WATER POLLUTION CONTROL RESEARCH SERIES WP-20-16

Strainer/Filter Treatment of Combined Sewer Overflows

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

Strainer/Filter Treatment

of

Combined Sewer Overflows

Federal Water Pollution Control Administration

Storm and Combined Sewer Pollution Control Branch

Contract No. 14-12-17

Final Report

-by-

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ABSTRACT

The primary objective of this feasibility study was to evaluate the principle of a 'self-cleaning strainer, self-cleaning filter' concept for the treatment of combined sewer overflows. The anticipated goal was to design and construct a prototype system capable of handling up to 1000 gallons per minute with a B.O.D. reduction near 60 percent, and with the capability of automatic operation in remote locations.

A combined sewer overflow in Providence, Rhode Island, was sampled and analyzed to determine the type and amount of contaminant discharged into the receiving stream. The average concentration was determined to be nearly equal to pure domestic sewage. It was also determined that the analysis reported for overflows is very dependent on the exact sampling method used. Automatic sampling devices utilizing small diameter tubing do not take a representative sample since the suspended solids distribution is not uniform over the cross-sectional area of the discharging stream. Based on overflow sample analysis data (samples taken manually), a syntnetic substrate solution was prepared to evaluate a forced flow self-cleaning strainer for significant operating variables.

The strainer and filter systems were evaluated using the syntnetic substrate, primary influent to two separate municipal treatment plants, fresh sewage solids and actual combined sewer flow. It was demonstrated that the strainer model produced consistent suspended solids removal rates near 35 percent under highly varying load conditions, at a flux of 25 gallons per minute per square foot.

The diatomite study showed operational success could be achieved at a 50 percent organic reduction rate at 4 gallons per minute per square foot of area, but at a minimum estimated operating cost of $1.50 per 1000 gallons.

This report was submitted in fulfillment of Contract 14-12-17 between the Federal Water Pollution Control Administration and the Fram Corporation.

Conclusions

This feasibility study has shown that sampling methods commonly used in evaluating the effect of combined sewer overflows on receiving streams cannot be considered reliable. The results indicate that most of the calculated loads that are based on automatic sampling stations have most likely understated the actual case. Visual observations have shown that whole sections of toilet paper and most large suspended solids are not sampled with small diameter, low velocity sampling probes.

The applicability of a self-cleaning strainer in the treatment of raw sewage has been demonstrated in terms of consistent removal of suspended solids. The question of the total level of organic removal that is possible has not been completely answered since actual overflow samples were not available in sufficient supply during the last seven months of the contract. The results obtained with primary influent to a municipal treatment plant and with fresh solids show that it should be possible to remove at least 30 percent of the organic load in a combined sewer overflow with a self-cleaning strainer.

The authors believe that a strainer-filter system of the type originally envisioned in this project is not feasible from a cost and operational point of view. It is their contention that if additional treatment is necessary beyond that attainable with a self-cleaning strainer, then a much simpler and less mechanically complicated secondary system can be constructed.

Recommendations

It is recommended that a full-scale study be undertaken to devise and establish a uniform approved method for the sampling of combined sewer overflows. Since the design of proposed combined sewer overflow treatment systems is based on data considered to be questionable, the projects themselves must be considered questionable.

Primary evaluation was made with 60 x 60 (230 microns), 80 x 80 (190 microns) and 100 x 100 (150 microns) mesh screens. Best overall results were obtained with the 80 x 80 square weave screens. These results combined with other studies indicate the need for a more prolonged study of screen configuration and materials of construction in full scale applications. Pore size to be studied should be in the 170 - 200 micron range.

This project in conjunction with the Glenfield-Kennedy field demonstration project should establish the efficiency and reliability of self-cleaning strainers for combined sewer treatment.

I. Introduction

A. Nature of the Problem

It has been stated that during heavy rains, sewer systems that carry combined storm-water and sewage can deliver up to 95 percent of a community's raw sewage to a receiving stream without any form of treatment. Storm-water runoff alone has been shown to contaminate streams. On the other hand, it is clearly evident that not enough is known about the highly variable nature of storm or combined sewer runoff to permit clear-cut solutions to these water pollution problems.

Combined sewer overflows are known to be an important source of pollution (previously understated), but their intermittent nature makes it difficult to obtain precise information about their total effect and specific characteristics. Preliminary results of several investigations suggest that stormwater overflows differ markedly in character from what might and has been expected. Researchers have expected a heavy runoff to dilute the sewage and cause light pollution. Instead, in some cases, the suspended solids concentration increased as the intensity of runoff increased. With storm flow three times that of dry-weather flow, samples taken during the first five minutes at one station showed suspended solids 2.5 times of average sewage. Samples taken more than thirty minutes later had a solids concentration only 30 percent of the original value. In some interceptors, therefore, it would appear that during dry-weather flow solids settle out, which are then ultimately flushed during storms.

