9200 l/kkg (2200 gal/ton) of beets processed. Total water used, including reused water, varies much less and totals approximately 20,900 l/kkg (5000 gal/ton) of beets sliced. Most of the water used in beet sugar processing plants is employed for condensing vapors from evaporators, and for the conveying and washing of beets (see Table VI). Since many process uses do not require water of high purity, considerable recirculation is possible without extensive treatment. The nature and amounts of these water reuses as influenced by in-plant controls and operational practices have a substantial effect on resulting waste water quantities and characteristics. Reduction in water use with minimum waste water volumes promises less difficulties in waste handling and disposal, and greater economy of treatment. Water uses for various operations in a beet sugar processing plant are further described below:

Flume or Beet Transport Water

As previously mentioned, transport of beets from piles, trucks or railroad cars into the plant is invariably accomplished by means of water flowing in a narrow channel (flume) which provides for handling and conveyance of the beets and removal of much adhered soil. Beets are lifted from the flume to a washer and then subjected to a final wash by sprays. The combined flume, wash and spray water constitutes the largest single usage of water in a beet sugar processing plant, and ranges between 5,000 to 17,000 l/kkg (1,200 to 4,000 gal/ton) of beets, averaging about 11,000 l/kkg (2,600 gal/ton.) In most plants, flume water is recycled after separation of much of the suspended soil. Flume water generally accounts for approximately 50 percent of the total plant water use. Water used for fluming in many plants is drawn in part from barometric condenser seal tanks. In some plants, fresh water is used, either alone or as a supplement to condenser water. The use of warm condenser seal tank water for fluming is often found to be advantageous in cold climates in order to thaw frozen incoming beets.

Process Water

Process water is associated with the operations of extraction of sugar from the beet. About 920 liters/kkg (220 gal of makeup water/ton) of beets are used for this purpose. Available data indicates considerably more water usage in some instances, but these instances apparently include some pulp transport water. Nearly all plants presently practice complete process reuse of pulp transport water, and return pulp press water to the diffuser. Dry pulp handling with elimination of pulp transport water is a common practice. The weight of raw juice drawn from the diffuser is approximately 125 percent of the weight of sliced beets entering the diffuser. This ratio, called "draft", varies between 100 and 150 percent. The discharged pulp contains about 95 percent moisture when it leaves the diffuser and is reduced to about 80 percent moisture by pressing. Any necessary makeup water in the diffuser may be obtained from fresh water supplies, condensate water from the heaters, barometric condenser water, or a combination of these sources. Barometric condenser water is not the most desirable source of makeup water since it contains undesirable dissolved solids after cooling and reuse. Heater condensate is preferred and generally considered to be far more suitable for use in the diffuser.

Lime Mud System

Raw juice impurities contained in the calcium carbonate sludge in the clarification process are removed from clarification tanks and conveyed to a rotary vacuum filter for dewatering. The resultant lime mud cake contains approximately 50 percent solids which is normally slurried with fresh or condenser water to about 40 percent solids and pumped to a lime mud pond. A high quality water for slurrying need not be required. Lime use within a beet sugar processing plant generally amounts to approximately 2.4 to 4.0 percent by weight of the beets processed. Water for slurrying and pumping of lime mud to land disposal facilities is not normally metered but may be estimated on the basis of the lime dosage used. At one plant, water usage for slurrying is estimated at 170 l/min (45 gal/min) or 40 l/kkg (10 gal/ton) of beets processed based on 22.6 percent calcium content of the lime mud cake and 12.0 percent in the lime mud slurry. The quantities actually used vary from less than 41.7 l/kkg (10 gal/ton) of beets to more than 417 l/kkg (100 gal/ton). Many plants use between 83.5 to 251 l/kkg (20 to 60 gal/ton) of beets sliced averaging about 208 l/kkg (50 gal/ton). Recent trends are toward reduced use of water in the lime mud slurry. The lime mud slurry, though relatively small in volume, is very high in BOD5 and suspended solids. With careful control, water usage for lime mud slurrying can be limited to less than 41.7 l/kkg (10 gal/ton) of beets processed for a straight-house operation. Semi-dry lime mud handling techniques as practiced at some plants are effective in limiting water use for lime mud slurrying purposes. Because of additional sugar extraction from straight house molasses in the Steffen operation through additional lime precipitation, the Steffen process results in increased lime mud volumes for disposal. Reduced water volume techniques for handling lime mud from straight house operations, are equally applicable to lime mud produced from the Steffen process.

Barometric Condenser Water

Barometric condensers are commonly employed in the operation of pan evaporators and crystallizers in the beet sugar processing industry. Water in large quantities is required for this purpose. The quality of the water is not of major importance, but since the most readily available source of cold water is generally the fresh water from wells or streams, it is usually relatively pure. In 20 of the 53 plants in the United States, condenser water is cooled by cooling towers or spray ponds and recycled in varying degrees to the condensers for reuse. In 38 of the beet sugar processing plants within the United States, spent condenser water frequently is reused, principally for fluming beets. The amount of barometric condenser water used varies between 5400 to 18,800 l/kkg (1300 to 4500 gal/ton) of beets processed The average usage is approximately 8250 l/kkg (2,000 gal/ton) of beets sliced.

Steffen Dilution Water (Steffen Process Only)

The Steffen process is employed by 20 beet sugar processing plants. In this process, molasses containing about 50 percent sucrose, is diluted with cold fresh water to produce a "solution-for-cooler" containing 5 to 6 percent sucrose.

In the South Platte River Basin, Steffen house process plants account for higher water usage than non-Steffen plants because of lower temperature and greater cooling water requirements in the processing of the molasses solution. The use of heat exchangers in these plants such as presently employed in other regions (e.g., California) for cooling the molasses solution could reduce this high fresh water usage for cooling and support the economic use of cooling towers.

Miscellaneous Water Uses

Condensate water from steam or vapors in heating and evaporation of raw juice produces high-quality water ranging between 150 to 200 percent of the weight of beets sliced. The purest of these condensates is collected and used as boiler feed. Normally, no other water is used for this purpose. Condensate waters are used for many other purposes:

diffuser supply (in part); press wash, i.e., washing of lime mud cake precipitate; centrifugal wash; and house hot water (cleaning evaporators, floors, etc.). Miscellaneous water uses vary widely among plants with housekeeping practices. Floor drainage water may vary between 38,000 and 1,500,000 l (10,000 and 400,000 gal) per day for plants ranging from 1360 to 6000 kkgs (1500 to 6600t) of beets sliced per day, respectively. The floor drainage waste may typically contain approximately 2400 mg/l BOD_5 and 3000 mg/l sugar as sucrose. Gas washer water also varies considerably from 30,300 to 1,326,000 l (8,000 to 350,000 gal) per day at plants in the industry.

TABLE VI
REPRESENTATIVE WASTEWATER CHARACTERISTICS AND TOTAL FLOW DATA FOR A TYPICAL BEET SUGAR PROCESSING PLANT (*)

Waste Source	Flow l/kkg of beets sliced (gal/ton)	BOD_5 (mg/l)	BOD_5 kg/kkg of beets sliced (lb/ton)	Suspended Solids (mg/l)	Suspended Solids kg/kkg of beets sliced (lb/ton)
Flume Water	10,842 (2600)	210	2.25 (4.5)	800-4,300	8.5-41.5 (17-93)
Process Water					
Screen (Pulp Transport) Water	1668 (400)	910	1.50 (3.0)	1,020	1.7 (3.4)
Press Water	751 (180)	1,700	1.30 (2.6)	420	0.3 (0.6)
Silo Water	876 (210)	7,000	6.15 (12.3)	270	0.25 (0.5)
Lime Mud Slurry**	375 (90)	8,600	3.25 (6.5)	120,000	45 (90)
Condenser Water	8340 (2000)	40	0.35 (0.7)	-	
Steffen Filtrate	500 (120)	10,500	5.20 (10.4)	100-700	0.05-0.35 (0.1-0.7)
Totals	23,352 (5600)		20.0 (40.0)		55.8-94.1 (111.6-188.2)

(*) All values are based upon no recirculation or treatment of waste waters (24,25,26,48).

(**) Relates to non-Steffen or straight house process.

Factors Affecting the Quantity and Quality of Waste Waters

Even though all beet sugar processing plants in this country and abroad use essentially the same basic processes for production of refined sugar, facilities for handling waste waters vary markedly from plant to plant.

Two relatively recent and important equipment changes have been made in United States beet sugar processing plants which have affected water usage and corresponding quantities of wastes. These are the installation of continuous diffusers and widespread use of pulp driers. Replacement of the Roberts (cell-type) diffuser by the continuous diffuser was completed in 1967 for all plants. The new type diffuser showed important reductions in water required in the process by permitting reuse of pulp press water. With the cell-type diffuser, pulp screen water and pulp press water were discharged as a waste. The first pulp drier was installed in an American plant over 50 years ago, and by October, 1973, it is anticipated that all plants will be equipped with modern driers. One plant presently uses a silo for disposal of wet exhausted beet pulp.

Concentration of the Steffen waste produced at Steffen process plants by evaporation is also commonly practiced. Before evaporation of Steffen waste was generally practiced, the BOD_5 discharge was 5.0 kg/kkg (10 lbs/ton) of beets from this source. Concentration of Steffen wastes now permits substantial reductions in waste volume which permits easier handling, disposal and by-product use.

The amount of water reuse varies greatly among beet sugar processing plants. At one plant in 1968, the total water usage, including reuse, exceeded the fresh water intake by only 24 percent; while at another plant, the total usage exceeded intake water by 1,300 percent as water shortages engendered maximum conservation. At most plants, fresh water intake constitutes one-third to one-half of the total usage; although fresh water constituted less than 20 percent of the total water use in six plants in 1968.

The greatest reduction in fresh water usage within the past two decades has been accomplished by the recirculation of flume water and by the reuse, after cooling, of condenser water. In a number of plants, considerable reliance has been placed upon the mechanical settling unit as an integral part of flume water recirculation systems. Use of mechanical clarifiers is widespread, as are earthen ponds to provide settling for flume water recycle systems. The British Columbia Research Council , although reporting favorable results with mechanical and pond settling devices, concluded that tare recovery and disposal is an ever-continuing problem. The Council suggested that soil buildup within the plant could be eliminated only by physical transport of the soil in the opposite direction to the fields. In the future, it is possible that the sugar beet producing farmer may be required to retrieve sludge solids from the processing plant system equivalent to his incoming tare (13). Elimination or minimization of soil loads on incoming beets is an integral part of best technology for overall pollution control for the beet sugar processing segment of the sugar processing industry.

Typical Process Waste Characterization

The most widely recognized and representative data of waste characterization for the beet sugar processing segment of the sugar processing industry is included in "An industrial Waste Guide to the Beet Sugar Industry" published by the U.S. Public Health Service. This waste data, circa 1950, is included in Table VI. The waste loads are representative of once-through water use without recycling or treatment. The data given in Table VI serves as a reliable base for determining the total waste load potential of a beet sugar processing plant. Because of the wide diversity of in-plant control, recycling, and treatment practices at present beet sugar processing plants, the data in Table VI does not reflect the combination of conditions existing at any single plant within the industry today. The data does reflect total waste load and waste water flow values associated with the individual waste source components, which may be predicably amended by various methods of controlling and handling these individual waste water sources within the industry. The total potential waste load and water requirement attributed to each of the waste producing production processes has particular significance and constantcy throughout the industry. In addition to providing a baseline of total pollutional load attributed to individual waste components, the data also serves to provide a basis for comparison between former and current waste handling techniques.

The former practice of beet sugar processing plants of discharging wastes containing between 15 and 20 kg BOD_5/kkg (30 to 40 lbs/ton) of beets sliced had been reduced to an average of less than 2.5 kg (5 lbs) by 1968. A further reduction in BOD5 load has taken place in most recent years with all plants soon to accomplish a discharge from zero to less than 1.0 kg BOD_5/kkg (2.0 lbs/ton) of beets sliced to surface streams. The total waste discharge to streams from the entire beet sugar processing industry in the United States in 1968 was estimated at about 215 billion l (57 billion gal) which contained a total of about 37 million kg (82 million lb) of BOD_5. However, the 24 million kkg (26 million-ton) crop in 1968 was unusually large -- a more normal crop would have been about 20 million kkgs (22 million tons) of beets processed. A number of plants currently recycle much of the flume and condenser waters, and some plants do not discharge any waste water to navigable waters at all.

The waste water flow data and waste load information in Table VI (and supported by data from other sources) is adopted as base total flow data and total waste load data associated with beet sugar processing for purposes of use in this document. Information generally supporting these data and supplemental information regarding characteristics of beet sugar processing plant wastes are summarized in Table VII. The effects of current practices of in-plant control, recycling, and reuse of waste waters within beet sugar processing plants on waste water contribution and characteristics are discussed in the following section. Values for waste water constituents are given to illustrate the variability of waste water qualities and quantities experienced in practice as dependent upon in-process control practices. Every beet sugar processing plant today employs some degree of waste water recycling or reuse.

Under present practices, process waters (pulp screen water, pulp press water, and pulp silo drainage), Steffen waste, and lime mud slurry have essentially been eliminated as polluting waste sources in terms of discharge to navigable waters. Process waters are universally recycled within the plant, Steffen waste is disposed of with by-product use or land disposal, and lime mud slurry receives land disposal. Flume water and barametric condenser water are presently two primary polluting sources.

Raw Waste Characteristics of Specific Operations

Flume Water

Flume water consists of beet transport water as well as various miscellaneous small waste streams generated within the plant. These include excess cooling water, pump gland leakage, accidental spills, beet washings and spray table overflows. This mixture when discharged from the flume water system is called spent flume water and is generally considered the main plant waste stream.

The Industrial Waste Guide describes waste values from flume water of 9,800 liters (2,600 gal) and 2.25 kg BOD_5/kkg (4.5 lb/ton) of beets processed in the United States. The British Columbia Research Council investigated flume waters of many plants both in the United States and Canada. Plants with a high degree of recirculation as well as those with once-through systems were included. The BOD_5 levels of these waters ranged between 115 and 1525 mg/l and averaged 565 mg/l; the suspended solids content ranged from a low of 127 mg/l to a high of 4500 mg/l; the average was 210 mg/l. In Europe the value was 2.5 kg BOD_5/kkg (5.0 lbs BOD_5/ton) of beets sliced.

Investigations have shown an increase in BOD_5 values of flume waters during the progression of the campaign. These increases are mainly attributed to the release of soluble organic matter from frozen beets or those deteriorating as a result of poor storage conditions in northern regions. The leaching losses of sugar into the flume water is also associated to some degree with the temperature of the flume water. To minimize this effect, cold fresh water is used for makeup in some plants. In others, barometric condenser water is first discharged through a cooling tower before being used for makeup in the flume system. However, when frozen beets are to be sliced, they are usually thawed with the hot barometric condenser water. Studies in Minnesota showed that the average BOD_5/unit weight of beets processed varied from 1.0 to 2.2 kg/kkg (2.0 to 4.4 lb/ton) at the beginning of the campaign to 4.6 to 5.14 kg/kkg (9.2 - 10.3 lb/ton) near its end. The "leveling off" of the BOD_5 in recycled flume water systems at many plants within the 6,000 - 7,000 mg/l range has been well established through estensive studies. It has been shown that for BOD_5 concentrations greater than 25 mg/l in flume water, the COD may be predicted at 150 percent of the BOD_5 concentration. COD concentrations in recirculated flume water systems range between 9,000-10,000 mg/l.

Flume waters vary considerably in their content of soil, stones, beet leaves, roots, and dissolved solids between locations, harvesting conditions, and from season to season. During fluming, large quantities of detritus are removed from the beets. Under certain conditions when incoming beets have great quantities of adhering soil, the flume water consistence may approach that of a slurry because of its solid content. In more favorable dry harvesting seasons, particularly in areas of light sandy soil, the adhering soil may only be 3 or 4 percent by weight when the beets are received at the plant, but during wet harvesting seasons, soil may range up to 20 percent by weight. The average soil tare ranges from 5 to 6 percent. As a result, a typical plant may receive about 19,900 kkg (22,000 tons) of incoming tare over the average campaign.

The basic flume water recycling system was first in operation at Brighton, Colorado, and was later firmly demonstrated at the Longmont, Colorado plant of the Great Western Sugar Company, under a project sponsored by the Beet Sugar Development Foundation and the Federal Water Pollution Control Administration. After overcoming initial mechanical operational problems in handling water surges, the system operated successfully. Recirculation of flume water is now a common practice within the beet sugar processing industry and involves lime addition for pH control, screening, settling to remove settleable solids, and discharge of solids to control buildup in the recirculation system. Large organic particles removed by screening are recovered for byproducts such as cattle feed.

Dissolved solids content of the flume water generally increases through the first 6 weeks of operation of the closed system, reaching a maximum total dissolved solids concentration of approximately 10,000 mg/l. The BOD5 level tends to reach an equilibrium concentration in the range of 6,000 to 7,000 mg/l during the campaign.

A number of studies have related bacterial densities that have been found on the outer surfaces of beets and associated dirt, trash, and fertilizers for beet sugar processing plants in the Red River of the North. Total coliform results indicate that the dirt from freshly unloaded beets contained 490,000 organisms pergram of solid material. Very high total coliforms were found on the surfaces of the sliced beets and on the beet trash removed from the flume. These levels were 13,000,000 and 17,200,000 total coliform per gram of material, respectively.

The bacterial loads varied from 0 to 68 Bacterial Quantity Units (BQU) of total coliform bacteria discharged per100t of beets sliced, and fecal coliform bacteria from 0 to 8.4 BQU. For comparative purposes, the raw sewage discharged by a human population of 1,000 persons would be expected to contain around 15-30 BQU of total coliform bacteria and 5-20 BQU of fecal coliforms . Relatively low bacterial loads have been attributed to some plants because of lime addition, contributing to very high pH levels in the total plant wastes. The field surveys have shown that pH levels exceeding 9.0 are particularly destructive to organisms of the coliform group.

Studies of fecal coliform to fecal streptococci ratios of sampled final waste discharges indicate bacterial pollution to be primarily and originally derived from the fecal excreta of animals rather than humans. The source of such pollution would be from livestock animals such as found on farm feedlots and stockyards or from storm water runoff Sugar beet wastes have been found to contain Streptococci bovis, a species strongly associated with cattle and other domestic animals feces. Within the plant, river water used for fluming and washing purposes may represent another source of fecal coliforms. These bacteria were found to originate generally from up-stream domestic wastewater discharges. The bacterial population found in beet sugar plants and in their waste streams are introduced into the plant through the flume. From the flume water they are transferred through the beet washer, spray table and the beet slicer to the diffuser.

An extremely favorable environment is created in the flume system for sustaining and enhancing bacteria growth by an abundance of nutrients, favorable temperatures, stagnant zones, and the availability of fixed surfaces. Control is easily achieved in the diffuser with formalin or other biocide treatment. Total bacterial destruction is accomplished by the subsequent heat effects in the evaporation process.

In the continuously recycled flume water system, the underflow volume (approximately 20%) has been demonstrated to compensate for the buildup of dissolved solids and BOD_5 in the recycled flume water. As a result the buildup to equilibrium concentrations presents no problem in the beet sugar processing and sugar production operation. However, to avoid contamination, the flume water must not enter the diffusion unit operation and, fresh water is used on a final spray wash of the beets prior to processing to assure no contamination.

The practice of discharging approximately 20% blowdown for solids control in recirculating water systems is widely supported by experience in the beet sugar and cane sugar processing industries as well as recirculating process water systems employed by other similar industries. This figure serves as a generally industry accepted value for needed blowdown to effect satisfactory solids control with fresh water makeup in this type of system.

Lime Mud Slurry

Hydrated lime is added to the raw juice as a purifying agent and then precipitated by carbon dioxide in the carbonation process. The resulting calcium carbonate sludge, with impurities removed from the juice, is vacuum filtered and slurried with water. This mixture is known as lime mud waste, lime-cake, or lime slurry residue. Steffen house plants use two to three times the quantity of lime employed in straight-house operations, and the lime-cake slurry is reported by the FWPCA to be about 50 percent higher in BOD_5 strength. Sludges from the concentrated Steffen filtrate process and boilouts from the cleaning of evaporators and vacuum pans may also be added to the lime mud for disposal.

Lime mud slurry or sludge is alkaline with extremely high organic and suspended solids content. Besides calcium carbonate, the sludge includes pectins, albuminoids, amino acids, other nitrogenous and proteinaceous comlb, and a significant amount of impure sugars. A study of 59 plants in the U.S. and Canada showed lime mud slurries to have an average BOD_5 of 6,370 mg/l with a range of 1,060 to 27,800 mg/l The suspended solids content of these slurries averaged 229,000 mg/l with a range from 143,000 to 357,000 mg/l. Amounts of water added to the filter cake from the vacuum filter varied greatly and were mainly responsible for the wide range demonstrated in BOD_5 and total suspended solids values.

Lime mud slurry may be expected to have unit waste values of 340 liters (90 gal) and 3.3 kg BOD_5/kkg (6.5 lbs BOD_5/ton) of beets sliced (49). From experiences in Europe and Great Britain, both lower and higher BOD_5 values have been reported. The survey conducted by FWPCA on beet sugar processing plants in the South Platte River Basin showed that lime mud wasting from a Steffen house plant could add about 2.5 kg (5 lbs) BOD5, 3.5 kg (7 lbs) COD, 45 kg (90 lbs) total suspended solids (TSS) and 22.5 kg (45 lbs) of alkalinity per kkg (ton) of beets processed to the basic plant loads. A straight-house factory would accumulate one-half to three-fourths of these respective levels.

Lime cake generated from juice purification operations amounts to 1.5 to 3.0 percent of the weight of beets processed in U.S. practice, and about 5.0 percent in European practice. The large difference between U.S. and European values has not been sufficiently explained. A plant handling 136,000 kkgs (150,000 ton) of beets over the season could produce 2000-4100 kkg (2200-4500 ton) of lime-cake. The weight of slurry would be considerably greater. The pollutional strength of lime mud slurries vary widely among beet sugar processing plants, depending in large part on the amount of water use in diluting the filter cake.

Steffen Filtrate

Steffen waste results from the extraction of sugar from the straight-house molasses by the Steffen process. Steffen filtrate (the source of wastes) originates from the filtering of saccharate cake in the precipitation of lime treated diluted molasses in the Steffen house.

The Steffen filtrate through the 1940's represented the most damaging waste product from the sugar plant. The filtrates are highly alkaline with a pH level near 11, with 3 to 5 percent organic solids. The Industrial Waste Guide describes Steffen filtrate as containing around 10,5000 mg/l BOD5, 25,000 to 40,000 mg/l total solids, and 100 to 700 mg/l total suspended solids.

The South Platte River Basin studies showed that elimination of Steffen waste from the effluent by concentration and disposal as a cattle food supplement reduced the pollution load of Steffen operations by about 115 kg of BOD5/kkg (230 lb of BOD5/ton) of molasses worked.

Condenser Water

Barometric condenser water is employed in multiple effect evaporators and across the vacuum pans to create vacuum for low temperature boiling of sugar solutions in the sugar production process. Steam and vapors from the fifth-effect of the multiple effect evaporator and from the vacuum pans are condensed by direct contract with the water passing through the barometric condenser. The cooling water remains relatively unchanged except for an increase in temperature to 50-65°C (122-149°F) (65). However, condenser waters generally accumulate some entrained solids and absorb ammonia from the evaporating juices. They are always alkaline, with a pH range from 8 to 10, but usually are less than 9.

The principal waste constituents in barometric condenser water include BOD_5, ammonia nitrogen, and sometimes phosphates from water treatment. Total solids are of importance in a "recycled" condenser water system. Ammonia, organics, and phosphorus are important in the eutrophication process and are a potential degrading influence in streams and lakes.

Data regarding the BOD_5 content of condenser water confirms previous findings; namely, that sugar lost by entrainment amounts to about 820 kg (1800 lbs) per day in a plant of 2300-2700 kkg (2500-3000 ton) capacity. Suspended solids in the condenser water which leaves the seal tank are low. The British Columbia Research Council study on various plants reported an average BOD_5 for condenser waters of 43 mg/l with a range of 25 to 130 mg/l BOD_5. Another study found an average BOD_5 of 50 ppm or less (65); a third reported 30 mg/l (74). Ammonia nitrogen concentration approached 3-15 mg/l as nitrogen with good operation. Suspended solids averaged 67 mg/l with a range from 0 to 100 mg/l.

The concentration of organics in condenser water with complete recirculation has reached an equilibrium concentration near 25 mg/l BOD_5 in present recirculation systems and has not been an operational problem. Degradation of biodegradable organics will occur in various cooling devices such as cooling towers, aeration ponds, or open cooling ponds designed primarily for cooling.

Experience indicates that accidents, shock loads, etc., cause heavy vapor entrainment into condenser waters, and these conditions are reflected in the waste loads. When overloading occurs, pan condensers receive intermittent quantities of liquor that boil over during the various stages of the boiling cycle. More carryover of organics into condenser water is generally experienced in the fall in the North and North Central portions of the United States as a result of beet deterioration. Based upon U.S. and European practices, good control procedures will lower the condenser BOD_5 concentration to 15-30 mg/l (13). Better operation with entrainment control devices can limit the degree of entrainment to 10-15 mg/l and virtual elimination of any entrainment occurs with best operation.

The source of fecal coliforms if present in condenser water would originate from the water supply source and generally would be of concern only where surface waters containing bacteriological contamination are used as the source of condenser water. The elevated temperatures with small entrainment of organics from the barometric condensers present favorable conditions for the growth of bacteria in the condenser water. However, because of its relative purity in comparison with other waste waters, condenser water is frequently used for both diffuser supply and flume water makeup. The latter practice is especially necessary in cold climates when processing frozen beets.

The practice of reuse of condenser water has increased in recent years. In 1968, 38 of the 58 beet sugar processing plants used condenser water for fluming and other in-plant usages; 20 cooled and recycled this water to condensers. Many plants made some in-plant use of condenser water and discharged the remainder to surface waters.

In most plants the condenser and cooling water systems are the principal sources of makeup water supply for the beet flumes and for beet washing. When not reused for fluming and beet washing, condenser water becomes another waste source. Its volume is substantially reduced by recycling.

Extensive recycle of condenser water requires some additive control measures in areas where the water is of poor or marginal quality. As recycling is increased, the scaling properties are increased by the concentration of solids through evaporation and by increased pH from the absorption of ammonia. Although most plants use some type of polyphosphate threshold treatment to prevent scaling, it may also be necessary to reduce the pH with acid.

The problem of dissolved solids accumulation may be controlled (and is generally accomplished in the industry) through periodic bleed-off (approximately 20 percent) of water from the system in order to maintain acceptable total dissolved solids levels (approximately 10,000 mg/l or less) for scaling control. Fresh water or clean water make up is necessary.

Various means of cooling are employed, such as spray ponds, natural draft, and induced draft cooling towers. The latter are generally necessary in warmer and more humid climates. In most cases, it is not possible to provide recycled water at as low a temperature as the normal primary cold water source. Because of this, the recycle system generally requires the addition of low temperature make-up water.

The use of cooling towers for condenser water recycle usually presents a potential problem in the growth of slime-producing organisms in the tower packing. In the presence of small amounts of sugar and other nutrients, and with warm temperatures, such growths are difficult to avoid, however, they are usually controllable by chlorination of the cooling-tower feed. The tendency of sugar liquors to foam requires efficient vapor entrainment separators in order to preclude the loss of significant quantities of sugar to the condenser water (28). The entrainment produced by boil-over and foaming can produce substantial shock loading of BOD_5 in the effluent condenser water. These two hazards necessitate careful and frequent analyses of condenser water for sugar in order to obviate the problem. The installation and utilization of superior entrainment separators and mist eliminators will aid materially in the reduction of condenser water contamination by sugar.

The additional use of level controllers on some equipment will assist materially in reducing contamination that originates from human error.

Miscellaneous

Various sources of wastewater, other than those previously described, are generated in a beet sugar plant. These waste sources are of less importance in load and volume than those previously described, and result from gas scrubber washing, miscellaneous cooling waters, flyash, juice water, waste water from cleaning of boilers, and floor washing.

Potable quality water is not necessary for gas washing purposes, but a sizeable volume of water is used. Crane of the British Sugar Corporation reports the reuse of clarified flume water in the gas washer, after which it is returned to the unclarified flume water portion of the system.

Crane also notes that selected cooling waters such as those used for cooling turbine oil can be recirculated through a separate cooling tower. Many of the other cooling water streams may be recycled to the main cooling tower and reused. Where furnace ash (flyash) is conveyed with water, a complete recirculatory system is reported, and a separate settling pond is provided where the water is decanted and recycled.

Periodic (weekly or biweekly) cleaning of pan evaporators to eliminate accumulated scale is accomplished by using caustic soda followed by acid treatment in the cleaning process with the discharge of "boil-outs" generally being sent to the flume system or lime mud slurry pond.

The primary source of water for miscellaneous use results from condensate and condenser waters.

Process Flow Diagrams

A schematic diagram of the beet sugar processing operation is given in Figure II. The flow diagram reflects a situation in which no recirculation or treatment of individual waste water streams is practiced and corresponds with the waste loads given in Table VI. The hypothetical plant includes the Steffen process. The three pulp waters (pulp screen water, pulp press water, and pulp silo drainage) are commonly referred to as process water. Since the stipulated conditions are without recirculation, maximum conditions of water requirement and waste water disposal are indicated.

A schematic of materials flow in a common recirculation system of a beet sugar processing plant is indicated in Figure III. Variations in this scheme of recycling waters as practiced within present plants are indicated in Figures IV through VI. The diagrams are presented with emphasis on direct process related uses of water within the beet sugar processing plant. Other water uses (e.g. boiler supply water, hot water for floor and evaporator cleaning, gas washer water, etc.) are not indicated on the diagrams for sake of simplicity. Boiler supply water, diffuser make-up, and hot water for cleaning purposes are supplied through in-plant water reuse of fresh water sources (primarily the purer condensate waters from juice evaporation). A more detailed description of other water uses are included in Mass Water Balance in a Beet Sugar Processing Plant, Section VII of this document.

Figure IV represents a water flow scheme in the industry. In this type all the fresh water is used in the barometric condensers of evaporators and pans, for miscellaneous cooling, and at Steffen plants for dilution of molasses. Spent condenser water is used for fluming and washing beets, for makeup in the diffuser and for other purposes. Plants employing this sequence of water use are equipped with continuous diffusers, pulp screens, pulp presses, and pulp driers. Pulp press water is returned to the diffuser. Settling ponds for removing soil from spent flume water and ponds for collecting lime mud are provided. The overflow from ponds and any excess condenser water may be discharged to streams.

Figure V represents a flow pattern involving more complete reuse of water. Fresh water, as represented in Type I, is used only in evaporator and pan condenser; for some miscellaneous cooling and at Steffen plants for dilution of molasses. During the campaign, flume water, after screening, is pumped to settling ponds and, after more or less complete removal of settleable solids, is returned to the flume. Water from the evaporator and pan barometric condensers is used as makeup water in the diffuser, in the beet washers and in sprays. Pulp water and pulp press water are returned to the diffuser. Lime mud is pumped to a separate lime pond. Most of the condenser water is cooled by cooling tower or spray pond and recycled to condensers. Steffen waste is evaporated to concentrated Steffen filtrate.

Figure VI represents an extensive recirculation pattern of flow, except that at the end of the operating campaign, ponds may be drained to municipal sewage treatment plants or land disposal.

TABLE VII

CHARACTERISTICS OF BEET SUGAR PROCESSING PLANT WASTES [1]

Characteristic	Flume Water	Barometric Condenser Water	Pulp Screen Water[8]	Pulp Press Water	Pulp Silo Drainage	Total Process Waste Water	Lime-Cake Slurry	Lime-Cake Lagoon Effluent	Steffen Waste	General Water Analysis
Volume, gal/ton	2200[3]	2000[5]	400[5]	180[5]	210[5]	660[3]	90[5]	75[5]	120[3]	
Beets	2000-3000[2] 2600[5]	2400 [1]				325[2]	75[3]			
BOD, mg/l	200[3] 200[2] 210[5]	40[5] 30[7]	910[5] 1020[2]	1710[5]	7000[5]	1230[3] 1600[2]	8600[5] 1420[3]	1420[5]	10,500[5] 10,000[3]	445[4]
Suspended solids mg/l	800[3] 400[2] 800-4300[5]	77[7]		420[5]	270[5]	1100[3] 1300[2]	120,000[5]	450[3]	700[3] 100-700[5]	4920[4]
Total solids, mg/l	1580[3]	153[7]				2220[3] 3800[2]	3310[3]		43,600[3]	6470[4]
Volatile solids, %	35[2]	86[7]				75[2]				
COD, mg/l	175[2]					1500[2]				
Protein-N, mg/l	10[2]					65[2]				
NH_3-N, mg/l	3[2]	6.8[7]				15[2]				
Kjeldahl Nitrogen mg/l		9.4[7]								
Nitrite Nitrogen mg/l		2.6[7]								
Nitrate Nitrogen mg/l		0.2[7]								
Total Phosphorus mg/l		0.06[7]								
Color		5[7]								
Turbidity		16[7]								
Sulfate, mg/l		105[7]								
Chloride, mg/l		35[7]								
Sucrose, mg/l	100[2]					1500[2]				
Dissolved solids mg/l	780[7]	780[7]				1120[3]	2850[3]		42,900[3]	
pH		8.5								7.9
Alkalinity, mg/l		296[7]								250[4]
Temperature, °C		39[7]								
Total coliform MPN/100ml.		1424[7]								
Fecal coliform MPN/100ml.		143[7]								
Fecal strep. MPN/100ml.	1354[7]									

(1 Represents typical characteristic values of beet sugar wastes prior to treatment

(2 As reported by Pearson, E., and C. N. Sawyer, "Recent Developments in Chlorination in the Beet Sugar Industry," Proceedings of 5th Industrial Waste Conference, Purdue University (November 1949) p.110.

(3 As reported by Elridge, E.F., Industrial Waste Treatment Practice, New York - McGraw-Hill Book Co., Inc., 1942, p. 84.

(4 As reported by Rodgers, H.G., and L. Smith, "Beet Sugar Waste Lagooning," Proceedings of 8th Industrial Waste Conference, Purdue University May 1953, p. 136.

