EPA-660/2-74-093
DECEMBER 1974

Environmental Protection Technology Series

Separation, Dewatering and Disposal of Sugar Beet Transport Water Solids

National Environmental Research Center
Office of Research and Development
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EPA-660/2-74-093
December 1974

SEPARATION, DEWATERING AND DISPOSAL OF SUGAR BEET TRANSPORT WATER SOLIDS

(PHASE I)

by

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Grant No. 12060 ESC
Program Element 1BB037
ROAP/TASK No. 21 BAB/083

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ABSTRACT

The objectives of this study were to determine the settling characteristics of solids from sugar beet washing and fluming operations in a clarifier, the filtering characteristics of the underflow slurry from a clarifier, and the disposal of the filter cake without subsequent development of objectionable odors. The results of this study were to be used to determine the feasibility of installing full scale filters for filtration and removal of the suspended solids from beet transport and wash water.

Buildup of organic matter in the water requires the maintenance of high pH to control bacterial growth. Slaked lime was used to maintain a high pH in addition to its use as a coagulant. Addition of paraformaldehyde was necessary, at times, to regain control of bacterial growth. Dosages are given.

Best conditions for filtration were obtained when the underflow from the clarifier was heated to 80 - 90 degrees C, when the pH was maintained over 10.5, and when the waste lime cake from beet juice purification was added to the clarifier feed.

The filter cake was disposed of on farm lands by three different methods: sanitary landfill, windrows two feet deep, and spreading at six inch depths. No objectionable odor developed from any of these disposal methods.

This report was submitted in fulfillment of the first phase of Grant 12060 ESC under the sponsorship of the U. S. Environmental Protection Agency and the American Crystal Sugar Company, Fargo, North Dakota. Work was completed as of June 1972.

CONTENTS

Section		Page
I	Conclusions	1
II	Recommendations	3
III	Introduction	4
IV	Methods and Materials	7
	Analytical Program	7
	Clarification Studies	11
	Filtration Studies	14
	Filter Cake Disposal Studies	16
V	Results and Discussion (Phase I)	18
	Clarification Studies	18
	Filtration Studies	26
	Filter Cake Disposal Studies	38
VI	Utilization of Phase I Results (Phase II)	41
	Full Scale Filtration Design	41
	Economic Evaluation of Full Scale System	43
VII	References	47
VIII	Publications	48
IX	Glossary	49
X	Appendices	50

FIGURES

No.		Page
1	Schematic diagram of transport water loop	9
2	Schematic diagram of pilot unit installation	10
3	Laboratory test leaf filtration apparatus	15
4	Filter yield vs percent solids in filter feed at constant pH, temperature and vacuum	28
5	Filter yield vs pH of filter feed at constant percent solids, temperature and vacuum	29
6	Filter yield vs pH and temperature at constant solids concentration and 15 in. Hg vacuum	30
7	Effect of temperature and polyelectrolyte on filter yield at constant solids concentration, pH and 15 in. Hg vacuum	31

TABLES

No.		Page
1	Analytical Testing and Sampling Schedule	8
2	Settling Rates for Polyelectrolytes	18
3	Solids Concentration in Main Clarifier Feed, Main Clarifier Overflow and Main Clarifier Underflow, 1971-1972	19
4	Polyelectrolyte Comparison in ENVIROCLEAR Thickener	21
5	Paraformaldehyde Treatment for pH Control	23
6	Screen Analysis of Underflow Mud from Clarifier Collected January 25, 1972	25
7	Size Distribution of -200 Mesh Fraction by Hydrometer ASTM Test Method 422	26
8	Filter Media Comparison	27
9	Filter Yields without Addition of Filter Aids	35
10	Filter Yields with Reconstituted Waste Lime Addition	36
11	Filter Yields with Fly Ash Addition	37
12	Filter Yields with Waste Lime Filter Cake Feed to Main Clarifier	38
13	Decomposition of Filter Cake Solids. Analysis for pH, Total N, Volatile Solids and COD	39

ACKNOWLEDGMENTS

The planning, direction and support of Mr. D. L. Stewart, Vice President and General Superintendent, Mr. W. W. Barr, General Chemist and Mr. P. A. Fick, General Engineer, American Crystal Sugar Co., throughout the project is acknowledged with sincere thanks.

The construction supervision and operation of the primary system and the construction and maintenance support for the pilot plant was handled by Mr. H. C. Roe, Superintendent and Mr. D. C. Russell, Master Mechanic of the Crookston plant. Mr. W. A. Eychaner, Chief Chemist, furnished laboratory space and provided much of the routine laboratory data in support of the project. Their support and cooperation is greatly appreciated.

The work of Mr. L. T. Carlson, Chemist and Mr. Gerald Baatz, Technician in providing the laboratory analysis is acknowledged with sincere thanks.

The technical assistance of Mr. A. M. Cooley, Professor of Chemical Engineering, University of North Dakota as technical advisor for the project and co-author of the report is acknowledged with sincere thanks.

The support of the project by the U. S. Environmental Protection Agency, and the help by Mr. Kenneth A. Dostal and Mr. Harold W. Thompson, the Grant Project Officer, are acknowledged with sincere thanks.

The preparation of the manuscript by Miss Elda Kastner is acknowledged with sincere appreciation.

SECTION I

CONCLUSIONS

1. Slaked lime as a coagulant in the feed to the clarifier provided adequate clarification for the closed loop transport water system. Under existing operating conditions the concentration of solids in the clarifier underflow was not adequate for satisfactory filter yields without further thickening. Anionic polyelectrolytes in the thickener provided adequate concentration of solids.

2. Vacuum filtration of thickened underflow from clarification of sugar beet wash and transport water was accomplished at cake rates of 5 to 10 pounds per square foot per hour (lbs/sq ft/hr) by the use of an EIMCOBELT filter. These rates are based on the total drum area. The solids content of the slurry fed to the filter was important with a minimum of 10 percent by weight of solids in the slurry necessary for cake pickup and preferably a solids content of 20 percent or over. A temperature of 80 to 90 degrees Centrigrade (°C) was used in these tests.

3. Addition of calcium hydroxide to increase the pH to around 11 improved the filtration rate. At pH values near 7 there was very little pickup of cake by the filter.

4. Addition of waste lime mud from juice purification to the clarifier influent gave an underflow which had the best filtration characteristics of the three combinations tried, however, reconstituted waste lime mud and fly ash were also effective filter aids.

5. When bacterial slime growth took place in transport water the thickener underflow was very difficult to filter. The transport water became acid due to bacterial action and slaked lime was no longer effective for pH control of bacterial growth. Paraformaldehyde, in dosages of .018 percent by weight of the circulating stream of transport water, added over a three hour period, accompanied by sufficient lime to neutralize the organic acids produced by bacterial activity, controlled bacterial growth. After this treatment slaked lime in amount of 2.5 to 5 pound per ton of beets sliced maintained the pH at 11 for bacterial control.

6. Disposal of filtered solids from clarifier underflow by sanitary landfill, dumping in two feet (ft) deep windrows, or spreading at six inch depths, resulted in virtually complete elimination or putrescible odors which are normally associated with the disposal, by ponding, of the clarifier underflow stream.

SECTION II

RECOMMENDATIONS

Pilot plant operations with a one ft by three ft diameter BIMCOBELT filter were used to determine conditions necessary for a filter yield of 5 to 10 lbs/sq ft/hr of total drum area. The results of small filter tests are fairly reliable for determining the gross effects of operating variables; but, operating effects due to variations in soil characteristics, durability of filter cloth media and general maintenance of the filter can only be determined by a full size unit. Thus a full scale demonstration is recommended.

Of the various methods of dewatering solids, filtration was the only method studied in this project. Variable soil types in other beet growing areas may be less amenable to filtration. Other methods of dewatering such as centrifugation and drying warrants further research.

The disposal of transport water solids in some factory sites is posing an ever increasing environmental and economic problem. Further research should be devoted to the ultimate disposal and/or possible economic utilization of these solids.

Air pollution abatement practices in the sugarbeet industry are likely to place an added burden on both liquid and solid waste treatment programs. The utilization of waste heat from various factory sources, and the possible generation of a heat source, as from an anaerobic digester for liquid waste, should be explored as sources of heat requirements in a filtration or drying process for dewatering of transport water solids.

SECTION III

INTRODUCTION

Beet sugar factories are large users of water, and treatment of this water before disposal is a problem affecting the entire economics of sugar processing. Beet washing and transport water is the process stream posing the greatest pollution control problem for both water and solids disposal. A 1968 survey by Fischer and Hungerford (1) of 58 United States beet sugar factories showed that dirt on beets averaged 5 to 6 percent of the beet weight and that the water needed to wash and flume beets ranged from 1,200 to 4,000 gallons (2,340 gallons average) per ton of beets sliced.

At the American Crystal Sugar Co. plant in Crookston, Minnesota (study site for Grant 12060 ESC) the water in the transport system was approximately 700,000 gallons for processing 4,000 tons of beets per day. The total daily water circulation was approximately 8 million gallons. This averages 2,000 gallons per ton of beets sliced, close to the average of 2,340 gallons for 58 factories as reported by Fischer and Hungerford (1). The circulation rate for the Crookston plant was approximately 333,000 gallons of water per hour.

Ten of 58 factories surveyed by Fischer and Hungerford(1) recycle transport water after returning from a settling pond. It is necessary to develop methods which will allow reuse of the clarifier underflow water with accumulation of a minimum amount for treatment prior to discharge to a receiving stream or retention for reuse without generation of putrescible odor.

At the Crookston plant the underflow from the main clarifier (consisting of soil, fine beet particles, and suspended solids in the transport water) is pumped to a 50 acre settling pond. The organic material included in the underflow solids produces odors and septic conditions. These conditions persist for several months during the spring and summer. It now appears that this nuisance could be avoided if the underflow from the clarifier was further dewatered by filtration and

the filter cake disposed of on land. The recycled water from the beet transport system at the end of the season could be treated by conventional methods with no odor problems.

Two EPA- Sugar Industry studies, the Tracy project (2) (Grant No. 93-04-68) and the Longmont project (3) (Grant No. 12060 FAK), dealt with the treatment of sugarbeet transport waters by lagooning techniques for recycling and for BOD reduction prior to ultimate discharge of such waters. This study was developed to compliment the previous studies by developing a faster and/or more effective method of removing and disposing of the solids in sugarbeet transport waters.

The objectives of this study (Phase I) were:

A: Optimize clarifier operation to allow recycle of beet wash and flume water.

B: Evaluate filtration characteristics of the clarifier underflow.

C: Evaluate land disposal of flume mud filter cake for generation of putrescible odors.

The data from Phase I were to be directed towards the design of a full scale filtration system for dewatering the underflow from the transport water clarifier and satisfactory disposal of the filter cake. This work will be conducted under Phase II of this grant.

The plan of operation for Phase I studies was to optimize clarifier operations and conduct laboratory studies on clarifier underflow thickening and filtration characteristics during September of 1970 and conduct pilot filter studies during October - December of 1970. The disposal of flume mud filter cake was to be evaluated during the spring of 1971. Laboratory thickening and filter test leaf studies in September indicated that thickening of the clarifier underflow with anionic polyelectrolytes was sufficient treatment to provide adequate filter yields by vacuum filtration. Delays in procurement of equipment and building construction delayed operation of the pilot units until December 24, 1970. Filter yields with the pilot filter were unsatisfactory, indicating a change in clarifier underflow characteristics. These changes were attributed to loss of pH control in the clarifier, accompanied by bacterial slime growth.

Further laboratory studies indicated that by raising the pH of the clarifier underflow with slaked lime and heating the thickener underflow to 90 °C would produce satisfactory filter yields. Additional pilot tests confirmed the laboratory results; however, the processing season was completed before a complete evaluation of the pilot study could be accomplished. Thus Phase I studies were continued during the 1971-72 campaign.

SECTION IV

METHODS AND MATERIALS

ANALYTICAL PROGRAM

Chemical analyses for this study were conducted in the factory laboratory. Special laboratory equipment furnished for this study included an OHOUS direct reading moisture balance, Model 6010, for rapid determination of moisture and total solids, and a Baush & Lomb Spectronic-20 Colorimeter for colorimetric analysis. Appendix A describes the analytical procedures used in this study. The analytical testing and sampling schedule is shown in Table 1.

A schematic flow diagram of the transport water loop is shown in Figure 1 (for detailed flow diagram see Appendix B). A schematic diagram of the pilot unit installation is shown in Figure 2.

Seven main points were selected as sampling stations (for locations see Figures 1 and 2). A brief description of each is as follows:

1. Feed to Main Clarifier.

   The sample of the main clarifier influent was sampled after the vibrating screens and slaked lime addition.

2. Main Clarifier Overflow.

   The main clarifier overflow was sampled from the clarified water line supplying the beet washer.