(5 As reported by U.S. Public Health Service, "An Industrial Waste Guide to the Beet Sugar Industry," 1950 (48)

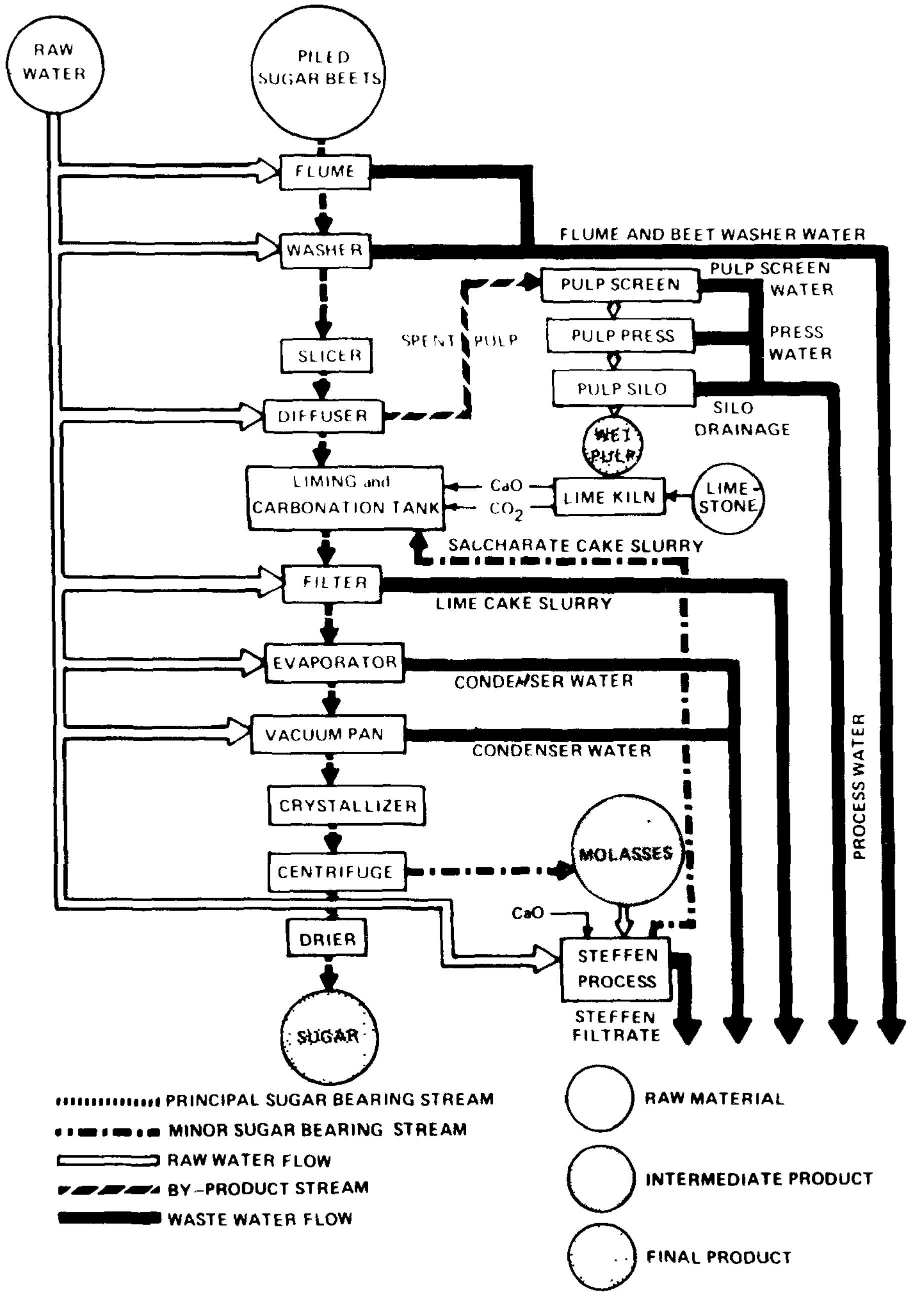
(6 Water - transported pulp in lieu of mechanical conveyor.

(7 As reported by Brenton, R.W., Condenser Water Survey, 1971 - 1972 campaign for beet sugar processing plants of The Great Western Sugar Co., March 1972 (47).

(8 Use of continuous - type diffusers is assumed - a universal practice in the industry today.

Figure II

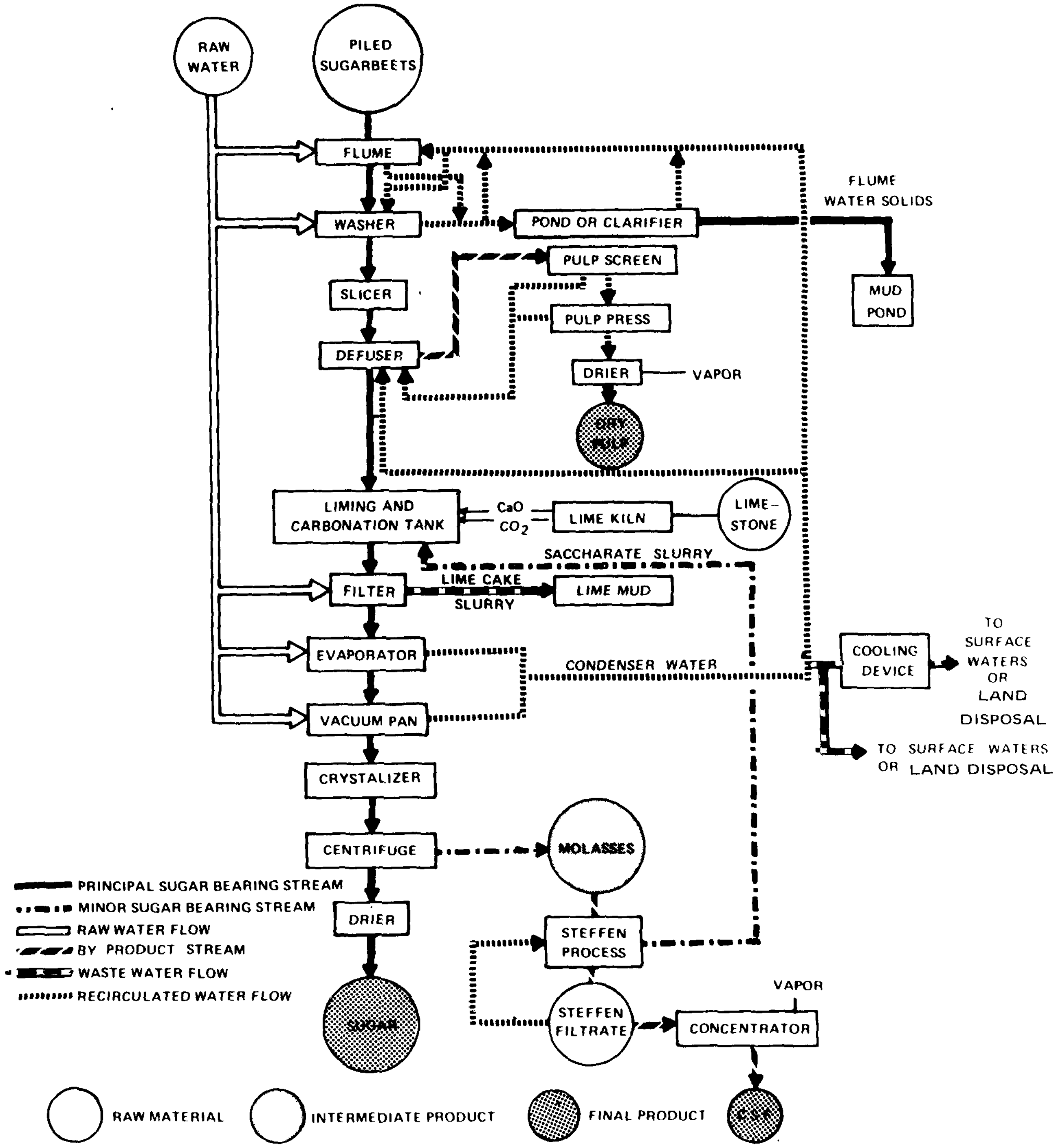
MATERIALS FLOW IN A BEETSUGAR PROCESSING PLANT WITH NO RECIRCULATION OR TREATMENT OF WASTE WATERS--- STEFFEN PROCESS [1]



[1] As taken from Beet-Sugar Technology, Second Edition, Edited by R.A. McGinnis, Beet-Sugar Development Foundation, Fort Collins, Colorado (1971) (65)

Figure III

MATERIALS FLOW IN BEET SUGAR PROCESSING PLANT WITH TYPICAL WATER UTILIZATION AND WASTE DISPOSAL PATTERN [1]



[1] As taken and modified from Beetsugar Technology, Second Edition, Edited by R.A. McGinnis, Beetsugar Development Foundation, Fort Collins. Colorado (p 645), 1971, (65)

Figure IV

WATER FLOW DIAGRAM FOR A BEET SUGAR PROCESSING PLANT WITH MINIMUM RECYCLE OR REUSE

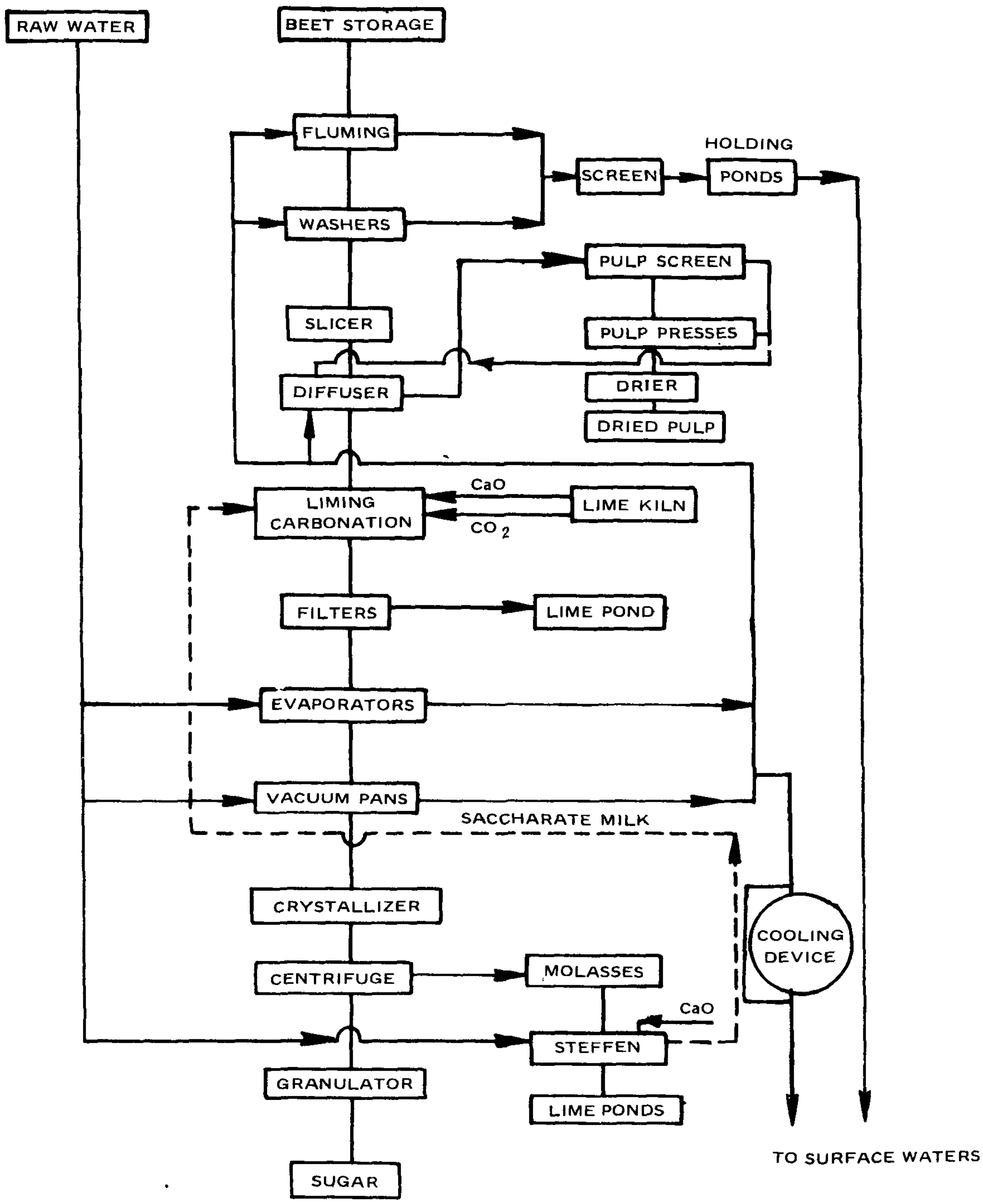


Figure V

WATER FLOW DIAGRAM FOR A BEET SUGAR PROCESSING PLANT WITH SUBSTANTIAL IN-PROCESS RECYLE AND REUSE

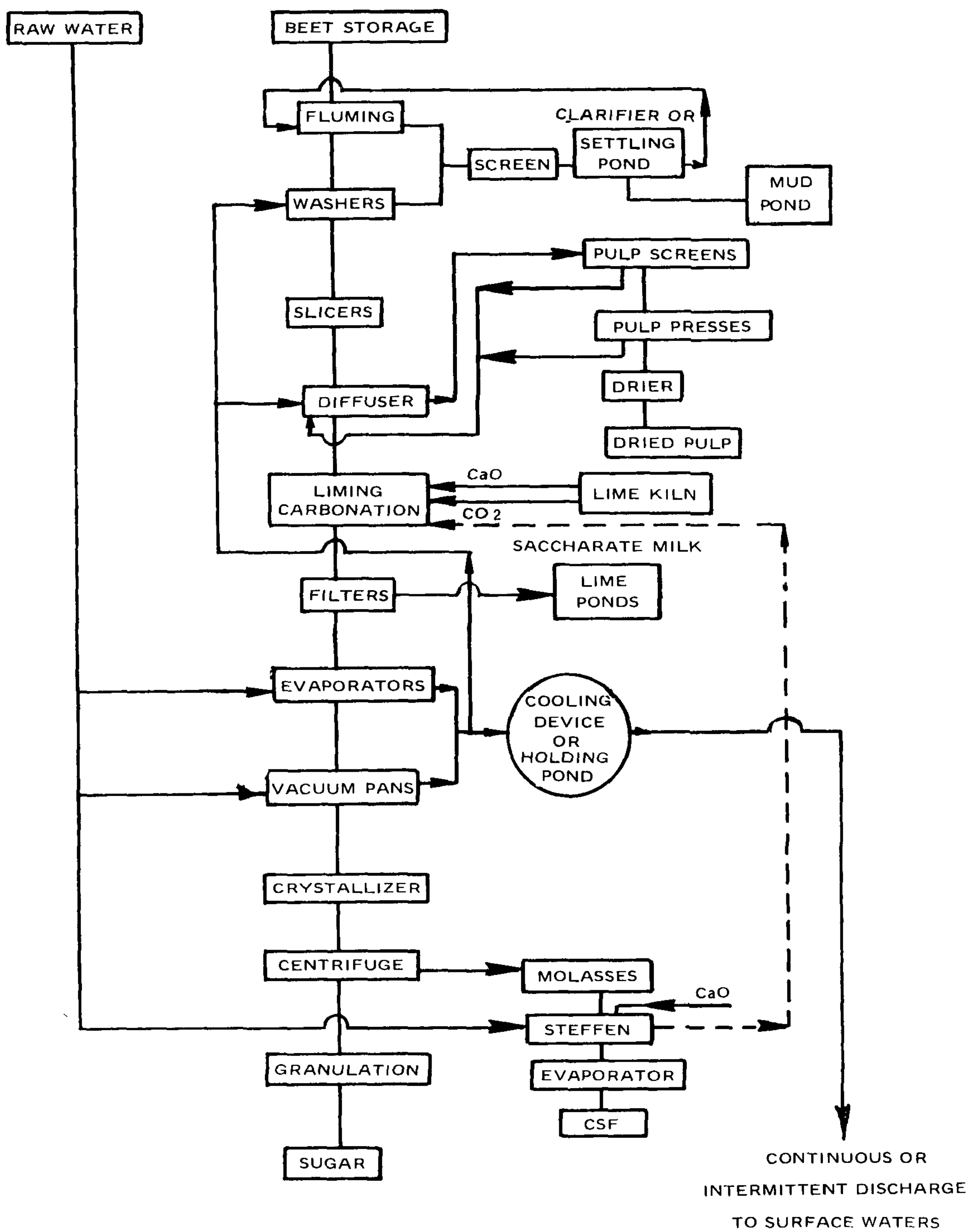
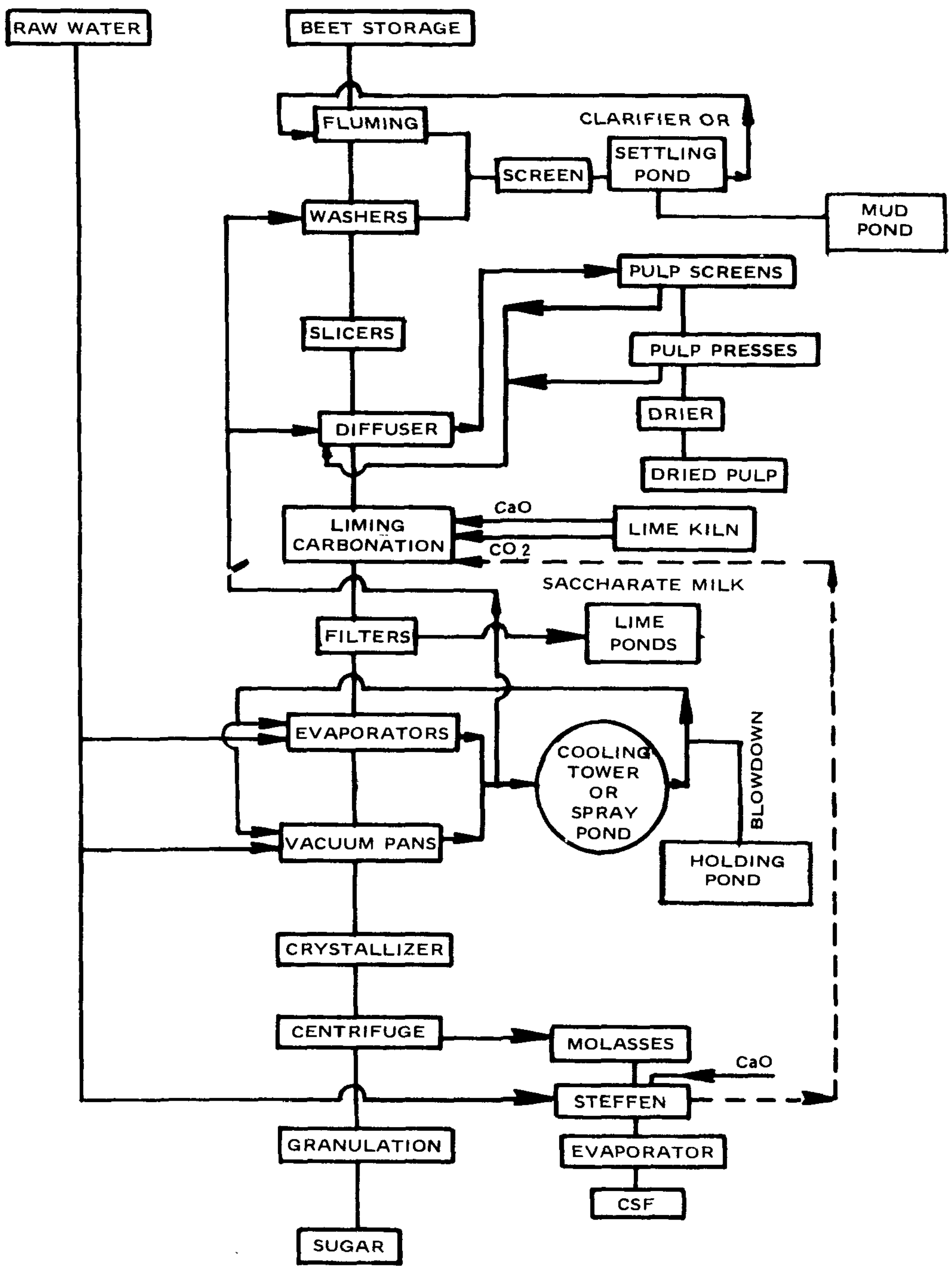


Figure VI

WATER FLOW DIAGRAM FOR A BEET SUGAR PROCESSING PLANT WITH MAXIMUM IN-PROCESS AND DISCHARGE CONTROLS



SECTION VI

POLLUTANT PARAMETERS

Major waste water parameters of pollutional significance for the beet sugar processing segment of the sugar processing industry include BOD5 (5-day, 20°C Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), fecal coliforms, pH, SS (Suspended Solids), alkalinity, ammonia nitrogen, total nitrogen, total phosphorus, TOC (Total Organic Carbon), total coliforms, and TDS (Total Dissolved Solids). On the basis of all evidence reviewed, there does not exist any other pollutants (e.g., heavy metals, pesticides) in wastes discharged from beet sugar processing plants. The use of waste water recycle systems with land disposal of excess waste water are capable of accomplishing zero discharge of all pollutants to navigable waters.

Waste parameters for the beet sugar processing segment of the beet sugar processing industry are discussed below.

Biochemical Oxygen Demand (5-day, 20°C (68°F) BOD5)

This parameter is an important measure of the biologically degradable organic matter in the waste, and is a widely used criterion for pollution control. Under improper land disposal techniques, pollution of ground water may result from inadequate filtration control or location. The equilibrium concentration of BOD5 in a completely recycled flume water system is generally found to be quite high (6,000 to 7,000 mg/l).

Bacteriological Characteristics

The South Platte River Basin study confirmed that the source of coliform organisms in flume waters is attributable to animal manures spread on fields where sugar beets are grown. Because of the origin of the organisms, it is likely that the indicator coliform organisms reflect the existence of pathogens in the wastes: Salmonella organisms have been isolated in flume (beet transport) wastes.

Bacteriological characteristics of flume water present no sanitary problems in the production process. In production, high pH conditions maintained in the recycled flume water system, final fresh water wash of incoming beets, use of biocides in the diffuser for pH control, and subsequent destruction of all bacteria in the evaporation process satisfactorily limit and control bacterial growth for production purposes. If fecal coliform bacteria are present in surface waters which serve as the water supply for condensers, prolific bacterial growth will occur in the heated condenser water with the normal concentration of organics through vapor entrainment. Bacteriological qualities of waste waters are not normally a pollution problem where inplant recycle, waste retention and land disposal are practiced. A problem of pollutional concern in ground waters may arise in the absence of necessary controlled filtration procedures with land disposal of waste waters. However, no ground water pollution problems are presently known to exist as directly attributed to land disposal of beet sugar processing wastes. At present, a large portion of the waste waters of the industry are disposed of on land in the absence of control filtration procedures.

pH

pH is a very important criteria for frequent measurement in providing in-process quality control (pH between 8 and 11) for efficacious recycling of flume water. High pH conditions help to control odors and inhibit bacterial growth. The pH condition of the waste water relates to the quality of waste water as affecting the growth of natural biota in the disposal environment, as well as the aesthetic value of waters for industrial use and human consumption.

Temperature

The temperature of condenser waters leaving the pan evaporation and crystallization process may approach 65°C (149°F). Where adequate cooling devices are provided for the heated condenser water (often with additional cooling provided by fresh water addition through well or surface water supplies) extensive recycling without surface or ground water pollution can result. However, if water at or near this temperature does reach surface or ground water formations, potentially serious imbalances in micro-ecosystems can occur with upsets of chemical equilibrium.

Heated waste discharges to surface waters create a variety of thermal pollution effects including adverse modification of the aquatic flora and fauna environment with the accompanying increase in the rate of biological reactions, and possible permanent temperature elevations over considerable stream areas with continued added thermal loading. Thermal conditions have considerable effects on the concentration of dissolved oxygen, the biochemical reaction rate, pH, and the physical activity of aquatic animals. Cooling of barometric condenser waters is necessary prior to discharge to navigable waters.

Alkalinity

Alkalinity is a measure of the presence of bicarbonate, carbonate and hydroxide ions in waste water. Alkalinity of beet sugar processing waste results from the addition of lime in flume water systems and from ammonia entrainment in barometric condenser waters. As far as is known, the alkalinity of water has little sanitary significance. However, highly alkaline waters are unpalatable, and disruptive to water treatment systems.

Ammonia Nitrogen and Other Nitrogen Forms

Ammonia nitrogen is present in barometric condenser waters (3 to 15 mg/l as nitrogen under best operation) due to vapor entrainment in barometric condenser waters. With progressive oxidation, ammonia is converted to nitrate nitrogen.

The U. S. Public Health Service (77) recommends that nitrate concentrations in ground water supplies not exceed 10 mg/l nitrate as nitrogen.

Amonia nitrogen in effluent has several undesirable features:

(1) Ammonia consumes dissolved oxygen in the receiving water;

(2) Ammonia reacts with chlorine to form chloramines which are less effective disinfectants than free chlorine;

(3) Ammonia has possible deleterious effects on fish life;

(4) Ammonia is corrosive to copper fittings;

(5) Ammonia increased the chlorine demand of waters for subsequent treatment;

Ammonia may be reduced in waste waters by physical methods and converted to nitrates by biological oxidation. A nitrified effluent,free of substantial concentrations of ammonia, offers several advantages:

(1) Nitrates will provide oxygen to sludge beds and prevent the formation of septic odors;

(2) Nitrified effluents are more effectively and efficiently disinfected by chlorine treatment;

(3) A nitrified effluent contains less soluble organic matter than the same effluent before nitrification.

Ammonia and nitrate are interchangeable nitrogenous nutrients for green plants and algae, as well as bacteria. At the present time, predictive generalizations cannot be made for the response of algae to nutrients for all receiving waters. Different geophysical systems appear to be responsive to different limiting nutrients. The nitrogen content of natural unpolluted waters is normally less than 1 mg/l, and during the growing season, soluble nitrogen compound are virtually completely depleted by growing plants and algae. Ammonia is rapidly adsorbed by soil minerals and particulate matter containing nitrogen is also effectively removed in the soil. However, if there is not sufficient plant growth in the soil to use the bound ammonia, it will be converted to nitrates by nitrifying bacteria.

Total Phosphorus

Phosphorus is found in flume waters as associated with incoming soil on beets and in condenser waters due to addition of de-scaling chemicals and entrainment of vapors from barometric condensers. Phosphorus is often a contributing element in the eutrophication of lakes and streams, having a "threshold" concentration" of about 0.01 mg/l or less. Where filtration of beet sugar processing wastes to water bodies is possible, phosphorus may be of concern. Even though phosphorus is readily absorbed tenaciously on soil particles once in sediment or benthos, the phosphorus may desorb to become an available nutrient. Surveys by Brenton indicate a total phosphorous concentration in condenser waters of 0.06 mg/l.

Total Dissolved Solids

Total dissolved solids in recycled flume and condenser waters reach a very high equilibrium level of approximately 9,000-11,000 mg/l. Periodic with drawal of recirculated waste water is required to maintain the equilibrium concentration. Seepage from land disposal in waste holding facilities may increase total dissolved solids levels of ground waters or subsequently, surface water sources. The amount of dissolved solids present in water is a consideration in its suitability for domestic use. Waters with total solids content of less than 500 mg/l are most desirable for such purposes, and is recommended whenever possible by the U. S. Public Health Service. Waters having higher solids content are often associated with catharic effects upon humans without acclimation. Water with natural dissolved solids concentrations greater than 500 mg/l have not been known to cause humans to experience ill effects. In potable waters, most of the solids matter is in dissolved form and consists mainly of inorganic salts, small amounts of organic matter, and dissolved gases. The total solids content of potable waters usually ranges from 20 to 1,000 mg/l and, as a rule, hardness increases with total dissolved solid content. The U. S. Public Health Service Standards recommend a limit of 1,000 mg/l of total dissolved solids for potable waters.

Ground waters are generally higher in dissolved solids than surface waters. The average concentration of dissolved solids is quite variable in surface waters that range from about 60 to 70 mg/l in major rivers of the United States. The total dissolved solids content of some inland brackish waters exceeds 1000 mg/l (87).

The total dissolved solids contained in the underflow "blowdown volume of an extensive recycle flume water system is due to the concentration of primarily sodium and potassium salts. Brackish water that contains appreciable amounts of sodium ions are known to interfere with the normal behavior of soap -an effect commonly referred to as pseudo-hardness.

Suspended Solids

Suspended solids as a parameter in completely recycled waste water systems serve most importantly in measuring the efficiency of solid separation devices such as mechanical clarifiers or earthen holding ponds for flume water. The performance of these settling measures are reasonably reliable and dependable. The suspended solids criteria has less importance in determining efficiency of settling, but more importantly for use as a control measure in determining the quantity of soil conveyed to the plant on incoming beets and subsequently transferred to the beet transport (flume water).

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

Introduction

Current technology for the treatment and control of beet sugar processing wastes does not provide a single scheme that is applicable to all geographical areas. The major treatment and disposal methods applicable to beet sugar processing wastes include reuse of wastes, coagulation, waste retention ponds or lagooning, and methods of irrigation.

In "arid" climates (California and Arizona), climatic conditions are favorable to permit no discharge of waste waters to navigable waters through land disposal. The waste waters are usually treated in waste stabilization lagoons for subsequent irrigation purposes or are contained in open earthen holding ponds where the waste water is eliminated largely by evaporation and soil filtration.

Detailed studies and previous efforts at various plants in the South Platte River Basin for treatment of beet sugar processing wastes (primarily through land spreading, aeration fields and waste holding ponds) have generally proven to be ineffective in obtaining waste water effluents of suitable quality for discharge without detrimental effects on receiving streams. The problems resulted from the unadaptability to the regional climatic conditions, physical design limitations of installed units, and poor operating and maintenance practices.

Pollution loads of wastes have been reduced by better control of inplant practices; reuse of some wastes as process water; recirculation of flume, condenser and other waste waters; screening; settling; waste water retention; and waste treatment in waste stabilization ponds.

The proper design, operation and maintenance of all waste treatment processes and pollution control facilities are considered essential to an effective waste management program. Awareness of the problem and priority recognition are necessary ingredients in an effective pollution control program. The 1971 FWPCA report of the beet sugar industry in the South Platte River Basin includes a discussion of recommended staffing patterns requisite to adequate waste water and process management.

In-Plant Control Measures and Techniques

In-plant control measures are extremely important in the overall scheme for pollution control of beet sugar processing wastes. These measures include the proper handling of sugar beets prior to reaching the plant, design of beet flume systems to facilitate dry-handling techniques, process water reuse, dry methods for handling lime mud cakes, conversion of Steffen filtrate to usable end-products, and the reuse and recovery of various flows in the beet sugar plant.

Handling of Sugar Beets

Although handling of the beets in the field and enroute to the plant are not strictly part of in-plant operations, these procedures are directly related to the waste disposal problems at the plant, and therefore warrant special attention. A major item of concern in handling of beets at the plant is the large quantities of soil brought into the plant with the incoming beets. The sugar processors, however, generally consider production factors, beet condition and sugar content to be of greatest concern.

The soil and associated trash become part of the plant waste and may, without proper control, eventually enter the receiving waterbody. Increased mechanization on the farm, mechanical harvesting of the beets, and harvesting during wet soil conditions has led to increases in amounts of tare accumulated at plants. Some solid waste or tare is removed by shaking and screening prior to processing, and it is returned to the beet delivery source. However, the large majority of delivered soil enters directly into the plant through the flume system.

To aid in waste abatement, a change in the method of harvesting and delivery of sugar beets to the plant is suggested. The removal of soil, leaves, and trash in the field would provide the plant with the cleanest possible raw product and tend to solve many present problems. Without adequate control measures, late season irrigation and wet-field harvesting contribute to increased waste treatment needs and cost of settling devices in complete recycled flume water systems. Many, if not all, beet sugar processors possess sufficient influence to require that proper measures be taken to reduce soil in the fields. Dry tare removal techniques are highly desirable but may result in some undetermined increase in harvesting costs. However, if extensive plant waste treatment or retention facilities are to be relied upon for removing these solid materials, the results will undoubtedly be even more costly and less efficient.

Whereas storage of beets in northern climates is necessary because of the short growing season, storage of beets prior to processing is generally not practiced in California and other southern climates of the U. S. There the beets are processed directly after shipment from the field. Storage of the beets in these areas for any length of time (days) results in a loss of sugar content of about 1 kg of sugar/kkg of beets sliced (2 lb/ton of beets sliced.)

Deterioration of the sugar beets within storage can be minimized by maintaining proper conditions in the stockpiles and reducing storage time as much as possible. More care should be given to preventing damage and breakage of the beets, and in this regard, the mechanical equipment and handling procedures for loading and unloading appear to suggest improvement needs. These measures are highly important for reducing pollution loads in the beet flume water.

A satisfactory method for storing beets for long periods has not yet become available for general use. The operation of the plants is therefore intermittent, and the sugar is extracted during a seasonal "campaign" of about 100 days duration mainly in the months of November through January in the greatest portion of the United States.

The Beet Fluming System

In recent years, many plants have reduced their available beet storage facilities, shortened their fluming system and integrated a truck delivery and a truck hopper installation on the processing line. Other plants have provided belt conveyors for transporting beets at least part of the way into the plant. Either minimum contact time between the sugar beets and the flume water, or dry handling procedures, serve to reduce the waste loads imposed upon the beet flume system. At least two plants have significantly reduced waste loads by this process (1).

From the standpoint of production, hydraulic fluming is an effective and expedient means of transporting and cleaning the beets, and of thawing frozen beets in the extreme northern climates. One disadvantage of this technique is the loss of sugar to the flume waters. An additional pollution control measure is the complete dry handling of beets until they reach the washer. Beets may receive mechanical shaking or scrubbing for removing most of the dirt and solids followed by high pressure spray jets at the washing table. Dry handling, however, can be a serious disadvantage in colder climates where flume waters promote necessary warming and thawing of sugar beets. If hot exhaust gases and steam are generally available at the plant, they may possibly be adaptable for satisfying this requirement.

The typical flume water recycling system, as is commonly used within the beet sugar industry, is judged a relatively inexpensive means of providing treatment for reuse and retention of flume water. Plants that recycle flume water have demonstrated that the suspended solids concentration of the waste are very amenable to gravity clarification, especially if lime is added. Land is required for the settling device and for the disposal of sludge removed from the clarification facilities. Mechanical clarifiers are preferred to earthen holding ponds for the settling and clarification of flume water because of reduced land area requirements, increased efficiency of solids removal, and better control of the chemical and physical characteristics of the recycled flume water. Odors can generally be controlled to acceptable levels with the addition of lime to maintain alkaline conditions (pH above 10).

Reuse of Process Water

The reuse of processing waste waters (pulp press water, pulp transport water, wet pulp screen waters) has been one of the better areas of waste source elimination by the industry. Process waters are reused for a variety of in-plant needs, although the general practice is to return them to the diffuser. The favorable economics in producing dry exhausted beet pulp for an established animal feed market, and additional sugar recovery obtainable through reuse of process waters have contributed in large part to this change.

The continuous diffuser has replaced multiple diffusion cells and created flexibility in process water reuse by significantly reducing the volume of waste waters generated as a result of the diffuser system. A continuous diffuser consists of an inclined cylinder in which hot water flows downwards by gravity while the beet cossettes are moved in the opposite direction by means of paddles. These spent cossettes are discharged continuously at the upper end of the diffuser. Process water return to the continuous diffuser requires careful control and in some cases, treatment. Although some decrease in processing rate may be experienced by use of continuous diffusers, these factors are offset by increased sugar recovery gains.

Pulp transport water has been eliminated in many plants by a dry conveyor system which moves exhausted pulp to the presses. Return of pulp press water to the diffuser is a universally accepted practice today. The quantity of pressed water obtained varies with the efficiency of the pressing operation.

Not all beet sugar processing plants return pulp press water to the diffuser, however, a few plants with full pulp pressing and drying facilities continue to discharge press waters to the drain rather than reuse them. The pulp press is effective in reducing the water content of the exhausted beet pulp from 95 percent as the pulp leaves the diffuser to 80 percent moisture from the presses.

Virtually the entire industry is now equippped with pulp drying facilities. The one remaining plant employing a wet pulp disposal through use of a pulp silo (Torrington, Wyoming) is scheduled for replacement of the silo with a pulp drier by October 1973. With installation of a pulp drier at this plant, pulp silo drainage water as a polluting source will have been completely eliminated. In addition to reducing a substantial waste disposal problem, pulp drying equipment can usually be justified economically. Dried pulp yields from a beet sugar plant average about 60 kg/kkg (120 lbs/ton) of beets processed. With molasses addition, the yield is about 75 kg/kkg 75 kg (150 lb/ton) This pulp is generally sold as a source of livestock feed. The price of pulp varies on the competitive market with grains but is presently selling for about $66/kkg ($60/ton) for use as livestock feed in early 1973.

Handling of Lime Muds

Handling of lime mud wastes has been associated with problems of fermentation and noxious odors at many plants. The calcium carbonate sludges are generated from "juice" purification and other operations within the beet sugar plant. Lime mud cake is recovered from vacuum filters at approximately 50 percent moisture content. The usual practice consists of adding water to the lime mud cake thereby producing a slurry which is easily transported by pumping to disposal locations.

Various techniques are presently in existence for the handling and reuse of lime mud slurry wastes. The general procedure is to dispose of the slurry through complete retention in an earthen holding pond. At the Manteca, California plant the deposited lime mud cake is recovered from the pond and recalcinated for reuse within the process. A similar procedure is employed at the Mendota, California plant in which a portion of the lime mud slurry is dewatered and recovered through a centrifuge operation while the remaining lime mud slurry is contained in a holding pond. At the Arizona plant, lime mud is handled by a low water dilution/air pump conveyance for movement to holding facilities rather than by the conventional method of slurring. Other plants project the use of similar conveyance facilities in the near future. A number of plants in Europe and Canada also employ dry means of disposal.

All plants presently impound waste lime mud generally in separate holding ponds. The lime mud pond must be sufficiently large and the lime mud as concentrated as possible so that pond size, with normal evaporation and seepage will permit complete containment. Lime mud pond discharge is an extremely strong waste, and discharge to receiving water bodies can not be permitted. In some plants excess lime mud pond water is recirculated to the fluming system. The industry commonly uses a single storage pond for lime mud, whereas European practice is to employ separate ponding of the settled solids and the supernatant.

Problems of fermentation and noxious odors have been associated with the long-term holding of lime mud wastes, but these can be avoided with a sufficiently shallow depth pond - optimum of 0.5 m (1.5 ft) for odor control. Allowing accumulated lime mud to dry by containment in holding ponds is commonplace. The industry is presently experimenting with lime reclaiming and reuse systems for recovery of solid lime waste. The lime mud may be recovered for use as a sweetener on acid soils. Studies have also been directed to the reuse of burnt lime residue within the plant and in the manufacture of cement and related products. The cost of these methods must be balanced against those of waste abatement and treatment costs that can be expected at the individual plant.

At one plant lime cake is dried in a kiln, pulverized, and optimum moisture content for land spreading is maintained at about 17 percent. A ton of lime mud filter cake may contain 3.2 kg (7 lb) organic nitrogen, 5.9 kg (13 lb) phosphoric acids, .91 kg (2 lb) potassium, and 200 kg (440 lb) organic matter (13).

Steffen Filtrate Conversion

Steffen filtrate generated in the Steffen process is generally converted to concentrated Steffen filtrate (CSF) and added to dried pulp as a component in animal feeds. An exception in one operation is that the Steffen waste is spread under controlled conditions within a 8.1 hectare (20 ac) holding pond for disposal.

Beet pulp with the addition of concentrated Steffen waste at most plants is presently sold for livestock feed at approximately $60/ton of pulp. However, the amount of concentrated Steffen filtrate which can be added to beet pulp for livestock feed is limited by the high ash content of the filtrate waste.

Barometric Condenser Waters

The beet sugar industry has demonstrated that waste water associated with the condenser can be reused in the sugar manufacturing process. These waters may be used for feed to the boilers, diffuser makeup water, raw water supply, beet flume recirculation system makeup, lime mud slurrying, gas washing and for miscellaneous uses. Many such uses for condenser water are made at plants exhibiting recycling and complete retention technology.

Entrainment of organic matter in condenser water requires careful control of the specific unit operation. However, entrainment separators on evaporators and vacuum pans are effective in greatly eliminating entrainment into condenser water. Most plants within the industry presently employ some type of entrainment control device. Condenser waters may be detrimental to the receiving water because of temperature reaching as high as (65°C) (149°F) and the almost complete absence of dissolved oxygen.

Where adequate water supply is available, the condenser waters are seldom recycled. In some areas, the waters are first passed through cooling devices and the pH level is controlled before subsequent disposition. Under normal operating conditions, the BOD_5 content of condenser waters may be as low as 15-30 mg/l. However, BOD_5 levels actually discharged to receiving waterbodies in excess of 100 mg/l have been documented. This was a result of careless operation and inadequate control procedures.

Treatment of condenser waters on a one time use basis (without recycling) is not judged technically or economically feasible because of the large volume and relatively low pollutant concentrations. Cooling towers or spray ponds may be used to permit recycling of condenser waters, and minimize total plant water use while containing discharge. The highest degree of control is represented by recycling the condenser waters in a separate system. A dual closed-loop condenser water system was recently installed at one plant. One system is employed to supply heated water for fluming purposes; the other system serves to cool the condenser water for recycle with makeup from fresh water sources.

In open recirculating systems, the evaporation of water in cooling ponds or towers increases its dissolved solids concentration, while windage loss removes dissolved solids from the system (108). Evaporation loss generally accounts for about 1 percent for each drop in temperature of 5.6°C (10°F) through the pond or tower. Windage losses are 1.0 to 5.0 percent for spray ponds, 0.3 to 1.0 percent for atmospheric towers and 0.1 to 0.3 percent for mechanical draft cooling towers. The mineral concentration can be held within desired limits by bleeding recirculating water from the system, or by softening or demineralizing the make up water. Slime and algal growths in condensers and heat exchangers may seriously impair their effective operation. Control of such growths is generally accomplished by the addition of cooling waters chemicals such as chlorine that will either prevent the formation of growths or destroy existing growths. Chlorine may be added intermittently to the system in an amount that will produce an excess of several milligrams per liter of free available chlorine for a short period to prevent slime growths. The free chlorine is readily removed from the recirculated water through the evaporative cooling process for temperature reduction.

Water Use and Waste Water Management

Experience within the industry has shown that proper management, design, construction, operation, and maintenance of waste treatment and disposal facilities all contribute to an overall efficiency in plant operation.

A broad spectrum of water reuse and waste disposal practices presently exists in the beet sugar industry throughout individual plants in the U. S. and abroad. In-plant measures have proven more effective than end-of-process waste treatment in contributing to a successful waste management program.

In recent years, the industry has recognized its responsibilities for pollution control and has begun programs to substantially reduce the pollution impact through improved waste management, design of facilities, reuse of waste water, flow reduction measures, and other pollution control devices.

Proper planning and design of treatment and control efforts is mandatory. Structures which bypass treatment or disposal sites should be eliminated. Similar structures for bypassing treatment to land disposal or standby storage should be designed with positive reliable controls to serve only in emergency. The facilities must provide for intercepting various spills and unintentional waste discharges and returning these to the waste treatment or disposal system. Proper compaction and construction of waste treatment lagoons and holding ponds are necessary to afford satisfactory treatment and to properly control land disposal of process waste waters.

Once the waste control and treatment facilities are established, operation and maintenance of these facilities are most important. All devices and procedures intended for waste abatement should be considered as important as the process operations.

The importance of good administrative control and plant records must also be emphasized in relation to the waste water control program. Without proper administration, a program will suffer serious shortcomings; a logical division of responsibility and organized approach are necessary. A successful program requires that lines of authority and responsibility be fully delineated and that each person clearly understand his explicit responsibilities. The importance of prescribed format of data gathering and recording is considered essential to a well-functioning pollution control program.

Treatment and Control Technology

Current Treatment and Control Practices Within the Industry

Classification of waste treatment and disposal techniques at the various beet sugar plants is difficult, since such practices range from little treatment to treatment, storage and land disposal of all wastes. Procedures for reduction of BOD_5 differ in principle, some companies rely chiefly on anaerobic fermentation in deep holding ponds; others on aerobic bio-degradation in shallow ponds with or without mechanical aeration. Presently, a total of 12 beet sugar processing plants handle all waste waters through extensive in-plant recycling and reuse and land disposal of waste holding ponds, stabilization lagoons or by irrigation. In California, use is made of lagoon contents in many cases for irrigation of crops. No effects on water quality are identifiable or attributable to this practice as the waste is completely disposed of on the land and precluded from entrance to surface waters. Plants presently accomplishing the level of technology resulting in zero waste water discharge to surface waters are located at Moses Lake, Washington; Hereford, Texas; Brawley, Spreckels (Salinas), Betteravia, Manteca, Mendota, Tracy, Woodland and Hamilton City, California; Chandler, Arizona; and Goodland, Kansas.

In general, plants in the North Central portion of the United States (Montana, Wyoming, Nebraska and Colorado) and in Michigan and Ohio have reported relatively higher amounts of BOD_5 per unit weight of beets sliced as discharged to streams. This generally is attributable to less favorable soil and climatic conditions for land disposal, location of plants near developed areas, and/or smaller and older plants generally located in these regions. Notable exceptions are the plants at Longmont, Eaton, and Brighton, Colorado. Present treatment and control practices characteristic of the industry are summarized in Table VIII entitled "Summary of Selected Pollution Control Practices at Beet Sugar Processing Plants." The practices summarized in Table VIII are applicable to individual beet sugar processing plants for handling and disposal of flume (beet transport) water and condenser water. These two waste sources are presently those of remaining primary importance within the industry. Process waters (pulp press, beet transport and pulp silo drainage) have been eliminated as a waste source by in-plant recycling or dry pulp transport. One plant still employes a silo for drainage of wet beet pulp. However, the silo is scheduled for replacement by

October, 1973. All other plants employ pulp dryers for handling exhausted beet pulp. Lime mud is universally discharged to holding ponds without discharge to surface waters. Steffen waste (Steffen process only) is concentrated for addition to dried beet pulp or disposed of on land in isolated cases without discharge to surface waters. Miscellaneous waste waters (floor drainage, gas washer water, chemical wastes from cleaning of evaporators and crystallizers, etc.) are discharged to flume (beet transport) systems or disposed of by separate land disposal facilities without discharge to surface waters.

Treatment and control technologies applicable to various waste water components of the beet sugar plant are discussed below.

Flume Water

A preventive measure that can be developed at all plants for the reduction of the flume water waste volume is dry handling and transport of beets after they reach the plant. One plant presently has dry beet handling facilities for conveyance of beets into the plant. The water fluming system is substantially reduced to approximately 15 meters (50 ft) in length and the beets are washed under high-pressure sprays.

If dry fluming is not employed, the initial step in the treatment of flume water is the screening process to remove suspended solid organic material (beet fragments, etc.) which would otherwise settle in holding ponds as slowly decaying organic material. In a recirculating flume water system, clarification of the recirculated waste water flow is accomplished through the use of earthern holding ponds or mechanical clarifiers. The sludge removed from the settling facilities is discharged to a separate earthen holding pond for complete retention.

The beet sugar processing industry has demonstrated that a drawoff or blowdown rate of 20 percent of the total water flow is sufficient to maintain the total dissolved solids concentrations at or below approximately 10,000 mg/l. Such a level of total dissolved solids concentration in the fluming system will not promote, under the prevailing pH conditions, an abnormal scaling of the piping in the waste water conveyance system.

The pH of flume water is a highly variable and erratic factor, requiring careful control by the addition of lime. Proper control can be accomplished through pH determinations on grab samples of flume water taken at least every two hours as is practiced at some plants. At a number of other plants, milk of lime is added to the flume water as it leaves the screens or as it enters settling ponds or clarifier facilities. This lime addition serves to keep the pH at a level which

Table VIII
Summary of Selected Pollution Control Practices at Beet Sugar Processing Plants

					Existing Pollution Control Practices									
Beet Sugar Processing Plant	Beets Sliced Metric tons/day	(Tons/day)	Molasses Worked Metric Tons/Day	(Tons/Day)	Discharge to Navigable Waters	Retention or Land Disposal for Flume Water	Maximum Flume Water Recycling	Partial Flume Water Recycling	Maximum Condenser Water Recycling or Re-use	Partial Condenser Water Recycling or Re-use	Land Disposal of Condenser Water	Discharge of Excess Waste Water to Municipal System	Treated Waste Water Used for Land Irrigation	Use of Cooling Devices for Condenser Water
Nampa, Idaho	8163	(9000)			Y	Y°	Y			Y	Y°	Y		
Moses Lake, Washington	7710	(8500)	204	(225)	N	Y	Y		Y		Y			Y
Rupert, Idaho	0100	(6725)			Y'	Y°	Y			Y				Y
Nyssa, Oregon	5964	(6575)	185	(204)	Y	Y°	Y							
Hereford, Texas	5895	(6500)			N	Y	Y		Y		Y			
Brawley, California	5895	(6500)			N	Y		Y	Y		Y		Y	Y
Salinas, California	5895	(6500)	317	(350)	N	Y	Y		Y		Y		Y	Y
Drayton, North Dakota	4716	(5200)			Y'	Y°	Y			Y	Y°			Y
Betteravia, California	4535	(5000)			N	Y	Y		Y		Y		Y	Y
Twin Falls, Idaho	4376	(4825)	205	(226)	Y	Y°	Y		Y					Y
Moorhead, Minnesota	4172	(4600)			Y'	Y°	Y			Y	Y°		Y	Y
Idaho Falls, Idaho	3991	(4400)	113	(125)	Y'	Y	Y			Y				Y
Billings, Montana	3809	(4200)	163	(180)	Y	Y	Y							
Manteca, California	3809	(4200)			N	Y	Y		Y		Y		Y	Y
Chandler, Arizona	3809	(4200)			N	Y	Y		Y		Y		Y	Y
Mendota, California	3809	(4200)	200	(220)	N	Y	Y		Y		Y		Y	Y
Crookston, Minnesota	3628	(4000)			Y'	Y°	Y				Y°			Y
Tracy, California	3628	(4000)	102	(123)	N	Y	Y			Y	Y		Y	Y
Toppenish, Washington	3464	(3825)			Y	Y	Y			Y				
Bay City, Michigan	3447	(3800)			Y	Y°		Y						
Woodland, California	3265	(3600)	103	(180)	N	Y		Y	Y		Y			Y
Sidney, Montana	3174	(3500)			Y'	Y°		Y			Y°		Y	Y'
Ft. Morgan, Colorado	3174	(3500)	167	(187)	Y	Y	Y							
Loveland, Colorado	3174	(3500)	172	(190)	Y	Y	Y				Y°			Y
Fremont, Ohio	3083	(3400)			Y	Y°	Y		Y		Y°	Y		Y
Rocky Ford, Colorado	3083	(340C)	85	(94)	Y	Y	Y			Y			Y	
Longmont, Colorado	2902	(3200)	171	(189)	Y'	Y	Y				Y°		Y	
Scottsbluff, Nebraska	2902	(3200)	59	(175)	Y	Y	Y				Y°			Y
Torrington, Wyoming	2902	(3200)	126	(139)	Y'	Y	Y			Y	Y°			
Goodland, Kansas	2902	(3200)			N	Y	Y		Y		Y			Y
Clarksburg, California	2721	(3000)			Y	Y	Y			Y			Y	
E. Grand Forks, Minnesota	2630	(2900)			Y'	Y°	Y		Y	Y°				Y
Ovid, Colorado	2542	(2800)			Y	Y	Y							
Garland, Utah	2449	(2700)	100	(110)	Y	Y	Y						Y	
Hamilton City, California	2267	(2500)			N	Y	Y		Y		Y			Y
Sterling, Colorado	2177	(2400)			Y	Y°		Y						
Mason City, Iowa	2177	(2400)			Y	Y°		Y	Y		Y°			
Bayard, Nebraska	2041	(2250)			Y	Y	Y							
Mitchell, Nebraska	2041	(2250)			Y'	Y°					Y°			
Brighton, Colorado	1995	(2200)			Y	Y	Y			Y	Y°			Y
Eaton, Colorado	1995	(2200)			Y	Y	Y			Y	Y°			Y
Greeley, Colorado	1995	(2200)			Y	Y	Y			Y	Y°		Y	Y
Lovell, Wyoming	1995	(2200)			Y	Y	Y				Y°			Y
Gering, Nebraska	1995	(2200)	91	(100)	Y	Y	Y							
Sebewaing, Michigan	1905	(2100)			Y	Y°		Y		Y				
Carrollton, Michigan	1814	(2000)			Y	Y°	Y							
Carol, Michigan	1814	(2000)			Y	Y°	Y			Y	Y°			Y
Worland, Wyoming	1746	(1800)	69	(76)	Y	Y	Y			Y				Y
Delta, Colorado	1633	(1800)	54	(60)	Y	Y	Y			Y	Y°			
Santa Ana, California	1633	(1800)	87	(96)	Y	Y°			Y		Y°	Y		Y
Findlay, Ohio	1406	(1650)			Y	Y°	Y		Y		Y°	Y		Y
Ottawa, Ohio	1451	(1600)			Y	Y°	Y		Y		Y°	Y		Y
Croswell, Michigan	1270	(1400)			Y	Y°				Y	Y°			Y

' Occasional discharge only
° Partial

Y = Yes
N = No

impedes bacterial action and thereby reduced odors and corrosive effects. It also assists in sedimentation as a flocculating agent.

The amount of soil associated with incoming beets varies with the wetness or dryness of the harvesting season, soil type, and location. A plant slicing 363,000 kkgs (400,000 ton) of beets during a campaign may accumulate 5,100 to 6,130 cu meters (20 to 24 thousand cu yd of soil in its settling ponds. At one plant 40,500 cu m (53,000 cu yd) of dirt were removed from lagoons in 1969 after processing 903,000 kkgs (995,000 ton) of sugar beets.

Barometric Condenser Water

Condenser water is characterized by:

1) relatively high temperature 55-65°C (131-149°F)
2) entrained organics from boiler vapor entrainment
3) alkaline properties

The pH varies between 8 and 10 but usually is less than 9 and results from entrainment of ammonia during the raw juice evaporation process. Reuse of condenser water is a common industry practice. In 1968, a total of 38 plants reused waste condenser water for fluming and other in-plant usages; 20 of these cooled and returned a portion of this water to the condensers. Many plants make some in-plant reuse of condenser water and discharge the excess to water bodies. A total of 12 plants presently accomplish complete retention of condenser waters without discharge to surface waters.

Cooling of condenser water before discharge to receiving streams, or re-cycling is usually necessary for protection of the quality of receiving waters.

Surface or non-contact condensers offer a possible means of non-contaminant use of condenser waters in lieu of entrainment control devices with conventional barametric condensers. Surface condensers provide positive control against contamination of condenser water through non-contact between vapors to be condensed and cooling water. The alternative method of control is relatively expensive (estimated at roughly $200,000 for the average sized beet sugar processing plant) and requires larger water volumes than barometric condensers. The method is reliable as a mechanism of pollution control, and is worthy of consideration at new beet sugar processing plants to be constructed.

When using cooling towers for condenser water cooling and recirculation, it has often been found economical and expedient to supplement the recycled condenser water with cool fresh water from wells in order to reduce the temperature of the recycled water. Where employed, such practices often do not result in conservation of water since larger water volumes are used than that needed to meet minimal barometric condenser requirements. In the Central and North Central portions of the United States, additional cooling requirements for molasses in Steffen operations is obtained through use of large volumes of water from existing surface or ground water sources; at other locations, e.g., in California, heat exchangers are commonly employed to meet additional cooling requirements of the Steffen process.

In recycle systems, cooling may be accomplished with spray ponds, cooling towers, evaporative condensers and air cooled heat exchangers. All but the last depend on the cooling effect of evaporation. The effectiveness of an evaporative cooling system is determined by the wet bulb temperature of the environment, since this is the absolute lower limit to which the water can be cooled by evaporation. The actual terminal temperature may range from a degree or two below atmosphere temperature at high humidity to -1°C (1°F) or more below atmospheric temperature when the air is very dry (88). Therefore, evaporative coolers are most effective in arid regions.

As a rule of thumb, cooling towers are capable of lowering temperatures on a once-through basis to within 12°C (22°F) of wet bulb temperature.

Forced draft cooling towers with bottom fans and countercurrent air flow are gaining favor over induced draft (top fan) and natural draft types for cooling heated waste waters. Cooling towers are generally more efficient than spray ponds for waste water cooling because of increased contact in the cooling tower between the heated water and circulating air.

Barometric condenser water resulting from beet sugar processing plants characteristically exhibits relative high nitrogen content, attributed largely to ammonia (3 to 15 mg/l NH_3 as nitrogen) introduced by juice evaporating and sugar crystallizing operations. Therefore, the removal of nitrogen centers on the removal of ammonia-nitrogen.

Pilot plant experiments by Lof, et. al. support the ability of air stripping to remove nitrogen from beet sugar plant condenser water effluent. Data for ammonia removal from a synthetic medium (prepared by the addition of NH_4Cl, $NaNO_3$ and $NaNO_2$ to tap water) indicate that most of the NH_3 removal in cooling tower operations occurs by air stripping, rather than by oxidation to nitrite nitrogen. Removal of ammonia nitrogen at the 16 to 18 mg/l as N range was shown to be 25 to 50 percent over a 24 hour interval (6.2 passes through the cooling tower) for G/L weight ratios of 0.3 and 0.6 respectively. The G/L weight ratio equals the weight rate ratio of air to water, e.g. kg (lb) of air per hr. divided by kg (lb) of water per hr.

Applications of combined cooling and biotreatment of waste waters have been utilized by means of cooling towers for refinery, corn milling operations and bleached board production plants. Among other constituents, cooling devices sometimes with the addition of synthetic packing have been demonstrated effective in reduced temperature, sulfides, chemical oxygen demand, biochemical oxygen demand and ammonia in this double duty role. BOD_5 and COD removals vary between 30 and 90 percent. Although heavy sliming occurred in several of the above cooling units, growth was reported not to be sufficient to cause any problem in cooling tower operation. Similar successful experiences with biological oxidation of pollutants are known to occur with efficient temperature reduction through use of aeration ponds, primarily at pulp and paper mills (6). BOD_5 reductions ranged from 80 to 95 percent. Aerobic treatment processes have been demonstrated effective in removing up to about 70 percent of total nitrogen in waste water (101). The air to water ratio required in cooling barometric condenser waters by cooling devices at beet sugar processing plants may be estimated based on the following thermodynamic considerations. Assuming ambient air with an absolute humidity of 0.011 kg (lb) water vapor per kg (lb) of dry air (75 percent relative humidity and 70°F dry bulb temperature), adiabatic cooling and air leaving the cooling device is saturated with water, exit conditions of air after use for cooling would have an absolute humidity of 0.012 kg (lb) water vapor per kg (lb) dry air under exit conditions (64°F dry bulb temperature and 100 percent relative humidity). Therefore, under the assumptions, 0.001 kg (lb) water vapor per kg (lb) of dry air would be added to the air during the evaporative cooling process. In reducing the barometric condenser water temperature from 60°C to 20°C (140°F to 68°F), a total temperature decrease of 40°C (72°F) has occurred. With approximately 555 kg cal/kg (1000 BTU/lb) as the heat of evaporation of water and an estimated 40 kg cal/kg (72 BTU/lb) of water recirculated, evaporation to accomplish the required temperature drop would be estimated at 0.072 kg (lb) of water evaporated/kg (lb) of water recirculated. Therefore, dry air requirements for evaporative cooling to accomplish the designated temperature decrease would be $72/0.012 \times (1000) = 6$ kg (lb) dry air/kg (lb) water recirculated.

Ammonia stripping as a treatment process has been demonstrated to be pH dependent, the optimum ammonia removal by stripping occurring at a pH of approximately 11. Studies conducted at the University of Wisconsin and others have substantiated high removals of ammonia (78 to 92 percent) by stripping at air/liquid loadings of 3345 l/l (447 cu ft / gal) and 4100 l/l (549 cu ft/gal) respectively.

The above discussion supports the conclusion that ammonia can be substantially removed from waste waters through appropriate cooling devices and aerobic waste treatment systems.

Ammonia is soluble in water and would be expected to be found within minimal concentrations under natural conditions. At atmospheric conditions, the solubility of ammonia in water is 0.89 mg/l, 0.53 mg/l, 0.33 mg/l and 0.07 mg/l at 0°C, 20°C, 40°C and 100°C respectively.

Lime Mud Wastes

Plants normally release lime mud in the form of a slurry which is contained in holding ponds.

Two plants now reburn lime mud cake for the production of lime. One recent lime mud cake reburning operation has been discontinued, reportedly because of objections to dust emitted from the rotary kiln and cost inefficiencies. Lime mud cake from this operation is now being shipped to another factory for reburning.

Dry handling of lime mud cake is accomplished at a number of plants. One plant indicates plans to install dry conveyance facilities for lime mud cake during 1973. By using a dry conveyance system, the lime mud cake is transported to the disposal area without the conventional addition of slurrying water in order to permit pumping. Injection of compressed air at 0.7 to 1.1 kg per sq cm (10 to 15 psi) to maintain fluidity of the semi-liquified mass has also been an effective method of transport at the Chandler, Arizaona plant.

Sale of lime mud cake for agricultural and other usages has not been notably successful. At only two plants, one in California and one in Washington, has any considerable outside use been made of the material. The rather large store of lime mud cake in California, is being sold to farmers for use on peat soils at a somewhat faster rate than it is being produced. In Washington, a commercial distributor collects lime mud cake from the dry ponds for sale at 55¢/kkg (50¢/ton) for use in areas with acid soils.

A typical beet sugar plant employs one or more lime mud ponds, var[illegible] in depth from 0.6 to 3.0 m (2 to 10 ft). On occasion, miscellan[illegible] wastes may be added to the lime mud ponds. Deposits from a [illegible] campaign are scraped from the pond bottom and added onto the dike wa[illegible]. Where large ponds are employed, solids removal is not necessary f[illegible] period of many years. Active fermentation may begin near the e[illegible] campaign in the central United States and is accelerated by the w[illegible] temperatures occuring through spring and summer (13). Cleaning of [illegible] mud ponds is a continuing, expensive chore at many plants. As a gen[illegible] practice, two or more lime mud ponds are available at a plant, ena[illegible] the operators to take one of the ponds out of service as required to permit removal of accumulated solid material.

The various difficulties in storing lime mud slurry, such as the viscous nature of the waste, land and construction costs, and possible offensive odors offer strong reasons for converting to a dry system of handling and disposal in most cases.

Steffen Waste - Steffen plants produce a liquid waste which has a high alkalinity as well as a high BOD5 and organic matter content. The solids content of the waste resulting from the Steffen process, in addition to the lime content, consist of the sugar and the nonsugars of the original molasses. The Steffen waste includes various inorganics, together with a variety of organic and nitrogenous comlb.

When Steffen waste biologically degrades, it soon loses its alkaline nature and various malodorous comlb are formed. Where this waste is disposed of in ponds, odor problems have become acute.

Because of the large variety of materials contained in Steffen wastes, it has been given considerable study as a potential source of byproducts. During World War I, a number of beet sugar plants concentrated the Steffen waste and burned the concentrate to produce a crude potash salt for fertilizer. Later, a successful process was developed to produce monosodium glutamate (MSG) from the concentrated Steffen filtrate (CSF). Feeding and nutritional studies have shown that CSF can partially replace molasses as a cattle feed supplement. This use has been the primary outlet for this material, since the attractiveness for sale of MSG has decreased.

When used as a dried-pulp additive, CSF is normally limited in livestock feed by the solids (ash) content. Experience has shown that only about 30% molasses by weight, may be added to dried pulp for cattle feed.

Land spreading is another alternative method of disposal of Steffen waste. This can be accomplished with a minimum of odor production, if managed properly. The dilute Steffen waste is spread in a thin layer over a land area which is quite level and divided into small parcels by low levees. This permits feeding the waste onto these parcels in sequence to allow absorption and drying before further additions. It is beneficial to disc or till the soil between campaigns to enhance its absorptive capacity. Such land spreading of Steffen waste with protection from runoff is practiced at the beet sugar plant near Salinas, California.

A study on a laboratory scale (68) demonstrated that Steffen waste can be treated with various yeasts, algae and bacteria to produce a potential feed stuff while stabilizing the waste. But another study incorporating a four-pond system, was judged high in installation and operating cost without subsequent production of a usable byproduct.

To reduce the cost of evaporating Steffen filtrate, considerable effort is made to keep the concentration of the waste as high as possible without adversely affecting the purity of the saccharate produced. One method used is the return of cold saccharate filtrate as part of the dilution water. The volume of Steffen waste is thus reduced from about 42 l/kkg (10 gal of waste/ton) of molasses to about 25 l/kkg (6 gal of waste/ton).

General Wastes - General waste including floor and equipment, wash waters, filter cloth wash, and miscellaneous effluents are usually discharged to the general or flume water ponds.

Demonstrated and Potential *Treatment and Control* Technologies

General - Biological treatment of beet sugar waste has been demonstrated. Two approaches to biological waste treatment are currently being used; they are anaerobic and aerobic fermentation. The former is believed to be the most efficient, resulting in the most nearly complete stabilized effluent. Anaerobic action does give rise to objectionable odors including particularly, the odor of hydrogen sulfide. At many plants, neighboring residents have protested the annual nuisance caused by anaerobic odors.

The removal efficiencies of waste treatment processes are difficult to assess. Adequate BOD_5 determinations are infrequently available in statistically significant numbers. Exceptions to this are the results of the intensive studies made by the EPA on the matter of pollution in the South Platte River Basin, and the various studies of experimental units conducted by companies or by the Beet Sugar Development Foundation. Past studies indicate that substantial BOD_5 reduction of beet sugar wastes can be accomplished by biological oxidation.

Common to all processes available for biological treatment of beet sugar plant wastes are the requirements for adequate screening of wastes to remove fragments of beets and other organic matter and facilities (mechanical or other) for separation of muds. Previous methods of handling the clarified or partly clarified liquid wastes were one of the following: 1) direct discharge to streams during periods of high water flows; 2) anaerobic biological treatment in deep ponds, followed usually by aerobic action in shallow ponds or ponds equipped with mechanical aerators; or 3) aerobic treatment alone.

Many studies have been performed on the treatment of beet sugar wastes utilizing biological means, including activiated sludge, trickling filters, waste stabilization lagoons and other methods (11). In many cases, results have been obtained well beyond the pilot-plant stage.

Even though numerous methods of treatment of the various wastes from beet sugar plants have been applied with the objective of producing an effluent suitable for discharge to surface waters, these methods are generally undesirable in comparison with inplant waste water reuse and recycling practices. Applicable treatment methods in the conventional sense present operational and economic questions as applied to large volumes of liquid produced during essentially a three month period of the year known as the beet sugar campaign. Large treatment plant facilities are required to handle the large waste volumes during a relatively short seasonal operation. If such conventional biological treatment systems are to be utilized, waste water would have to be stored in large storage facilities to help sustain organic and hydraulic loading for the treatment facilities on essentially a year round basis.

Inplant process control with reuse of waste waters rather than treatment and discharge has been generally adopted by the industry as an expedient and economical approach to pollution control from beet sugar industrial operations. Various waste treatment and control methods applicable to beet sugar processing plants are discussed below.

Coarse Solid Collectors - Trash collectors, traps, and other recovery devices are normally placed at all major waste collection points within the plants. Proper design, installation, and maintenance of these devices are essential for adequate performance. Solids control is necessary not only for routine waste but also for spills, leakage and inadvertent releases to the floor drains.

Fine-Mesh Screening - The screening operation is a preliminary step in waste treatment intended to reduce waste loads placed upon subsequent treatment and control units. For screening of flume water, inclined vibrating screens are generally preferred by the industry because they are more effective and less costly than other screening devices. Adequate screening of the waste flows from a typical plant may remove from 9 to 36 kkg (10 to 40 ton) of coarse wet solids daily. The recovered screenings are shredded and introduced into the pressed pulp and fed to the dryer. Screenings removed from recycled flume water are also generally fed to livestock with or without drying.

One plant provides dual vibrating screens which have 0.32 by 1.59 cm (1/8 by 5/8 in) slotted openings, as the first unit within its flume water recirculation system. The screens remove about 29.7 kkg (27 tons) of wet solids daily which are sold directly to local farmers for use as stock feed. Another operation employs three vibrating screens installed in parallel; the screens are preceded by a liquid cyclone or hydroseparator for removal of heavy grit and solids.

Grit and Solids Removal - Mechanical clarifiers or earthen settling ponds preceeded by coarse screening, are generally used in recycle flume water systems. Mechanical settling units are usually preferred in the industry. The objective is to remove as much dirt, soil and other solids as possible. The large quantities of accumulated dirt and debris are deposited into sludge storage ponds.

Both earthen ponds and mechanical clarifiers can cause serious problems without proper operation, maintenance and control but the mechanical clarifier merits careful attention. It is important that sludge underflows and flotable scum and grease be removed quickly, preferably on a continuous basis. If waste detention times are excessive, organic fermentation may occur in the settling facilities, resulting in organic acid and hydrogen sulfide buildup. Chlorination or pH control with lime addition may be used to retard such odor-producing action. In any case, efficient course screening ahead of the settling tank is essential. Indications are that clarifiers with detention times from 30 minutes to several hours will produce effective solids removal with minimum odors. With continuous flume water recirculation, dissolved organic material may increase to rather high levels (approximately 10,000 mg/l), necessitating blowdown and water makeup in the system for solids and scaling control.

Current state-of-the-art practices for mechanical clarifiers on wastes with settleable solids of 30 to 125 mg/l, result in waters containing 0.3 to 1.0 mg/l of settleable material. Fine clay particles which do not readily settle must be removed by chemical flocculation in the pH range 10.5 to 11.5. Addition of lime not only retards fermentation but serves to raise the pH to the level necessary for effective flocculation.

Waste Holding Ponds - Waste holding ponds have widespread use in the beet sugar industry. Their function is similar to that provided by mechanical settling. Less care is generally given to their design, operation, and maintenance. The pond facilities normally serve for retention of wastes as contrasted to treatment benefits. Waste water detention times in earthen holding ponds generally range from 24 to 48 hours. Minimum detention times are encouraged for minimizing noxious odors associated with organic fermentation when ponds are used for solids settling. Holding ponds, as distinguished from waste stabilization lagoons, serve for solids removal, short term retention or long term storage without discharge to surface waters. In the latter case (long term storage), the waste water is disposed of by evaporation and filtration. Waste stabilization ponds, on the otner hand, are specifically designed and constructed to provide waste treatment for subsequent controlled land disposal, irrigation, or discharge to surface waters.