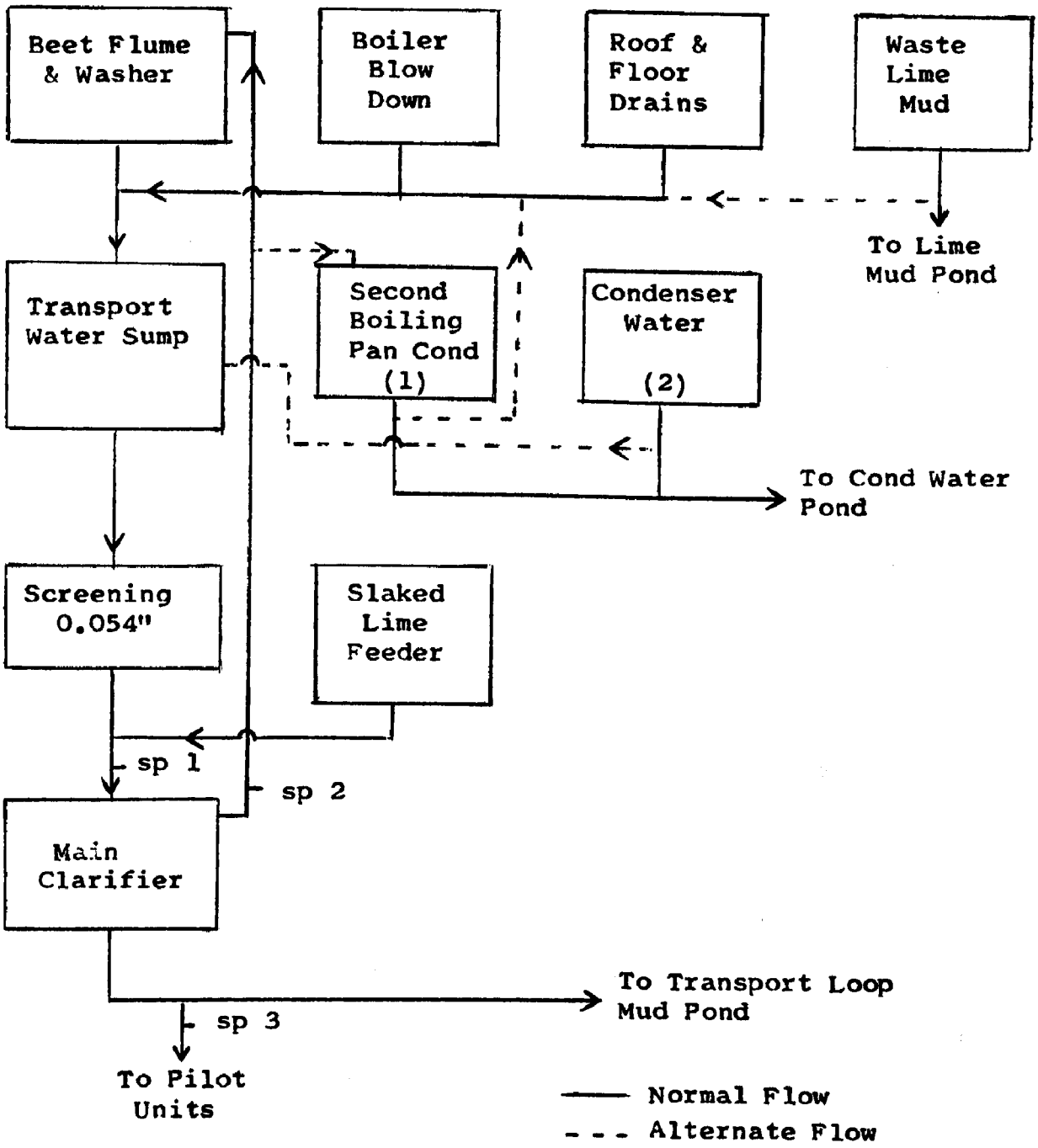
3. Main Clarifier Underflow.

   The main clarifier underflow containing the settled solids was sampled at the point where the underflow stream was diverted to the pilot units.

Table 1. ANALYTICAL TESTING AND SAMPLING SCHEDULE

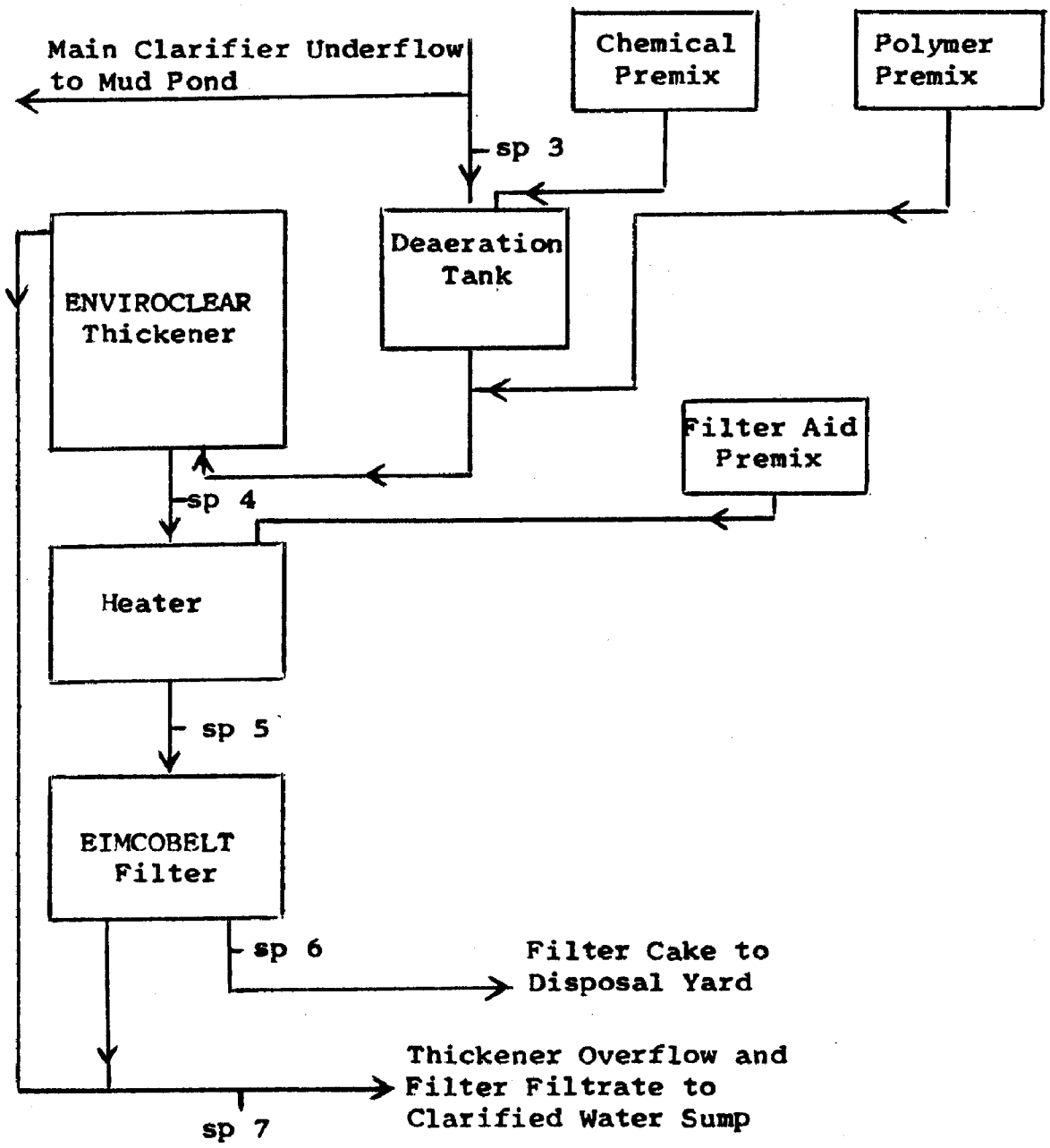
	Feed to Clarifier (1)	Clarifier Overflow (1)	Clarifier Underflow (2)	Thickener Overflow & Filtrate (2)	Thickener Underflow (2)	Feed to Filter (3)	Filter Cake (2)
pH	x	x	x	x	x	x	x
Settleable Solids	x	x					
Suspended Solids	x	x		x			
Residue on Evap			x		x	x	x
Filterable Solids	x	x		x			
Org & Vol Solids							x
Direct Polarization (4)		x					
Total Sugars	x	x		x			
Organic Acids	x	x		x			
Total CaO	x		x		x	x	x
Soluble CaO	x						
Phosphate	x	x		x			
Ammonia-N		x		x			
Organic-N		x		x			
Total-N							x (6)
BOD_5 (5)	x	x		x			
COD (5)	x	x		x			x (6)
Odor							x

(1) 24 hr comp of hourly grab samples, Mon thru Fri
(2) 8 hr comp of hourly grab samples, Mon thru Fri
(3) Grab sample of each batch
(4) Daily average of hourly analysis
(5) Analysis 3 days per week
(6) Analysis on composite of frozen samples



sp 1 - Sample point for feed to main clarifier
sp 2 - Sample point for main clarifier overflow
sp 3 - Sample point for main clarifier underflow
(1) - Used as needed for temp control
(2) - Used as needed for volume makeup

Figure 1. Schematic diagram of transport water loop



sp 3 - Sample point for main clarifier underflow
sp 4 - Sample point for thickener underflow
sp 5 - Sample point for filter feed
sp 6 - Sample point for filter cake
sp 7 - Sample point for combined thickener overflow and filter filtrate

Figure 2. Schematic diagram of pilot unit installation

4. Thickener Underflow.

The ENVIROCLEAR thickener was operated on a continuous flow basis and its underflow stream was sampled at the point of discharge from the thickener.

5. Filter Feed.

The filter was operated on a batch basis and filter aid materials were added in the heater tank. This sample was collected at a point just ahead of the filter.

6. Filter Cake.

The filter cake was sampled as it fell from the filter cloth.

7. Combined Thickener Overflow and Filter Filtrate.

This sample was obtained at a point where the two streams were combined prior to their discharge to the transport water system. The thickener overflow was also sampled separately for clarification studies.

CLARIFICATION STUDIES

In this study the transport water stream at average flow rates of 5600 gallons per minute (gpm) was screened over .054 in. slotted vibrating screens and the settleable solids were separated in a 115 ft diameter (dia) by 8 ft deep EIMCO clarifier. Slaked lime at addition rates of 2.5 to 5 pounds per ton of beets sliced was used as a coagulant, and to maintain pH in the clarifier effluent at 11.0-11.5 to reduce bacterial activity. The overflow was returned directly to the beet flume and the underflow was pumped to a mud pond for settling and accumulation of solids. A portion of the underflow stream was diverted for pilot plant studies for further concentration and filtration.

In the Crookston recycle fluming system the clarified transport water is pumped from the clarifier overflow sump to the wet hopper, to nozzles located along the bottom of the flume, and to the beet washer. The transport water conveys the beets through the flume to the beet wheel which lifts the beets from the flume into the beet washer. The transport water then returns to the waste water sump from which it is pumped over the screens and flows by gravity to the clarifier.

The main clarifier, 115 ft dia x 8 ft side wall, has a surface area of 10,387 sq ft, a capacity of 623,215 gallons and a wier length of 361 ft. The pumpage rate for the transport water system averaged 5,600 gallons per minute. For an assumed mud tare of 5 percent and an average slice rate of 4,000 tons of beets per day and an underflow solids concentration of 8 percent, the clarifier would have the following loadings:

1.	Hydraulic overflow	776 gal./day/sq ft
2.	Solids loading	38.5 lbs/day/sq ft
3.	Hydraulic underflow	56.6 gal./day/sq ft
4.	Wier loading	22,338 gal./day/ft
5.	Detention time	1.9 hours

The clarifier underflow is pumped to a settling pond. The water pumped from the underflow must be replaced to maintain the proper operating level in the clarifier to provide water for fluming beets. In the original design of the Crookston plant, all waste water streams were directed to the waste water sump. These waste water streams included roof drains, storm drains, floor drains, carbon dioxide gas washing water, sugar cooler cooling water, boiler blow down water, and condensate waters not reused in the process of producing sugar. With the installation of the recycled transport water system, the condenser water was segregated from the transport water system, and pumped to a stabilization lagoon. Excess condensate waters and sugar cooler cooling water were included in the condenser water system. The remaining waste water streams provided more make up water than required for the transport water system. Thus it was necessary to operate the clarifier underflow pumps at full capacity to maintain the proper level in the clarifier. This practice is not conducive to solids thickening in the clarifier, and the operating procedure should be corrected.

Temperature in the transport system is a compromise between that which does not permit rapid bacterial growth and that which will allow handling of frozen beets. Temperature is not controlled during normal, early season operations and will range from 12 to 20 °C depending on weather conditions. When beets freeze in the hoppers or dirt is frozen on the beets, warmer water is necessary to permit handling and washing. Clarified water is used in one pan condenser and returned to the transport water loop. Temperature of the transport water is thus raised to approximately 30 °C.

pH control in the main clarifier at 11.0 to 11.5 was achieved by the addition of slaked lime. Lime is obtained for factory operations for the juice purification process by burning lime rock in a vertical, coke fired kiln. A portion of the lime is fed to a horizontal, rotary lime slaker with a rated capacity of 10 tons of lime rock per day. Lime addition rates to the transport water stream entering the main clarifier were manually controlled based on pH values of hourly grab samples of the clarified effluent (See Figure 1 - sp 2).

When frozen or partially deteriorated beets were being processed acid production in the transport water system from bacterial action exceeded the neutralizing capacity of the lime feeding system. To regain pH control paraformaldehyde was added to retard bacterial action until a pH of 11.0-11.5 could again be obtained by the use of lime. It was found that a formaldehyde concentration of 0.018 percent in the transport water was adequate to retard bacterial action for a period of 18 to 24 hours.

Particle size analysis of the transport water solids was made by wet screening through Tyler sieves. The fraction passing the 200 mesh screen was further analyzed by the ASTM hydrometer test Method 422 (4).

Clarification studies on transport water for polyelectrolyte comparison were made by laboratory jar studies. A properly diluted polymer at 0.05 percent concentration was added to 500 millileters (ml) of transport water feed to the clarifier at dosages of 0.5 to 2 parts per million (ppm). The solution was stirred by hand with a spoon for 30 seconds and poured into a 500 ml graduated cylinder. The volume of settled solids was observed at timed intervals. Suspended solids determinations by gravimetric methods were not made on the jar studies, but clarity of the supernatant was observed visually. Three anionic polymers, Nalco 674, Betz 1420 and Zuclar 110, two experimental anionic polymers, Nalco 7460 and Nalco ID16-71, and one cationic polymer, Nalco 607, were compared in the jar studies.

Clarification studies were conducted on the clarifier underflow in the ENVIROCLEAR thickener under continuous flow conditions. Two anionic polymers, Betz 1420 and Nalco 41A06 (commercial form of Nalco ID16-71), and one cationic polymer, Betz 1260, substituted for Nalco 607, were used in the jar studies on transport water. The substitution was made because of the poor results obtained with Nalco 607.

FILTRATION STUDIES

A pilot Model, 3 ft dia, 150 gallon (gal.) capacity ENVIROCLEAR clarifier was used for concentrating the main clarifier underflow. This unit is referred to as the thickener in this report. The unit was equipped with a deaeration tank, feed pump, polymer premix tank with feed pump and dilution pump, flow rate meter and underflow discharge pump.

The underflow discharge from the thickener was regulated by an electric eye actuated by the depth of the sludge bed. The function of the deaeration tank was to permit entrained gases to escape before entering the thickener and disrupting the settling rate of the sludge bed.

Filter cloth selection was made by comparing the filtration rates for three filter media under several conditions of clarifier underflow. Filtration rates were calculated with an EIMCO 1/10 sq ft test leaf filter. The laboratory set up for these tests is shown in Figure 3. The filter media compared were: A- Cotton Duck cloth, 16 ounce (oz) (Wellington Cotton Mills A63); B- Polypropylene Multifilament cloth (National Filter Media No. POPR222-006-02); and C- Polypropylene Monofilament cloth (National Filter Media No. POPR224-005-08). Tests were conducted at 2 minutes submergance time and 4 minutes drying time. The vacuum source was the factory vacuum lines supplying factory process at approximately 17 in. mercury (Hg) vacuum.

After selecting a filter cloth, laboratory test leaf filtration studies, to determine optimum filtration conditions, were conducted with the same test equipment as shown in Figure 3. The polypropylene multifilament filter media was used for all tests in this study. A 2 minute pick-up cycle and a 4 minute drying cycle was used in all tests. Two liters of clarifier underflow were placed in a one gallon container and agitated with an electric stirrer during test periods. Temperature was regulated by means of a gas burner. pH adjustments, when necessary, were made with slaked lime slurry, or concentrated acetic acid. Polyelectrolyte used in this study was Betz 1420 (anionic).

Three pilot model filter units were used in the initial pilot filtration studies during the 1970-71 campaign on thickened underflow, to evaluate the three filter types:

1 - EIMCOBELT 3 ft dia x 1 ft face drum vacuum filter.

2 - EIMCO 3 ft dia x 1 ft face drum pre-coat vacuum filter.

3 - INDUSTRIAL FILTER and PUMP MANUFACTURING CO pressure leaf filter, Model 112 BMD, Series R-80 with 8 sq ft filter area.

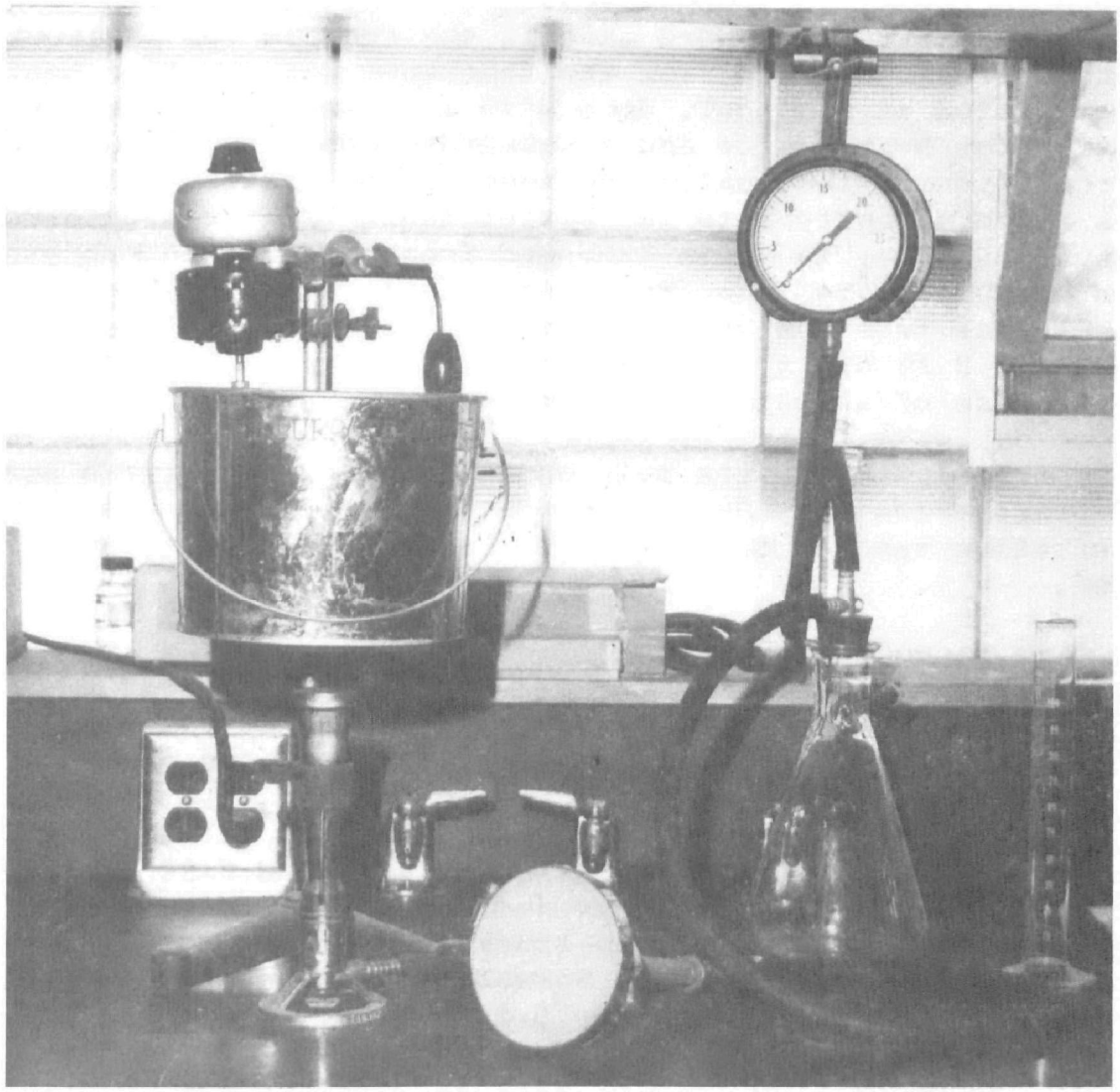


Figure 3. Laboratory test leaf filtration apparatus

Pilot unit filtration studies during the 1970-71 campaign were conducted by batch thickening of the clarifier underflow in a pilot model EIMCO clarifier with Betz 1420 polymer addition. pH adjustment was made by batch treatment with slaked lime on the thickened underflow. Experience indicated that temperature adjustment was necessary. Temperature adjustment was made by direct steam injection.

Pilot unit filtration studies conducted during the 1971-72 campaign season were made on a thickened stream of main clarifier underflow. pH adjustment by slaked lime addition and polymer addition (Betz 1420) were made in the feed to the ENVIROCLEAR thickener. The underflow from the thickener was fed to a heater which consisted of a 55 gal. drum with a closed steam coil in the bottom for heat source and a submerged centrifugal sump pump for circulation in the heater and feed to the filter. Filter aid was added directly into the heater tank. Filter aids used in this study were: 1- Waste lime mud from carbonation process filters; 2- Dry waste lime from waste lime mud disposal pond; and 3- Fly ash from the bottom of the intercampaign boiler stack. An EIMCOBELT 3 ft dia x 1 ft face drum vacuum filter was used for this phase of the study. Filter yields are based on the weight of dry cake in lbs/sq ft/hr. Wet cake was collected for one timed revolution of the belt and weighed on a platform scale to the nearest 1/4 oz. Dry solids determination was made on representative samples of the cake. Cake thickness was also recorded.

FILTER CAKE DISPOSAL STUDIES

During the 18 days of pilot filtration study (1971-72 campaign) approximately 15 tons of wet filter cake solids were accumulated at the pilot unit site. The solids were trucked to a field disposal area. Three methods of disposal of the filter cake solids were studied. They were: 1- Sanitary land fill at three foot depth x 2 ft x 3 ft with one foot of earth cover; 2- Windrow distribution on land by dump truck at approximately two foot depth of pile x 3 ft x 5 ft; 3- Spreading on land by dump truck at approximately six in. depth by 5 ft x 5 ft. The three storage areas were located 50 ft apart. Sampling of the filter cake solids for decomposition studies were made in the Spring after the piles had thawed out and thereafter at two week intervals for six weeks. Samples were taken from six locations in each pile by 1 in. dia cores the full depth of the pile. Core samples were composited for each pile and a representative sample of the composite used for analysis. Odor analysis was made by sense of

smell by the analyst during daily visits to the disposal site and during collection of samples for the decomposition studies.

SECTION V

RESULTS AND DISCUSSION (PHASE I)

CLARIFICATION STUDIES

Transport Water

A comparison of settling rates using several polyelectrolytes on transport water (Sample Point 1) was made by jar studies at different polymer concentrations by measurement of concentrated solids volume at different time intervals as shown in Table 2.

Table 2. SETTLING RATES FOR POLYELECTROLYTES

Poly Conc	Settled Solids in ml/500 ml								
	0.5 ppm (1)			1 ppm (2)			2 ppm (3)		
Settling Time (min)	2	5	10	2	5	10	2	5	10
Nalco 674 (Anionic)	70	50	45	55	45	40	110	70	62
Nalco 7460 (Anionic)	65	47	42	40	35	35	110	70	62
Nalco ID 16-71 (Anionic)	150	47	42	40	35	27	100	65	57
Betz 1420 (Anionic)	62	45	40	30	30	30	75	55	50
Zuclar 110 (Anionic)	450	62	50	60	45	42	90	65	55
Nalco 607 (Cationic)	490	70	60	325	70	55	475	120	87

(1) 1.5 percent Solids at 8.7 pH
(2) 2.8 percent Solids at 9.9 pH
(3) 1.4 percent Solids at 9.9 pH

The data on the operation of the main clarifier in terms of pH, solids concentration and five day Biochemical Oxygen Demand (BOD_5) in the feed to the clarifier and the clarifier overflow, and the percent solids in the clarifier underflow for a period of 30 days is shown in Table 3. No polyelectrolyte was used in the main clarifier during this study. Additional data on the clarifier operation are shown in Appendix C, Tables I - V.

Table 3. SOLIDS CONCENTRATION IN MAIN CLARIFIER FEED, MAIN CLARIFIER OVERFLOW AND MAIN CLARIFIER UNDERFLOW, 1971-72

	Feed to Clarifier					Clarifier Overflow		Clarifier Underflow
Date	pH	Sett Solids ml/l	Susp Solids mg/l	Filt Solids mg/l	BOD_5 mg/l	Susp Solids mg/l	BOD_5 mg/l	Percent Solids
Nov. 15	6.5	27	640	9840		420		8.2
Nov. 16	6.5	33	1210	9130		540		10.5
Nov. 17	7.6	2	680	9710		230		9.0
Nov. 18	7.3	11	1420	11410		540	12900	8.5
Nov. 23	5.3	60	560	16060	9600	600		11.4
Nov. 24	6.1	38	270	17450		480		15.8
Nov. 25	6.3	17	320	17430		300		11.0
Nov. 29	6.4	30	630	12320		170		10.9
Nov. 30	6.8	75	520	13660		240		14.0
Dec. 1	6.5	15	650	11010	9600	200	8500	
Dec. 6	11.9	15	440	8240		340		8.0
Dec. 7	12.0	16	500	12650	10500	240	7500	5.5
Dec. 8	11.4	17	850	6620		370		6.0
Dec. 9	11.6	15	1120	15360	11400	560	8100	7.0
Dec. 16	11.4	17	660	17670	12200	620	10900	3.8
Dec. 20	11.4		510	13540	6500		7250	6.8
Dec. 21	11.6	20	510	13550	8300	400	6900	6.7
Dec. 22	11.8	21	490	12690	6900	520	6650	4.0
Dec. 23	11.3	16	700	12950		410		6.0
Dec. 28	11.5	12	810	10820	5250	460	5850	7.5
Dec. 29	11.8	10	990	10430	6200	550	5700	4.2
Dec. 30	11.4	4	880	10130	9150	580	8250	6.0
Jan. 3	11.2	5	1370	10860		470		8.0
Jan. 4	11.2	17	1010	10700	8100	650	6000	5.5
Jan. 5	11.6	8	620	11240	9150	690	8850	4.8
Jan. 6	11.1	10	1130	10720	6310	830	7500	3.2
Jan. 10	11.4	12	1160	13290		670		5.8
Jan. 11	9.5	3	1360	11230		620		4.6
Jan. 12	11.8	10	1240	13330	6900	580	6600	5.2
Jan. 13	11.2	15	820	12410	8550	440	8700	4.5
Avg:								
Nov. 15-Nov. 30	6.5	31	690	12800	9600	370	10700	11.0
Dec. 2-Jan. 13	11.3	13	860	11920	8290	500	7600	5.6
Overall	9.8	20	810	12210	8450	460	7960	7.2

The treatment of transport water for clarification is complicated by a number of controlled variables such as pH and temperature, and uncontrolled variables including beet tare, beet quality, addition of water from boiler blow-downs and factory spills. These variables are discussed in the following paragraphs.

The suspended solids content in the feed to the clarifier depends on beet tare which varies with soil conditions during harvest and beet quality during processing. Beet tare, as stated earlier, averages 5 to 6 percent of the weight of beets, but may vary from 3 to 10 percent. Adverse weather conditions occurred during late October and early November and heavy wet snow resulted in extreme muddy conditions in the fields. Extreme cold weather resulted in some beets frozen in the ground. The harvesting and processing of these frozen beets resulted in higher than average mud tare and the fluming and washing of the frozen beets resulted in sloughing off of beet tissue which was not completely removed in the screening of the transport water. As shown in Table 3, the average settleable solids from Nov. 15 thru Dec. 1st was 31 millileters per liter (ml/l), and the average settleable solids from Dec. 6 thru Jan. 13th, while processing stock pile beets harvested before the adverse weather conditions was 13 ml/l. The suspended solids in the clarifier overflow during the same periods does not reflect any difficulty in clarification resulting from high beet tare.

The percent solids in the clarifier underflow reached a higher than average concentration during the period of processing beets with high tare. A higher concentration of solids in the clarifier underflow could have been obtained had the underflow discharge been operated on the basis of solids concentration in the underflow. This was not the case, however. The underflow discharge was regulated on the basis of water level in the clarifier as a means of maintaining the proper clarifier level. More in-plant water sources can be removed from the transport water loop and thus reduce the volume of underflow discharge necessary to maintain the proper level in the clarifier. The solids concentration in the underflow was not high enough for satisfactory filtration without further thickening.

The biochemical oxygen demand, with some variations due to processing of frozen beets, reached a high level and remained rather constant. This has been the experience of others as reported by Blankenbach and Willison (5). The highest BOD concentration reported was 12900 mg/l on Nov. 22nd, while processing field frozen beets.

The introduction of boiler blow down water into the transport water loop may have an adverse effect on clarification, however the effect of boiler blow down on clarification is not adequately reflected in the data collected. A boiler blow down volume of approximately 65,000 gal. per day as a continuous flow, containing 30 to 60 mg/l of phosphate enters the transport water loop. The extent of the deflocculating capacity of the phosphate is not reflected in the data.

Mud Thickener

A comparison of solids concentration in the underflow and clarity of the overflow in the ENVIROCLEAR pilot thickener was made for three polyelectrolytes at two concentrations with results shown in Table 4. The feed to the ENVIROCLEAR for this comparison was screened transport water combined with main clarifier underflow to provide a uniform feed rate of 15 gpm to the thickener at a pH of 11.4 without additional slaked lime addition, and a solids concentration in the feed of 8 percent. The retention time of the liquid phase in the thickener was 10 minutes.