Jensen states that the pond system, using single or multiple basins, has been the most common means of solids removal for beet sugar waste waters. He recommends that the system be shallow and flowing in order to avoid the odor nuisances of hydrogen sulfide gas generation. From his experience, Henry favored settling ponds for reasons of economy and also suggested the following principles in relation to these ponds. First, the waste water should enter the settling pond with minimum velocity and circulate evenly but quickly without interference with settling. Second, the use of large ponds is advisable in order to minimize dike construction. Third, pond bottoms should be level, and grass and weeds should be removed from the bottom and sides on a frequent schedule. Other studies conducted in Great Britain have indicated that the ideal shape for a settling pond may be a rectangle five to six times as long as wide, providing a flow-through velocity of about 0.24 m/min (0.8 ft/ min). The British investigations also suggested that small ponds were advantageous in the event of dike rupture, since less waste material would accidently enter the receiving stream.

Experience within the industry has indicated that odor problems accompanying the imlbment of waste waters in earthen ponds at many plants can be minimized by the maintenance of shallow pond depths (optimum of 45.7 cm or 18 in). In the U. S., shallow lagoons are preferred to deep ponds, and operating depths are generally in the range of 0.92 to 1.53 m (3 to 5 ft) However, effective settling depths will range from less than 0.3 m (1 ft) to 6.1 m (20 ft). In actual practice the holding ponds may fill rapidly with solids.

In the construction and operation of holding ponds, sealing of pond bottoms to eliminate or control percolation to acceptable maximum rates may be necessary even though a mat of solid organic material often provides some degree of self-sealing. The general criteria, adopted by many State pollution control agencies for waste stabilization lagoons for municipal wastes, is a 0.635 cm (1/4 in) drop in liquid depth per day. This has general application to waste holding ponds as a practical limit of filtration and should not be exceeded. No contamination of ground water must result from controlled ground soil filtration. Holding ponds in use in the industry today have no specific provision for filtration control.

A number of storage retention or land disposal systems have been investigated, some systems proving to be of little or no protection against polluted discharges. In this regard, two types of long-term waste ponding have been generally in use: (1) waste retention with controlled regulated intermittent discharge of holding pond contents to surface receiving waters (2) and long-term waste storage and disposal with no discharge to navigable waters. The first practice of controlled discharge from holding facilities to receiving waters is practiced at the Moorhead, Crookston, and East Grand Forks, Minnesota, and at Drayton, North Dakota plants. In this region, waste flows are contained in holding ponds during the processing season and the contents are discharged under controlled conditions to receiving waters during the spring high stream flow period. Some reduction in BOD_5 content of the ponded waste takes place during the winter storage period and prior to regulated discharge to the river, but the BOD reduction is usually not significantly great.

The first extensive study of long-term waste storage was conducted at the Moorhead, Minnesota plant during the 1949-1951 campaign. Waste flume waters, together with pulp press waters, were released into two 3.7 meter (12 ft) ponds identical in capacity, with a total area of 33 hectares (82 ac) and a total volume of 1340 million liters (354 million gal). A third lagoon, .9 meters (3 ft) deep, covering 20 hectares (50 ac) and providing 190 million liters (50 million gal) capacity, was maintained in reserve until late in the campaign. The total campaign used 1600 million liters water volume (423 million gal) in 1950. Uncontrolled discharge from the ponds began in early spring following severe winter conditions and much ice cover over the ponds.

The study showed that waste treatment during the campaign itself was effected largely by settling of suspended matter within the ponds. Over this period, BOD_5 reductions ranged from 48 to 58 percent, and suspended solids removal was indicated at about 97 percent. After the processing campaign ended, the stored waste waters underwent no further decrease in BOD reduction. This was attributed to complete cessation of biological activity within the ponds because of freezing conditions and possible lack of secondary nutrients. The study concluded that long-term waste storage, even in cold climates, would provide effective removal of suspended solids, but would be effective in removing only one-half of the BOD_5 load.

A later study, undertaken in 1964-1965 in the Red River of the North, included the Moorhead, East Grand Forks and Crookston, Minnesota plants. Discharge was controlled according to the amount of flow, dissolved oxygen and BOD_5 in the receiving stream, and was permitted prior to and following ice cover on the river. The results of the study showed that the Moorhead pond effluent contained 449 mg/l BOD_5, 163 mg/l total suspended solids, and had median values of 1.5 million total coliform bacteria and 1.25 million fecal coliform bacteria per100 ml. The discharge at the East Grand Forks, N. D. plant had effluent values of 164 mg/l BOD_5, 54 mg/l total suspended solids, 22,100 total coliforms per 100 ml and 1,720 fecal coliforms per 100 ml. Waste removal efficiencies were not determined.

Land Spreading of Wastes or Aeration Fields - The term aeration fields is applied to the process of spreading wastes from beet sugar plants over large land surfaces. The wastes infiltrate into the ground in numerous, shallow channels, and are collected and disposed of at the opposite end of the field.

The history of aeration fields for beet sugar processing waste in the U. S. start with studies conducted at the Loveland, Colorado plant in 1951. The aeration field there covered 539 ha (133 ac). Suspended solids and alkalinity removals were reasonably good, but organic loads (BOD_5) were reduced only to a minumum degree. The facility provided less than equivalent primary treatment, and waste concentrations in the final effluents remained at high levels. The merits of maintaining this type of extensive treatment area were seriously questioned in view of the results obtained.

A similar aeration field that was formerly used at Windsor, Colorado, was found even less effective than Loveland, producing less than 10 percent removal of BOD_, 60 percent removal of COD and 60 percent reduction of TSS. The waste water entering the Cache la Poudre River contained approximately 1100 mg/l BOD_5, 1060 mg/l TSS, and 6.6 million total coliform bacteria per 100 ml.

Full scale aeration field facilities were also constructed at a Nebraska plant during 1952, and evaluation studies were carried out over the 1952-1953 campaign. The total combined plant wastes were delivered to a 1,069 by 534 meter (3,500 by 1,750 ft) area of fairly level contour. Although native buffalo grass was present, only part of the field was described as a grassland filter as compared to installations in Europe. Waste channeling was quite evident and only 50 percent of the waste volume disappeared by downward percolation before reaching the end of the field.

The 1952-1953 survey results showed that incoming waste levels of 482 mg/l BOD_5 were reduced to 158 mg/l in the aeration field or that 67 percent BOD_5 removal occurred. Corresponding values of total suspended solids were 5,125 mg/l and 63 mg/l, giving 99 percent apparent total suspended solids reduction. Similarly, total coliform bacteria numbers were reduced 89 percent. Although algal and fungal growths were abundant, the dissolved oxygen was quite low in the field. Average waste detention approximated 14 hours, and the results indicated that odor production was at a minimum. aeration field is no longer in use.

Aeration fields were also used during the 1963-1964 campaign at three Colorado plants. It was observed that these treatment facilities did not embody many of the favorable characteristics of the earlier installation, and the aeration fields were beset with numerous operational and maintenance problems. The 1968 South Platte River Basin studies concluded that aeration fields, as they were maintained, could not by any means satisfy the water quality criteria recommended for the receiving waterbody. Further conclusions were that aeration fields support little or no vegetative growth, and because of short circuiting, the wastes often obtained application on only a small portion of the field. Although the majority of suspended solids were removed, there is little or no other apparent benefit from aeration fields.

Waste Stabilization Ponds or Lagoons - Waste stabilization ponds or lagoons are distinguished from waste holding ponds in that the former are designed, constructed, operated and maintained by established design criteria and procedures for the primary purpose of effecting waste treatment for pollutant reduction. Waste holding ponds, while affording some benefit of waste treatment, serve primarily to store or retain the waste with or without discharge of pond contents to surface waters.

Many of the plants in California utilize waste stabilization lagoons for treatment of excess flume and condenser system waste waters. The impetus to provide treatment of waste waters has resulted from the advantages obtained by utilizing the treated waste waters for cropland irrigation in water-short regions. The installations are characterized by the use of many interconnected ponds generally in series, specifically designed for settling, biological oxidation, evaporation and filtration. The various lagoons range generally from 0.6 to 3.0 meters (2.0 to 10 ft) in depth, with surface areas up to 80 ha (197 ac). The shallow ponds are aerobic, whereas the deeper basins were designed for controlled anaerobic digestion. The BOD_5 of the waters pumped from the final aerobic pond in series for irrigation is relatively low, of approximately 105 to 190 mg/l or less. The suspended nature of the BOD_5 is demonstrated by the fact that studies show that the BOD_5 of the pond effluent may be reduced to 7 to 10 mg/l by effective filtration. Essentially complete removal of total suspended solids by filtration is obtained.

Anaerobic-aerobic lagoons have been utilized in a pilot study basis for treating beet sugar wastes with encouraging results (65). Encouraged by the successful application of these principles in the treatment of other wastes, The Beet Sugar Development Foundation with funding support from EPA initiated a pilot plant study in California. The major objectives of the study were to demonstrate the waste removal efficiencies of the system and to determine methods to minimize odor in connection with this means of treatment. The system was evaluated with respect to the effects of varying feed rates and recirculation ratios upon organic waste removal, and the degree of odor control and microbial growth associated with the operations.

Hopkins et. al. found that if total beet sugar wastes were discharged uniformly across the upper end of 2 ha (5 ac) shallow lagoons with a detention time of about one day, virtually all suspended solids, 55 percent of the concentration of BOD_5 and 63 percent of the weight of BOD_5 were removed. This procedure also reduced the alkalinity by 69 percent, completely eliminated nitrate nitrogen and reduced ammonia nitrogen by 94.3 percent. Coliform type bacteria increased, but phosphates were unchanged. Water loss was 4,040 cu meters (3.27 ac ft) per day of which 222 cu m (0.18 ac ft) was due to evaporation and 3818 cu m (3.09 ac ft) due to filtration.

At the California pilot plant, screened, settled plant waste water (principally flume water) was treated in a series of three ponds. These consisted of a 4.6 m (15 ft) deep anaerobic pond, a faculative pond 2.1 m (7 ft) deep, and an aerobic pond 0.9 m (3.0 ft) deep, from which the effluent could be discharged and also recycled to the anaerobic pond. Detention times varied from about 10 to 25 days in the anaerobic pond, 10 to 30 days in the faculative pond, and 10 to 20 days in the aerobic pond. Over the first two years of the study, the anaerobic, faculative and aerobic ponds were used respectively as the first, second, and third units in series. During September and October, 1966, influent BOD_5 values generally ranged from 1,200 to 1,650 mg/l. In the first experimental run, the applied organic loadings were 1383 kg BOD_5/ha/day (1,235 lbs BOD_5/ac/day) for the anaerobic pond, 931 kg BOD_5/ha/day (831 lbs BOD_5/ac/day) for the faculative pond, and 739 kg BOD_5/ha/day (660 lbs BOD_5/ac/day) for the aerobic pond. The results of the first run represented an overall waste detention period of about 35 days and provided 70 percent BOD_5 removal and 38 percent COD removal. The BOD_5 concentrations from inflow to outflow were reduced from approximately 1,200 mg/l to 350 mg/l. Another test, where there was no recirculation and the applied loadings were 1838 kg BOD_5/ha/day (1,640 lb BOD_5/ac/day) for the anaerobic pond, 502 kg BOD_5/ha/day (448 lbs BOD_5/ac/day) for the faculative pond, and 355 kg BOD_5/ha/day (317 lbs BOD_5/ac/day for the aerobic pond, with overall waste retention time of 70 days, provided approximately 90 per cent BOD_5 removal and 77 percent COD removal. Correspondingly, the BOD_5 concentrations were reduced from about 1,650 mg/l to 170 mg/l. These studies included the enumeration of algae, coliform, and fecal streptococci bacteria present within the system. Efficient removals were achieved in regard to both coliforms and fecal streptococci organisms reaching 99.99 percent in practically all cases. Although mechanical and other disturbances resulted in less than desirable treatment operation, the system indicated that beet sugar plant wastes could be successfully treated by such a system. BOD_5 and COD were effectively removed in the pond system with the highest removal rates occurring in the heavily loaded anaerobic pond. As long as algae were present in the aerobic pond, recycle of waste water from the aerobic pond to the anaerobic pond was beneficial in the prevention of odors. Without recirculation, there were odor problems in the anaerobic pond.

The use of waste water treatment lagoons for the propagation of fish at plants in California has been investigated and has been reported by industry representatives to have met with only partial success.

Laboratory studies have been conducted by the British Columbia Research Council to determine the feasibility of using aerated lagoons to treat waste flume waters. The studies also provided data on optimum load conditions, determination of the time required in startup relative to the beginning of the campaign, and adaptability of the aerated lagoon method to intermittent operation and to temperature change. The waste flume water was obtained from a plant with a high degree of recycling and the initial BOD_5 values ranged from 821 to 1121 mg/l. Results showed that effluent BOD_5 values range from 30 to 140 mg/l.

The efficiency of a lagoon system depends to a large degree on the climatic conditions, organic loading, and the ability to maintain uniform flows through the lagoon system. Lagoon systems are effective in removing essentially all the suspended solids. Effluents of low BOD_5 can be attained only by maintaining long retention periods which require large land areas. The water in the lagoons must be kept shallow, and water movement is preferable in order to avoid the generation of hydrogen sulfide with its attendant nuisance odors (28). Preliminary screening of beet processing wastes to remove particular organic matter prior to discharge to lagoons substantially lessens the occurence and intensity of noxious odors.

Waste stabilization lagoons for treatment of beet sugar plant wastes would undoubtedly perform more efficiently in warm arid climates such as Southern California than those in northern, colder climates such as the Red River Valley of North Dakota and Minnesota. Relatively large land requirements for lagoons result where treatment of waste water for irrigation use is the primary objective. Lagoons must be located so as not to contribute to ground water pollution. Selection of the proper site by a qualified geologist to prevent pollution of nearby aquifers is recommended.

Odors have been experienced with operation of some of the stablization lagoons in California. The settling pond and the initial anaerobic ponds in some cases have been found to be covered by a heavy proteinaceous scum layer, and the anaerobic ponds at times have produced serious odors. The utilization of purple sulfur bacteria (Thiopedia and Chromatium) has been a recent innovation and has been quite effective for odor control in waste treatment lagoons in California. The bacteria impart a pinkish to reddish color to the pond surface, and serve as biological deodorizers by converting hydrogen sulfide photosynthetically to produce elemental sulfur and sulfates. Where these bacteria are present in sufficient numbers, hydrogen sulfide odors are usually greatly diminished or eliminated. Experience with the use of these bacteria for odor control have shown that although they are quite effective in warm climates they are less efficient under the cooler climatic conditions existing at Hereford, Texas.

Chemical Treatment - Although chemical additives are in fact used throughout the beet sugar process cycle, this discussion is limited to chemical flocculation as a unit operation employed in waste treatment.

Studies at one operation offer a noteworthy example of waste treatment by chemical precipitation. Waste flume waters were received into a grit separator for heavy solids removal then treated by chemical flocculation, with 40 percent of the treated waters being returned to the beet flume and the remainder being discharged to the river. The sludges from both the grit separator and the setting basin were directed to sludge ponds and supernatants were returned to the grit chamber. This plant utilized dry handling techniques in moving the sugar beets from storage piles to the wet hopper. This resulted in minimum waste loadings in the flume system. The average BOD_5 level in the flume waters before treatment was 223 mg/l. Treatment results showed that the chemical flocculation system obtained 90 percent removal of suspended solids, and reduction of final BOD_5 levels between 70 and 130 mg/l or a 57 percent reduction in BOD_5 content, equal to a residual waste load of 0.43 kg/kkg (0.86 lb/ton) of beets processed. Other plant wastes were not accounted for in the total waste balance. These included the continuous discharge of excess condenser waters and some overflow from the lime mud ponds to the river.

The British Columbia Research Council has given preliminary attention to chemical flocculation as a polishing means following activated sludge treatment. The Council found that effluents from aeration units were measurably improved by adding lime or lime together with a coagulation aid.

The use of polymers to promote solids settling in mechanical clarifiers has been used with success at the Winnipeg, Manitoba plant in Canada. In the United States, polymers have not received widespread use because reliance for the improvement of settling in the flume water is made with the addition of lime to the mechanical clarifier or to the earthen holding ponds.

Land Irrigation - The use of beet sugar plant effluents for irrigating agricultural lands directly or indirectly is widely practiced throughout the Western United States. Examples of this practice exist at plants in California and Texas, and in the South Platte River Basin within Colorado. Beet sugar processing wastes are applied directly to agricultural lands when the processing campaign coincides with the growing season. This is true for the warmer climates such as those existing in California. Over much of the remaining Western United States, the waste waters are generally stored in ponds or reservoirs until irrigation commences the following spring. A high degree of water reuse in the water-short areas of the Western United States, predominantly for agricultural irrigation, is strongly reinforced by Western water law.

Irrigation in general does not require as high a water quality but results in a completely consumptive use of the waste waters, with no resultant discharge to surface waters under properly controlled conditions.

Activated Sludge - It has been shown on a pilot scale basis that activated sludge can effectively reduce the organic load in waste flume waters by 83 to 97 percent. The maximum time required in fully adapting the floc to the substrate was less than 96 hours. Bi-oxidation of beet sugar wastes at about 239°C (75°F) was successful, and initial BOD_5 values of 1(35 to 2,000 mg/l were lowered to less than 50 mg/l within 20 to 30 hours.

Pilot plant evaluation of activated sludge treatment at Hereford, Texas has provided favorable results. The study showed that an activated sludge system could produce good organic removals, but the system was rather easily upset. A system loading of 1 kg COD/kg (lb/lb) mixed liquor volatile suspended solids/day with 3,000 to 4,000 mg/l mixed liquor volatile suspended solids was suggested.

Laboratory activated sludge units were also used in Great Britain for treating waste waters received from a plant settling pond. Aeration periods varied from 6 to 24 hours. The first three runs used aeration times of 6 to 17 hours and provided BOD_5 reductions of 48 to 83 percent. The active floc may not have been fully adapted to the waste in these runs. Five other runs using aeration times of 18 to 24 hours produced BOD_5 reductions in the range of 89 to 95 percent. Initial BOD_5 values in the above tests were approximately 400 mg/l. When pond muds were used as a source of innoculum, startup rates were slower than desirable, but with an established active floc, the rates of BOD_5 removal were entirely adequate to handle high BOD_5 loadings. Maximum BOD_5 removal rates for flume wastes, employing an active floc, were obtained within 96 hours. A later report of experiments in which flume wastes from 38 beet sugar plants were subjected to bio-oxidative treatment showed that significant BOD5 reduction was obtained after 72 hours startup period with aerobic treatment.

Trickling Filters - Trickling filter studies undertaken in Texas, Idaho and at many full-scale installations in Great Britain and Western Europe have suggested that such filters may have merit in beet sugar waste treatment. On the other hand, two full-scale trickling filter treatment plants have been constructed for the treatment of beet sugar wastes in the United States (Idaho and Utah). In both cases, treatment performance was most disappointing, and both plants have since been closed. The failures were largely attributed to a gross underestimation of the waste water production rate and difficulty in design and selection of treatment units at these plants.

In Idaho, a conventional trickling filter plant was completed in the summer of 1965 to provide treatment of wastes expected from the Rupert plant during the following campaign. Lime mud slurry was separately impounded, and other plant wastes which comprised essentially the flume and condenser waters were directed for treatment. The facility consisted of a screen station with six vibrating screens in parallel, twin hydro-separators also arranged in parallel followed by a primary settling tank, a single high rate trickling filter, secondary settling tank, and a brush aerator installed on the effluent discharge canal. The hydroseparators provided for removal of the heavier solids; flows in excess of 347 l/sec (5,500 gpm) through the separators were returned to the beet flumes. From the separators, the waste water entered the primary clarifier which was approximately 37 m (120 ft) in diameter, 3.1 m (10 ft) deep and provided a waste retention period of about 2.5 hours. the treatment plant was grossly overloaded, and only 189 l/sec (3,000 gpm) of settled waste water was subsequently applied to the trickling filter; the remaining 158 l/sec (2,500 gpm) was discharged to the receiving stream. Sludges from both the separators and primary settler were pumped to a storage pond. The trickling filter was approximately 60 m (200 ft) in diameter, 3 m (10 ft) deep, and contained 5.1 to 5.2 cm (2 to 6 in) slag material. The slag material was not uniformly distributed within the filter. The recirculation ratio was about 3:1 for this single stage filter. Filter effluent was then received into the secondary clarifier, and the final effluent was released into the receiving stream. The design plants specified 3,200 kkg (3,500 ton) of beets/day to be processed by the Rupert plant; however, during the very first campaign the average processing rate actually amounted to 5,900 kkg (6,500 ton)/day. Treatment plant overload was inescapable and drastic. Although firm data were not available concerning Rupert, it was estimated (13) that the hydraulic load onto the trickling filter approximated 234 million l/ha/day (25 million gal/ac/day), and that the waste load was in the order of 12.6 to 21.6 kg BOD5/cu m of filter media/day (7 to 12 lbs BOD5/cu yd of filter media/day) including recirculation. These applied loads are extremely high. Besides poor distribution of media, there was little or no visible biological growth on the surface of the filter. Water vapor forming over the filter during cold weather retarded air movement in the filter bed, thereby tending to provide insufficient air supply to the bed. Provisions for including air undercurrents through the side and bottom of the bed possibly would have alleviated this condition (13). Furthermore, an automatic skimming device on the primary settler would have aided in removing the substantial accumulation of scum and grease present. Information obtained on Rupert indicated that the treatment plant was providing around 30 to 40 percent BOD_5 removal for that portion of the beet sugar wastes receiving treatment. The conditions as described above were observed principally during the 1965 and 1966 season and do not reflect changes since that time.

The trickling filter in Utah was constructed in 1961 and was intended for treating and recycling waste flume water. During the off-season the filter received various wastes from the plant holding pond. The facility consisted of a screen station, grit chamber, a mechanically-operated clarifier 37 m (120 ft) in diameter by 3.0 m (10 ft) deep, followed by a single trickling filter 37 m (120 ft) in diameter by 1.5 m (5 ft) deep. Two and one-half hours waste detention was provided in the primary settler; a portion of the filter effluent could be returned to the clarifier. The treatment system was reported in 1963 to have major defects. Serious deficiencies in the trickling filter included a poor underdrainage system and improper media specifications. The underdrain system experienced frequent flooding and required additional pumping capacity. Compaction of the media and damage to the underdrains were suspected. The reduction of media interspace served to minimize air circulation through the filter and retarded biological growths. The Lewiston plant wastes also indicated an inorganic nutrient deficit, which may have caused even further difficulty in treatment.

Operation of the filter was initiated too late in the 1961 season to develop adequate biological growth. The filter was reactivated in March, 1962, using holding pond wastes. The results collected during March - May, 1962, showed 0 to 30 percent BOD_5 reduction, with hydraulic and organic loads (including recirculation) of 43.9 l/ha/day (4.7 million gal/ac/day) and 10.8 kg BOD_5/cu m of filter media per day (6 lbs BOD_5/cu yd of filter media/day), respectively. Through June, 1962, the BOD_5 removal increased to the 40 to 60 percent level, with applied filter loads of about 6.3 kg BOD_5/cu m of filter media/day (3.5 lbs BOD_5/cu yd of filter media/day). By November, 1962, the treatment plant BOD_5 reduction dropped to a level of 10 to 50 percent.

Trickling filters have found wide favor at a number of beet sugar plants in Great Britain and Western Europe. Crane described the process by which some plants have contained the wastes in ponds from which the water is passed over trickling filters before discharge to a stream.

During startup in the operation of the filters, it has been necessary to use waste dilution and recycle to avoid overloading the filter system. The contents of the pond are treated and discharged over a period of many months, with maximum BOD5 of the discharged effluent of less than 20 mg/l. Phipps of Great Britain has suggested that trickling filters offer one means of treating accumulated waste waters resulting from the integrated flume and condenser water recycling system. The waste water is stored over the campaign in a large pond and drawn off for treatment at a relatively slow rate throughout the year. The average plant would probably required storage capacity of 75.7 to 113.6 million liters (20 to 30 million gal). Phipps preferred a shallow rather than a deep pond to take advantage of wind mixing and aeration. Research was conducted in this regard, using an 8.1 ha (20 ac) lagoon and a percolating frilter 18.3 m (60 ft) in diameter and 1.8 m (6 ft) deep Filter inflow was diluted with stream water and ranged from 17 to 230 mg/l BOD5; the outflow from 7 to 71 mg/l BOD5. The results showed the filter system produced BOD5 reductions from 60 to 90 percent.

The full-scale waste treatment system at the Bardney beet sugar processing plant in Great Britain consisted of a single filter operating either at low or high rate application and receiving settling pond effluent diluted with river water prior to filter dosing. The pond effluent varied in BOD5 concentrations from 1239 mg/l in March, to about 38 mg/l in October. The waste water temperature varied from 3 to 21°C (39 to 60°F), and filter loadings ranged from 0.13 to 1.39 kg BOD5/cu m of filter media/day (0.07 to 0.77 lbs BOD5/cu yd of filter media/day) with an average load around 0.72 kb BOD5/cu m of filter media/day (0.4 lbs BOD5/cu yd of filter media/day). Total waste volume treated was 144 million l (38 million gal). BOD5 reductions varied from 55 to 97 percent, with removals of 83 percent or higher occurring in 9 of the 12 months. Final effluent BOD5 values were approaching 20 mg/l. British studies have shown that properly operated filters could consistently produce effluents with less than 20 mg/l BOD5 when the initial levels were between 105 and 180 mg/l. In starting operation of a filter, domestic sewage was recommended to be applied together with the beet sugar plant waste to reduce the time required for full filter adaptation. Primary and secondary settling were considered essential, and it was further recommended that for every 100 mg/l BOD5, the waste water should contain a phosphorous equivalent not less than 1 mg/l. A reference was made to Russian experiences where strong beet sugar wastes of 4,000 to 5,000 mg/l BOD5 have been directly applied at low loading rates to a three-stage filter system resulting in 75 to 85 percent BOD5 reduction.

Recirculation - Reuse Systems - In plants presently utilizing good pollution control technology, both recirculation-reuse systems and biological treatment systems are used to achieve waste load reduction. The nearly-closed waste water recirculation system represents the best level of rigorous waste water control, and has generally proven to be superior to biological methods in terms of overall results.

Flume Water Recycle Systems - A flume water recirculation circuit can be described as one with continuous recycling of waste flume waters and with essential treatment units in the line, thus providing efficient water reuse. Flume water recycling systems are in use or are planned at essentially all beet sugar plants. The extensive recycling flume water system commonly in place or planned at beet sugar processing plants has largely eliminated pollution originating from fecal coliforms in plant waste water.

Mechanical clarifiers providing generally a 30 minute detention period with lime addition may be employed for settling of flume water. Mechanical clarifiers are preferred because they provide better pH control of the recycling operations and require less land. Sludge withdrawn from the clarifier or earthen pond facilities is generally conveyed to a mud holding pond for complete retention; overflow from the mud holding pond is contained in subsequent holding facilities. In most cases where land is available, flume mud is allowed to accumulate within the pond without removal. However, the accumulated mud at the plant at Longmont, Colorado (an initial experimental project sponsored by the Beet Sugar Development Foundation and Federal Water Pollution Control Administration) must be periodically removed from alternate mud settling ponds for disposal on adjacent land. Industry personnel report the cost of removing the accumulated solid material from the pond at approximately $15,000 per campaign or approximately $1.98 per cu meter (50 cents per cu yard) of solid material removed).

Condenser Water Recycling Systems - Partial or most expensive recycling of water for barometric condenser purposes is widely practiced in the industry. A total of 17 plants accomplish recycling of condenser water within the plant, the only waste water discharged being that necessary for total dissolved solids control in the system to prevent excessive scaling. The discharged volumes are disposed of to navigable waters. Ground filtration of waste water is generally not controlled at these installations.

Integrated Flume and Condenser Water Recycling Systems - Condenser waters may be added into the flume recycle circuit because of the flume need for heat thawing of beets or other reasons. Many plants in Europe employ the integrated system in whole or part. Integrated flume and condenser water systems are in use in two U. S. plants. One system was installed in 1956 and has as its basic components a screen station, mechanical settling tanks, sludge pond, spray pond, lime pond, excess water storage pond, and a distribution line leading from the excess water pond back into the plant. Reclaimed waters are pumped from the excess water pond to the plant main water supply tank which in turn serves to supply the beet flumes, beet washer, roller spray table, the condenser system, and to slurry the lime mud.

Alternative methods of flume water recycling include separate discharge of condenser water, dry methods of conveying beets into the plant, or a combination of various inplant and treatment measures to achieve desired waste load reduction. A multiplicity of choices and process alternatives exists in the latter case. However, no discharge of process waste water pollutants to navigable waters is possible through mechanisms of water reuse and recycling in a beet sugar processing plant with control and disposal of excess waste water.

One of the early systems was examined in 1962 by Force for possible improvement. Two areas were found to be of particular significance; first, separate flume and condenser water recycling systems would serve to reduce the high flume water temperatuares existing in early fall. The addition of a spray pond or other cooling device would be desirable on the condenser water circuit. In colder weather, the two systems could be combined thus taking advantage of the warm condenser water which is desirable within the flume waters during colder weather. Second, the lime pond overflow should be eliminated from the circuit because of the many problems caused by high solids. Similar exclusion of sludge pond overflow would aid the circuit, although to a lesser extent.

Land Waste Water Disposal Without Discharge to Surface Waters. Waste disposal of all beet sugar plant wastes without discharge to surface waters may be accomplished through extensive inplant waste water recycling and control and disposal. Any excess waste is ultimately by evaporation and controlled filtration, or in some cases by use of waste water after treatment for irrigation.

One plant in the western portion of the U.S. practices remarkable recirculation and reuse of waste waters with very low intake of 900 l/kkg (215 gal of fresh water per ton) of beets. Although large areas are available for ponding of wastes, actually little is used. There is no discharge to surface waters.

Mass Water Balance in a Beet Sugar Processing Plant

An account of water gains and losses that occur in a typical beet sugar processing operation is given in this subsection. Schematic diagrams of water balance (net gains and losses) for typical flume, condenser and overall process operations are given in Figures VII, VIII and IX respectively.

Water Gains

Water gains in a beet sugar plant result from incoming sugar beets and fresh water intake. Incoming beets normally have between 75 and 80 percent moisture. A moisture content of 80 percent is assumed in subsequent calculations.

Water from incoming beets (75-80% moisture) = 800 l/kkg of beets processed (192 gal/ton)

The quantity of fresh water intake for a beet sugar processing plant is highly variable. Factors to be considered are chemical, physical and temperature qualities of water supplies (ground water or surface sources), and "blowdown" water makeup requirements for solids and scaling control in recycled flume and condenser water systems. Total water requirements for flume and condenser water purposes amount to 10,840 l/kkg (2600 gal/ton) of beets sliced and (2000 gal/ton) of beets sliced, respectively (49). Industrial experience has shown that approximately 20 percent "blowdown" in volume is required to maintain dissolved solids level and scaling control in a "closed" system with fresh water makeup. This would amount to a water volume blowdown of 2170 l/kkg (520 gal/ton) of beets sliced and 1670 l/kkg (400 gal/ton) of beets sliced for the recirculating flume and condenser water systems, respectively.

Water losses in the plant result from:

- Wet weeds and leaves
- Carbonation tank venting
- Drum filter vapor
- Sulfitation vapor
- Ammonia venting on evaporators
- Pulp drying
- Molasses production
- Molasses dilution (Steffen process only)
- Cooling devices

Wet weeds and leaves contribute to water loss in the plant. The moisture content is attributed by Iverson to account for 1 percent by weight of beets sliced. This amounts to 10 l/kkg of beets processed (2.4 gal/ton).

Small amounts of water vapor are lost through venting of carbonation tanks. This water quantity is estimated by Iverson (75) to be 3 percent by weight of beets processed.

Carbonation Tank venting water loss = 30 l/kkg of beets processed
(7.2 gal/ton)

Drum filter vapor is another source of water loss estimated by Iverson to be 1 percent by weight of beets processed.

Drum filter vapor = 1 percent by weight of beets processed
Water Loss = 0.01x(2000)/8.34
= 2.4 gal/ton of beets processed.

Sulfitating of the purified and clarified thin juices is conducted to control juice color formation, to improve the boiling properties of the juices, and to reduce excess alkalinity. Liquid sulfur dioxide is introduced directly into the thin juice pipeline from the second carbonation filters.

Sulfitation vapor water loss = 1 percent of the beets sliced by weight
= 10 l/kkg of beets processed
(2.4 gal/ton)

Some small undetermined water loss occurs through ammonia venting lines on the stream chest of multi-effect evaporators. The venting lines and valves are periodically opened to bleed off small accumulations of ammonia gas in the evaporators.

Pulp drying produces the largest single loss of water in a beet sugar processing plant.

Weight of dried pulp (7-10 percent moisture)=45 kg/kkg of beets sliced
(94 lbs/kkg)

Water in dried pulp (7-10 percent moisture) = 2.9 l/kkg of beets processed
(0.7 gal/ton)

Water loss in pulp drying operation = 159 l/kkg of beets sliced (38 gal/ton)

Iverson reports a total water loss through dryer exhaust of 15 percent on beets. Water loss would then account for 150 l/kkg of beets processed (36 gal/ton).

The values of 159 and 150 l/kkg of beets sliced (38 and 36 gal/ton) are in close agreement. A water loss value of 159 l/ton of beets sliced (38 gal/ton) is selected.

Molasses production in a straight-house operation ranges between 4 to 6 percent by weight of the beets sliced for a Steffen-house operation production is 5 to 7 percent by weight of beets sliced (65). Total molasses production is 5.5 percent by weight of sliced beets (standard industry parameter). A typical analysis of beet sugar molasses is 85 percent dry substance and 15 percent water.

Total molasses produced (5.5 percent by weight of beets sliced) =
55 kg/kkg of beets sliced (110 lbs/ton)

Water in molasses (15 percent) = 8.3 l/kkg of beets sliced (2 gal/ton)

Iverson reports a loss of water in molasses produced of 1 percent of the weight of beets sliced equals 10 l/kkg (2.4 gal/ton) of beets sliced. The values of 8.3 and 10.0 liter/kkg (2.0 and 2.4 gal/ton) of beets sliced are in general agreement. A value of 8.3 l/kkg (2.0 gal/ton) of beets sliced is taken.

Solids in molasses = 0.85(55)
= 47 kg/kkg of beets sliced (94 lbs/ton)

Approximately 30 percent of molasses produced (maximum) may be disposed of on dried beet pulp for animal feeds, or approximately 2.1 percent molasses percent by weight of beets sliced (standard industry practice).