Table 4. POLYELECTROLYTE COMPARISON IN ENVIROCLEAR THICKENER

Poly	Poly Feed mg/l	Underflow Percent Solids	Overflow Susp Solids mg/l
Betz 1420 (Anionic)	3	18.2	248
	5	29.0	136
Nalco 41A06 (Anionic)*	3	16.6	182
	5	20.2	188
Betz 1260 (Cationic)	5	15.8	186

* Commercial Form of Nalco ID16-71

Higher concentrations of polyelectrolyte were necessary in the clarifier underflow than in the feed to the clarifier to achieve the desired thickening in a shorter time period of 10 to 15 minutes in the thickener. 0.5 ppm to 2 ppm polyelectrolyte gave adequate clarity to the feed to the clarifier in the jar studies as reported in Table 2. 3 ppm to 5 ppm polyelectrolyte was required in the clarifier underflow.

The data on settling rates for the polyelectrolytes compared in the study indicate that the strong anionic polymers, Betz 1420 and Nalco 41A06, gave faster settling and a heavier concentration of settled solids than a cationic polymer, Betz 1260. In general, the polymers giving the faster settling rates also had better clarity.

The data in Table 4 for polyelectrolyte comparison in the thickener confirms the jar study data that anionic polymers are more effective in concentrating settled solids in the underflow than the cationic polymer. Increasing the polymer feed rate from 3 ppm by weight to 5 ppm resulted in a 59 percent increase in solids concentration in the underflow for Betz 1420 polymer and a 22 percent increase for Nalco 41A06.

Transport Water System pH Control - Paraformaldehyde

Extreme cold weather and snow in late October resulted in beets frozen in the ground. The processing of these field frozen beets resulted in excessive diffusion of sugar and beet juices in the transport water system. On November 6th the pH of the clarified water dropped below 7.0 and remained below 7.0 for 12 days. The bacterial activity in the transport water system produced acids at a rate exceeding the neutralizing capacity of the lime handling system for the transport water loop. A definite odor build-up in the transport water system occurred during this period.

Experimental treatments of the transport water system with paraformaldehyde was tried as an aid in regaining control of the pH in the transport water system. Corruthers and Oldfield (6) have reported the use of formaldehyde at 0.018 - 0.023 percent concentrations on beets in diffusion juice as being an effective treatment for control of bacterial activity. Based on a 700,000 gallon transport water volume and a formaldehyde concentration of 0.018 percent, 1,050 pounds of paraformaldehyde was used per treatment. The paraformaldehyde was dissolved in 300 gallons of pH 11 caustic solution and the solution introduced into the beet flume leaving the beet washer room over a three hour period. This method of application resulted in no formaldehyde odors in the plant. A tabulation of laboratory data and treatment schedule is shown in Table 5.

The initial treatment of 1,050 pounds of paraformaldehyde, made on November 19th, began to show an improvement in pH in 18 hours after treatment and a corresponding increase in the direct polarization of the clarified water 8 hours after treatment. An increase in polarization indicated a reduction in the rate of

Table 5. PARAFORMALDEHYDE TREATMENT FOR pH CONTROL

Day Ending 8 AM	Feed to Clarifier pH	Clarifier Overflow pH	Feed to Clarifier Pol (1)	Treatment and Comment (2)
Nov				
17	8.9	6.8	.04	
18	8.1	6.2	.06	
19	8.0	6.4	.08	
20	7.8	6.5	.11	(Shift avg Pol .06, .10, .18) 1050# paraformaldehyde 1 PM
21	10.2	9.7	.39	Waste Lime Mud to clarifier- 1 PM - 6 PM
22	10.1	7.5	.52	
23	9.1	6.3	.44	
24	7.5	5.8	.10	
25	8.4	6.8	.24	1050# paraformaldehyde 2 PM (Shift avg Pol .02, .24, .47)
26	8.5	6.9	.62	
27	6.5	6.1	.25	Waste Lime Mud to clarifier 9 AM - 6 PM
28	6.2	5.4	.07	1050# paraformaldehyde 10 AM
29	7.3	5.7	.10	600# paraformaldehyde 10 AM 600# 8 PM CW lime slaker to floor drains
30	7.2	6.1	.18	1050# paraformaldehyde 12 N Waste Lime Mud at 4 PM
Dec				
1	8.0	6.4	.11	Waste Lime Mud on continuously to 12-5-71
2	8.0	6.4	.08	
3	9.0	7.0	.30	1050# paraformaldehyde 9 AM (Shift avg Pol .14, .35, .42)
4	9.4	6.5	.29	(Shift avg Pol .41, .26, .19)
5	9.4	7.9	.16	1050# paraformaldehyde (Shift avg Pol .08, .08, .32) (pH 6.0, 7.6, 10.1)
6	11.7	11.5	.85	Waste Lime Mud to clarifier stopped 12 N
7	11.8	11.8	.96	
8	12.0	11.9	1.04	
9-12	11.6	11.6	1.05	

(1) Pol - direct polarization in percent sucrose
(2) Treatment in addition to slaked lime

bacterial inversion of sucrose. A high pH of 10.3 was reached 30 hours after treatment, but started to slip 36 hours after treatment. Waste lime mud was diverted to the transport water system for 5 hours. Because of apprehension over freezing of the waste lime line, it was not left on longer. The purpose in adding the waste lime mud to the transport water system was to utilize the residual alkalinity of the waste lime mud to aid in neutralizing the acidity of the transport water.

On November 24th a second 1,050 pounds of paraformaldehyde was added to the transport water system and followed on November 26th with waste lime mud for 8 hours. The results were similar to those of the first treatment.

On November 27th, 100 ml of clarified water were titrated with standard NaOH solution to pH 11.0 and 11.5. On the basis of this titration, 15,400 pounds of caustic would be required to neutralize the acids in the transport water system and raise the pH to 11.5. This would be the equivalent of 19.5 tons of lime rock or approximately twice the daily capacity of the transport water loop lime slaker.

On November 28th additional slaked lime was added to the transport water system thru a floor drain and on November 30th all the waste lime mud was diverted to the transport water system for continuous flow. On December 3rd titration of the clarified water indicated that 3,600 pounds of additional caustic would be required to raise the pH to 11.5. pH control of the clarifier was regained on December 6th.

The first treatment with paraformaldehyde eliminated the odor in the plant from the transport water system. The series of treatments indicated that the formaldehyde was effective in the system for a period of 18 to 24 hours when sugar inversion resulting from increased bacterial activity again became evident with decreased polarization of sucrose in the system.

The cost of paraformaldehyde treatment at 10.5 cents per pound for paraformaldehyde was $110 per treatment. With the cost of lime treatment for pH control ranging from $35 to $70 per day plus the added benefit of lime being an effective clarifying agent in the transport water system, the use of paraformaldehyde for routine pH control cannot be justified.

Particle Size Analysis of Clarifier Underflow

A single grab sample of slurry from the underflow of the transport water clarifier was wet screened and the minus 200 mesh material was sized by ASTM hydrometer method 422 (4).

The fractions above 200 mesh were collected, dried and weighed. The material above 48 mesh was mostly beet fragments and while this was only about 3.2 percent of the total weight of solids, its bulk was very high in proportion to the high density inorganic solids consisting primarily of clay, with some fine sand. Screen analysis of the plus 200 mesh fractions is shown in Table 6.

Table 6. SCREEN ANALYSIS OF UNDERFLOW MUD FROM CLARIFIER COLLECTED JANUARY 25, 1972

Tyler Mesh	Percent by Wt
+20	1.9
-20 +35	.4
-35 +48	.9
-48 +65	.6
-65 +100	1.5
-100 +150	1.3
-150 +200	2.6
-200	90.8

Table 7 shows the size distribution of the minus 200 mesh material.

The results of hydrometer test, ASTM Method 422, as shown in Table 7, were obtained after deflocculating the mud with hexametaphosphate, as described in the test procedure. A sample with no deflocculant settled to a relatively clear top liquid within 30 minutes but after addition of the deflocculant there was no clear top fluid after 24 hours. The particle size analysis shows the ultimate particle size of the soil but not the flocculated aggregate in the feed to the filter.

Table 7. SIZE DISTRIBUTION OF -200 MESH FRACTION BY HYDROMETER ASTM TEST METHOD 422

Size Microns	Percent by Wt
Less than 1	20
1-2.5	3.5
2.5-3	1
3-5	5.5
5-10	15
10-20	16
20-30	10
30-74	29

According to Wintermeyer and Kinter (7), sodium hexametaphosphate is one of the better dispersants for clay soils. When sodium hexametaphosphate is added to clay soils, the calcium ion in the clay reacts with the phosphate to form an insoluble, inert material and the clay accepts the sodium cation left over. A sodium clay is thus formed with excellent dispersion properties. It would follow, then, that excess sodium and phosphate ions in the clarifier system should be avoided for best flocculation of the soil particles.

FILTRATION STUDIES

Filter Media

A comparison of filtration rates for three filter media under several conditions of clarifier underflow treatment is shown in Table 8.

Data were collected on a 1/10 sq ft test leaf filter at 2 minute submergence and 4 minute drying time. Test equipment is shown in Figure 3. Test data indicates that a multifilament filter media has a greater filtrate filtration rate in gpm/sq ft than the monofilament media. Monofilament media blinds rapidly from the fine pulp fiber present in the transport water solids. Test data also indicates filtration rates can be improved by the use of anionic polyelectrolytes and filter aids. Data on filtrate clarity and cake pick up and drying were not collected during this series of tests, which was conducted to select a suitable filter

media for further studies. The multifilament media was found to be superior to the monofilament media.

Table 8. FILTER MEDIA COMPARISON

Filter Media	Underflow Treatment	Temp °C	Filtration Rate (gpm/sq ft)
A	None (1)	30	0.463
B	" (1)	30	0.106
C	" (1)	30	0.066
A	1 ppm Polymer (Betz 1420) (Anionic) (1)	30	0.370
B	" " (1)	30	0.278
C	" " (1)	30	0.095
A	" " (1)	70	0.384
A	1 ppm Betz 1420 + Filter Aid (1) (2)	70	0.889
B	" " (1) (2)	70	0.649
B	None (3)	30	0.637
B	1 ppm Nalco 607 (Cationic) (3)	30	0.622
A	" " (3)	30	0.508
C	" " (3)	30	0.265
B	1 ppm Nalco 80C02 (Anionic) (3)	30	0.688
B	1 ppm Betz 1420 (Anionic) (3)	30	0.944

(1) pH 5.9, 28 in. Hg Vacuum
(2) Diatomatious Earth Filter Aid (J. M. Celite 599)
(3) pH 10.4, 28 in. Hg Vacuum

(A)- Cotton duck cloth, 16 oz
(B)- Polypropylene multifilament cloth
(C)- Polypropylene monofilament cloth

Lab Test Leaf Filtration Studies

The results of the laboratory test leaf filtration studies to determine optimum filtration conditions using a 1/10 sq ft test leaf filter are shown in Appendix C, Tables VI thru IX and in Figures 4 - 7. All tests were conducted on grab samples of clarifier underflow (sample point No. 3). Due to the unstable

characteristics of the underflow, fresh samples were collected for each series of tests. Polypropylene, multifilament filter media was used for all lab filtration tests in this series.

The laboratory bench scale tests were conducted early in the season before any substantial bacterial slime growth appeared. The tests reflect characteristics of a suspended solids content uncomplicated by bacterial slimes. The pH could be controlled with 3 - 5 ml/gal. of lime slurry and flocculation could be achieved at the controlled pH with 0.5 to 2 mg/l of polyelectrolytes. The solids content of the clarifier underflow was very critical in filter cake formation. Rapid settling of part of the inorganic solids left a liquid suspension which would not form a satisfactory cake.

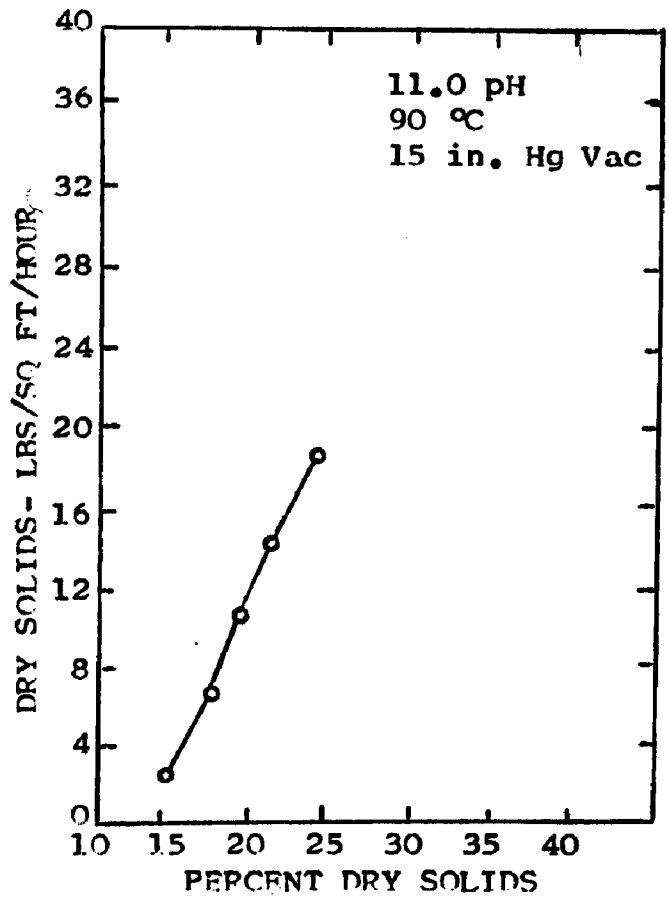


Figure 4. Filter yields vs percent solids in filter feed at constant pH, temperature and vacuum

In order to build up the solids content of the slurry fed to the filter, dry lime cake from refuse disposal piles was reconstituted and was used as a means of retarding the settling rate of the sand fractions and as a filter aid. The effect of solids on filter yields is shown in Figure 4. The solids added were of such fine particle size that they aided filtration mainly by keeping the coarser sand fractions in suspension and thus formed a more permeable and firm cake. Pilot runs later with the belt filter gave good filter yields without the use of reconstituted lime mud if the solids were concentrated to 15-20 percent in the thickener. See Table 9.

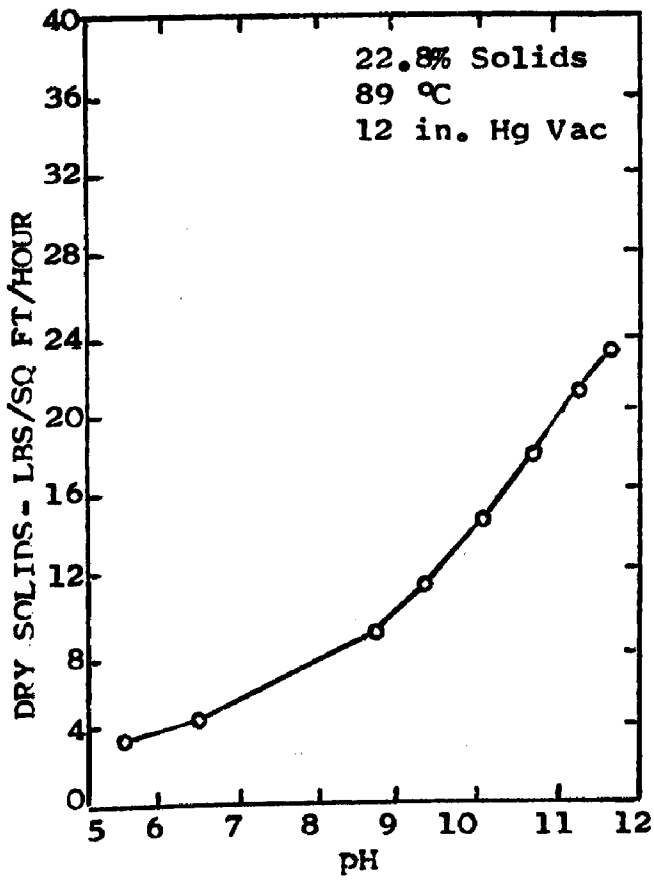


Figure 5. Filter yields vs pH of filter feed at constant percent solids, temperature and vacuum

The addition of slaked lime to control pH had a very great effect on the filter yields. In this series of experiments the alkaline underflow from the clarifier was adjusted to a pH of 5.5 by the addition of acetic acid and then adjusted to increasing pH values by addition of calcium hydroxide. The 3 - 5 ml/gal. of calcium hydroxide slurry necessary for pH adjustment was insufficient to affect the solids content of the slurry appreciably. Increased addition of lime as indicated by higher pH values increased the filter yields very markedly as shown in Figure 5.

The effect of temperature on the filter yields at two pH values are shown in Figure 6 for a solids content feed of 25.8 and 34.5 percent. Increase in temperature resulted in an increased filter yield and again the higher filter yield was at the higher pH value.

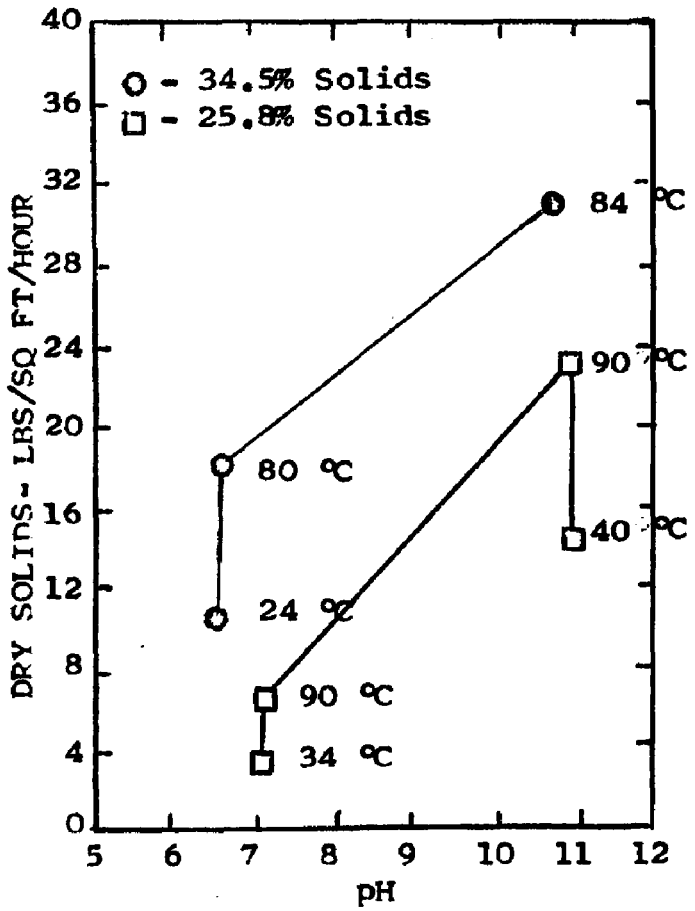


Figure 6. Filter yields vs pH and temperature at constant solids concentration and 15 in. Hg vacuum

Figure 7 shows the effect of temperature and polyelectrolyte on the filter yields at two pH values at a solids content of 28 percent and 19.2 percent for the feed to the filter. The higher temperature and pH values again improved the filter yield. The pH adjustment was made with calcium hydroxide and the increased filter yield may have been due to the coagulating effects of lime rather than pH as such. The addition of 1 ppm Betz 1420 anionic polyelectrolyte further increased the filter yields.

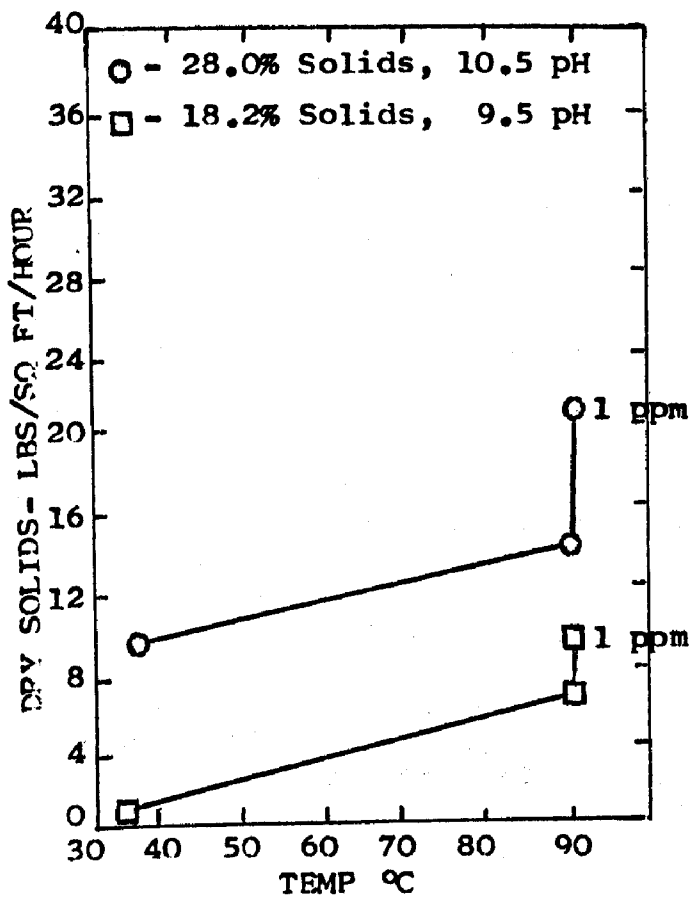


Figure 7. Effect of temperature and polyelectrolyte on filter yield at constant solids concentration, pH and 15 in. Hg vacuum

The best filter conditions were obtained on clarifier underflow at pH of 10.5 or above, treated with an anionic polymer, thickened to a solids concentration above 20 percent and heated to 90 °C and filtered at a vacuum of approximately 15 in. Hg. The maintenance of a high pH with lime treatment appears to have the greatest influence on filterability. High solids concentration is necessary for satisfactory filter yields because of the rapid blinding of the filter media from fine particles and bacterial slimes. Satisfactory filter yields may be obtained at low temperatures under ideal conditions, but high temperature always improved filter yields.

Pilot Filter Units

Results of filtration trials with the three pilot units during the 1970-71 test period were unsatisfactory until the final day of operation for various reasons as discussed below. No data were obtained during the 1970-71 season. Data from pilot filtration during the 1971-72 season is presented in the section on pilot filtration.

Initial lab test leaf studies conducted in early campaign of 1970 indicated that satisfactory filter cakes could be obtained without extensive clarifier underflow treatment other than further thickening. Delayed procurement and construction schedules delayed pilot unit tests until mid December. Low pH in the clarifier with accompanying bacterial slime formation accounted for poor filtration characteristics of the underflow during the 1970-71 tests.

Initial trials with the EIMCOBELT filter were unsatisfactory, with filtration rates ranging from 0.100 to 0.422 gpm/sq ft of filter drum area. These poor results were attributed to low solids, low temperature and low pH of the feed to the filter.

Trials with the pre-coat drum filter resulted in rapid blinding of the pre-coat surface with very slight cake pick-up. A filtration rate of 4.5 gpm/sq ft at the end of the pre-coat cycle dropped to .4 gpm/sq ft with thickened transport water solids. The pre-coat filter appeared to have no advantages over the cloth drum filter.

The BMD pressure leaf filter discharged filter cake from the leaf by shock vibration on signal from a sensing device for sensing predetermined cake thickness. If the filter blinds before sufficient cake thickness builds up, the thin cake does not discharge

freely from the filter media. The discharged cake falls to the bottom of the pressure vessel, where it is repulped and pressure discharged on signal from a density sensor. The BMD pressure leaf filter, equipped by the supplier with monofilament filter cloth, was operated at 0.04 gpm/sq ft filter rate. Rapid cloth blinding and pressure build-up with resultant short cycles resulted with low solids and low temperature feeds. The addition of waste lime mud to the thickener underflow at volume ratio of 1 part lime mud to 4 parts underflow and elevated temperatures increased the cycle lengths. The nature and design of the test filter required the recycling of the filter feed through the force pump system. This resulted in breaking up the floc formed in the coagulation and thickening process with a resultant loss in filtration rates. The BMD discharge varied from 40 - 50 percent solids. Better filtration rates may have been obtained had multifilament filter media been available.

Of the three pilot filter units tested, the EIMCOBELT vacuum filter was the most practical unit for evaluating the filtration characteristics of the transport water solids, in that it provides for continuous cloth washing and visible cake, and rapid clean up between varying test conditions. Satisfactory filter yields achieved on the last day of the 1970-71 campaign were the basis for continuation of the studies during the 1971-72 campaign.

Pilot Filtration

A series of 89 test runs covering 18 days of plant operations during the 1972 campaign was made with an EIMCOBELT pilot model filter with 3 ft diameter by 1 ft wide drum. Test results were tabulated under four different operating conditions:

A: Main clarifier underflow with pH adjustment followed by additional thickening in the ENVIROCLEAR pilot thickener and temperature adjustment of the final underflow. Data tabulated in Table 9.

B: Main clarifier underflow with pH adjustment followed by additional thickening in the ENVIROCLEAR pilot thickener and additional solids added as reconstituted waste lime. Data tabulated in Table 10.

C: Main clarified underflow with pH adjustment followed by additional thickening in the ENVIROCLEAR pilot thickener and additional solids added as lignite fly ash. Data tabulated in Table 11.

D: Main clarifier underflow and additional thickening with the addition of all of the lime cake from juice purification to the main clarifier. Data tabulated in Table 12.

The feed to the filter came directly from the underflow of the 115 ft main clarifier with the provision also that this underflow could be thickened further in a pilot model ENVIROCLEAR thickener. A heating tank was installed between the thickener and the filter; chemical treatment or addition of filter aids could be done in this heating tank, which was equipped with an agitator.

In the recycling of transport water organic matter builds up to levels favorable for bacterial growth. In order to keep bacterial growth under control slaked lime was added to maintain a 10 - 11.5 pH. When the pH did lower unavoidably below 8 because of bacterial growth the slime formation adversely affected the filtration rate. Other variables such as percent solids, temperature and vacuum interacted at times so that it was difficult to separate cause from effect.

Easily filtered material also dried quickly in the dewatering segment of the filter and cracked to such an extent that high vacuum could not be maintained. The vacuum for best cake pickup sometimes was at 8 - 10 in. Hg vacuum. The vacuum pump was a wet type pump and the supply of water to the building housing the filter was through a single pipeline. The supply could be either hot or cold. It was found that hot water was desirable for cleaning the filter belt after discharge of the cake but if this water was used through the vacuum pump the vacuum was several inches less than when cold water was used.

The addition of slaked lime at the rate of 0.31 lbs per 10 gal. of underflow from the main clarifier to raise pH, and additional thickening in the ENVIROCLEAR pilot thickener before filtration resulted in satisfactory cake pickup and cake separation from the belt when filtered on the EIMCOBELT filter. During the few instances of poor cake pickup it was noticed that temperatures were down and also pH values had decreased. This latter effect was due to a lack of sufficient lime and, as in the filtration with the leaf filter, lime was observed to be beneficial in filtering with the belt filter. Data for this series is shown in Table 9. Betz 1420 anionic polyelectrolyte at 2 ppm was added to the thickener for all tests unless otherwise noted in the data tabulation.

Table 9. FILTER YIELDS WITHOUT ADDITION OF FILTER AIDS

Run	pH	Temp °C	Feed Percent Solids	Vac in. Hg	Dry Cake Lbs/Sq Ft/Hr	Additions to Thickener Underflow
5	12	82	13.3	11	4.4	None
6	12	60	13.3	10	4.5	"
7	12	62	13.3	9	3.6	"
8	12	78	13.3		3.1	"
9	10.9	90	16.2	9	6.5	"
10	10.9	80	16.2	11	8.5	"
11	10.9	70	16.2	10	6.4	"
12	10.9	57	16.2	16	5.8	"
13	10.9	65	16.2	10	4.4	"
14	10.9	60	16.2	10	4.6	"
15	6.5	33	8.1*	11	Cloth Blinded	"
16	6.5	85	8.1*	11	Thin Wet Cake	"
17	12.1	45	8.1*	10	Thin Wet Cake	"
18	12.1	85	8.1*	8	5.7	"
19	12.1	70	8.1*	10	6.0	"
20	12.1	95	8.1*	14	5.4	"
21	12.1	93	8.1*	15	5.1	"
22	12.1	85	8.1*	16	5.0	"
23	11.8	66	11.2	14	3.6	"
24	11.3	95	15.1	16	7.3	"
25	11.3	70		17	3.5	"
26	9.9	75	18.5	17	2.8	"
27	9.9	95		17	3.7	"
28	9.9	95		18	5.3	"
29	11.8	77	17.6	15	7.1	"
30	11.6	90	20.9	15	11.4	"

* No polymer added to thickener

In operating condition B, (Table 10) the underflow from the main clarifier was run to the thickener and then treated with additional lime solids from dry waste lime cake reconstituted in the thickener underflow to increase the solids content. The pH was controlled by the addition of calcium hydroxide. The cake pickup

was variable but, except for the beginning of a day's filtration, was very good. The additional solids increased cake pickup.