Molasses disposed of on pulp (30% of total molasses produced) =
= 0.021(2000)
= 21 kg/kkg of beets sliced (42 lbs/ton)

Water in molasses disposed of on pulp = 3.2 l/kkg of beets sliced (0.8 gal/ton)

Water in molasses not disposed of on pulp = 5.1 l/kkg of beets sliced (1.2 gal/ton)

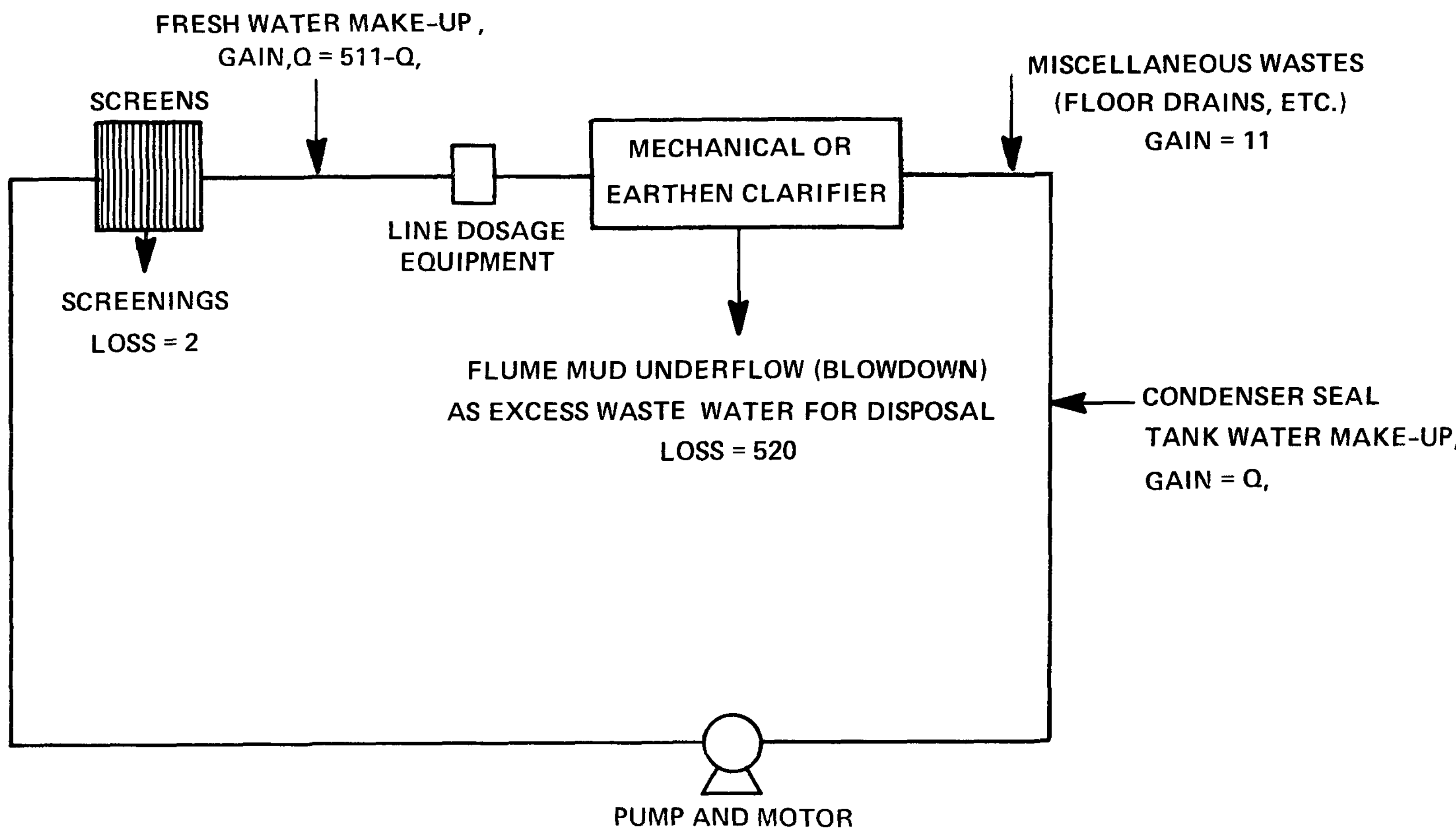
Straight-house molasses containing 85 percent dry substance by weight is diluted with water to approximately 6 percent sugar for processing in the Steffen process.

Solids in straight-house molasses=45 kg/kkg of beets sliced (94 lb/ton)

Weight of molasses after dilution=783 kg/kkg of beets sliced (1568 lb/ton)
Weight of water in diluted molasses = 736 kg/kkg of beets sliced (1473 lb/ton)

Figure VII

WATER BALANCE DIAGRAM FOR A TYPICAL BEET SUGAR PROCESSING PLANT
NET GAINS AND LOSSES [1] FOR FLUME WATER SYSTEM

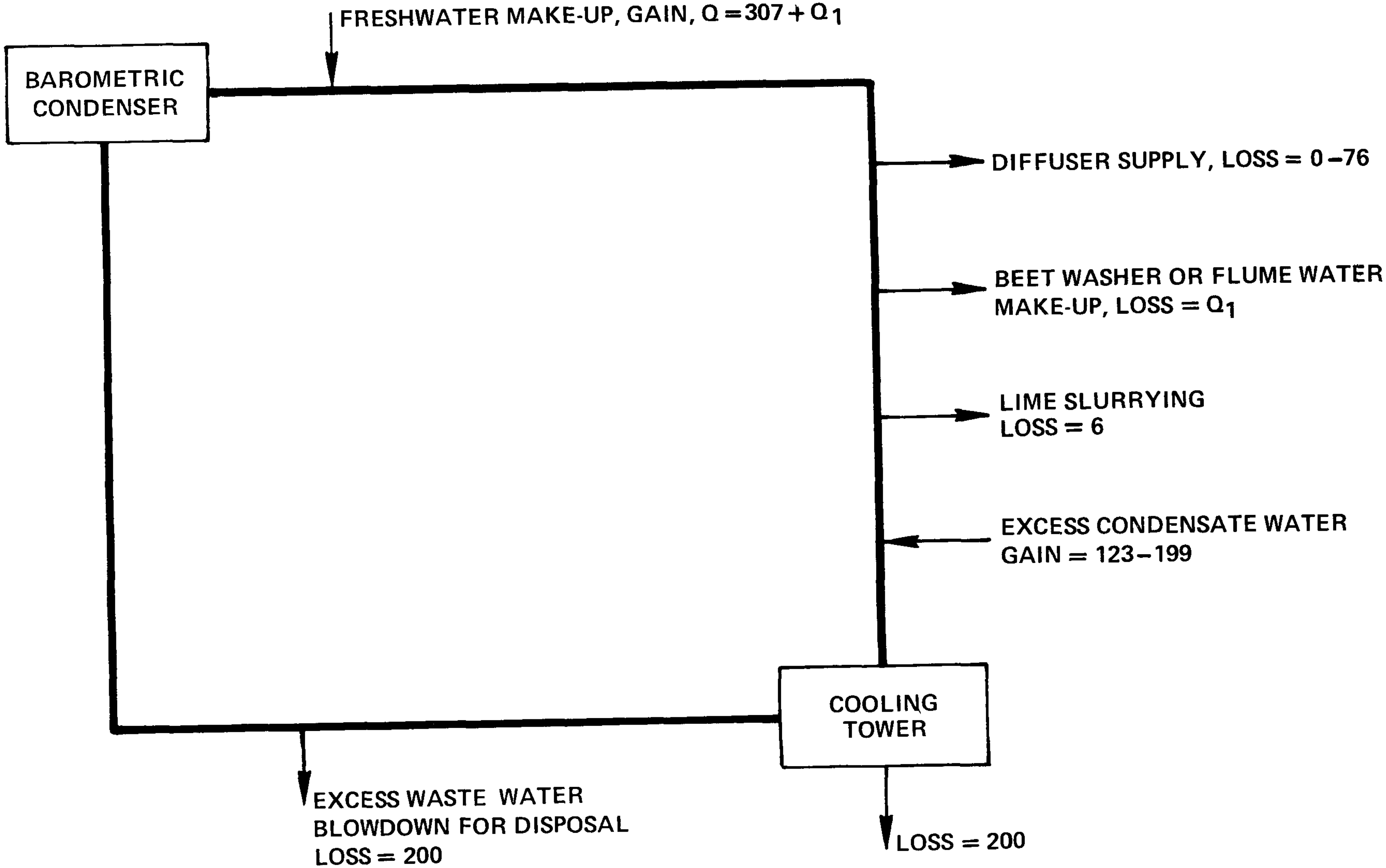


[1] All water gains and losses are expressed in terms of gallons per ton of beets sliced

Figure VIII

WATER BALANCE DIAGRAM FOR A TYPICAL BEET SUGAR PROCESSING PLANT

NET GAINS AND LOSSES[1] FOR CONDENSER WATER SYSTEM

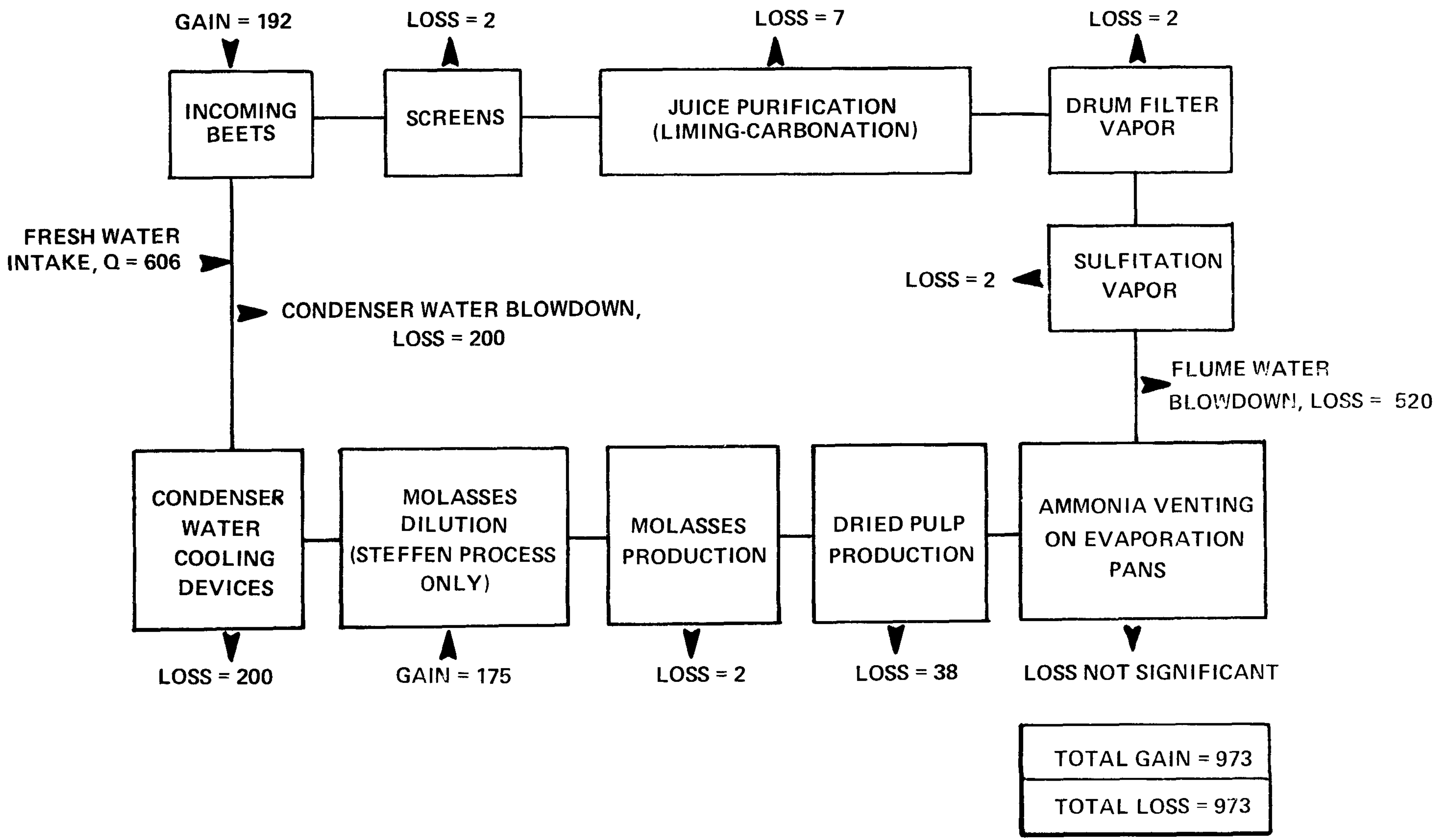


[1] All water gains and losses are expressed in terms of gallons per ton of beets sliced.

Figure IX

WATER BALANCE DIAGRAM FOR TYPICAL BEET SUGAR PROCESSING PLANT

NET GAINS AND LOSSES [1] FROM TOTAL PROCESSING OPERATION



[1] All water gains and losses are expressed in terms of gallons per ton of beets sliced

Volume of water in diluted molasses (Steffenhouse) =
736 l/kkg of beets sliced (176 gal/ton)

Required dilution water for molasses = 736 - 7
729 l/kkg of beets processed (175 gal/ton)

Cooling devices (spray ponds, open cooling ponds, cooling towers, etc.) result in evaporative water losses in the process of cooling condenser and other heated waters. Cooling towers account for an evaporative loss of 10 to 15 percent of the total condenser water volume (8350 l/kkg of beets processed) (2000 gal/ton). of beets sliced). A 10 percent evaporative loss through cooling of condenser waters is assumed where cooling devices are employed for condenser water (835 l/kkg of beets processed) (200 gal/ton).

In-plant Water Uses

Pulp press water originates from the pressing of exhausted beet pulp removed from the diffuser.

Weight of wet pulp from diffuser (80 percent of beets sliced by weight)
= 800 kg/kkg of beets processed (1600 lbs/ton)

Water contained in wet pulp from the diffuser (95 percent moisture)
= 764 l/kkg of beets sliced (183 gal/ton)

Dry solids in wet pulp from diffuser = 40 kg/kkg of beets sliced (80 lb/ton)

Water contained in the exhausted pulp after pressing ranges between 76 and 84 percent. Eighty percent moisture of pressed pulp is common.

Weight of wet pulp after pressing (80 percent mixture)
= 200 kg/kkg of beets sliced (400 lbs/ton)

Water contained within pulp after pressing (80 percent moisture)
= 163 l/kkg of beets sliced (39 gal/ton)

Water extracted by pulp pressing = 764 - 163
= 600 l/kkg of beets sliced (144 gal/ton)

The diffusion process involves the extraction of sucrose from sliced beets. The sugar-laden liquid (raw juice) and exhausted pulp resulting from the process are used subsequently in the processing operation. Total diffuser supply water is normally made up by 65 percent from pulp press water (601 l/kkg of beets sliced) (144 gal/ton of beets sliced) which is returned to the diffuser. Estimated total diffuser supply of this basis of water equals 918 l/kkg of beets sliced (220 gal/ton).

Raw or diffusion juice has 12 to 15 percent solids or sugar, which is about 98 percent of the sugar which was contained in the beets when sliced. Fifteen percent solids in diffusion juice is assumed (standard industry parameter). Fifteen percent sucrose content is a normal figure for beets.

Sugar contained in diffusion juice = 0.15 x 1820 x 0.98
0.15 x 2000 x 0.98
= 147 kg/kkg of beets processed (294 lbs/ton)

Total weight of diffusion juice = 983 kg/kkg of beets sliced (1960 lb/ton)

Weight of water contained in diffusion juice = 836 kg/kkg of beets sliced (1670 lbs/ton)

Volume of water in diffusion juice = 835 l/kkg of beets sliced (200 gal/ton)

Raw juice "draft" normally runs between 100 and 150 percent in the diffusion process (120 percent is used in this calculation).

$$\text{Draft (percent)} = \frac{\text{Weight of diffusion juice drawn from diffuser}}{\text{Weight of cossettes introduced (beets sliced)}} \times 100$$

Weight of raw juice from diffuser = 1200 kg/kkg of beets sliced (2400 lb/ton)

Weight of solids in raw diffusion juice = 180 kg/kkg of beets sliced (360 lb/ton)

Weight of water in raw diffusion juice = 1020 kg/kkg of beets sliced (2040 lb/ton)

Volume of water in raw diffusion juice = 1020 l/kkg of beets sliced (245 gal/ton)

The diffusion process water supply requirements as determined by the somewhat different approach above (835, 918, 1020 l/kkg of beets sliced (200, 220, and 245 gal/ton) are in general agreement. A value for total diffuser water supply requirements of 918 l/kkg of beets sliced (220 gal/ton) is taken as an industry-wide practice. On the basis of total water supply requirements for diffusion purposes of 918 l/kkg of beets sliced (220 gal/ton) and return of 600 l/kkg (144 gal/ton) of beets sliced of pulp press water to the diffuser, requirements for diffuser water makeup from other sources (condensate water, condenser water, etc.) would be 918 - 600 = 318 l/kkg of beets sliced (76 gal/ton)

Condensate water, generally the purest water source within the plant, is generated in large quantities through the process of concentrating the purified, thin juice after liming and carbonation. In the concentrating process, the raw juice is reduced from 10 to 15 percent solids to 50 to 65 percent solids. When raw juice is concentrated, water is produced in the concentration process through condensation of vapors from juice boiling. A typical juice concentration of 55 percent solids is taken as common practice (standard industry parameter).

Weight of solids in raw diffusion juice (15 percent solids) =
= 180 kg/kkg of beets sliced (360 lbs/ton)

Volume of water in raw diffusion juice = 1020 l/kkg of beets sliced
(245 gal/ton)

Total weight of "thick" juice after concentration = 327 kg/kkg of beets
(655 lbs/ton)

Weight of water in "thick" juice after concentration
= 148 kg/kkg of beets sliced (295 lbs/ton)

Total condensate water produced from concentration of raw juice =
= 1022 - 146 = 876 l/kkg of beets sliced (210 gal/ton)

Condensate water is commonly used for boiler feed and makeup diffuser supply, floor washing, or other uses in the plant. Vapor in multi-effect evaporation are used sequently in evaporators for heating effects. Excess vapor from evaporation are generally used for heating purposes. Condensate from the first evaporation effect is generally preferred for the supply of diffuser water. Condensate from the second through fifth evaporator effects is employed for boiler feed, washing filters, washing floors, and diffuser water makeup.

Total condensate volume (918 l/kkg of beets sliced) (220 gal/ton) may be attributed to diffuser supply (317 l/kkg of beets sliced) (76 gal/ton), floor washings (46 l/kkg of beets sliced) (11 gal/ton), and an excess of approximately 510 l/kkg of beets processed (123 gal/ton). The excess condensate volume is not generally metered, and is usually discharged to the condenser water system. Condensate water is essentially pure and may be satisfactorily used for makeup in condenser systems for total solids control.

Boiler feed is supplied by condensate water from the first, second and third pan evaporation processes.

The steam has a temperature and pressure of about 302°C (575° F) and 28.2 atm (400 psi). The pressure of the exhaust steam after power generation is 4.1 atm (45 psi). Makeup required by the necessity of blowdown for solids control in the boiler system is reported normally to account for 4 percent of the generated steam.

Press water is supplied directly from condensate water from the fourth and fifth effect evaporators, overflow from the boiler feed system, and miscellaneous other sources such as second high raw and evaporator pans, heaters, and juice boilers. The press water is used for washing lime mud during dewatering of precipitated lime from juice purification on vacuum filter. The combined filtrate and wash water from the rotary vacuum filters is called "sweet water", and this is used to supply milk of lime in a straighthouse, or saccharate milk in a Steffen house. Excess "sweet water" is returned to first or second carbonation stages. The quality of condensate water utilized for press water is unknown, and is not metered at most plants. No reliable estimate can be made.

Floor washing is accomplished with a condensate water use as high as 192 l/sec (50 gpm) at one 5900 kg/day (6500 ton/day) plant. The quantity of water used for floor washing would be expected to be largely independent of plant size. Water use is approximately = 46 l/kkg of beets processed (11 gal/ton).

Lime mud from vacuum filters is diluted with water from 50 percent to 40 percent solids to facilitate pumping to holding facilities.

Lime slurry volume = 375 l/kkg of beets processed (90 gal/ton)

Specific gravity of solids $Ca(OH)_2$ = 2.08

Weight of solids in lime slurry = 23 kg/kkg of beets processed (46 lb/ton)

Weight of water in lime slurry = 22 kg/kkg of beets processed (44 lb/ton)

Volume of water in the lime slurry = 22 l/kkg of beets processed (5.3 gan/ton)

Water use for lime slurrying is reported to be as high as 170 l/min (45 gpm)
(5900 kkg/day) = 41 l/kkg of beets processed
(6,500 ton/day) = 10 gal/ton of beets processed.

The values, 22 and 41 l/kkg, (5.3 and 10 gal/ton) of beets processed are in general agreement. A value of 25 l/kkg (6 gal/ton) of beets processed is taken as an industry-wide figure. The water used for lime slurrying may be provided from condenser water sources.

The mass water balance for the average sized (3600 ton/day) beet sugar processing plant indicates the necessity to adequately dispose of 9.8 million l/day (2.6 million gal/day) (2700 l/kkg) (720 gal/ton of beets processed) of waste water generated over an average 100 day processing campaign.

The length of the processing campaign may be considerably longer in warm and arid climates, e.g. California (220 to 290 slice days); however, land availability and climatic conditions in these locations permit controlled land disposal of all waste waters or use after treatment for crop irrigation purposes. Adequate disposal of waste waters from beet sugar processing plants with zero discharge to navigable waters can be accomplished through controlled land disposal. Controlled land disposal is accomplished by limitation of maximum filtration in waste water holding ponds (0.635 cm (1/4 in) drop in liquid surface per day); and acceptable reduction in pollutants by treatment, if necessary, to permit crop irrigation. No pollution of discrete underground aquifers may result from the land disposal method, and surface runoff from irrigated lands must be practically excluded from runoff from adjacent land areas.

Identification of Water Pollution Related Operation and Maintenance Problems at Beet Sugar Plants

Improper design and control of biological-recirculation systems, variability of waste water quantities and qualities, and process variables can give rise to operation-related problems at beet sugar plants. These operational problems are generally related to reduced performance of waste treatment facilities, or odor and nuisance level control.

Variability in the quantity and qualities of flume water, condenser water, and floor washing can present difficulties in treatment of these wastes. Variability may often be accounted for due to accidental spills and introduction of deteriorated beets into the fluming system.

Condensate water used as house hot water for evaporator and floor cleaning often require the addition of acids or caustic soda. The wastes are generally discharged to the main sewer of the plant and the flume water system. The flow is intermittent and often results in sudden change in the pH of the waste water as discharged to ponds. This accounts, in part, for erratic behavior of waste treatment processes and is indicative of the need for pH control facilities.

Improvement in the design and arrangement of new equipment for the industry should help prevent unintended losses of miscellaneous waste waters into the treatment and disposal system. Expanded use of automation will also assist in maintaining better plant control and reducing shock waste loads.

Difficult problems often result from the use of waste lagoons and mechanical clarifiers for treatment of beet sugar wastes. The problems incurred generally relate to improper operation and maintenance, and result in offensive odors from the state of anaerobic conditions established in these facilities. Screening of effluent wastes, and periodic removal of accumulated solids can substantially reduce or minimize odor and nuisance-related problems.

Odors generated from various pollution control related operations are a problem at a number of plants. Plants have used various aeration devices in holding ponds with maintenance of shallow pond depths to control odors. Holding ponds may receive overflow from the flume mud pond, clarifier effluent from the flume system, and excess barometric condenser water. Aeration may be accomplished by means of a spray system. Mechanical aeration devices are often employed for the initial anaerobic pond of an extensive anaerobic-aerobic lagoon system for odor control.

Poor operation and maintenance (a common practice at many plants) contributes to many difficulties. Where shallow ponds are employed for waste treatment, the failure to remove routinely accumulated solids when necessary from the ponds reduces the effectiveness of waste treatment. Improper waste retention results in low organic removal, solids carryover, and low bacteriological reduction efficiency. Waste retention is severely limited by solids filling, extensive weed growth, and uneveness of the pond bottom.

Of greatest concern in the recycling of flume water is control of odorous and corrosive properties of the recycled flume water. These factors are primarily related to the maintenance of alkaline pH conditions (pH 8-11) in the system, which is generally accomplished by the addition of lime under carefully controlled and monitored conditions. Lime addition also enhances the ability of solids to settle in the recirculated flume water system.

The leaching of sugar from beets which have been frozen is considerably higher than that from unfrozen beets in the flume system. Freezing and thawing of beets destroys the structural integrity of the outer beet fibers, releasing sugar contained in the beets to the flume waters. The dislodged fibers of the beets often pass through screening devices and are discharged to the flume water clarifier or earthern holding ponds. These conditions present nuisance-related problems and operational difficulties. Foaming within the flume and condenser water system is a major problem particularly during the latter part of the campaign in regions when processing frozen beets. The foaming problem is particularly enhanced by low pH conditions.

Fecal streptococcus organisms are known to increase dramatically in a recirculating flume water system. This growth has been found to increase as the processing season progresses. The bacterial growth present no pollution or production-related problems in the recycling process. A final freshwater wash of the sugar beets prior to slicing is necessary for the beets prior to processing for production control purposes.

The continuous processing of sugar beets over the entire processing campaign without "shut down" presents difficulties (particularly in older plants) with proper maintenance of acceptable housekeeping practices, and continuous operation of equipment. Because of the nature of the processing operation, leaks and breakages in waste water and molasses conveyance lines are not repaired expediently. Water hoses are frequently left running at intervals to control foaming, to flush spilled materials into drains, and for other purposes. These practices result in wasteful use of water with increased waste water contributions for subsequent treatment and disposal. Much improved housekeeping procedures are needed within the industry to minimize pollution, particularly at older plants. The beet sugar industry has recently made substantial efforts toward reducing pollution by improved housekeeping.

Improvements in the mechanical harvesting equipment for sugar beets are being made to the end that the crops will be received at the plants in cleaner condition. Improvements are also being made, almost routinely, in the equipment used for dry separation of the unwanted material from the sugar-bearing material.

Soil As A Waste Water Disposal Medium

With increasingly rigid pollution control standards for surface waters emphasis has been placed in recent years on land disposal of industrial wastes and municipal sewage effluents. In land disposal of waste waters, the soil acts as an effective filter in removal of particular contaminants. Aerobic biological action near the soil surface is effective in substancial removal of biodegradable organics. The soil particles are quite effective in removal of many substances, particularly phosphates, by absorption and ion exchange. Of concern in land disposal of waste waters is the current lack of complete knowledge of the hydrology and hydro-mechanics of the ground water region, with predictable regard for the fate and effects of subsurface pollutants. Dissolved materials derived from wastes water particularly non-biodegradable inorganic salts may tend to be persistent in ground waters in as much as the capacity of the soil to remove minerals by absorption and ion exchange could be exhausted, with decreased efficiency with the passage of time. Effluent spraying on land has been demonstrated on a full scale basis with total nitrogen removals from waste water from 54 to 68 percent and 76 to 93 percent removal in total phosphorus (101).

Pollutant removal efficiencies are dependent on soil loading and climatological conditions.

Agricultural is the major contributor to percolating of ground water contaminants -- chlorides, nitrates, and non-biodegradable organic materials.

Agriculture contamination of ground water is intensified in arid areas where ground water is used for irrigation process. Salt is inherently concentrated in the irrigation process with water intake by growing plants. Most contamination of ground waters in inland areas occurs from breaching of imperious barriers between fresh and saline waters. Ground water pollution problems are most evident in areas of intensive land use. The build-up of contaminates in ground waters from percolating pollutants is seldom dramatic, and sources of percolating pollutants are both diffuse and diverse.

In inland areas of the U.S. approxomately two-thirds of the conterminous region is underlain by saline waters containing greater than 1,000 mg/l disolved solids. This condition has resulted largely by natural geological factors with the washing of soluble salts from the soils in large basins where the salts have been concentrated by evaporation. Possible processes or combinations of processes for conversion of inland saline water as well as sea water to fresh water for agriculture, industrial, municipal, and other uses have been investigated since 1952, by the U.S. Dept. of the Interior under authority of Public Law 448. The Office of Saline Water, U.S. Department of the Interior classifies any water containing from 1000 to about 35,000 ppm as brackish. Sea water contains approximately 35,000 ppm and water containing more dissolved solids than sea water, such as the Great Salt Lake is classified as brine.

Processes include vapor-compression methods, ion exchange, solar (multiple effects) distillation, freezing, osmotic processes, electrodialysis (membrane process) and ultrasonics. Ion exchange appears particularly promising when the concentration of dissolved materials is below 4000 to 5000 mg/l. Several plants applying this method have been constructed in recent years. At the present state-of-the-art, large scale treatment of brackish waters with a comparatively low content of dissolved solids is possible. Most existing installations are limited in capacity, producing fresh water quantities on thousands of l/day rather than millions of liters daily. The membrane processes, reverse osmosis and electrodialysis, have their primary application in the desalting of brackish waters in the general range of 2000 to 10,000 ppm of total dissolved solids.

Large demonstration plants (1 MGD) have been constructed at Freeport, Texas; San Diego, California; and Roswell, New Mexico.

The cost of converting saline water has been reduced substantially during the last 10 years. Conversion cost ranges from about $0.6 to $1.50 per 3785 liters (1000 gal) exclusive of distribution costs depending on the process used, the brackishness of the raw water, the capacity of the plant, and other factors. Desalination is an expensive process from the standpoint of capital investment and daily operating costs.

Industry in the United States consumes on an average about 2 percent of its total water use (619 billion l/day (140 billion gal/day in 1960)). The heaviest consumption is in connection with irrigation where 60 percent or more of the water is lost to the water system through evaporation and transpiration. About 17 percent of water used for public supplies is consumed. Consumptive use of water is the quantity of water discharged to the atmosphere (evaporated) or incorporated in the products of the process in connection with vegetative growth, food processing or incidental to an industrial process. In the western portion of the U.S., present salinity conditions resulting from irrigation return flows (approximately 40 percent of all water withdrawn from surface and ground sources in the United States is for irrigation) far outweigh the salinity contribution attributed to the beet sugar industry. Furthermore, the majority of beet sugar processing plants are located in low intensity land use areas

Control of salinity and total dissolved solids contributions from beet sugar processing wastes can be accomplished without ground water pollution through proper location of land disposal sites, regulatiocn of waste water filtration rates, consideration of geographical, hydrologic and geologic factors and conduct of an adequate monitoring program of nearby underground aquifers. At present all beet sugar processing plants incorporate land for disposal of all or part of the waste water flow. No serious ground water pollution problems are known to occur as attributed to these practices.

In any method of dissolved solids removal, concentrated salt solutions as a byproduct of the desalting technology must be disposed. The likely method for disposal of this material is land disposal under controlled conditions.

SECTION VIII

COST, ENERGY, AND NON-WATER QUALITY ASPECTS

Cost and Reduction Benefits of Alternative Treatment and Control Technologies

A detailed analysis of the costs and pollution reduction benefits of alternative treatment and control technologies applicable to the beet sugar processing segment of the sugar processing industry is given in Supplement A of this document. The basic results are summarized below for an average-sized 3300 kkg/day (3600 ton/day) beet sugar processing plant.

Alternative A - No Waste Treatment or Control

Effluent waste load is estimated at 5.8 kg BOD5/kkg (11.7 lbs BOD5/ton) of beets processed (22 lbs BOD5/ton of beets processed including Steffen wastes) for the selected typical plant at this minimal control level. Disposal of Steffen waste on dried pulp, byproduct recovery or land disposal is assumed, as this is universally practiced in the industry. No control of lime mud slurry, flume water discharge, or condenser water flow is assumed. Pulp transport and press waters are recycled with the plant process.

Costs. None. Reduction Benefits. None.

Alternative B - Control of Lime Mud But Discharge to Receiving Streams of All Other Wastes

This alternative includes control of lime mud slurry in earthern holding ponds without discharge to navigable waters but no control for other wastes. This practice is used at all plants presently within the industry. Effluent waste load is estimated at 2.6 kg BOD5/kkg (5.1 lbs BOD5/ton) of beets processed for the better plant at this control level.

Costs. Increased capital costs are approximately $50,000 over Alternative A, thus total capital costs are $50,000.

Reduction Benefits. An incremental reduction in plant BOD5 of 57 percent compared to Alternative A is evidenced. Total plant reduction in BOD5 is also 57 percent.

Alternative C - Extensive Recycle of Flume Water Without Discharge to Navigable Waters

Under Alternative C there would be extensive recycle of flume water with no discharge of process waste water pollutants to navigable waters, incorporating treatment of flume water by screening and settling, and with mud drawoff to holding ponds for controlled land disposal. This technique is presently practiced by a large portion of the industry. Present industry plans call for complete installation of extensive flume water recycling systems by 1975. Effluent waste load is estimated at 0.25 kg/kkg (0.5 lbs BOD5/ton) of beets processed for a better plant at this control level. Presently, all but 6 plants employ recirculating flume water systems.

Costs. Increased capital costs of $228,000 to $310,000 over Alternative B would be incurred, thus producing total capital costs of $278,000 to $360,000.

Reduction Benefits. An increment reduction in BOD5 of 90 percent in comparison to Alternative B would result, thereby producing a total reduction in plant BOD5 of 96 percent.

Alternative D - Extensive Recycle of Condenser Water Without Discharge to Navigable Waters

Alternative D would result in complete recycling of condenser water with land disposal of excess waste waters without discharge to navigable waters. Extensive water recycling and reuse within the plant process is assumed. Effluent waste load is zero kg BOD5/kkg (zero lb BOD5/ton) of beets processed for the better plants at this control level.

Costs. This alternative would require increased capital costs of $176,000 to $316,000 over Alternative C, or total capital costs of $454,000 to $676,000.

Reduction Benefits. There would be an increment reduction in BOD5 of 100 percent in comparison to Alternative C, or a total reduction in plant BOD5 of 100 percent.

In consideration of land availability factors as variables in the application of land based technology for accomplishing zero discharge of waste waters to navigable waters, the following four conditions are recognized as being applicable to existing plants within the beet sugar processing industry. The capital costs of the application of technology to accomplish zero discharge of all waste waters to navigable waters is given for each of the various conditions are given curves representation of the various conditions are given in Figures X through XIV. Cost figures reflect land requirements based on a 0.635 cm/day (1/4-in/day) filtration rate, an average sized plant of 3300 kkg/day (3600 ton/day) capacity, and an average 100-day processing campaign.

Condition A serves as the basis for the cost estimates and pollutant reductions associated with zero discharge of waste waters to navigable waters. Further datails of this analysis are given above under Alternative A through D for varying levels of pollution control for this condition. Other conditions described below (Conditions B, C, and D,) serve to delineate possible restraints of land availability and their resulting effects on the cost effectiveness of successful incremantal pollutant removals under these land availability restraints.