Table 10. FILTER YIELDS WITH RECONSTITUTED WASTE LIME ADDITION

Run	pH	Temp °C	Feed Percent Solids	Vac In. Hg	Dry Cake Lbs/Sq Ft/Hr	Waste Lime Additions to Thickener Underflow Lbs/40 Gal.
31	10.9	85	19.9	17	4.1	
32	10.1	90	22.2	17½	3.9	10
33	11.2	87	28.0	17	6.3	20
34	11.2	80	29.0	18	5.1	30
35	12.0	75	17.0	10	11.6	30
36	12.0	78	17.0	15	6.4	
37	12.1	95	11.0	14½	3.5	20
38	12.1	95	11.0	14	7.4	10
38A	12.1	95	11.0	9	6.7	10
39	10.5	95	11.0	15	2.3	20
39A	10.5	90	11.0	16	4.1	20
40	12.2	80	20.6	14	11.2	20
41	12.3	85	17.8	11	10.8	20
42	12.1	95	13.6	12	9.2	20
43	12.3	80	19.4	12	10.5	10
44		90		16	3.4	10
45		90		17	4.3	10
46		90		17	8.8	20
47		95		16	5.1	20
48	11.6	90	24.6	17½	4.7	10
49	12.0	95	29.9	17	7.8	20
50	12.3	95	28.0	16½	10.1	20
51		95		16½	9.1	10
52	12.3	94	25.6	15	9.6	10

The addition of fly ash under operating condition C, (Table 11) after additional thickening of the main clarifier underflow and adjustment of pH with lime was effective as a filter aid although it does not appear to be significantly different than equal amounts of reconstituted waste lime filter cake.

Table 11. FILTER YIELDS WITH FLY ASH ADDITION

Run	pH	Temp °C	Feed Percent Solids	Vac In. Hg	Dry Cake Lbs/Sq Ft/Hr	Fly Ash Additions to Thickener Underflow Lbs/40 Gal.
53	12.4	95	24.8	16	6.0	10
54	12.0	95	24.0	16		10
55	12.4	95	24.4	10	10.0	10
56	12.4	95	22.5	11	12.6	5
57	12.5	95	21.6	16	11.7	2.5
58	12.3	95	22.4	17	9.1	None
59		95		16		None
60		95		16½		10
61	11.9	95	17.6	14½	4.6	10
62	11.7	95	29.0	17½	4.3	10
63	11.8	95	26.0	16½	3.2	10
64	12.1	95	26.2	17½	5.2	(1)
65	12.0	90	18.0	11	6.1	(2)
66	12.1	80	19.6	10	7.5	(3)
67	12.0	80	21.0	12	8.4	10

(1) 20# Waste lime substituted for fly ash
(2) 10# Waste lime substituted for fly ash
(3) 5# Waste lime + 5# fly ash

Under operating condition D, (Table 12), the addition of all of the lime filter cake resulting from juice purification to the clarifier and the adjustment of the pH with calcium hydroxide and additional thickening in the thickener resulted in a filter feed which filtered at a higher rate than any other combination. The solid cake was friable and non-sticky and the pickup was much better than that when waste lime or fly ash were used as filter aids. Decreasing the temperature decreased cake pickup as shown in run No. 70 and 70A. When both the temperature and pH were lowered the cake pickup was very poor as shown in run No. 72.

Table 12. FILTER YIELDS WITH WASTE LIME FILTER CAKE FEED TO MAIN CLARIFIER

Run	pH	Temp °C	Feed Percent Solids	Vac In. Hg	Dry Cake Lbs/Sq Ft/Hr	Additions
68	12.1	95	23.6	14	16.3	Lime Cake to Main Clarifier
69	12.0	90	19.8	11	11.1	"
70	12.1	64	11.6	8½	9.8	"
70A	12.1	40	11.6	10½	8.7	"
71	11.3	30	8.0	8	9.3	"
72	7.0	60			Thin Wet Cake	"
73	11.4	80	26.0	14	10.8	"
74	11.5	95	21.4	14	12.6	"
75	11.6	87	15.8	16½	9.5	"

Cake yields of 4 lbs/sq ft/hr, dry basis, produced cakes of 1/16 in. thickness which discharged freely from the filter media at 50 percent moisture or less. It would appear from the data presented for the pilot filter and comparing lab test leaf data with filter yields on the belt filter that the lab test leaf filter was much more effective in terms of pounds of dry solids per hour square foot. The data for the belt filter was calculated on the basis of total drum area rather than area submerged and consequently is about 2/3 less than it would be if calculated on the basis of area forming cake. The filter yields in the two types of equipment were roughly equivalent when calculated on effective filter area.

The conditions of the filter feed which produced the best filter yields were pH above 11, solids concentration above 20 percent and temperature above 80 °C.

Additional analytical data on the thickener overflow and underflow are shown in Appendix C, Tables X - XII.

FILTER CAKE DISPOSAL STUDIES

Filter cake solids from pilot filtration studies had moisture contents ranging from 40.0 to 50.0 percent as shown in Appendix C, Table XIII. The results of the filter cake decomposition

studies are shown in Table 13. Odors of the filter cake as produced were characteristic of damp soil with a slight beet odor. No strong, foul, or objectionable odors were detected in the cake as produced at any time. Mold growth was evident in the 2 ft deep windrows.

Table 13. DECOMPOSITION OF FILTER CAKE SOLIDS, ANALYSIS FOR pH, TOTAL N, VOLATILE SOLIDS AND COD

	Date	pH	Total N % *	Vol Solids % *	COD ppm
Original Filter Cake	**	10.4	0.39	15.8	146000
Sanitary Land Fill	5-23-72	9.2	0.25	11.3	172000
Windrow at 2 ft Depth	4-25-72	9.0	0.42	14.8	-
	5-8-72	9.4	0.36	13.3	143000
	5-23-72	9.1	0.37	13.3	129000
Spreading at 6 in. Depth	4-25-72	9.2	0.43	14.7	-
	5-8-72	9.6	0.41	14.0	146000
	5-23-72	9.4	0.41	12.7	141000

* Percent by Wt on Dry Substance
** Average of two composites of 18 daily frozen composites of 82 individual samples

Distribution of the filter cake solids were made in January under frozen conditions. Sampling for decomposition studies was done first on April 25th, and at two week intervals thereafter for 6 weeks. The land fill site was still frozen at sample depth on the May 8th sampling and the high water table at the site resulted in unsatisfactory sampling. The trench for the land fill had partially filled with water and frozen before the filter cake solids were dumped and covered. The lower levels of total nitrogen and volatile solids found in the land fill sampled on May 23rd may be attributed to leaching from the high water table present at the site.

No significant change was found in the total nitrogen levels in the samples for windrow distribution at 2 ft depth or spreading at 6 in. depth, indicating no significant release of volatile nitrogen compounds. A reduction of 16 percent of the volatile solids in the filter solids in the 2 ft deep windrow and 20 percent reduction in the volatile solids spread 6 in. deep indicate that decomposition was progressing, but at a rate slow enough to permit oxidation of odorous compounds by the atmosphere. Test data indicates that the sanitary land fill method of disposal would not be necessary for the control of odors from the filter cake solids.

SECTION VI

UTILIZATION OF PHASE I RESULTS (PHASE II)

FULL SCALE FILTRATION DESIGN

The schematic flow diagram for a full scale operation of a transport water solids dewatering system by filtration is as shown in Figure 1 for the primary clarification step and in Figure 2 for the secondary thickening and filtration steps. (For detailed flow diagram see Appendix B).

To minimize the amount of water accumulated for treatment from the transport recycle system it is necessary to minimize both the quantity of water within the recycle system and the volume of blowdown (clarifier underflow) from the system. Since the system is already installed there is little that can be done to reduce the volume of water contained within the system. The quantity of blowdown should be regulated to maintain a uniform density of solids in the underflow. In order to accomplish this, the volume of make-up to the recycle system must be equal to the volume of underflow removed from the system. This can be accomplished by regulating the amount of in-plant water streams entering the recycle system.

The design of the secondary thickening and filtration installation is based on the following factors:

Length of Operating Season	150 Days
Tons of Beets Sliced per Day	4000
Average Mud Tare on Beets (Percent)	5
Transport Water Flow Rate	6000 gpm
Concentration of Solids in Clarifier Underflow (Percent)	8
Density of Clarifier Underflow	8.5 lbs/gal.
Flow Rate of Clarifier Underflow	410 gpm

Concentration of Solids in Secondary Thickener Underflow (Percent)	20
Density of Thickener Underflow	9.5 lbs/gal.
Flow Rate of Secondary Thickener Underflow	146 gpm
Temperature of Secondary Thickener Underflow	25 °C
Filter Capacity- (Lbs/Sq Ft/Hr Dry Solids)	12

The clarifier underflow will be fed to a deaeration tank of a 15 ft dia by 4 ft 4 in. side wall ENVIROCLEAR thickener. The thickener will provide a 12.5 min retention time for the 410 gpm feed from the clarifier. Since pH control is provided in the clarifier, no additional pH control should be required in the thickener. Milk of lime would be fed to the thickener deaeration tank if necessary for pH adjustment. Polymer addition to the thickener feed will require two 125 gal. premix tanks with air agitation, a 0-2 gpm metering pump and a 10 gpm dilution pump.

Addition of filter aids to the thickener underflow may not be required. Provision for the addition of waste lime mud to the thickener feed will be provided for by direct pipe line of waste lime mud from factory production as required. No additional handling cost for waste lime mud as a filteration aid would be incurred.

Thickener underflow will be pumped to the filters by a 175 gpm diaphragmsludge pump. Density control of the underflow will be an integral part of the ENVIROCLEAR thickener provided by the supplier. Thickener overflow will be returned to the clarifier or to the transport mud pond as necessary for level control of the clarifier.

Heat requirements to raise the thickener underflow from 25 °C to 90 °C are 8-10 million British Thermal Units (BTUs) per hour. Direct steam injection provided the most efficient heat transfer. Direct, in line steam injection in the filter feed line will provide the least expensive heat exchange mechanism. Steam will be supplied from existing plant facilities. In the event that direct steam injection reduces the filter yields below acceptable levels from excessive dilution or attrition of particle agglomerates formed during clarification and thickening, an indirect heat exchanger would be provided.

Filter requirements for 400,000 lbs of dry solids per day and a filter cake rate of 12 lbs per sq ft per hour are 1,388 sq ft of filter area. Three 12' x 12' rotary filters provide 1,362 sq ft of filter area. Filter cake discharge from the filter will be conveyed by belt conveyor to a dump truck for truck haul to the disposal area and dumped in windrows. Filtrate from the filters will be returned to the transport water system.

ECONOMIC EVALUATION OF FULL SCALE SYSTEM

Cost data for a complete separation, dewatering and disposal of sugarbeet transport water solids by filtration is presented under two categories, the primary clarification and closed loop recirculating system which is currently in use, and the secondary thickening, filtration and disposal system as developed for this project.

Cost data for the primary clarification system and transport water recycling are:

Capital Costs:

	Item	Cost Dollars (1971)
1-	3- 6 ft x 12 ft Vibrating Screens with Trash Disposal System- Material and Installation	38,175
2-	Housing for Screens	24,150
3-	1- 115 ft dia x 8 ft Sidewall Clarifier Material and Installation	109,700
4-	Lime Treatment System: 1- 10 ton/day Lime Slaker and Pump- Material and Installation	10,500
5-	2- Clarified Water Recirculating Pumps and Motors- Installed	12,300
6-	2- Clarifier Underflow Mud Pumps and Motors	4,300
7-	Clarified Water Sump and Housing for Water and Underflow Pumps	38,175

8-	Electrical Systems- Material and Installation	25,000
9-	Piping	40,500
	Total Capital Costs	302,800

Operating Costs:

	Item	Cost Dollars (1971)
1-	Power: 155 HPH x .745 = 119.2 KWH 119.2 KWH x 24 H x 1.83¢/KWH x 150 days =	7,853
2-	Utilities (Heat and Lights at $15/day)	2,250
3-	Maintenance and Repair	4,500
4-	Operation (1 Man Day at $3/hr) $3.00 x 24 x 150 =	10,800
5-	Chemical Lime- 10 T/day at $7.00/ton x 150	10,500
6-	Administration and Supervision at 10% of Labor Cost	1,080
7-	Amortization of Capital Costs (15 Years) $302,800 at 7 percent Interest	33,245
	Total Annual Operating Costs	70,228

Total Annual Operating Costs Per Ton of Beets

$$\frac{70,228}{4,000 \times 150} = 11.71 \text{ cents } (¢)/\text{ton}$$

The above cost data do not include taxes, land acquisition for and construction of waste water ponds, waste water pumping station, separation of condenser water and transport water loops, and engineering costs.

Cost estimates for the secondary thickening filtration and disposal system are:

Capital Costs:

	Item	Cost Dollars (1973)
1-	Building- 60 ft x 24 ft	45,000
2-	1- 15 ft dia x 4 ft 4 in. sidewall ENVIROCLEAR thickener	41,088
	Installation	10,272
3-	2- 175 gpm Underflow Pumps with 5 HP Motors- Installed	2,350
4-	Polymer Feed System	740
5-	Heat Exchanger- Steam Injection at 10 Million BTU/hr	1,000
6-	3- 12 ft x 12 ft Rotary Vacuum Filters with Pumps and Receivers	179,000
	Installation	53,700
7-	Filter Cake Conveyor and Drive	2,500
8-	Instrumentation	
	Density Control	2,500
	Temperature and Flow	3,000
9-	2- Clarified Water and Filtrate Pumps	3,200
10-	Electrical System Material and Installation	9,500
11-	Piping	3,500
	Total Capital Costs	357,350

Operating Costs:

	Item	Cost Dollars (1973)
1-	Power: 198 HPH x .745 = 147.5 KWH 145 KWH x 24 x 1.83¢/KWH x 150 days =	9,717

2-	Utilities (Heat and Light at $15/day)	2,250
3-	Maintenance and Repair	5,000
4-	Operation- 1 Man Day at $3.00/hr	10,800
5-	Administration and Supervision at 10 percent of Labor Costs	1,080
6-	Chemical Polymer at $15/day	2,250
7-	Steam	19,200
8-	Disposal of Filter Cake 16.6 T/hr at 35¢/ton (less than 1 mile) 16.6 x 24 x .35 x 150	20,916
9-	Amortization of Capital Costs (15 yrs) 357,350 at 7 percent Interest	39,235
	Total Annual Operating Cost	110,448

Total Annual Operating Cost Per Ton of Beets

$$\frac{110,448}{4,000 \times 150} = 18.41¢ \text{ ton}$$

Tha above analysis does not include taxes, land acquisition and preparation of filter cake disposal area, annual maintenance of disposal area, engineering costs, nor cost of an alternate direct heat exchange system for heating thickener underflow.

Total annual operating costs for a complete separation, dewatering and disposal of transport water solids by filtration are 11.71¢ + 18.41¢ = 30.12¢ per ton of beets processed. Assuming a 5 year average sugar content in beets of 14.8 percent in the Red River Valley and a factory extraction of 75.4 percent, the annual cost per hundred weight (cwt) of sugar would be:

$$\frac{30.12}{2,000 \times .148 \times .754} \times 100 = 13.50¢/\text{cwt sugar}$$

SECTION VII

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SECTION VIII

PUBLICATIONS

1. Fordyce, I. V. and A. M. Cooley. "Separation, Dewatering, and Disposal of Sugarbeet Transport Water Solids," Environmental Protection Technology Series EPA-R2-72-018. Technical Paper presented at the Third National Symposium on Food Processing Wastes sponsored by the U. S. Environmental Protection Agency. March 28-30, 1972 in New Orleans, LA.

SECTION IX

GLOSSARY

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

Clarifier - A holding tank for the removal of turbidity or other suspended solids from the suspending liquid.

Dewatering - Any process of water removal or concentration of a sludge slurry, as by filtration, centrifugation, or drying.

Inter Campaign - The period of the year during which the factory is not processing beets.

Polarization - Measurement of the optical rotation of a solution by a polarimeter calibrated in International sugar degrees and the measurement expressed as percent sucrose.

Polyelectrolyte - Long-chained, high molecular weight, synethetic, water soluble, organic coagulants; also referred to as polymers.

Transport Water - Water used to convey beets through a flume from a receiving hopper to the factory for cleaning and processing.

Waste Lime Mud - The washed calcium carbonate filter cakes, including sludges from first and second carbonation.

Tare - Material which must be discarded.

SECTION X

APPENDICES

		Page
A.	Analytical Procedures	52
B.	Flow Diagram for Beet Transport Water System	54
C.	Data Tabulation	56
	Table I: Main Clarifier Influent, 1971-72 Campaign Pilot Test Period. Composite Sample Analyzed for pH, Settleable Solids, Suspended Solids, Filterable Solids, COD, BOD_5	57
	Table II: Main Clarifier Influent, 1971-72 Campaign Pilot Test Period. Composite Sample Analyzed for Soluble CaO, Total CaO, Total Sugar, Organic Acids, Total PO_4-P	58
	Table III: Main Clarifier Overflow, 1971-72 Campaign Pilot Test Period. Composite Sample Analyzed for pH, Settleable Solids, Suspended Solids, Filterable Solids, COD, BOD_5	59
	Table IV: Main Clarifier Overflow, 1971-72 Campaign Pilot Test Period. Composite Sample Analyzed for Apparent Sucrose, Total Sugar, Organic Acids, Total PO_4-P, NH_3-N, Organic- N	60
	Table V: Main Clarifier Underflow, 1971-72 Campaign Pilot Test Period. Composite Sample Analyzed for pH, Total CaO and Residue on Evaporation	61

Table VI:	Filter Yields vs Percent Solids in Filter Feed at Constant pH and Vacuum	62
Table VII:	Filter Yields vs pH of Filter Feed at Constant Solids Cencentration, Temperature and Vacuum	62
Table VIII:	Filter Yields vs pH and Temperature at Constant Solids Concentration and Vacuum	63
Table IX:	Effect of Heat and Polyelectrolyte on Filter Yields at Constant Solids Concentration, pH and Vacuum	63
Table X:	Combined Thickener Overflow and Filter Filtrate. Composite Samples Analyzed for pH, Suspended Solids, Filterable Solids, COD and BOD_5	64
Table XI:	Combined Thickener Overflow and Filter Filtrate. Composite Samples Analyzed for Total Sugar, Organic Acids, Total PO_4-P, NH_3-N, Organic- N	64
Table XII:	Thickener Underflow with Polymer Addition Rate. Grab Sample Analyzed for pH, Total CaO and Residue on Evaporation	65
Table XIII:	Filter Cake. Composite Samples Analyzed for pH, Moisture, Organic and Volatile Matter, and Total CaO	66

APPENDIX A

ANALYTICAL PROCEDURES

BOD - Biochemical Oxygen Demand - "Standard Methods for the Examination of Water and Waste Water" (hereafter referred to as S.M.) 13th Ed., 1971, Pages 489-94 (All data are 5-day BOD (BOD_5) unless otherwise noted).

CaO - Soluble - An aliquat of filtered sample was titrated with standard EDTA solution to the Hach Univer-I endpoint by the procedure outlined in Hach Chemical Co. Catalogue No. 10, 1967, Page 28-32.

CaO - Total - A ten gram sample is boiled with excess nitric acid, cooled, made to volume and a filtered aliquat is titrated with standard EDTA solution to the Univer I endpoint as for soluble CaO.

COD - Chemical Oxygen Demand. S.M. 13th Ed., 1971, Pages 495-99.

Organic Acids - Hach Volatile Acids Colorimetric Method. Hach's Water and Wastewater Analysis Procedures, Catalogue No. 10, 1967, Page 72. Color compared photometrically with Bausch and Lomb Spectronic 20 at 510 millimicron wavelength against acetic acid standards.

Pol - Direct polarization as read in a polarimeter calibrated in international sugar degrees and expressed as percent sucrose.

Phosphate - Total PO_4-P - S.M. 13th Ed., 1971, Page 530. Stannous chloride method.

Residue on Evaporation - S.M. 13th Ed., 1971, Page 535.

Filterable Solids - S.M. 13th Ed., 1971, Page 290. Glass fiber filter disc.

Non Filterable Solids - S.M. 13th Ed., Page 291. Determination made by difference between residue on evaporation and filterable solids.

Organic and Volatile Solids - S.M. 13th Ed., 1971, Page 536.

Percent Solids - Moisture loss determined by evaporation on OHAUS direct reading moisture balance.

Settleable Solids - S.M. 13th Ed., 1971, Page 539.

Suspended Solids - S.M. 13th Ed., 1971, Page 537.

NH_3-Nitrogen - Ammonia nitrogen. S.M. 13th Ed., 1971, Page 222, Section 132A and 132 B. Ammonia determined colorimetrically by Nesslerization.

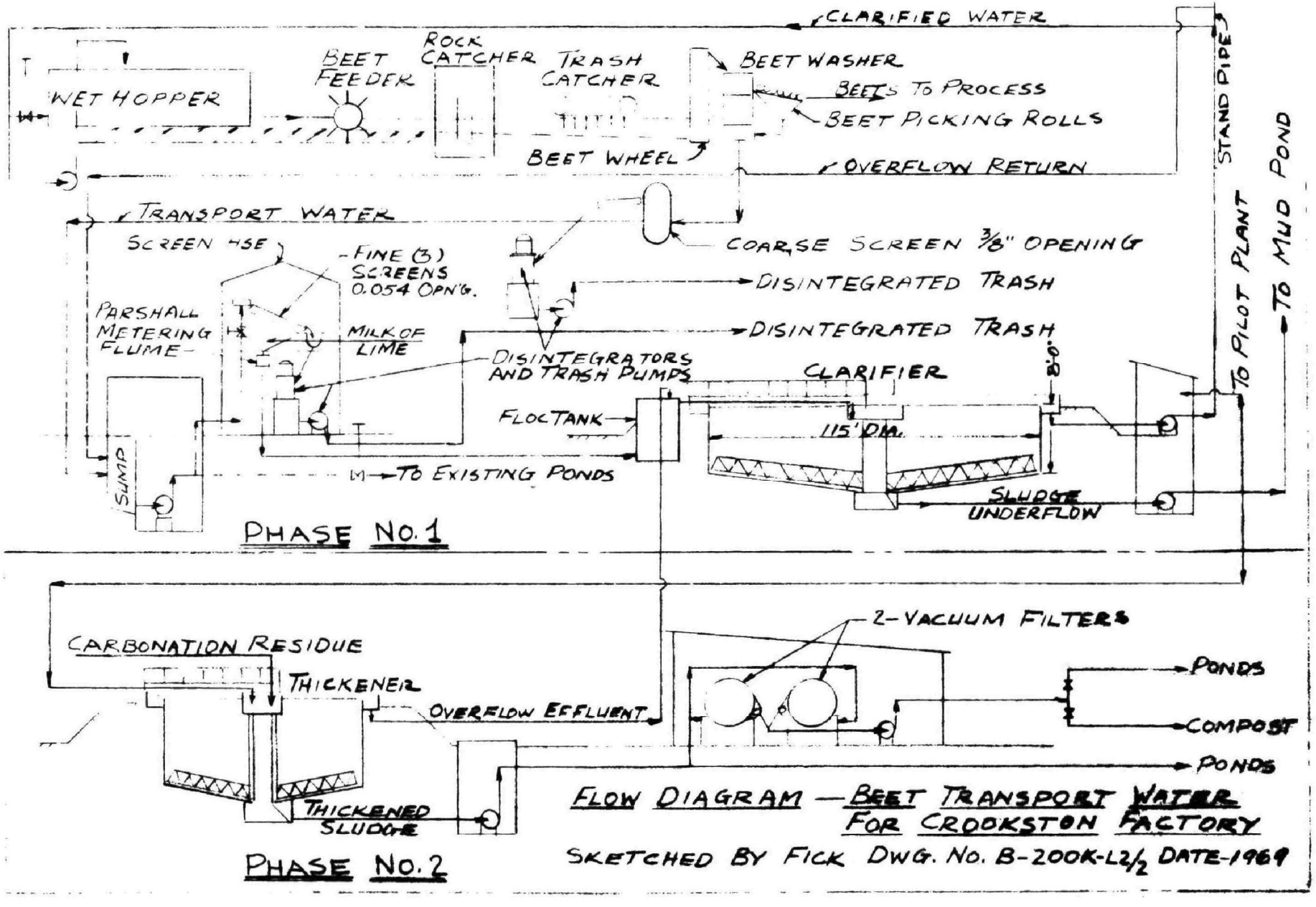
Organic Nitrogen - S.M. 13th Ed., 1971, Page 468. Kjeldahl-N minus Ammonia-N.

Total Nitrogen - Methods of Analysis, AOAC, 10th Ed., 1965, Section 2.045, Page 16.

Total Sugar - Anthrone Method. 1 ml of filtered sample is mixed with 5 ml of anthrone-sulfuric acid solution, heated in a boiling water bath for 10 minutes. A color is developed which is proportional to the amount of sugar present. The absorbency of the color is read on a colorimeter and compared with a graph of the absorbency of standard sucrose solutions.

APPENDIX B

FLOW DIAGRAM FOR BEET TRANSPORT WATER SYSTEM



FLOW DIAGRAM — BEET TRANSPORT WATER FOR CROOKSTON FACTORY

SKETCHED BY FICK DWG. NO. B-200K-L2/2 DATE-1969

APPENDIX C

DATA TABULATION

Table I. MAIN CLARIFIER INFLUENT, 1971-72 CAMPAIGN PILOT TEST PERIOD. COMPOSITE SAMPLE ANALYZED FOR pH, SETTLEABLE SOLIDS, SUSPENDED SOLIDS, FILTERABLE SOLIDS, COD, BOD_5

Date	pH	Sett Solids ml/l	Susp Solids mg/l	Filt Solids mg/l	COD mg/l	BOD_5 mg/l
11-15	6.5	27	640	9840		
11-16	6.5	33	1210	9130		
11-17	7.6	2	680	9710		
11-18	7.3	11	1420	11410		
11-22	5.7	30	1550	11980		
11-23	5.3	60	560	16060	19200	9600
11-24	6.1	38	270	17450		
11-25	6.3	17	320	17430		
11-29	6.4	30	630	12320		
11-30	6.8	75	520	13660		
12-1	6.5	15	650	11010	31360	9600
12-2	8.0	33	590	6500		
12-6	11.9	15	440	8240		
12-7	12.0	16	500	12650	39200	10500
12-8	11.4	17	850	6620	11760	
12-9	11.6	15	1120	15360	19600	11400
12-13	11.8	10	470	12910		
12-14	11.8	30	690	14630		
12-15	11.4	20	170	17650	18360	9000
12-16	11.4	17	670	17670	19560	12200
12-20	11.4		510	13540		6500
12-21	11.6	20	510	13550	26500	8300
12-22	11.8	21	490	12690	32640	6900
12-23	11.3	16	700	12950	8160	
12-27	11.1	10	1290	10960	8160	
12-28	11.5	12	810	10820	16320	5250
12-29	11.8	10	990	10430	16000	6200
12-30	11.4	4	880	10130	16000	9150
1-3	11.2	5	1370	10860		
1-4	11.2	17	1010	10700	40000	8100
1-5	11.6	8	820	11240	12000	9150
1-6	11.1	10	1130	10720	8800	6310
1-10	11.4	12	1160	13290	7160	
1-11	9.5	3	1360	11230	9600	
1-12	11.8	10	1240	13330	14400	6900
1-13	11.2	15	820	12410	11850	8550

Table II. MAIN CLARIFIER INFLUENT, 1971-72 CAMPAIGN PILOT TEST PERIOD. COMPOSITE SAMPLE ANALYZED FOR SOLUBLE CaO, TOTAL CaO, TOTAL SUGAR, ORGANIC ACIDS, TOTAL PO_4-P

Date	Sol CaO mg/l	Total CaO mg/l	Total Sugar (1)	Organic Acids mg/l	Total PO_4-P mg/l
11-15				13200	
11-16				6400	
11-17			2550		7.2
11-18			2200		16.8
11-22			7000	2000	13.6
11-23			4800	1400	17.8
11-24			5800	1600	15.0
11-25			10800	2240	14.6
11-29			4400	2200	
11-30			13300	5000	7.2
12-1			4600	3800	22.8
12-2			8000	1200	15.8
12-6			31200	400	1.4
12-7			31200	400	1.0
12-8			18800	400	8.0
12-9			23700	100	5.2
12-13	800	1700	18000	780	
12-14	690	2000	22000	1160	15.0
12-15	700	1500	22000	1620	10.8
12-21	900	1800	19600	1280	6.8
12-22	750	1500	19600	1360	8.0
12-23	600	1340			7.8
12-27	500	1250	18000	1000	8.4
12-28	550	1550	18000	720	8.6
12-29	500	1500	16000	840	7.8
12-30					6.4
1-3		1500	18000	1220	6.8
1-4		1250	18400	1160	8.7
1-5		1100	16400	1120	8.1
1-6		1000	15400	1060	8.5
1-10		1500	16100	1090	7.9
1-11		500	12500	1530	9.3
1-12		1400	16700	1190	9.8
1-13		1000	17500	1120	8.7

(1) Milligrams per liter as sucrose

TABLE III. MAIN CLARIFIER OVERFLOW, 1971-72 CAMPAIGN PILOT TEST PERIOD. COMPOSITE SAMPLE ANALYZED FOR pH, SETTLEABLE SOLIDS, SUSPENDED SOLIDS, FILTERABLE SOLIDS, COD, BOD_5