Condition A - Land requirements for controlled land waste water disposal are physically available adjacent to the plant site and under the ownership of the plant. Total land costs are assumed at $810/ha ($2000/ac) which includes costs of holding pond construction and infilatration control measures.

Total capital costs = $454,000 to $676,000 Cost-effectiveness curves are shown in Figure X and XI.

Condition B - Land requirements for controlled waste water disposal are physically available adjacent to the plant site but <u>not</u> under the ownership of the plant. Land costs are taken at $1220/ha ($3000/ac) including $405/ha ($1000 per ac) purchase price and $815/ha ($2000/ac) costs for pond construction and seepage control measures.

Total capital cost = $609,000 to $800,00 A cost-effectiveness curve for this condition is presented in Fig. XI.

Condition C - Land requirements for controlled land waste water disposal are not physically available adjacent to the plant site, but suitable land is available under ownership of the plant within the plant vicinity. Suitable land for controlled waste water disposal is assumed to be available at 4.82 km (3 mi) from the plant site. Land costs are taken at $810/ha ($2000/ac) including costs for pond construction and seepage control measures. Waste treatment costs are assumed to include all construction costs including pipeline, pumping station, engineering and design, right-of-way acquisition and contiuency costs. Costs of right-of-way are taken at $2050 per ha ($5000/ac) with 0.38 ha required/km (1.5 ac required/mi) of pipe. A 3.7 m (12 ft) right-of-way is assumed.

Condition D - Land requirements for controlled land waste water disposal are not physically available adjacent to the plant site. Suitable land for controlled waste disposal is located within 4.82 km (3 mi) of the plant site but not under ownership of the plant. Land costs are taken at $1220/ha ($3000/ac) purchase price including $405/ha ($1000/ac) purchase price and $815/ha ($2000/ac) costs for pond construction and seepage control measures. Waste transmission costs are assumed to include all contruction costs including pipeline, pumping station, engineering and design, right-of-way acquisition, and contigency costs. Costs of right-of-way are taken at $2030/ha ($5000/ac) with 0.38 ha/km (1.5 ac /mi) of pipe. A 3.7 m (12 ft) right-of-way is assumed.

As expected, the cost relative to increased effectiveness in removal of pollutants (as measured by BOD_5) increase as the level of pollutant in the effluent decreases. This relationship is shown in Figure XI. As illustrated, in proceeding from Alternative C to Alternative D the increased capital costs perunit of pollution load reduced rises by a factor of 5 to 12.

As developed in Supplement A, total industry capital costs with consideration of existing pollution control facilities and processes (Conditions A) are estimated to range between approximately $9 million and $16 million for extensive recycling and reuse of flume (beet transport) and condenser water without discharge to navigable waters. Corresponding total industry wide annual costs including operation and maintenance, depreciation and annualization of capital expenditures are estimated at approximately $2.3 to $3.8 million for existing conditions.

Basis of Assumptions Employed in Cost Estimation

Judgments and Assumptions Used

Annual interest rate for capital costs = 8%
Salvage value of zero over 20 years for physical plant facilities and equipment
Straight line depreciation of capital assets
Annual operating and maintenance expenses of 10 percent of capital costs for pollution control measures, permanent physical facilities and equipment, except that an additional cost of $15,000 is allowed for solids removal from the flume water mud pond. The costs include all expenses attributed to operation and maintenance of control facilities routine maintenance of equipment, and facilities, labor, operating personnel, and monitoring and power costs.

All economic terms are used as described in the Glossary (Section XV) of this document.

Where adjustment of cost data to August 1971 dollars (the baseline of this report, the cost figures have been adjusted in accord with indices published for use in EPA publication "Sewage Treatment Plant and Sewer Construction Cost Index," September, 1972. Cost-effectiveness relationships for the above alternative technologies are shown in

Figures X and XIV. The basis for development of the curves is covered in detail in Appendix A to this document, and the curves are included here for purposes of clarity of presentation.

Related Energy Requirements of Alternative Treatment and Control Technologies

Processing of sugar beets to refined sugar requires about 1.32 kw (1.61 hp) of electrical energy per kkg of beets sliced per day. This electrical energy demand is affected by factors such as: 1) the type of beet receiving and cleaning facilities, 2) whether or not a Steffen house is provided, 3) the lime production method, 4) the drying and pelletizing of beet pulp, and 5) the number of steam drive units compared to electrical motor drives, particularly in the higher power units.

The electrical energy consumption perunit of product output has continually increased over the years, and this trend appears unlikely to change in the foreseeable future. Among the primary reasons for increased demand are the extensive mechanization of the process, higher lighting illumination levels, and new practices; i.e., waste water treatment, requiring additional electrical power for circulation pumps and aerators.

For the "typical" 3300 kkg (3600t) per day beet sugar processing plant, total energy requirements are estimated at 4320 kw (5800 horsepower) under operating conditions. Principal power requirements attributable to pollution control in a beet sugar processing plant are related to recirculation of waste water flows (primarily flume and condenser water) for in-plant reuse. Iverson reports the energy requirements, on the basis of experience with plants of the Great Western Sugar Company to permit recycling of flume water flow. At a "typical" plant this is approximately 370 kw (500 horsepower). Because of the general similarity of waste volumes attributed to flume and condenser water, power requirements for recycling condenser water may logically be assumed to be the same as that for the recirculation of flume water. Thus, the total power requirement for recycling of both flume and condenser water is approximately 740 kw (1000 horsepower) or 20 percent of the total plant power requirement. Iverson also estimates that the additional annual power costs for pollution abatement purposes incorporating both the flume and condenser water recycling systems is estimated at approximately $22,000. The cost of energy is taken at 1 cent per kwh.

Because of its need for relatively large quantities of low pressure process steam, the beet sugar industry usually finds it economical to generate its own electric power. The power plant normally uses a noncondensing steam turbine generator which exhausts steam at the pressure required by the process. This power can be generated for about half the fuel required in a condensing steam turbine generator plant used for power generation only.

Regardless of the source of electrical power, steam-boiler facilities must be provided to supply the process steam requirements. With in-plant generation, the fuel chargeable to power is the additional fuel needed over that required for operation with purchased power. The cost of fuel chargeable to electric power generation by a noncondensing steam turbine is 0.425 mils per kwh for each 10 cents of fuel cost per 250,000 kg cal (1,000,000 Btu). Thus, using 40 cent fuel, and with a cost of purchased power of 8 mils/kwh with an assumed load of 4000 kw (5300 horsepower), the plant could pay for the entire installation cost of a noncondensing steam-turbine generating set in approximately 3 years, not including taxes.

The reliability of the main steam supply system and the need for process steam has made it normal practice to power the large horsepower individual loads with mechanically-driven, noncondensing steam turbines. Typical of such units are the carbon - dioxide and Steffen-refrigeration compressors. Turbine-driven compressors allow the steam designer further flexibility in balancing out the steam requirements in the whole plant.

Almost all beet sugar plants purchase some outside electrical power for standby usage when the plant is not in operation. Power is required for plant maintenance, liquid sugar production, bulk sugar handling, packaging operations, lighting, and office - machine operation. In the event of power plant disturbances and loss of plant generated power, the standby power provides for critical electrical loads, such as emergency lighting, and boiler plant and water systems. Usually it is not economical to size the utility company purchased power standby source to meet the total electrical demand of the plant. Generally, it is sized for about 20 percent of the total plant demand.

If properly designed, the electrical power system may be expanded readily with a minimum amount of additional investment.

Non-Water Quality Aspects of Alternative Treatment and Control Technologies

Air Pollution

There are three main items of air pollutional significance in the beet sugar processing industry: suspended particulate matter, sulfur oxides and odors. Fogging in the area of cooling towers or other cooling devices may present visibility problems in isolated cases.

Suspended Particulate Matter. The primary sources of potential particulate emissions result largely from the steam boiler and pulp drier stacks. Minor sources of particulate emissions include granulator exhaust, dry sugar, dried pulp, limestone, burnt lime and coal handling equipment, waste ponds, and kiln booster fans.

Properly designed and maintained gas and oil fired boilers should present no particulate emission problems. Fuel oil, however, can present a sulfur dioxide emission problem. One of the most economical methods to avoid sulfur dioxide emissions is to burn only low sulfur fuels.

Since some plants burn coal as a primary fuel, particulate emissions can be a problem. Fly ash, an emission common to all coal burning units, is composed of the ash and unburned combustibles which become airborne in the firebox and find their way to the atmosphere because of the velocity of the flue gas through the boiler and up the stack. The type of stoker equipment used has much to do with the amount of fly ash emitted. In terms of fly ash emission control, pulverized coal spreader stoker and chain grate and underfeed stoker units emit lesser amounts of fly ash to the atmosphere in that respective order.

Fly ash emissions can usually be controlled with multicyclone mechanical collectors or electrostatic precipitators. A properly designed and installed mechanical collector will do a satisfactory job on virtually all types of coal-fired boilers except pulverized coal. Electrostatic precipitators are generally required on pulverized-fuel fired units. They have the advantage of increased efficiency with a low draft loss. Generally, the lower the sulfur content of the coal, the poorer the efficiency of the precipitator. Precipitators are the most costly of the commonly used particulate collectors in boiler plants.

Smoke is unburned carbon and results from poor combustion. Smoke emissions are usually the most troublesome and visible at a beet sugar processing plant. Smoke emission problems from a boiler plant stem from many sources. Some of the main sources include the type of coal, load on the boiler, distribution of coal on the grate, overfire air, fuel to air ratio, fuel oil atomization, and grate and setting air seals. All of these problems may be alleviated through proper design, operation, and maintenance of the boiler facilities. These considerations are discussed in detail in Beet Sugar Technology, Second Edition. The other major source of air pollution emanating from a beet sugar plant is that of the exhaust gases from the pulp dryer. These pollutants are pulp dust, molasses dust, fly-ash (if coal or oil fired) and smoke. Reduced emissions have been found to result by installing multiple cyclones of smaller diameter, or skimming a cyclone vent stack, thus removing much of the particulate matter load and return the purified air to the furnace as dilution air for temperature control. A skimming system has two major advantages. First, a large portion of the particulate matter is removed from the exhaust; second, up to 10 percent increased thermal efficiency can be realized because of the smaller heating load on the dilution air, since the recycle gas is already above 93°C (200°F). The other source of air pollution in the pulp dryer is the dust created by the handling of dried pulp and pelleting equipment. This source can be controlled with a well-designed hood pickup system and a high efficiency mechanical collector.

Sulfur Dioxide. Boiler flue gas contains sulfur dioxide as an important air pollution source. Sulfur is present in all coals and most heavy fuel oils. Common gas scrubbing systems for removal of particulate material are generally rather ineffective in removal of sulfur dioxide. However, within the past year a Venturi-type scrubber has been installed at one beet sugar plant in the U. S. The installation was installed at a cost of $500,000 and is reported to be quite effective in removal of sulfur dioxide as well as particulate solids. A similar installation is planned in the near future at Loveland, Colorado. The Venturi scrubber for boiler flue gas at the Longmont, Colorado, plant has an additional advantage as it utilizes barometric condenser water in the scrubbing process. This use results in reduction of condenser water volume through vaporization which is a benefit where disposal of excess condenser water is a serious consideration. Barometric condenser water (1900 to 2300 l/min) (500 to 600 gal/min) is employed for the scrubbing process primarily for removal of fly ash.

The industry has generally found that change of the fuel source from coal to gas has been economically expedient in control of air pollution because of the large capital and operating expenditures required in scrubbing equipment needed for coal systems.

Odors. One of the most challenging problems of waste disposal at beet sugar processing plants is related to the matter of odor. When most of the plants were built, i.e., prior to 1930, they were located downstream from small towns. Inevitably, the towns have grown, often pressing close to the plant.

Odors of significance at beet sugar processing plants result largely from anaerobic bacterial action in waste water treatment systems, the pulp dryer and beet piles where deterioration of the beets is occurring.

Ponding, particularly in deep anaerobic ponds, frequently promotes the growth of sulfur reducing organisms. It has been observed that careful screening of wastes to remove organic matter lessens or minimizes settling and septic deposits of solids on the bottom of ponds, thereby reducing the quantity of noxious gases produced. Screening of waste water for removal of suspended organic material prior to discharge to holding ponds can substantially reduce the likelihood of noxious odor generation. The maintenance of shallow holding ponds (approximately 0.45 m optimum) (1.5 ft) and alkaline pH conditions aid in odor reduction and minimization. Purple sulfur bacteria (Chromatium and Thiopedia) have been found to be successful odor control mechanisms when cultured in waste stabilization lagoons utilized for beet plant wastes at plants in California.

Fogging. A feature of cooling tower operation often overlooked is the generation of fog. This can create a hazard to highway traffic by impairment of visibility. A circle of influence of 0.8 km (0.5 mi) is usually regarded as a safe distance for avoidance of the effects of fog from such sources. Fogging due to water vapor in the vicinity of draft cooling towers could be expected to present problems with visibility at several existing plant locations. Such fogging practices would not be in the best environmental control practice or in some cases comply with local air pollution ordinances and state regulations. The potential problem is surmountable by the use of closed, air-cooled heat exchanger cooling systems for these isolated instances. Such systems would incur an additional capital cost with reference to natural-draft or forced draft cooling towers and can technologically help to alleviate the problem. Air-cooled heat exchangers waste no water by evaporation, but they can cool only to within a few degrees of atmospheric temperature, and thus are limited to relatively high temperature applications. Comlbing systems to cool as far as possible with air and then to further accomplish temperature reduction in a cooling tower or evaporative system of another type is often a more economical way of handling cooling loads.

Solid Waste Disposal

The large volumes of dirt and solid material removed from beets at the plant poses a perplexing problem for permanent disposal. Generally, about 50 kg of soil/kkg (100 lbs/ton) of beets sliced is contributed by a typical beet sugar processing plant. Where holding ponds are employed, solids accumulated in the ponds are removed annually and disposed of by adding the material to pond dikes. These ponds are generally abandoned after useful performance, with new pond facilities being established.

Sugar beets stored in large piles at the plant site or in outlying areas such as railroad sidings may be exposed to rodent activity and additional pollution from truck or railroad car unloadings. Rainfall may assist the spread of existing contamination.

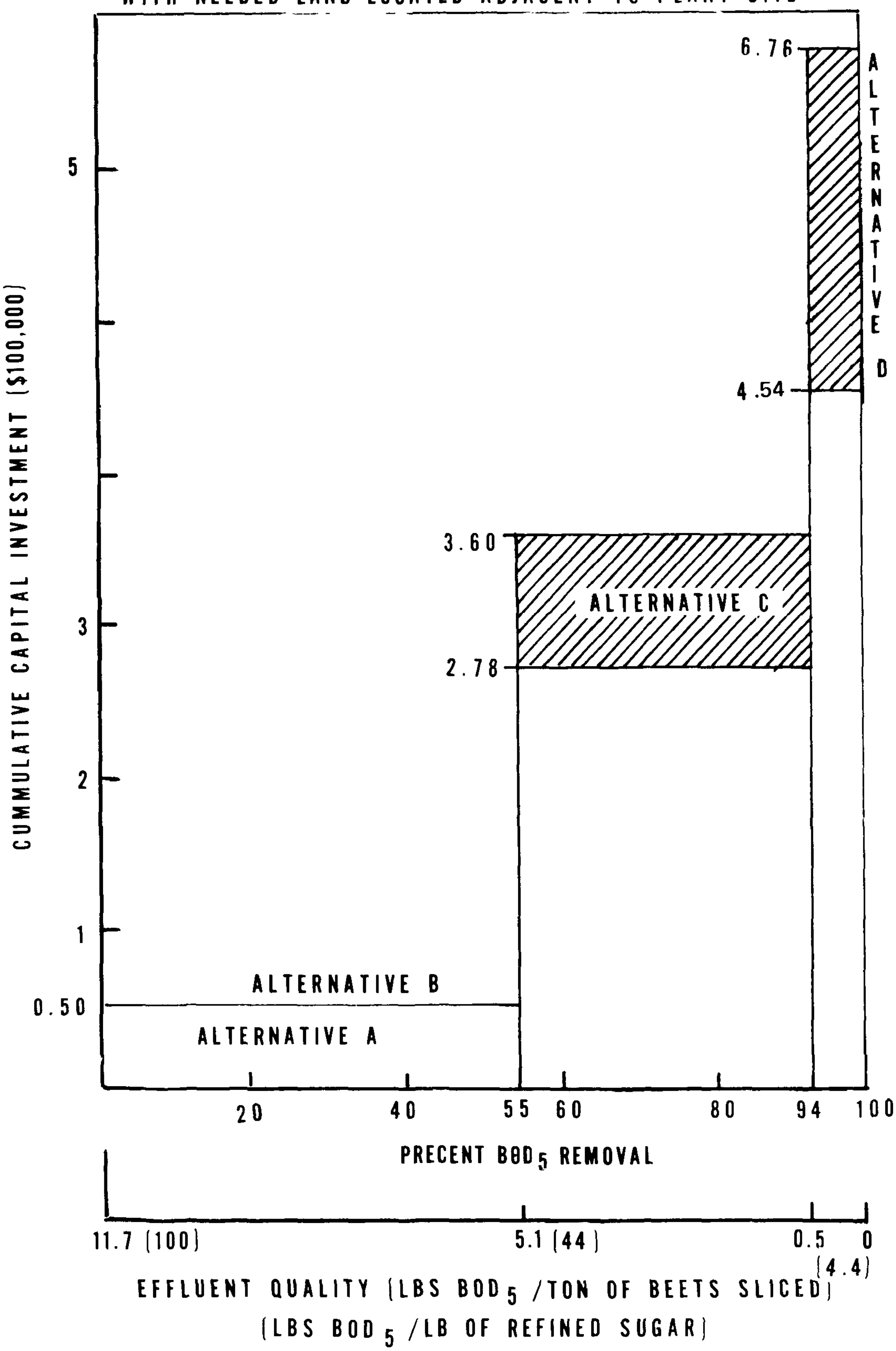
In addition to the large volumes of soil delivered to the plant with the incoming beets, solid waste is also generated in terms of trash normally associated with municipal activities. Disposal of this material may be at the plant site, or the waste material may be collected by the local municipality with disposal by incineration or sanitary landfill. The solid waste or trash consists of packaging materials, shipping crates and similar dry combustible materials.

Sanitary landfills are generally best suited for non-combustible material and organic wastes which are not readily combustible such as decomposed beets, weeds and peelings. Composting offers a viable alternative for disposing of organic materials such as decomposed beets, weeds and peelings. Experience with this method in the disposal of municipal wastes has proved more costly than sanitary landfill operations, however. The sanitary landfill is probably the lower cost alternative, provided that adequate land is available.

Consideration of a suitable site is a prime factor in location of a landfill site. Requirements in selection of a landfill site include sufficient area, reasonable haulage distance, location relative to residential developments, soil conditions, rock formations, transportation access, and location of potential ground water polluting aquifers. Location of sanitary landfills in sandy loam soils is most desirable. Proper sloping of the landfill soil cover to promote runoff rather than ground percolation is necessary to prevent ground water pollution. Other factors to be considered include no obstruction of natural drainage channels, installation of protective dikes to prevent flooding when necessary, location of the base of the landfill operation above the high water table and consideration of possible fire hazards. The general methods and desirable practices in operation of municipal sanitary landfill operations are equally as applicable to disposal of solid waste from beet sugar processing plants. Open burning of combustible wastes on the plant site is an undesirable and often unlawful method of solid waste disposal. The need for a scrubber or particulate collector on the stack of an incinerator must be evaluated on an individual basis.

Figure X

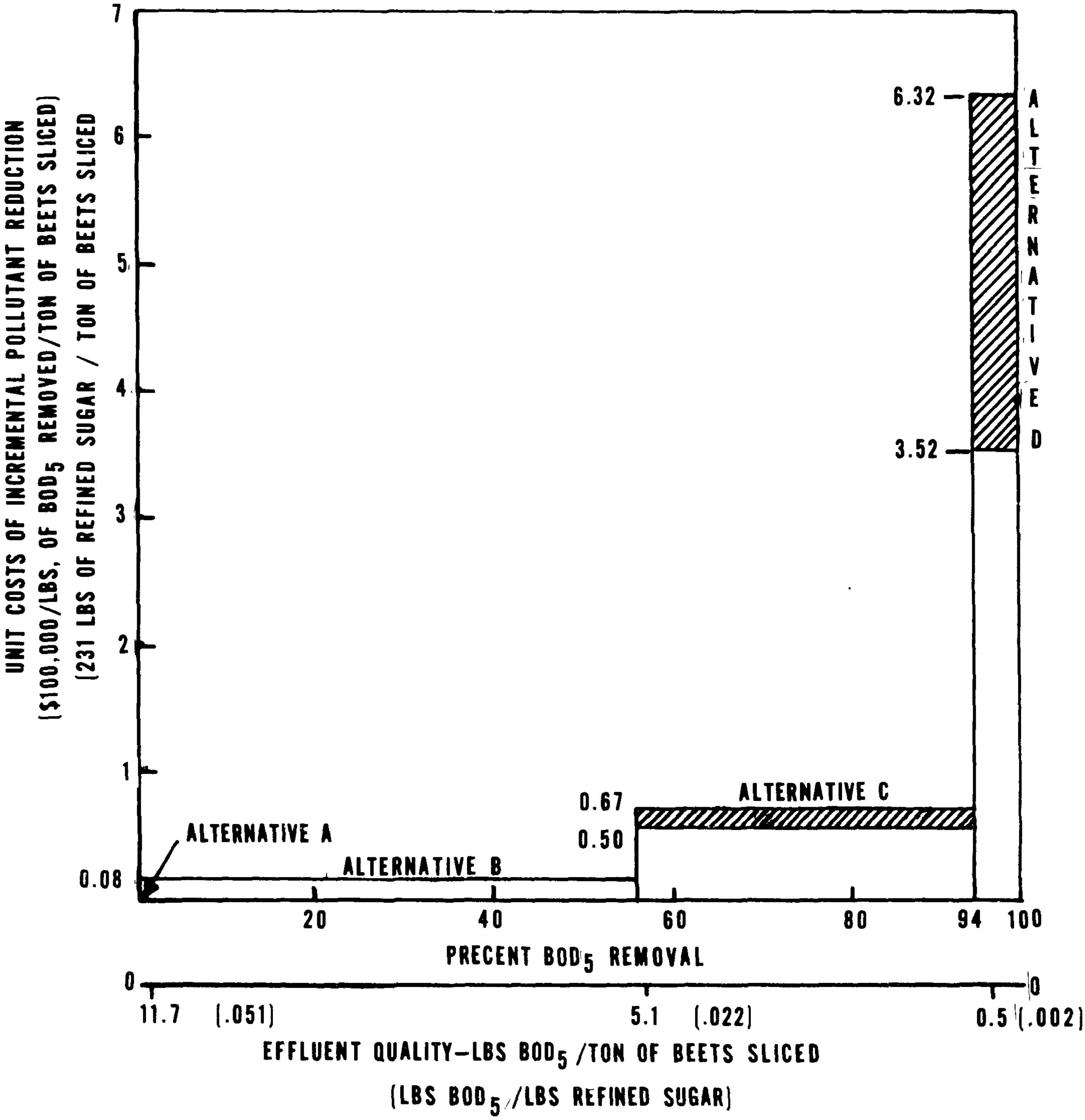
TOTAL COST EFFECTIVENESS RELATIONSHIP FOR COMPLETE LAND DISPOSAL WITH NEEDED LAND LOCATED ADJACENT TO PLANT SITE



LAND COSTS ATTRIBUTED AS $2000 PER ACRE INCLUDING POND CONSTRUCTION AND INFILTRATION CONTROL MEASURES. BASED ON 3600 TON PER DAY (832,000 LBS OF REFINED SUGAR PER DAY) PLANT, 100-DAY CAMPAIGN AND ¼INCH/DAY INFILTRATION RATE.

FIGURE XI

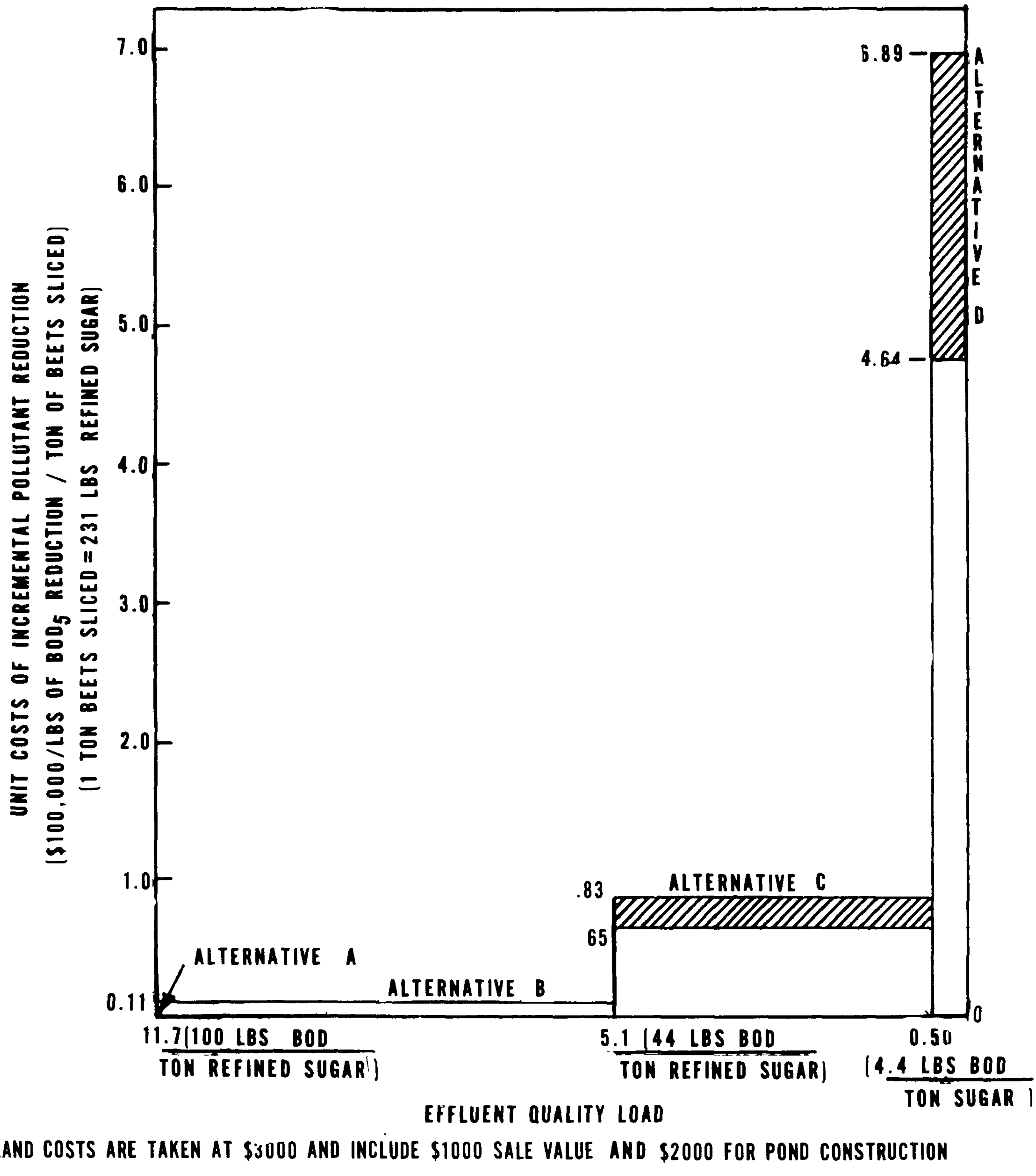
UNIT COST EFFECTIVENESS RELATIONSHIP WITH LAND FOR WASTE WATER DISPOSAL LOCATED ADJACENT TO PLANT SITE AND PRESENTLY UNDER PLANT OWNERSHIP



[1] LAND COSTS ATTRIBUTED AS $2000 PER ACRE INCLUDING POND CONSTRUCTION AND SEEPAGE CONTROL MEASURE 3600 TONS PER DAY (832,000 LBS REFINED SUGAR PER DAY) PLANT, 100 DAY CAMPAIGN AND 1/4 INCH PER DAY INFILTRATION RATE.

FIGURE XII

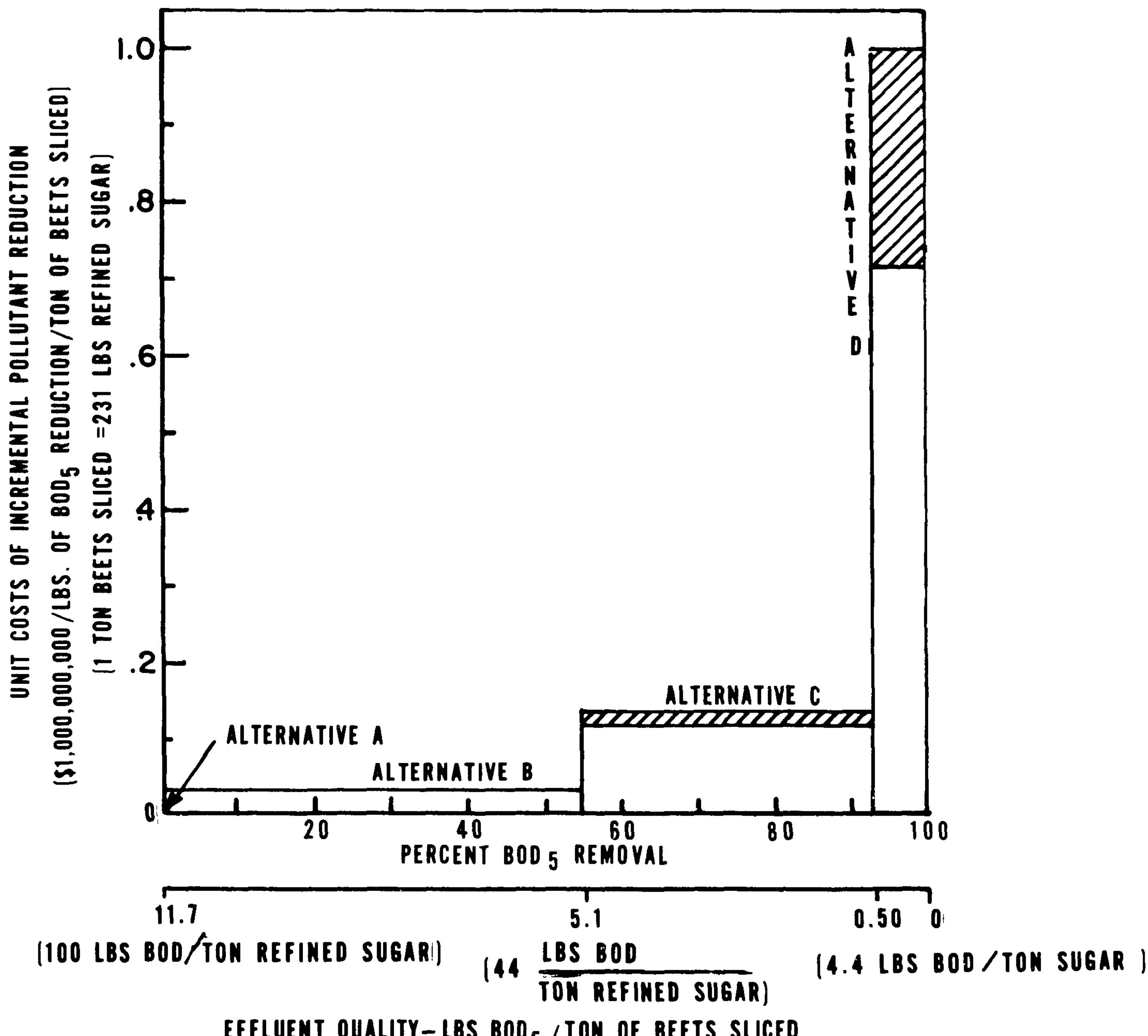
UNIT COST EFFECTIVENESS RELATIONSHIP WITH LAND FOR WASTE WATER DISPOSAL LOCATED ADJACENT TO PLANT SITE NOT PRESENTLY UNDER PLANT OWNERSHIP BUT AVAILABLE FOR PURCHASE AT A REASONABLE COST[1]



[1] LAND COSTS ARE TAKEN AT $3000 AND INCLUDE $1000 SALE VALUE AND $2000 FOR POND CONSTRUCTION AND INFILTRATION CONTROL MEASURES. AN INFILTRATION RATE ¼" PER DAY AND 100-DAY LENGTH CAMPAIGN IS ASSUMED. BASED ON 3600 TON/DAY (832,000 LBS REFINED SUGAR / DAY) CAPACITY PLANT

FIGURE XIII

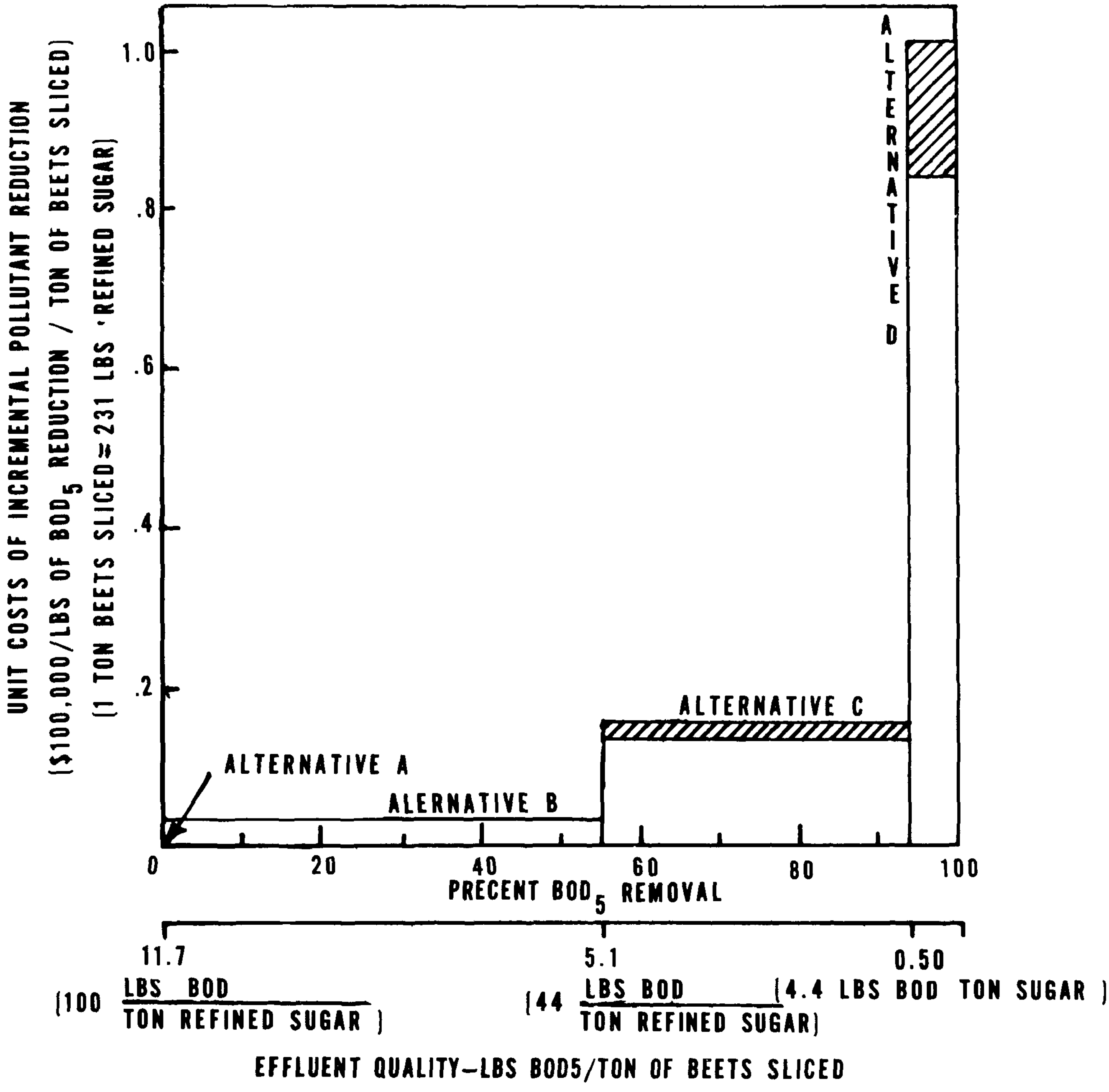
UNIT COST EFFECTIVENESS RELATIONSHIP WITH SUITABLE LAND NOT PHYSICALLY AVAILABLE ADJACENT TO THE PLANT SITE; SUITABLE LAND LOCATED AT A REASONABLE DISTANCE UNDER PLANT OWNERSHIP



LAND COSTS OF $2000 PER ACRE ASSUMED, INCLUDING POND CONSTRUCTION AND SEEPAGE CONTROL MEASURES. THREE MILE DISTANCE TO DISPOSAL SITE IS ASSUMED. RIGHT-OF-WAY COSTS OF $5000 PER ACRE. BASED ON 3600 TON/DAY/PLANT, 100 DAY CAMPAIGN AND ¼ INCH PER DAY INFILTRATION RATE.

FIGURE XIV

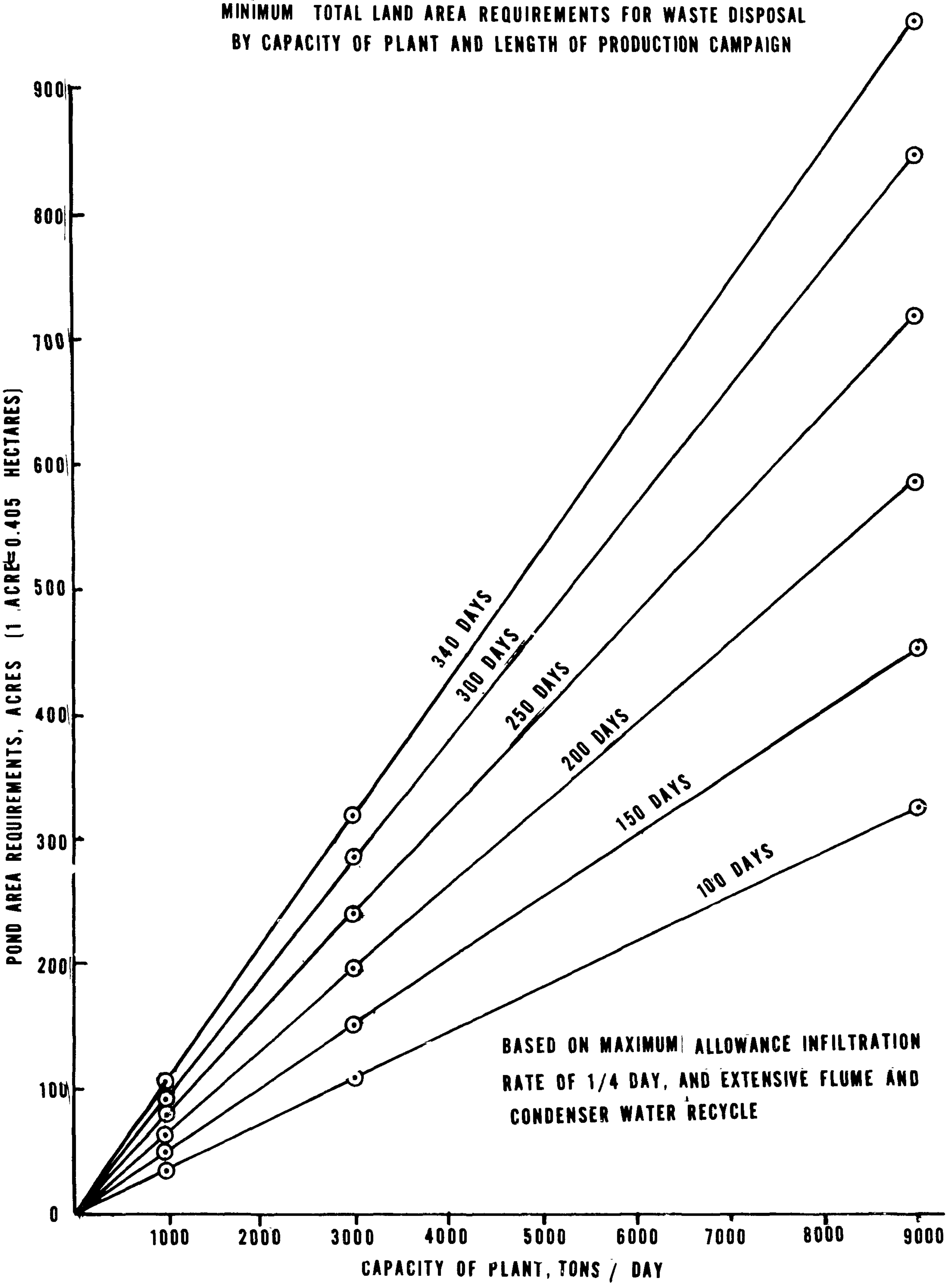
UNIT COST EFFECTIVENESS RELATIONSHIP WITH SUITABLE LAND FOR WASTE WATER DISPOSAL NOT PHYSICALLY AVAILABLE ADJACENT TO THE PLANT SITE; SUITABLE LAND LOCATED AT A REASONABLE DISTANCE NOT UNDER PLANT OWNERSHIP BUT AVAILABLE FOR PURCHASE AT A REASONABLE COST



1) LAND COST OF $3000 PER ACRE IS ASSUMED, INCLUDING PURCHASE PRICE, POND CONSTRUCTION AND SEEPAGE CONTROL MEASURES. THREE MILE DISTANCE TO DISPOSAL SITE ASSUMED. RIGHT-OF-WAY COSTS OF $5,000 PER ACRE BASED ON 3600 TON/DAY PLANT, 100-DAY CAMPAIGN AND ¼ INCH/DAY INFILTRATION RATE.

FIGURE XV

MINIMUM TOTAL LAND AREA REQUIREMENTS FOR WASTE DISPOSAL BY CAPACITY OF PLANT AND LENGTH OF PRODUCTION CAMPAIGN



SECTION IX

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE EFFLUENT LIMITATIONS GUIDELINES

Introduction

The effluent limitations which must be achieved by July 1, 1977 are to specify the degree of effluent reduction attainable through the application of the Best Practicable Control Technology Currently Available. Best Practicable Control Technology Currently Available is generally based upon the average of the best existing performance by plants of various sizes, ages and unit processes within the industrial category and peror subcategory industry. This average is not based upon a broad range of plants within the beet sugar processing industry, but rather upon performance levels achieved by better plants. Consideration must also be given to:

a. The total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application;

b. the size and age of equipment and facilities involved;

c. the processes 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).

Also, Best Practicable Control Technology Currently Available emphasizes treatment facilities at the end of a manufacturing process but includes the control technology within the process itself when the latter are considered to be normal practice within an 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 commencement of construction or installation of the control facilities.

Effluent Reduction Attainable Through the Application of Best Practicable Control Technology Currently Available

Based upon the information contained in Sections III through VIII of this document, a determination has been made that the degree of effluent reduction attainable through the application of the Best Practicable Control Technology Currently Available is no discharge of waste water pollutants to navigable waters.

The effluent limitation of no discharge of process waste water pollutants to navigable waters is based upon the availability of suitable land for controlled filtration of the excess process waste water. If suitable land is not available for controlled filtration the effluent limitation may be varied to allow the discharge of barometric condenser water derived from sugar evaporation and crystallization within the pollutant limitations set forth in the following table:

Effluent Characteristic	Limitation
BOD_5	Maximum for any one day 3.3 kg/kkg refined sugar (3.3 lb/1000 lb) Maximum average of daily values for any period of 30 consecutive days 2.2 kg/kkg refined sugar (2.2 lb/1000 lb)
Temperature*	
pH	6.0 to 9.0 units

*No discharge of heat from waste waters to navigable waters except that resulting from blowdown from a recirculating system, the temperature of which after cooling must not exceed the temperature of cooled water returned to the heat producing process.

"Availability of suitable land" shall mean that amount of land as determined by the formula set forth below which is adjacent to the point source, under the ownership or control of the point source discharger, his agents or representatives. The amount of land required for controlled filtration of process waste waters is determined by the application of the following formula:

$A = 14.26(CL/S) \times 10^{-5} + 5.36C \times 10^{-2}$ (for metric system units)

where A = land area requirements for controlled waste water disposal, hectares

C = processing capacity of plant, kkgs of refined sugar production per day

L = length of sugar production campaign of plant (including extended use campaign), days

S = actual soil filtration rate for waste water to be disposed of on land, cm. per day not to exceed 0.635 cm. per day

$A = 6.31(CL/S) \times 10^{-4} + 6.01C \times 10^{-2}$ (for English system units)

where A = land area requirements for controlled waste water disposal, ac

C = processing rate or capacity of plant, ton of refined sugar production per day

L = length of sugar production campaign of plant (including extended use campaign), days

S = actual soil filtration rate for waste water to be disposed of on land, in. per day not to exceed 1 /4 in. per day

The soil percolation rate for existing and to be constructed waste water holding ponds for land disposal must not exceed 0.635 cm (1/4 in) drop in liquid surface per day. For facilities to be constructed, pond area requirements must be based on a soil percolation tests as prescribed in the "Manual of Septic Tank Parctice", PHS Publication 526, U. S. Public Health Service (1962), or equivalent. The soil percolation rate must be determined at the bottom of the waste water holding pond as proposed to be constructed.

Identification of Best Practicable Control Technology Currently Available

Best Practicable Control Technology Currently Available for the beet sugar processing segment of the sugar processing industry is extensive recycle and reuse of waste waters within the beet processing operation with no discharge of process waste water pollutants to navigable waters. To implement this level of technology requires:

a. Recycling of beet transport (flume) waters with land disposal of excess waste water. This includes (1) screening; (2) suspended solids removal and control in the recirculating system; and (3) pH control for minimization of odors, bacterial populations, foaming, and corrosive effects.

b. Recycling of barometric condenser water for condenser or other inplant uses with land disposal of excess condenser water.

c. Land disposal of lime mud slurry and peror reuse or recovery.

d. Return of pulp press water and other process waters to the diffuser.

e. Use of continuous diffusers.

f. Use of pulp driers.

g. Concentration of Steffen waste for disposal on dried beet pulp or use for byproduct utilization. Alternative methods such as land disposal may be considered.

h. Dry conveyance of beet pulp from diffusers to pulp driers.

i. Handling of all miscellaneous wastes, e.g., floor and equipment washes, filter cloth washes, etc. within the processing plant by subsequent treatment and reuse or land disposal.

Where the exception for land availability applies as set forth above, the Best Practicable Control Technology Currently Available for the beet sugar processing segment of the sugar processing industry is recycle of flume (beet transport) water with no discharge of process waste water pollutants to navigable waters. Implementation of this level of technology includes all of the requirements above except that discharge of barometric condenser water is permitted with extensive recirculation and cooling. Entrainment control devices must be installed on barometric condensers, and operation and control of the processes to minimize entrainment is strongly encouraged.

Rationale for the Selection of Best Practicable Control Technology Currently Available

Basis for Units of Measurement in Effluent Limitations Without Land Availability. The inherent variability in the sugar content of beets to be processed as influenced by climatic, soil and cultural practices, and the application of effluent guidelines for condenser waters, particularly at those plants employing the "extended use" campaign, supports the rationale for use of effluent limitations for condenser water based on unit production of refined sugar rather than based upont of beets sliced.

The sugar solutions after thickening in the sugar end of the process are relatively uniform in quality and predictable as to crystalline sugar yield. Condenser water quantities and characteristics are related to factors inherent in the processing of the relatively uniform sucrose - containing product. Sugar beets to be processed contain between 10 to 16 percent sugar. Sucrose content in sliced beets (cossettes) averaged 14.36 per cent in 1969 (Table II). Refined beet sugar production in the U. S. in 1969 was 115 kg per kkg (231 lbs. per ton) of beets sliced, with an averaged extraction rate of 80.43 percent.

Basis of Pollutant Limitations for the Exception of Land Non Availability

The pollutants of significance in barometric condenser water as originating from beet sugar processing are BOD_5, temperature, and ammonia.

BOD_5 (5-day, 20°C (68°F) Biochemical Oxygen Demand)

With proper attention to operation of evaporative and crystallizers in the sugar making process, vapor entrainment through the condensing process may be limited to between 30 - 50 mg/l BOD_5. Under reasonable control, BOD_5 loading in condenser water can be limited to 2.2 kg BOD_5/kkg (2.2 lb/1000 lbs) of refined sugar. This level of control corresponds with barometric condenser water use of 8300 l/kkg (2000 gal/ton) of beets sliced at a BOD_5 concentration of 40 mg/l as now practiced at the majority of plants within the industry. Calculations based on the 0.5 lb BOD_5/ton of beets processed, and the average production of 115 kg of refined sugar per kkg (231 lbs. per ton) of beets sliced, yields the established effluent limiation of 2.2 kg BOD_5/kkg (2.2 lb/1000 lb) of refined sugar produced. On this basis the discharge of BOD_5 during any period of 30 consecutive days shall not exceed 2.2 kg/kkg refined sugar. The discharge of BOD_5 during any one day period shall not exceed 3.3 kg/kkg refined sugar. This increased limitation for any one day discharge is justified on the basis of the occasional occurance of process upsets and mechanical failures. Further reductions of BOD_5 in condenser waters are possible through reduction allowances for cooling devices (15-50 percent) and elaborate entrainment control mechanisms where discharge of condenser water would be permitted under the limitations set forth herein.

Temperature

The quantity of barometric condenser water utilized or required at on individual beet sugar plant varies with vapor condensing requirements, raw water source, process temperature considerations, and climatic factors. Condenser water leaving the barometric condenser process normally exhibits temperature characteristics at or near 65°C (149°F). Technology exists for cooling the condenser

water prior to discharge to navigable waters. Cascading, reuse, or recycling of the mildly contaminated condenser water can reduce the requirements and expense of facilities for cooling the total condenser water flow. In practice, cooling of heated waters is accomplished with spray ponds, cooling towers, evaporative condensers, and air-cooled heat exchangers. All but the latter depend on the cooling effect of evaporation. The terminal temperature to which heated water may be cooled may range from several degrees below atmospheric temperature at high humidity, to 17°C (30°F) or more below atmosperic temperature when the air is dry (88). Evaporative coolers are most effective in arid regions.

A technological standard for cooling of waste waters, proposed by the Effluent Guidelines Division, Environmental Protection Agency for the power industry stipulates no discharge of heat from waste waters resulting from the industrial facility except that contained in blowdown from a recirculating system. The blowdown must be at or below the temperature of cooled water returned to the barometric condenser process. This practically means that the condenser water system blowdown must be discharged on the"cool" side of the recirculation system (i.e. in the circuit between the cooling device and the heat producing barometric condenser).

Auxilliary cooling devices for cooling of blowdown are technological possibilities, however, they are not judged to constitute Best Practicable Control Technology Currently Available for the industry. The limit for heat has been adopted for the discharge of barometric condenser water to navigable waters where variance for non-suitability of land for controlled land disposal of waste waters without discharge to navigable waters is applicable as defined herein.

Ammonia

Ammonia in barometric condenser water varies between 3 and 15 mg/l (NH_3 as nitrogen depending upon the condition of beets processed and the existence, non-existence, or effectiveness of entrainment control devices. Higher ammonia entrainment in condenser water is evident during the later stages of the processing campaign particularly in areas where storage of beets is practiced and progressive deterioriation of the beets results. Ammonia, like other dissolved gases, may be separated by heat or agitation and leave no residue on evaporation. Evaporative cooling devices for heated waste waters are effective in accomplishing essentially complete removal of ammonia through stripping. Because of this phenomenon no specific numerical standard for ammonia nitrogen in barometric condenser discharge water is established.

pH

Condenser water picks up ammonia from the evaporating juices, hence is always alkaline ranging from pH 8 to 11, but usually less than 9. Reduction of ammonia concentrations will effectively control the pH within the designated limits. On this basis and in accord with accepted water quality standards the pH of the discharge must be maintained within the range of 6.0 to 9.0.

Total Cost of Application in Relation to Effluent Reduction Benefits

The cost - effectiveness of attaining zero discharge of waste waters to navigable waters for the beet sugar processing industry is given in Figures X through XII for various identified conditions. A detailed cost analysis is presented in Supplement A. The requirement for land availability may practically preclude the attainment of this level of pollutant reduction at some beet sugar processing plants for best practicable control technology currently achievable where unfavorable soil, climate, land availability, and land costs exists. The cost - effectiveness impact of these adverse land availability factors, where they exist, are given in Figures XI through XIV, and discussed in Section VIII. The cost - effectiveness relationships bear particular significance to the relative costs of achieving the elimination of barometric condenser water from navigable waters and the associated land availability requirements. Exception to the effluent guideline limitation of no discharge of process waste water pollutants to navigable water is justified on the basis of practical land availability considerations, and economic factors to be imposed upon industry in achieving this limitation for affected plants by July 1, 1977. BOD_5 reduction is accomplished through effective entrainment control devices in pan evaporators and crystallizers. An undertermined amount of BOD_5 reduction (probably 15 to 50 percent) occurs as a secondary benefit in the required cooling device. The amount of BOD_5 reduction under the specified technology cannot be reliably predicted. The BOD_5 reduction effected would be dependent to a large extent on individual operating practices and type of facilities.

Age and Size of Equipment and Facilities

As set forth in this document, industry competition and general improvements in production methods have hastened modernization of plant facilities throughout the industry.

Age and size are not within themselves determining factors in the application of Best Practicable Control Technology Currently Available for the beet sugar processing segment of the sugar processing industry. Estimated costs of pollution reduction tend to vary uniformly with plant size because of the land based waste disposal technology and variance of raw waste contribution directly with plant capacity. Age and size of plant are most appropriately related to general land availability - a factor receiving appropriate consideration in establishing practical effluent reduction levels attainable for this level of technology. Based upon the information contained in Section VIII and Supplement A of this report, the industry as a whole would have to invest less than an estimated maximum of $36,000,000 to achieve zero discharge of waste waters to navigable waters. This amounts to approximately a 2.0 percent maximum increase in projected total capital investment, and an anticipated increase of $13.50 to $19.20/kkg ($6.10 to $8.70/ton) in the cost of bulk refined sugar having a current cost of about $517.00/kkg ($235.00/ton). It is therefore concluded that the reduction to no discharge outweighs the cost. As 24.5% of plants are now achieving this standard, it can be practically applied to the remaining 75.6% of the industry.

Processes Employed

All plants in the industry manufacture refined sugar using the same or similar production methods, the discharges from which are also similar. There is no evidence that operation of any current process or subprocess will substantially affect capabilities to implement Best Practicable Control Technology Currently Available.

Engineering Aspects of Control Technique Applications

There are presently 12 of 53 beet sugar processing plants in the United States accomplishing no discharge of process waste water pollutants to navigable waters. This level of technology is generally being accomplished through extensive recycling and peror reuse of waste water with disposal of excess waste waters by soil filtration or for crop irrigation after biological treatment with waste holding. No discharge of waste waters to surface waters occurs from these waste disposal and treatment operations. The plants accomplishing no discharge of process waste water pollutants to navigable waters are identified in Table VIII. Even though these plants are generally in water short areas, where factors are relatively favorable for land disposal, such a technology can be technically accomplished at all beet sugar processing plants if the necessary land is available.

The use of controlled land disposal of waste waters is a widespread practice for many types of wastes including both municipal and industrial within and outside the United States. As noted in Table VIII, essentially all present beet sugar processing plants rely either in whole or in part on land disposal. Such disposal on land by filtration through holding ponds, or use after treatment for irrigation, is not generally accomplished under controlled filtration conditions and no significant problems of water quality from such waste water disposed have been identified or recognized.

Land disposal of food processing and other wastes is extensively practiced in many areas of the country without ill effects. A fully developed water technology should make maximum practicable use of ground water recharge.

The concepts are proven, available for implementation and required production and waste management methods may be readily employed through adaptation or modification of existing production units. Exceptions to the established effluent reduction limitations attainable are made based on practicable land availability factors.

Process Changes

In-process technology is as an integral part of the whole waste management program now being implemented within the industry. Some degree of in-process control is now practiced by all plants in the industry.

Land Availability

The total land requirements for disposal of waste waters by soil filtration is dependent upon size of the beet processing plant, length of processing campaign, and filtration characteristics of the soil. The land requirements are related in terms of these variables in the formulation given above in definition of land availability. Extensive recycle and reuse of flume (beet transport) water and condenser water are assumed, such that only "blowdown" from these systems is required for land disposal together with land containment of lime slurry waste. The allowable soil filtration rate must not exceed 0.635 cm (1/4 in) drop in holding pond liquid surface per day--a practical limit to infiltation control commonly accepted by State pollution control agencies for application to waste stabilization lagoons. The filtration rate is representative of a relatively impermeable soil. Infiltration control measures are available through the use of various methods of pond lining, and must be employed where found necessary (through the results of a soil percolation tests or actual pond level observations) to control soil filtration within the maximum allowable limit.

While technologically accomplishable, factors of land availability, soil filtration rate and length of processing campaign at individual beet sugar processing plants preclude the practical achievement (both technologically and economically) of no discharge of process waste water pollutants to navigable waters as best practicable control technology currently achievable for all plants. Practical considerations for land nonavailability are made as exceptions to the general effluent limitation guidelines of no discharge of process waste water pollutants to navigable waters set forth for this technology level.

Alternative criteria for effluent limitations for individual plants must reasonably apply where the total area requirements under ownership of the company and adjacent to the plant site is less than that given by the total land area formulation for requireed land for controlled disposal of waste water. In such case, the total land area requirements for various plant capacities and length of production campaign are shown in Figure XV for the maximum allowable seepage rate of 0.635 cm (1/4 in) per day. Discharge of the equivalent of the condenser water flow is allowed within the reasonable levels of containminants specified. Achievement of the effluent limitations may be accomplished technologically through adequate cooling of heated condenser waters, with careful control and utilization of entrainment separators for the barometric condensing process. At present, essentially the entire industry employs or is planning within several years to incorporate extensive recycling systems for flume water, thereby eliminating all waste discharges to navigable waters with the exception of barometric condenser water. Where discharge of barometric condenser water to surface streams is presently employed, some type of cooling devices for cooling the waste prior to discharge to surface waters are generally employed. Discharge of barometric condenser water to streams is accomplished only on an occasional basis (See Table VIII).

Climatic Factors

Climatic factors of precipitation and evaporation vary substantially throughout the regions in which beet sugar processing plants are situated in the United States. Examination of evaporation and rainfall records in these locations reveals that the most critical region for disposal of waste water by evaporation is in the Ohio-Michigan area where annual rainfall and lake evaporation approximately compensate one another. All other areas of the country in which beet sugar processing plants are located experience a net evaporation effect.

The mechanism for controlled waste water land disposal adapted for purposes of this document relies solely upon land disposal by controlled soil filtration. Reliance upon controlled soil filtration would in all cases except in the Michigan-Ohio area provide for increased benefits for reduced land requirements due to actual net evaporation which occurs. Therefore, reliance upon controlled seepage for waste water disposal effectively eliminates or minimizes the effects of climatic factors on the established pollution control technology. Effects of land requirements and soil filtration rates have been appropriately discussed under the heading of land availability above.

Climatic conditions, together with varying soil conditions, harvesting procedures, and geographic factors may affect soil loads on incoming beets and condition of beets are received for processing at the processing plant. Increased soil loads on incoming beets result in increased mud handling costs and expense of disposal. These increased handling costs are assumed by the plant in accepting sugar beets from growers and are a relatively insignificant expense relative to total production costs. Increased soil loads may result in the need for more frequent cleaning of flume water settling and holding ponds.

Non-Water Quality Environmental Impact

There are two essential impacts upon major non-water elements of the environment: a limited degree of direct effects upon ambient air quality (e.g., fly ash from pulp driers, odors); a potential effect on soil systems due to strong reliance upon the land for ultimate disposition of final effluents. In the former case, responsible operation and maintenance procedures have been shown to obviate the problems. Moreover, the vast enhancement to water quality management provided by using the various production perwaste processes substantially outweigh these controllable air effects.

With respect to the latter concern, it is addressed only in a precautionary context since no evidence has been discovered which even intimates a direct impact--all evidence points to the contrary. Technology and knowledge available to assure land disposal or irrigation systems are maintained commensurate with crop need or soil tolerance.

Land disposal of waste waters without discharge to surface waters would result in a possible net loss of water from surface streams from the most extensive waste water recirculation system of 2500 l/kkg (600 gal pert) of beets sliced. The total water loss of this tonnage volume would consist of 650 l/ kkg (160 gal/ton) of beets sliced loss to the atmosphere through process venting and evaporation and molasses production; and 1900 l/kkg (450 gal/ton) of beets sliced loss due to land disposal of required blowdown from flume and condenser water recycling systems.

In consideration of water gains and losses in an average-sized (3300 kkg (3600 ton) of beets sliced per day) beet sugar processing plant, net loss of water to a stream would be estimated at about 8.3 million l (2.2 million gal) per day assuming the complete source of fresh water is a surface water source. However, because of cooling considerations for barometric condenser water, many beet sugar processing plants utilize cooler ground water supplies as the source of fresh water requirements. In such cases, approximately 6.1 million liters (1.6 million gal) per day may be returned to ground water supplies through land disposal without discharging process waste water pollutants to surface waters. Where crop irrigation is practiced, uptake of water by plants offers a consumptive but beneficial use of the waste water.In addition to fresh water, incoming beets constitute a major source of water addition (8.0 million l/kkg (190 gal/ ton) of beets sliced) to the extensive recycling system

A detailed discussion of water gains and losses is included under the heading of Mass Water Balance in a Beet Sugar Processing Plant of Section VII of this document.

SECTION X

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE EFFLUENT LIMITATIONS GUIDELINES

The effluent reduction attainable through the application of the Best Available Technology Economically Achievable is no discharge of process water pollutants to navigable waters as developed in Section IX without variance. Factors by which the effluent reduction standards may be varied are no longer needed due to the extended time period available for obtaining the recommended land resources with which to meet the requirement of no discharge of process waste water pollutants to navigable waters.

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

The standard of performance for new sources representing the degree of effluent reduction attainable through the application of the best available demonstrated control technology has been determined to be no discharge of process waste water pollutants to navigable waters. An allowance for a variation of the standard is not needed since land availability requirements should be considered in site selection for a new point source. The rationale for the standard of no discharge of process waste water pollutants to navigable waters is as developed in Section IX.

Introduction

This level of technology is to be achieved by 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." This level of 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 and/or treatment techniques.

Effluent Reduction, Identification and Rationale for Selection of of New Source Performance Standards

The effluent limitations for new sources is no discharge of process waste water pollutants to navigable waters as developed in Section IX.

SECTION XII

ACKNOWLEDGEMENTS

The research and preparation of this document was accomplished through the efforts of Mr. Richard V. Watkins, P. E., and Dr. Valentin Ulrich, Professor in the Department of Agriculture at West Virginia University. During the early stages of the document preparation, Dr. Ulrich was employed as a Consultant to the Effluent Guidelines Division.

Dr. Ulrich performed some of the basic work associated with preparation of certain basic segments of the first draft document, and was primarily involved in preliminary editing, technical data collection and analysis, and collection and evalution of cost related information.

Mr. Watkins is a Sanitary Enginneer within the Effluent Guidelines Division, Office of Air and Water Programs, EPA. As the Project Officer, the work was performed largely under his responsibility and primary authorship.

Mr. George R. Webster, Chief, Technical Analysis & Information Branch, Effluent Guidelines Division, provided a careful review of the preliminary draft document and suggested organizational, technical and editorial changes. Mr. Webster was also most helpful in making arrangements for the drafting, printing, and distribution of the document.

Mr. Joseph G. Ross, Jr. was quite helpful in the critical examination of the draft document. Mr. Ross offered many helpful suggestions through his many years of experience in the editing and production of scientific and technical publications.

The figures contained within the document were prepared by Mr. Dick Owens of the Audio-visual Branch, Facilities and Support Services Division of EPA.

Great assistance was provided in review of the document by the Working Group/Steering Committee. This Committee was established for in-house EPA review of the document, provided many helpful comments and suggestions. The Committee was composed of the following EPA personnel:

C. R. McSwiney	Chairman, Effluent Guidelines Division
Richard V. Watkins	Project Officer, Effluent Guidelines Division
George Webster	Effluent Guidelines Division
Kit Krickenberger	Effluent Guidelines Division
Swep Davis	Office of Planning and Evaluation
George Keeler	Office of Research and Monitoring

Ken A. Dostal	Office of Research and Monitoring Corvallis, Oregon
Harold W. Thompson	Office of Research and Monitoring Corvallis, Oregon
Ed Brooks	Office of Toxic Substances
Ed Struzeski, Jr.	National Field Investigation Center Denver, Colorado
Kit Smith	Office of General Council
Erik Krabbe	Region II
M. Shamaiengar	Region V
R. L. Markey	Region VII
Melvin McCorkle	Region VII
Bob Burm	Region VIII
Irwin Dickstein	Region VIII
Robert D. Shankland	Region VIII

Mr. Allen Cywin, Director, Effluent Guidelines Division, offered many helpful suggestions during briefing sessions conducted on the project and greatly assisted in the development of the project through his enthusiasm and leadership.

Miss Kit Krickenberger of the Effluent Guidelines Division was particularly helpful and cooperative in her untiring efforts during editing and preparation of the document. Her work is greatly appreciated.

Acknowledgement and appreciation is also given to the secretarial staff of the Effluent Guidelines Division for their efforts in the typing of drafts, making necessary revisions and final preparation of the document.

Appreciation is extended to various personnel within the beet sugar processing industry for their willing cooperation in providing requested data, and their assistance in regard to on-site plant visits. Mr. Clare H. Iverson, Chief Engineer, The Great Western Sugar Company; Mr. J. P. Abbott, Chief Engineer, Holly Sugar Corporation; and Mr. Ernest W. Beck, Jr., Vice President - Operations and Mr. William O. Weckel, Assistant to Vice President of Spreckels Sugar Division, Amstar Corporation deserve special mention.

SECTION XIII

REFERENCES

1. Anonymous, "State-of-Art, Sugarbeet Processing Waste Treatment", A report prepared for the Beet Sugar Development Foundation for the U. S. Environmental Protection Agency, U. S. Government Printing Office, Washington, D.C., July 1971.

2. Request for Proposal No. WA 73X-002 Effluent Limitation Guidelines, Part II, Description of the Requirement, U. S. Environmental Protection Agency, October 1972.

3. 1967 Census of Washington, Sugar and Confectionery Products Publication MC67(2)-20F, Bureau of the Census, U. S. Department of Commerce, U. S. Government Printing Office, Washington, D. C. 20242, August 1970.

4. Gurnham, C. F., _Industrial Wastewater Control_ Academic Press, New York, 1965.

5. Force, S. L., "Beet Sugar Factory Wastes and Their Treatment, Primarily the Findlay System", 17th Purdue Industrial Waste Symposium. (1962)

6. Lof, George O. G., Ward, John C. and Hao, O. J., "Combined Cooling and Bio-treatment of Beet Sugar Factory Condenser Water Effluent," Environmental Resources Center, Colorado State University, Fort Collins, Colorado, Completion Report OWRR, Project No. A-008-COLO submitted to Office of Water Resources Research, U. S. Department of the Interior, Washington, D. C. 20242, June 30, 1971.

7. Roy F. West, Inc., Preliminary unpublished summary report of sugar industry, 1972.

8. Brent, Ronald W. and Fischer, James H., "Concentration of Sugarbeet Wastes for Economic Treatment with Biological Systems." Proceedings First National Symposium on Food Porcessing Wastes, April 6-8, 1970, Portland, Oregon, Water Pollution Control Research Series 12060--04 per70, U. S. Department of the Interior, Federal Water Quality Administration.

9. _Sugar Statistics and Related Data_. Volume II (Revised). U. S. Department of Agriculture Statistical Bulletin No. 244, Washington, D. C., 1969.

10. Howard, T. E. and Walden, C. C. Treatment of Beet Sugar Plant Flume Water, British Columbia Research Council, University of British Columbia, Vancouver, B. C. 1964.

11. Tsugita, Ronald A., Oswald, William J., Cooper, Robert C. and Golueke, Clarence G., "Treatment of Sugarbeet Flume Waste Water by Lagooning, a Pilot Study". J. Am. Soc. Sugar Beet Technology 15(4): 282-297, 1969.

12. Lof, George O. G., and Kneese, Allen Y., The Economics of Water Utilization in the Beet Sugar Industry, Resources of the Future, Inc., Washington, D. C. The Johns Hopkins Press, Baltimore, Maryland (1968).

13. The Beet Sugar Industry---The Water Pollution Problem and Status of Waste Abatement and Treatment , U. S. Department of the Interior, Federal Water Pollution Control Administration, South Platte River Basin Project, Denver, Colorado (June 1967).

14. Standard Methods for the Examination of Water and Wastewater, Thirteenth Edition, American Public Health Association, New York, New York (1971).

15. Jensen, L. T., Sugar Found in Industrial Wastewater Control,(A Textbook and Reference Work) edited by Gurnham, C. F., Academic Press, Inc., Publishers, New York and London (1965).

16. Jensen, L. T., "Recent Developments in Waste Water Treatment by the Beet Sugar Industry", Proceedings of the Tenth Industrial Waste Conference, Purdue University, 439, May 9-11 (1955).

17. Unpublished data in the files of the Technical Advisory and Investigation Section, Technical Services Program, U. S. Department of the Interior, Federal Water Pollution Control Administration, Cincinnati, Ohio.

18. "Proceedings of the Conference in the Matter of Pollution of the Interstate Waters of the Red River of the North, North Dakota - Minnesota, September 14, 1965", Fargo, North Dakota, U. S. Department of Health, Education, and Welfare, Public Health Service, Washington, D. C. (September 1965).