Date	pH	Sett Solids ml/l	Susp Solids mg/l	Filt Solids mg/l	COD mg/l	BOD_5 mg/l
11-15	6.5	2.0	420	10170		
11-16	6.5	1.0	540	9240		
11-17	7.5	0.2	230	9940		
11-18	7.2	0.5	540	9290		
11-22	5.4	0.8		11980		12900
11-23	5.4	1.2	600	16940		
11-24	5.6	6.5	480	17740		
11-25	5.9	17.5	300	17030		
11-29	5.9	0.2	170	13490		
11-30	6.4	0.5	240	13600		
12-1	6.4	0.7	200	13250	31360	8500
12-2	6.4	0.4	180	11520		
12-6	11.9	0.4	340	12800		
12-7	12.0	0.7	240	13970	7840	7500
12-8	11.7	1.0	370	14080		
12-9	11.4	0.5	560	15240	7840	8100
12-13	11.5	0.1	330	12840		
12-14	11.7	0.5	470	15240	12480	
12-15	11.3	0.2	500	18880	20400	9200
12-16	11.3	0.5	620	14110	12490	10900
12-20	11.3					7250
12-21	11.6	0.6	400	13920	28560	6900
12-22	11.9	0.6	520	14240	30600	6650
12-23	11.4	0.4	410	11860	20400	
12-27	11.1	0.1	580	12360	16320	
12-28	11.5	0.1	460	11220	8160	5850
12-29	11.8	0.2	550	10820	4000	5700
12-30	11.6	0.4	580	10480	4000	8250
1-3	11.2	0.1	470	11770		
1-4	11.1	0.1	650	10790	28000	6000
1-5	11.3	0.5	690	10820		8850
1-6	10.6	2.0	830	10780		7500
1-10	11.4	0.6	670	14400	9320	
1-11	9.2	0.5	620	14160	11200	
1-12	11.8	0.4	580	13240	13600	6600
1-13	11.2	0.4	440	14560	11060	8700

Table IV. MAIN CLARIFIER OVERFLOW, 1971-72 CAMPAIGN PILOT TEST PERIOD. COMPOSITE SAMPLE ANALYZED FOR APPARENT SUCROSE, TOTAL SUGAR, ORGANIC ACIDS, TOTAL PO_4-P, NH_3-N, ORGANIC-N

Date	Apparent Sucrose (1)	Total Sugar (2)	Organic Acids mg/l	Total PO_4-P mg/l	NH_3-N mg/l	Organic-N mg/l
11-15	.09		14000		3.7	3.9
11-16	.04	2170	5200			
11-17	.06	2170		8.4	3.7	42.2
11-18	.08	2200		17.6	3.7	3.8
11-22	.44	5800	400	16.4		
11-23	.10	4800	1800	24.2		
11-24	.24	5000	3800	14.4	4.6	129.4
11-25	.62	9200	1720		10.8	35.3
11-29	.18	4600	3600			
11-30	.11	4800	1200	40.0	4.5	110.2
12-1	.08	4600	6200	25.6	3.7	36.9
12-2	.30	7800	3000	15.0	16.2	48.3
12-6	.96	30000	400	1.4		
12-7	1.04	34800	400	0.8		
12-8	1.06	18800	400	2.0	35.0	10.3
12-9	1.17	22000	200	3.2	15.6	10.6
12-13	1.05	18000	748			
12-14	1.22	22400	972	3.0	16.2	17.7
12-15	1.39	23000	1348	3.8	21.2	122.5
12-16	1.35	19400		2.6	23.7	138.7
12-21	1.03	21400	1260	2.6	27.5	99.7
12-22	1.00	21600	1200	2.8	20.0	101.2
12-23	.96			4.4	31.2	87.2
12-27	.82	18800	740	3.8		
12-28	.89	18800	620	4.6	22.5	95.0
12-29	.81	17200	520	4.8	26.7	109.5
1-3	.87	14200	1308	5.0		
1-4	.85	14400	1240	4.8	27.5	63.7
1-5	.84	16000	1152	4.8	21.2	75.0
1-6	.84	15800	1100	5.1	23.0	13.2
1-10	1.01	15900	1350	4.9		
1-11	1.09	10500	1800	5.3	22.4	45.8
1-12	.98	14400	950	5.9	24.0	75.6
1-13	1.12	15800	1150	5.2	22.3	83.4

(1) Direct Polarization as Percent Sucrose
(2) Milligrams per liter as Sucrose

Table V. MAIN CLARIFIER UNDERFLOW, 1971-72 CAMPAIGN PILOT TEST PERIOD. COMPOSITE SAMPLE ANALYZED FOR pH, TOTAL CaO AND RESIDUE ON EVAPORATION

Date	pH	Total CaO Percent by Wt	Residue on Evaporation Percent by Wt
11-15	6.7	1.3	8.2
11-16	6.8	1.7	10.5
11-17	7.6	1.5	9.0
11-18	7.3	1.3	8.5
11-22	7.0	1.4	
11-23	7.6	0.5	11.4
11-24	6.4	0.4	15.8
11-25	7.4	0.6	11.0
11-29	6.5	0.5	10.9
11-30	7.5	3.0	14.0
12-6	11.5	0.9	8.0
12-7	12.0	0.8	5.5
12-8	11.8	0.5	6.0
12-9	11.5	0.4	7.0
12-16	11.5	0.2	3.8
12-20	11.0	0.5	6.8
12-21	11.2	0.5	6.7
12-22	11.4	0.4	4.0
12-23	11.6	0.5	6.0
12-27	11.7	0.6	5.1
12-28	11.1	1.2	7.5
12-29	11.3	0.3	4.2
12-30	11.3	0.7	6.0
1-3	11.4	1.1	8.0
1-4	11.1	0.8	5.5
1-5	10.6	0.4	4.8
1-6	11.2	0.3	3.2
1-10	11.4	0.5	5.8
1-11	10.6	0.2	4.6
1-12	11.2	0.4	5.2
1-13	11.6	0.4	4.5
1-14	11.2	0.5	4.7

Table VI. FILTER YIELDS vs PERCENT SOLIDS IN FILTER FEED AT CONSTANT pH AND VACUUM (INCREASE IN SOLIDS CONTENT FROM DRY WASTE LIME SOLIDS)

pH	Feed Percent Solids	Temp °C	Vacuum In. Hg	Dry Cake Lbs/Sq Ft/Hr
11.0	15.0	92	15	2.1
11.0	17.3	90	15	6.7
11.0	19.5	90	15.5	10.4
11.0	21.5	94	16	13.8
11.0	23.5	90	16	18.4
11.0	23.5	76	15.5	18.8
11.0	23.5	61	15.5	16.3
11.0	23.5	45	15	<1

Table VII. FILTER YIELDS vs pH OF FILTER FEED AT CONSTANT SOLIDS CONCENTRATION, TEMPERATURE AND VACUUM

pH	Feed Percent Solids	Temp °C	Vacuum In. Hg	Dry Cake Lbs/Sq Ft/Hr
5.5	22.8	88	13	3.8
6.5	22.8	90	12	4.1
8.7	22.8	89	11.5	8.7
9.4	22.8	89	11.5	10.7
10.0	22.8	89	11.5	14.6
10.8	22.8	89	12.5	17.8
11.2	22.8	92	13	21.2
11.7	22.8	89	13	23.4

Table VIII. FILTER YIELDS vs pH AND TEMPERATURE AT CONSTANT SOLIDS CONCENTRATION AND VACUUM

pH	Feed Percent Solids	Temp °C	Vacuum In. Hg	Dry Cake Lbs/Sq Ft/Hr
6.6	34.5	24	15	9.8
6.6	34.5	80	12	18.2
10.9	34.5	84	13	30.9
7.2	25.8	34	13	3.2
7.2	25.8	90	14.5	5.2
11.0	25.8	90	14	23.8
11.0	25.8	40	15	13.7

Table IX. EFFECT OF HEAT AND POLYELECTROLYTE ON FILTER YIELDS AT CONSTANT SOLIDS CONCENTRATION, pH AND VACUUM

pH	Feed Percent Solids	Temp °C	Polyelectrolyte ppm (1)	Vacuum In. Hg	Dry Cake Lbs/Sq Ft/Hr
10.5	28.0	35	0	16	9.5
10.5	28.0	90	0	15	14.4
10.5	28.0	90	1	16	20.7
9.5	19.2	32	0	14.5	1.6
9.5	19.2	90	0	14.5	7.7
9.5	19.2	90	1	12.5	9.9

(1) Betz 1420 (anionic)

Table X. COMBINED THICKENER OVERFLOW AND FILTER FILTRATE. COMPOSITE SAMPLES ANALYZED FOR pH, SUSPENDED SOLIDS, FILTERABLE SOLIDS, COD AND BOD_5

Date	pH	Susp Solids mg/l	Filterable Solids mg/l	COD mg/l	BOD_5 mg/l
11-15	11.9				
11-16	11.9		10090		
11-17	10.0		8720		
11-18	9.8		10720		
11-24	11.4	230	13790	23520	
11-25	11.8	220	15140	13200	7450
11-26	12.3	150	15570	3140	2400
11-29	11.4	430	14690		
11-30	11.9	230	12500		
12-6	10.3	380	11550	17840	
12-7	11.1				7900
12-8	10.0	230	7960	13920	2750

Table XI. COMBINED THICKENER OVERFLOW AND FILTER FILTRATE. COMPOSITE SAMPLE ANALYZED FOR TOTAL SUGAR, ORGANIC ACIDS, TOTAL PO_4-P, NH_3-N, ORGANIC-N

Date	Total Sugar mg/l	Organic Acids mg/l	Total PO_4-P mg/l	NH_3-N mg/l	Total-N mg/l
11-15	4400	12800			
11-16	4400	7200		16.8	36.2
11-17	2200		1.8	17.0	28.0
11-18	2170		3.8	0.6	50.4
11-24	5200	1360		4.4	90.4
11-25	7000	1440	3.4	16.3	91.3
11-26	8800	1560	2.0	10.0	100.0
11-29	5000	600	11.0	13.0	88.2
11-30	5600	4200	12.4	7.5	93.0
12-6	38800	400	3.4		
12-8	13600	20	5.2	28.5	81.5

Table XII. THICKENER UNDERFLOW WITH POLYMER ADDITION RATE. GRAB SAMPLE ANALYZED FOR pH, TOTAL CaO AND RESIDUE ON EVAPORATION

Date	pH	Total CaO Percent by Wt	Residue on Evaporation Percent by Wt	Polymer Addition mg/l (1)
11-15	12.3	7.2	11.0	4
11-16	12.0	2.1	13.3	2
11-17	10.9	3.1	16.2	5
11-18	12.1	2.0	8.1	0
11-19	11.8		11.2	0
"	11.3		15.1	2
"	9.9		18.5	3
"	11.8		17.6	0
"	11.6		20.9	4
11-23	10.9	0.9	19.9	2
11-26	12.3	1.0	22.4	2
11-30	12.1	4.7	23.6	2
"	12.0	3.8	19.8	2
"	12.1	2.8	11.6	2
"	12.1	2.8	11.6	2
"	11.3	2.1	8.0	2
12-1	11.4	5.8	26.0	2
"	11.5	4.9	21.4	2
12-5	11.6	4.5	15.8	(*)
12-6	11.4	5.0	22.0	3
"	11.2	4.4	22.6	3
"	11.1	4.2	22.4	3
12-7	11.8	3.9	21.5	5
12-8	11.6	1.8	28.8	5
"	11.5	1.5	27.6	5

(1) Betz #1420 anionic polymer
(*) Betz #1260 cationic polymer 5 mg/l

Table XIII. FILTER CAKE. COMPOSITE SAMPLES ANALYZED FOR pH, MOISTURE, ORGANIC AND VOLATILE MATTER, AND TOTAL CaO

Date	pH	Moisture Percent (1)	Organic and Volatile Percent (1)	Total CaO Percent (1)
11-15	12.1	46.6	6.4	9.3
11-16	11.9	48.3	6.7	8.8
11-17	10.6	42.0	6.5	9.3
11-18	11.3	45.0	6.8	8.8
11-19	10.4	42.0	5.8	8.0
11-23	11.3	45.0	6.3	7.6
11-24	11.4	41.9	5.7	7.8
11-25	11.7	44.3	7.0	6.9
11-26	12.4	40.0	7.6	5.8
11-29	11.4	50.0	4.8	7.5
11-30	12.1	45.0	5.4	9.2
12-1	11.1	45.2	5.1	8.3
12-5	10.5	43.0	4.9	9.8
12-6	10.5	44.0	6.7	8.9
12-7	10.5	46.2		8.0
12-8	10.6	43.8		5.0
12-9	10.4	41.9	7.2	7.6

(1) Percent by Wt on Original Cake

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-660/2-74-093	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE SEPARATION, DEWATERING AND DISPOSAL OF SUGARBEET TREANSPORT WATER SOLIDS		5. REPORT DATE December 1974
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) I. V. Fordyce, A. M. Cooley		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS American Crystal Sugar Company P.O. Box 419 Denver, Colorado 80201		10. PROGRAM ELEMENT NO. 1BB037
		11. CONTRACT/GRANT NO. 12060 ESC
12. SPONSORING AGENCY NAME AND ADDRESS Pacific Northwest Environmental Research Laboratory National Environmental Research Center Corvallis, Oregon 97330		13. TYPE OF REPORT AND PERIOD COVERED Final report
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

The objectives of this study were to determine the settling characteristics of solids from sugar beet washing and fluming operations in a clarifier, the filtering characteristics of the underflow slurry from a clarifier and the disposal of the filter cake without subsequent development of objectionable odors. The results of this study were to be used to determine the feasibility of installing full scale filters for filtration of and removal of the suspended solids from the transport water and complete recycling of water.

Buildup of organic matter in the water and consequent bacterial growth necessitated the maintenance of high pH by addition of slacked lime. It was necessary also at intervals to add paraformaldehyde to control bacterial growth. Dosages are given.

Best conditions for filtration were obtained when, the underflow from the clarifier was heated, the pH was maintained over 10.5 and when the waste lime cake from beet juice purification was added to the feed to the clarifier.

The filter cake which was accumulated was disposed of on farm land by three different methods and did not develop objectionable odors in any of the methods used. (Cooley-University of North Dakota)

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Wastewater Treatment, Wastewater Quality Control, Water Reuse, Industrial Waste Treatment, Treatment Facilities, Pollution Abatement	Sugarbeet Waste Treatment, pH Control, Coagulation, Filtration, Sludge Disposal	

18. DISTRIBUTION STATEMENT Release Unlimited	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
	20. SECURITY CLASS *(This page)*	22. PRICE

EPA Form 2220-1 (9-73)

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