19. "Procedings, Volume I, II and III, of the Conference in the Matter of Pollution of the South Platte River Basin in the State of Colorado, Second Session, Denver, Colorado, April 27-28, 1966", U. S. Department of the Interior, Federal Water Pollution Control Administration, Washington, D. C. (April 1966).

20. Black, H. H. and McDermott, G.N., "Industrial Waste Guide - Beet Sugar", Sewage and Industrial Wastes, 24, 2, 181, February 1952; also presented at the first Ontario Industrial Waste Conference, Ontario Agricultural College, Guelph, Ontario June 15-18,1954.

21. "Treatment of Beet Sugar Flume Water - Project Report 64-117-B", Prepared for the Beet Sugar Development Foundation, British Columbia Research Council, University of British Columbia, Vancouver 8, Canada (December 1964).

22. "Rate Studies for BOD Removal in Beet Fluming Water - Progress Report No. 3", Prepared for the Beet Sugar Development Foundation, British Columbia Research Council, Vancounver 8, Canada (June 1965).

23. Nemerow, Nelson, L., Theories and Practices of Industrial Waste Treatment, Addison-Wesley Publishing Company, Inc., Reading, Massachusetts (1963).

24. Pearson, E., and Sawyer, C. N., "Recent Developments in Chlorination in the Beet Sugar Industry", Proceedings of the 5th Industrial Waste Conference, Purdue University, p. 110, November 1949.

25. Elridge, E. F., Industrial Waste Treatment Practice, New York, McGraw-Hill, Inc. (1942).

26. Rodgers, H. G., and Smith, L., "Beet Sugar Waste Lagooning", Proceedings of 8th Industrial Waste Conference, Purdue University p. 136, (May 1953).

27. Hopkins, G., et al. "Evaluation of Broad Field Disposal of Sugar Beet Wastes" Sewage and Industrial Wastes Journal, 28, 12, 1466, (December 1956).

28. Industrial Wastewater Control--A Textbook and Reference Work, Edited by C. Fred Gurnham, Academic Press, New York (1965).

29. Southgate, B. A., Treatment and Disposal of Industrial Waste Waters, London: His Majesty's Stationery Office (1948).

30. Hungerford, E. H. and Fischer, James H., "State-of-Art Sugarbeet Processing Waste Treatment", Proceedings of Second National Symposium on Food Processing Waste, Denver, Colorado, March 23-26, 1971, Water Pollution Control Research Series 12060--03 per71 Superintendent of Documents, Washington, D. C. (1971).

31. "Summary Report on the Beet Sugar Processing Industry (SIC 2063)", U. S. Environmental Protection Agency, Office of Water Programs, Division of Applied Technology, The Industrial Wastes Studies Program (1972).

32. Oswald, William J., Galueke, Clarence G., Cooper, Robert C. and Tsugita, Ronald N., Anaerobic-Aerobic Ponds for Treatment of Beet Sugar Wastes, Denver, Colorado, March 23-26, 1971, Water Pollution Control Research Series, 12060---03 per71, Superintendent of Documents, Washington, D. C. (1971)

33. Partially drafted report of findings and results of Phase I of EPA Project No. 11060 ESC "Separation, Dewatering, and Disposal of Sugarbeet Transplant Water Solids", Environmental Protection Agency, Washington, D. C. (1973).

34. "Effluent Limitation Guidance for the Refuse Act Permit Program, Beet Sugar Processing Industry", U. S. Environmental Protection Agency, Washington, D. C. (June 13, 1972).

35. "Beet Sugar Companies in the United States (Executive offices and Staffs, Factory Locations, Capacities, and Principal Personnel)," Washington, D. C. (October 25, 1972).

36. "Sugar Statistics and Related Data", Administration of the U. S. Sugar Acts, Volume II (Revised), Statistical Bulletin No. 244, Agricultural, Manufacturing and Income Statistics for Domestic Sugar Areas, Revised February 1969, USDA, Washington, D. C. (Feb. 1970).

37. "Sugar Statistics and Related Data," Compiled in the Administration of the Sugar Acts, Volume I (Revised), Statistical Bulletin No. 293, Supplies, Distribution, Quota Operations, Prices and International Data through 1968, Revised December 1969, USDA, Washington, D. C. (February 1970).

38. The Gilmore Louisiana - Florida - Hawaii Sugar Manual 1971, Edited by Aldrich C. Bloomquist, The Gilmore Sugar Manual Division, Bloomquist Publications, Fargo, North Dakota.

39. "Economic Impact of Water Pollution Control Requirements on the Sugar Beet Industry", A report prepared by Development and Planning Research Assoc., Inc., for U. S. Environmental Protection Agency, Office of Water Programs, Division of Applied Technology, Washington, D. C. (1972).

40. "Cost of Waste Water Treatment Processes". A report prepared by the Advanced Waste Treatment Research Laboratory, Robert A. Taft

Research Center for U. S. Department of the Interior, Federal Water Pollution Control Administration, Washington, D. C. (1968).

41. "Pretreatment Guidelines for the Discharge of Industrial Waste to Municipal Treatment Works." Roy F. West, Inc., West Chester, Pennsylvania, Draft prepared for the U. S. Environmental Protection Agency, Washington, D. C., Contract No. 68-01-0346 (November 17, 1972).

42. Linsley, Ray H., Kohler, Max A. and Paulhaus, Joseph L. H., Hydrology for Engineers, McGraw-Hill Book Co., Inc., New York (1950).

43. Steel, Ernest W., Water Supply and Sewage, McGraw-Hill Book Co., Inc., New York (1960)

44. Grant, Eugene L. and Ireson, W. Grant, Principles of Engineering Economy. The Ronald Press Co., New York (1960).

45. "Sewage Treatment Plant Design." Prepared by A Joint Committee of the Water Pollution Control Federation and the American Society of Civil Engineers. Water Pollution Control Federation, Washington, D. C. (1959).

46. "Recommended Standards for Sewage Works," A report of the Committee of the Great Lakes-Upper Mississippi River Board of Sanitary Engineers, Health Education Service, Albany, New York (1968).

47. Brent, Ronald, W., "Condenser Water Survey 1971-72 Campaign," Memorandum (March 1972).

48. Smith, Robert and Eilers, Richard G., "Cost to the Consumer for Collection and Treatment of Waste Water," Water Pollution Control Research Series. Project No. 17070, Environmental Protection Agency (1970).

49. U. S. Public Health Service, "An Industrial Waste Guide to the Beet Sugar Industry," (1950).

50. Minnesota State Department of Health, "Progress Report on Study of the Disposal of Beet Sugar Wastes by the Lagoon Method: Sept. 1950 to March 1951", (1951) 51. McAdams, William E., Heat Transmission, Chemical Engineering Series, Third Edition, Sponsored by the Committee on Heat Transmission National Research Council, McGraw-Hill Book Company, Inc., New York (1954).

52. McKelvey, K. K. and Brooke, M. The Industrial Cooling Tower Elsevier, Amsterdam, (1959).

53. Berman, L. D. Evaporative Cooling of Circulating Water, Pergamon Press, N.Y. (1961).

54. Parker, Frank L. and Krenkel, Peter A. "Thermal Pollution Status of the Art," Report No. 3 Prepared for the Federal Water Pollution Control Administration, Washington, D. C. (1969).

55. Cotter, T. J. and Lotz, R. W., "Cooling Pond Design in the Southwest," Journal of the Power Division, ASCE 87, 85-103 (1961).

56. Climatic Atlas of the United States, U. S. Department of Commerce, U. S. Government Printing Office, Washington, D. C. (1968).

57. Statistical Abstracts of the United States, 92nd Annual Edition, U. S. Department of Commerce, Bureau of Census, Washington, D. C. (1971).

58. Provided by Mr. Clare H. Iversen, Chief Engineer, The Great Western Sugar Company, Denver, Colorado (January 2, 1973).

59. Provided by Mr. Herbert O. Ebell, General Chemist, Michigan Sugar Company, Saginaw, Michgan (February 1973).

60. Cost Information as provided by Black & Veatch Consulting Engineers, 1500 Meadowlake Parkway, Kansas City, Missouri (February 1973).

61. Information as provided by Mr. Dale Blant, Fluor Industry, Santa Rosa, California (February 1973).

62. Beet Sugar Industry, Background Information on Development of Effluent Limitations, Office of Refuse Act Permit Programs, Environmental Protection Agency, Washington, D. C. As provided to the Effluent Guidelines Division, EPA by the Office of Permit Programs, January 4, 1973 (1973).

63. Provided by Mr. David C. Carter, Executive Vice President, U. S. Beet Sugar Association (January 26, 1973).

64. Fordyce, I. V., and Cooley, A. M., "Separation, Dewatering and Disposal of Sugar Beet Transport Water Solids, Phase I," A project conducted under the sponsorship of the Office of Research and Monitoring, Environmental Protection Agency, Washington, D. C., Grant Project #12060 ESC (June 1972).

65. Beet-Sugar Technology, Edited by R. A. McGinnis, Second Edition, published by Beet Sugar Development Foundation, P. O. Box 538, Fort Collins, Colorado (1971).

66. Blankenbach, W. W., and Williams, W. A., 15th Meeting American Society of Sugar Beet Technology, Phoenix, Arizona (February 1968).

67. Miller, P. H., Eis, F. G., and Oswald, W. J., Pres. at 15th Meeting American Society Sugar Beet Technology, Phoenix, Arizona (February 1968).

68. Ichikawo, K., Golueke, G. G. and Oswald, W. J., Pres. at 15th Meeting American Society Sugar Beet Technology, Phoenix, Arizona (Feb. 1968).

69. Crane, G. W., "The Conservation of Water and Final Treatment Effluent". Proc. at 19th Technical Conference British Sugar Corporation, Ltd. (June 1968).

70. Tsugita, R. A., Oswald, W. J., Cooper, R. C. and Golueke, C. G., Pres. 15th Meeting American Society Sugar Beet Technology, Phoenix, Arizona

71. Querio, C. W. and Powers, T. J., Proc. of the 34th Annual Meeting Water Pollution Control Federation, *Milwaukee, Wisconsin, (Oct. 1961).

72. "Policy on Subsurface Emplacement of Fluids by Well Injection." A policy statement issued by the U. S. Environmental Protection Agency with accompanying "Recommended Data Requirements for Environmental Evaluation of Subsurface Emplacement of Fluids by Well Injection," Washington, D.C. (February 1973).

73. "Treatment of Selected Internal Kraft Mill Wastes in a Cooling Tower," report of findings and results prepared by the Georgia Kraft Company Research and Development Center under Program #12040 EEK, Grant #WPRD 116-01-68 for the Environmental Protection Agency, Washington, D. C. Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. (Aug. 1971)

74. As obtained by on-site plant visits by EPA personnel during January--February 1973.

75. Iverson, Clair H., "Water Consumption of A Typical Beet Sugar Factory," The Great Western Sugar Company, Denver, Colorado (February 1973).

76. Sawyer, Clair N., Chemistry for Sanitary Engineers, McGraw-Hill Book Company, New York, New York (1960).

77. Public Health Service Drinking Water Standards, Revised 1962, U. S. Department of Health, Education and Welfare, U. S. Public Health Service

Publication No. 956, U. S. Government Printing Office, Washington, D. C. (1962).

78. "Methods for Chemical Analysis of Water and Wastes," Environmental Protection Agency, National Environmental Research Center, Analytical Quality Control Laboratory, Cincinnati, Ohio (1971).

79. Environmental Protection Agency, "Proposed Drinking Water Standards" 1971 Revision, U. S. Environmental Protection Agency, Office of Media Programs, Office of Water Hygiene, Division of Water Hygiene, Washington, D. C. (1971).

80. "Existing and Proposed Effluent Criteria for Common Pollution Indices," Proposed by Refuse Act Permit Program, U. S. Environmental Protection Agency, Region VIII, Denver, Colorado, (subject to revision) (May 1972).

81. Fairall, J. M., Marshall, L. S. and Rhines, C. E., "Guide for Conducting an Industrial Waste Survey (Draft)", U. S. Environmental Protection Agency, Office of Air and Water Programs, Effluent Guidelines Division, Engineering and Sciences Staff, Cincinnati, Ohio (1972).

82. Cooling Towers, Prepared by editors of Chemical Engineering Progress, A technical manual published by American Institute of Chemical Engineers, New York, New York (1972).

83. Kolflat, T. D., "Cooling Towers - State of the Art", Department of Interior perAtomic Industrial Forum Seminar, Washington, D. C., February 13-14, 1973 (1973).

84. Cost of Wastewater Treatment Processes, Report No. TWRC-6, Robert A. Taft Water Research Center, Federal Water Pollution Control Administration, Cincinnati, Ohio (December 1968).

85. Proceedings of a Symposium on Waste Stabilization Lagoons, A Review of Research and Experiences in Design, Construction, Operation and Maintenance, Kansas City, Missouri, Public Health Service Publication No. 872, Superintendent of Documents, Washington, D. C.

86. Glossary Water and Sewage Control Engineering, Published Under the Joint Sponsorship of American Public Health Association, American Society of Civil Engineers, American Water Work Association and Federation of Sewage and Industrial Wastes Associations.
87.Hardenberghbb, W. A. and Edward B. Rodie, Water Supply and Waste Disposal, International Textbook Company, Scrant, Pennsylvania, Third Printing, August, 1966.

88. Manual on Water, ASTM Special Technical Publication No. 442, American Society for Testing and Materials, Third Edition, March, 1972.

89. Select Committee on National Resources, vs. Senate, "Water Supply and Demand", Committed Print No. 32, 1960.

90. McGuinness, C. L., "The Role of Ground Water in the National Situation," vs. Geological Survey Water - Supply Paper 1800, 1963.

91. Subsurface Pollution Problems in the United States, Technical Studies Report: TS-00-72-02, Office of Water Programs, U.S. Environmental Protection Agency, Washington, D.C., May, 1972.

92. Proceedings of the National Ground Water Quality Symposium, Cosponsored by the U.S. Environmental Protection Agency and the National Water Well Association, August 25-27, 1971, Denver, Colorado, Contract No. 68-01-0004, U.S. Government Printing Office, Washington, D.C.

93. Report on Water Quality Investigations, North Platte River Basin Tarringt, Wyoming - To - Bayard, Nebraska, Office of Enforcement, National Field Investigations Center - Denver, Colorado and Region VIII, Kansas City, Missouri, April, 1972.

94. Memorandum Report on the Evaluation of Great Western Sugar Mills in the North Platte River Basin, Nebraska, Environmental Protection Agency, Water Quality Office, Division of Field Investigations - Denver Center, Denver, Colorado, January, 1973.

95. Perry, John H., Chemical Engineering Handbook, 4th Edition, McGraw Hill, New York, New York (1963).

96. Handbook of Chemistry and Physics, 36th Edition, Chemical Rubber Publishing Company, Cleveland, Ohio (1954).

97. The Cost of Clean Water, Volume I, Summary Report, U. S. Department of Interior, Federal Water Pollution Control Administration, January 10, 1968.

98. The Economics of Clean Water, Volume I, Detailed Analysis, U. S. Department of the Interior, Federal Water Pollution Control Administration, March, 1970.

99. Cost of Clean Water, Volume II, Cost Effectiveness and Clean Water, Environmental Protection Agency, Water Quality Office, March, 1971.

100. Proceedings of the Advanced Waste Treatment and Water Reuse Symposium, Session 1 - 5, Sponsored by the U. S. Environmental Protection Agency, Dallas, Texas, January 12-14, 1971.

101. Martin, Edward J. and Leon W. Weinberger, Eutrophication and Water Pollution, Publication No. 15, Great Lakes Research Division, the University of Michigan, 1966.

102. St. Amant, Percy P. and Louis A. Beck, Methods of Removing Nitrates from Water, Agricultural and Food Chemistry, Sept. perOct., 1970.

103. Water Quality Management Problems in Arid Regions, Federal Water Quality Administration, U. S. Department of the Interior, Program #13030DYY, October, 1970.

104. Nitrogen Removal from Waste Waters, Federal Water Quality Administration, Division of Research and Development, Advanced Waste Treatment Research Laboratory, Cincinnati, Ohio, May, 1970.

105. Anaerobic - Aerobic Ponds for Beet Sugar Waste Treatment, Environmental Protection Technology Series, EPA - R2 - 73 - 025, Office of Research and Monitoring, U. S. Environmental Protection Agency, Washington, D. C., February, 1973.

106. Cost of Wastewater Treatment Processes, Report No. TWRC - 6, The Advanced Waste Treatment Research Laboratory, Robert A. Taft Water Research Center, U. S. Department of the Interior, Federal Water Pollution Control Administration, Cincinnati, Ohio, December, 1968.

107. Cost and Performance Estimates for Tertiary Wastewater Treating Processes, Report No. TWRC - 9, The Advanced Waste Estimates for Tertiary Wastewater Treating Processes, Treatment Research Laboratory, Robert A. Taft Water Research Center, U. S. Department of the Interior, Federal Water Pollution Control Administration, Cincinnati, Ohio, June, 1969.

108. Fair, Gordon M. and John C. Geyer, Elements of Water Supply and Wastewater Disposal, John Wiley and Sons, Second Printing, New York, September, 1961.

SECTION XV

GLOSSARY

Activated Sludge Process

A biological sewage treatment process in which a mixture of sewage and activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated sewage (mixed liquor) by sedimentation, and wasted or returned to the process as needed. The treated sewage overflows the weir of the settling tank in which separation from the sludge takes place.

Aeration

The bringing about of intimate contact between air and a liquid by one of the following methods: Spraying the liquid in the air; bubbling air through the liquid; or by agitation of the liquid to promote surface absorption of air.

Aeration Period

(1) The theoretical time, usually expressed in hours, that the mixed liquor is subjected to aeration in an aeration tank undergoing activated sludge treatment; is equal to (a) the volume of the tank divided by (b) the volumetric rate of flow of the sewage and return sludge. (2) The theoretical time that water is subjected to aeration.

Air Pollution

The presence in the atmosphere of one or more air contaminants in quantities, of characteristics, and of a duration, injurious to human, plant, animal life, or property, or which unreasonably interferes with the comfortable enjoyment thereof.

Alkalinity

A quality of waste waters due to the presence of weak bases, composed primarily of bicarbonates, carbonates and hydroxides.

Ammonia Nitrogen

All nitrogen in waste waters existing as the ammonium ion.

Anaerobic

Living or active in the absence of free oxygen.

Ash

The solid residue left after incineration in the presence of oxygen. 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. It is sometimes determined indirectly by measure of the electrical conductivity of solutions of the products.

Bacterial Quantity Unit (BQU)

One measure of the total load of bacteria passing a given stream location and is particularly useful in comparing relative loads between stations. The number of BQU's is derived as the product of flow in cfs and coliform density in MPN per100 ml, divided by 100,000.

Beet End

The part of the sugar plant which includes the process through the evaporators. In plants where the vacuum pans are heated by vapors, the evaporators are usually included in the sugar end.

Beet Pulp

The vegetable matter left after sugar is extracted from cossettes. Used, wet, dehydrated or pelleted as commercial cattle feed.

Biological Filtration

The process of passing a liquid through a biological filter containing media on the surfaces of which zoogleal films develop which absorb fine suspended, colloidal, and dissolved solids, and release end products of biochemical action.

Biological Process

The process by which the life activities of bacteria, and other microorganisms in the search for food, break down complex organic materials into simple, more stable substances. Self-purification of sewage polluted streams, sludge digestion, and all so-called secondary sewage treatments result from this process. Also called Biochemical Process.

Beet Wheel

A large wheel with baffles projecting radially inward from the surface of the perforated rim, and used to raise beets to a higher plane and separate them from the flume water; e.g., as from a flume to a beet washer.

BOD5 - 5-day, 20°C Biochemical Oxygen Demand

The quantity of oxygen used in the biochemical oxidation of organic matter over a five-day period of incubation at 20°C. The procedure is a standard test used in accessing waste water pollutional strength. (The term is printed as BOD5 rather than using the subscript number because of printing limitations.)

Blowdown

A discharge from a system, designed to prevent a buildup of some material, as in a boiler to control dissolved solids.

Brix

A hydormeter scale, calibrated to read percent sugar by weight in pure sugar solutions. Originated by Balling, improved and corrected by Brix.

Calcination

The roasting or burning of any substance to bring about physical or chemical changes; e.g., the conversion of lime rock to quicklime.

Campaign

The period of the year during which the beet plant makes sugar.

Carbonation

The process of treatment with carbon dioxide gas.

Caustic

Capable of destroying or eating away by chemical action. Applied to strong bases.

Chain-grate Stoker

A stoker system which moves the coal in a continuous bed from the bottom of a feed hopper into the furnace by means of a moving grate, consisting of a continuous belt constructed of many individual cast - iron chain links so assembled as to allow air to pass through.

Clarification

The process of removing undissolved materials from a liquid. Specifically, removal of suspended solids either by settling or filtration.

Coagulation

(1) The agglomeration of colloidal or finely divided suspended matter by the addition to the liquid of an appropriate chemical coagulant, by biological processes, or by other means. (2) The process of adding a coagulant and necessary other reacting chemicals.

COD - Chemical Oxygen Demand

A measure of the oxygen consuming capacity of inorganic and organic matter present in water or waste water. It is expressed as the amount of oxygen consumed from a chemical oxidant in a specific test.

Conductivity

A measure of the ability of water in conducting an electrical current. In practical terms, it is used for approximating the salinity or total dissolved solids content of water.

Cossette

Long, thin strips into which sugar beets are sliced before sugar-containing juices are extracted. The strips somewhat resemble shoestring potatoes.

Crop Year

In the sugar beet area in Southern California and all other States the crop year corresponds to the calendar year of planting. In Northern California, a crop of sugar beets planted in the interval beginning November 1 of one calendar year through October 31 of the following calendar year is designated by crop year to correspond with such following calendar year.

Depletion or Loss

The volume of water which is evaporated, embodied in product, or otherwise disposed of in such a way that it is no longer available for reuse in the plant or available for reuse by another outside the plant.

Diffuser

An apparatus into which water and cossettes are fed, the water extracting sugar from the sugar beet cells.

Detention Period

The theoretical time required to displace the contents of a tank or unit at a given rate of discharge (volume divided by rate of discharge.)

DO - Dissolved Oxygen

The oxygen dissolved in waste water or other liquid expressed in mg/l or percent of saturation.

Dust Box

A device to remove sugar dust from air, usually employing water sprays; a dust collector.

Effluent

(1) A liquid which flows out of a containing space. (2) Sewage, water, or other liquid, partially or completely treated, or in its natural state, as the case may be, flowing out of a reservoir, basin, or treatment plant, or part thereof.

Earthen Pond

A pond constructed with or without filtration control measures for the purpose of detention, long-term storage, or land disposal of influent waste waters.

Electrostatic Precipitator

A gas cleaning device using the principle of placing an electrical charge on a solid particle which is then attracted to an oppositely-charged collector plate. The device used a d-c potential approaching 40,000 volts to ionize and collect the particulate matter. The collector plates are intermittently rapped to discharge the collected dust into a hopper below.

Extraction Rate Efficiency

The percentage relationship between the sugar recovered and the sugar content in sugar beets.

Faculative Pond

A combination aerobic-anaerobic pond divided by loading stratification into aerobic surface,and anaerobic bottom, strata.

Fecal Coliform Bacteria

A group of bacteria of fecal origin within the coliform group inhabiting the intestines of man or animal. The group comprises all of the aerobic and facultative anaerobic, gram negative, non-spore forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C. In addition, the bacteria will produce gas within 24 plus or minus 3 hours at 43 plus or minus 0.2°C when inoculated into EC culture medium.

Filtrate

Liquid after passing through a filter.

Filtration

Removal of solid particles from liquid or particles from air or gas stream by passing the liquid or gas stream through a filter media.

Flume Waste Water

The normal term applied to the discharge of flume water which is employed to convey beets into the beet sugar processing plant.

Gas Washer

Apparatus used to remove entrained solids and other substances from carbon dioxide gas from a lime kiln.

Glucose

(1) An alternate chemical name for dextrose. (2) A name given to corn syrup which is obtained by the action of acids and peror enzymes on cornstarch. Commercial corn syrups are nearly colorless and very viscous. They consist principally of dextrose and another sugar, maltose, combined with gummy organic materials known as dextrins, in water solution.

Granulator

A rotary drier used to remove free moisture from sugar crystals prior to packaging or storing.

Ground Water

Water in the ground beneath the surface. In a strict sense the term applies only to water below the water table.

Holding Pond

An earthen facility, with or without lining to control seepage, constructed for the primary purpose of waste detention prior to discharge, or containment of waste water without direct discharge to surface waters by the mechanism of evaporation and ground seepage. Within the context of the meaning of the term seepage used in this report, seepage shall imply controlled ground seepage within specified limitations, and such as not to contribute adversely to the quality of ground or surface waters. Seepage control measures may be required to limit seepage from holding ponds within this context.

Lime Cake

The lime mud resulting upon clarification and purification of the raw sugar juice by heating, lime addition and precipitation in a insoluble precipitate contains both organic and inorganic two-step process through carbon dioxide addition. The impurities.

Lime Mud Slurry

The product resulting from the addition of water to lime cake to facilitate pumping of the material for disposal.

Lime Pond

A large diked area to which the lime mud slurry or waste filter cakes are held.

Massecuite

The mixture of mother liquor and sugar crystals, produced in the sugar boiling process (literally, a "cooked mass").

Mechanical Clarifier

A man-made device designed specifically for the detention of waste water for the purpose of removal of the settleable solids from the waste under controlled operating conditions.

Molasses

A dark-colored syrup containing non-sugars produced in processing both beet and cane sugar. Beet molasses is used as commercial cattle feed or in the manufacture of monosodium glutamate, a food flavoring agent, alcohol, yeast, citric acid and other products.

Mother Liquor

The solution from which crystals are formed.

MPN - Most Probable Number

In the testing of bacterial density by the dilution method that number of organisms perunit volume which, in acccordance with statistical theory, would be more likely than any other possible number to yield the observed test result or which would yield the observed test result with the greatest frequency. Expressed as density of organisms per100 ml.

Nitrification

The oxidation of organic nitrogen into nitrates through biochemical action.

Nonsugar

Any material present, aside from water, which is not a sugar.

Pan

A single-effect evaporator used to crystallize sugar.

Percentage Reduction

The ratio of material removed from water or sewage by treatment to the material originally presented (expressed as a percentage.)

pH

A measure of the relative acidity of alkalinity of water. The reciprocal of the logarithm of the hydrogen ion concentration. A pH value of 7.0 indicates a neutral condition; less than 7.0 indicates a predominance of acids, and greater than 7, a predominance of alkalis.

Process Effluent or Discharge

The volume of water emerging from a particular use in the plant.

Pond Lime

Lime cake after being run into waste ponds.

Population Equivalents (P.E.)

Describe the pollutional effect of various waste discharges in terms of a corresponding effect of discharging raw sewage from an equivalent number of human population. Each P.E. represent the waste contributed by one person in a single day generally equivalent to 0.17 lbs BOD_5.

Process Water

Water which is used in the internal juice streams from which sugar is ultimately crystallized.

Pulp Press

A mechanical pressure device which squeezes the exhausted cossettes (pulp) to remove a portion of the inherent water.

Pulp Screen Water

Water which is drained from the wet insoluble pulp after the diffusion process but before the pulp is pressed to remove extraneous water and sugar.

Pulp Silo Drainage

Drainage water resulting from discharge of pulp from the diffuser with screenings to a silo equipped with channels for drainage water collection.

Purity

A measure of the actual sugar content in relation to the total dry substance in sugar beets. Specifically, the percentage of sucrose in total solids.

Raw Sugar

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

Raw Value

Raw value is a computed weight of sugar used in the Sugar Act for a common expression of different types and qualities of sugar. The major types of sugars are converted to raw value as follows:

(1) For hard refined crystalline sugar multiply the number of lb thereof by 1.07.
(2) For raw cane sugar, multiply the number of lb by the figure obtained by adding to 0.93 the result of multiplying 0.175 by the number of degrees and fractions of a degree of polarization above 92 degrees.
(3) For sugar and liquid sugar, testing less than 92 degrees by the polariscope, divide the number of lb of the "total sugar content" thereof by 0.972.

Raw Sugar Juice

The liquid product remaining after extraction of sugar from the sliced beets (cossettes) during the diffusion process.

Riparian

An adjective pertaining to anything connected with or adjacent to the banks of a stream or other body of water.

Refined Sugar

A high purity sugar normally used for human consumption.

Saccharate Milk

A slurry of calcium saccharate from the Steffen process.

Screening

The removal of relatively coarse floating and suspended solids by straining through racks or screens.

Seal Tank

The tank on the bottom of a barometric leg pipe.

Sedimentation

The sedimentation of suspended matter in a liquid aided or unaided by chemicals or other special means and without provision for the decomposition of deposited solids in contact with the sewage.

Slicer

Usually a drum on which V-shaped corrugated knives are mounted. This machine produces the cossettes.

Slicing Capacity

Processing capacity. The number of ts of sugar beets a plant is capable of processing in a 24-hour period of time.

Sludge

The settled mud from a thickener clarifier. Also, in the Steffen process, the vacuum filter tray bottoms returned to the process as wet lime for preliming the diluted molasses. Generally, almost any flocculated, settled mass.

Steffen Process

A process employed at some beet sugar plants for recovery of additional sucrose from molasses. The process is generally carried on in conjunction with the main sugar extraction process at non-Steffen or "straight-house" plants. The process consists of the addition of finely ground calcium oxide to dilute molasses under low temperature conditions. Sugar, Steffen filtrate and insoluble calcium saccharate is produced, filtered out, and generally reused at the main purification step of the normal "straighthouse" extraction process.

Steffen Filtrate

The waste which is separated from the calcium saccharate.

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 and beet sugars are essentially 100 percent sucrose.

Sugar

A sweet, crystallizable substance, colorless or white when pure, occurring in many plant juices, and forming an important article of human food. The chief sources of sugar are the sugar cane and the sugar beet, the completely refined products of which are identical and form the granulated sugar of commerce. Chemically, sugar is a disaccharide with the formula $C_{12}H_{22}O_{11}$ formed by union of one molecule of dextrose with one molecule of levulose.

Supernatant

The layer floating above the surface of a layer of solids.

Spray Irrigation

Irrigation by means of nozzles along a pipe on the ground or from perforated overhead pipes.

Surface Irrigation

The process of sewage irrigation in which sewage is applied to and distributed over the surface of the ground.

Suspended Solids

(1) The quantity of material deposited when a quantity of water, sewage, or other liquid is filtered through an asbestos mat in a Gooch crucible. (2) Solids that either float on the surface of or are in suspension, in water, sewage, or other liquids; and which are largely removable by laboratory filtering.

Sweetwater

Dilute sugar solution, formed from washing filter cakes or granular carbon beds, too dilute to continue with the filtrate into the main process stream. Normally used in making milk of lime and saccharate milk.

Tare

Waste material which must be discharged. Also, the empty weight of a container used for weighing or transporting material.

Total Coliform Bacteria

Represents a diverse group of microorganisms whose presence have been classically used as indication of sewage pollution in water supplies. They are always present in the intestinal tract of man and other warm-blooded animals and are excreted in large number in fecal wastes. Where such fecal pollution exists, there is always the possibility of the presence of enteric pathogenic bacteria and other pathogenic entities. Increasing density of the coliform bacteria group is assumed to represent an increase in the quantity of pollution, and therefore, greater hazard. It must be noted under some circumstances total coliform may be present which are derived from sources other than fecal excreta.

TDS - Total Dissolved Solids

The solids in water, sewage or other liquids, it includes the suspended solids (largely removable by filter paper) and the filterable solids (those which pass through filter paper).

Trickling Filter

A filter consisting of an artificial bed of coarse material, such as broken ste, clinkers, slate, slats, or brush, over which sewage is distributed and applied in drops, films, or spray, from troughs, drippers, moving distributors, or fixed nozzles, and through which it trickles to the underdrains, giving opportunity for the formation of zoogleal slimes which clarify and oxidize the sewage.

Vacuum Filter

A filter consisting of a cylindrical drum mounted on a horizontal axis, covered with a filter cloth, revolving with a partial submergence in liquid. A vacuum is maintained under the cloth for the larger part of a revolution to extract moisture. The cake is scraped off continuously.

Vapor

Derived from boiling juices, as differentiated from steam generated in the boiler house or obtained from exhaust of turbines or engines.

Vernalization

To produce premature flowering or fruiting of a plant.

Wet Scrubbing

A gas cleaning system using water or some suitable liquid to entrap particulate matter, fumes, and absorbable gases. The collected substances are then withdrawn along with the scrubbing liquid.

Waste Discharged

The amount (usually expressed by weight) of some residual substance which is suspended or dissolved in the plant effluent after treatment, if any and conveyed directly to surface waters.

Waste Generated

The amount (usually expressed as weight) of some residual substance generated by a plant process or the plant as a whole and which is suspended or dissolved in water. This quantity is measured before treatment.

Waste Water

All water used in or resulting from the processing of sugar beets to refined sugar, including process water, barometric condenser water, beet transport (flume) water, and all other liquid wastes including cooling waters.

Watercourse

A channel in which a flow of water occurs, either continuously or intermittently, and if the latter, with some degree of regularity. Such flow must be in a definite direction. Watercourses may be either natural or artificial, and the former may occur either on the surface or underground. A different set of legal principles may apply to rights to use water from different classes of watercourses.

Water Rights

The rights, acquired under the law, to use the water occurring in surface or ground waters, for a specified purpose and in a given manner and usually within the limits of a given period. While such rights may include the use of a body of water for navigation, fishing, and hunting, other recreational purposes, etc., the term is usually applied to the right to divert or store water for some beneficial purpose or use, such as irrigation, generation of hydroelectric power, domestic or municipal water supply. In some states, a water right by law becomes appurtenant to the particular tract of land to which the water is applied.

Water Recirculation or Recycling

The volume of water already used for some purpose in the plant which is returned with or without treatment to be used again in the same or another process.

Water Use or Gross Use

The total volume of water applied to various uses in the plant. It is the sum of water recirculation and water withdrawal.

Water Withdrawal or Intake

The volume of fresh water removed from a surface or underground water source (stream, lake, or aquifer) by plant facilities or obtained from some source external to the plant.

Zooglea

A jelly-like matrix developed by bacteria. The word is usually associated with activated sludge growths in biological beds.

TABLE XVIII

CONVERSION TABLE

MULTIPLY (ENGLISH UNITS) by TO OBTAIN (METRIC UNITS)

ENGLISH UNIT	ABBREVIATION	CONVERSION	ABBREVIATION	METRIC UNIT
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram - calories
British Thermal Unit/pound	BTU/lb	0.555	kg cal/kg	kilogram calories/kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	1	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	F°	0.555(°F-32)1	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	1	liters
gallon/minute	gpm	0.0631	1/sec	liters/second
horsepower	hp	0.7457	kw	killowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig +1)1	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
tons (short)	ton	0.907	kkg	metric tons (1000 kilograms)
yard	yd	0.9144	m	meters

1 Actual conversion, not a multiplier