Older cities such as Providence, Rhode Island, have systems that were installed in the late 1800's or 1900's. The population growth has naturally produced increased sewage flow and spills can occur during dry-weather conditions. Additionally, regulator malfunctions can frequently cause unexpected discharge into a stream. The U. S. Public Health Service has estimated that three to five percent of all raw sewage is discharged to receiving streams by combined sewer overflows. This would mean at least 68 billion gallons of raw sewage enter the nation's rivers and streams per year.

Complete separation of existing combined sewers is not considered a practical solution since the cost and inconvenience is a burden the taxpayer is not prepared to assume. It has already been pointed out that stormwater alone is a source of pollution and thus this approach is only a partial solution from the standpoint of pollution control. A number of alternatives have been suggested: separation at the source; separation in existing systems; express sewers; reduced stormwater input; temporary storage; and point of discharge treatment. Analysis of reports from various large cities in the United States indicate that almost all combined sewer systems will have to be engineered on a best-fit basis and that more than one method will be used per system.

This particular program is concerned with the point of discharge treatment approach. Specifically the project considered solids separation without storage, and chlorination of the effluent prior to discharge into a receiving stream. The basic concept is one of using a self-cleaning strainer in series with a self-cleaning diatomaceous earth filter capable of operating in remote locations on demand without the need of on-site operating personnel. The system would be designed to process a variable flow up to 1000 GPM.

The basic function of the two components tested and evaluated in this project are described below. The operation sequence of the original total design concept is described and illustrated on pages 47 - 51 in the Appendix.

In most cases, the storm sewer overflow outlets would require extensive modification to adapt for any treatment system. The most practical approach would be the construction of a receiving basin at the mouth of the discharge line. A pipe attached to a sturdy cage resting on the bottom of the basin would be the source of contaminated water for the proposed strainer-filter. Such a receiving basin, with an appropriate cage guard on the pipe, would prevent large objects such as animal corpes, tree branches, construction timbers from blocking water flow to the strainer unit. Periodic removal of such objects from the basin during times of no discharge would be the only maintenance required to keep the receiving basin operative. A level sensing device in the basin would activate and deactivate the strainer-filter system. The system would be provided with portable refuse bins to receive dewatered solids discharged from the filter unit. At each storm sewer discharge installation, access for periodic truck pick-up of the refuse bins would be required.

Self-Cleaning Strainer

The strainer is a modified version of the current Fram self-cleaning device. It was proposed that the unit would utilize permanent screening on the strainer support basket which would be continuously rotating with periodic blowdown cycles to be determined by a pressure differential across the strainer screen. The backwash pump would operate continuously at sufficient pressure to backwash the strainer screen. An internal baffling arrangement directs the backwash contaminated liquid into the vessel sump from which it would be discharged on the blowdown cycle.

It was proposed that the screen would be a permanent structure in the self-cleaning strainer with a particle selectivity of approximately 50 microns and would be designed to relieve the self-cleaning filter from all coarse particles larger than 50 microns, thereby permitting the diatomite filtration unit to operate more efficiently in the removal of fine suspended particles.

Self-Cleaning Filter - Vacuum Process

This unit is a new concept involving a non-pressurized rectangular cross-sectional vessel incorporating a rotary drum filter, utilizing a filter cloth material capable of receiving a precoat of diatomaceous earth and various powered or liquid chemicals which would be desirable for water purification or for filtration efficiency. The filter drum would be operated in cycles, based on pressure differential, by a lever control switch on the suction side of the effluent pump. The lower two-thirds of the filtration basket would be submerged in the liquid to be filtered with the upper one-third being exposed to warm dry air circulation to enhance the ability to discharge a relatively dry filter cake.

The proposed method of backwashing and discharging of the filter cake is considered unique. At the present time, one of the basic faults of practically all diatomaceous earth equipment is that a completely satisfactory dry cake discharge system has not been developed. The proposed filter cake discharge method should permit a much more satisfactory operation. The backwash would occur by a forced hot air stream slightly ballooning the filter cloth against an adjustable rubber scraper. This is, in turn, followed by a high pressure water discharge spray to remove any remaining traces of diatomaceous earth from the pores of the filter cloth.

B. Previous Investigations

Large concentrations of sediment, gravel or other coarse contaminants have been filtered with self-cleaning strainers of the heavy duty bar screen type and with strainers capable of removing contaminants down to 50 micron size. Although screen systems can be chosen to reduce the maximum particle down to less than 15 microns, these self-cleaning strainers tend to clog or blind-off with hard filter cakes that are not easily removed by conventional backwashing techniques. Self-cleaning strainers have been used to remove organic suspended solids from waste streams. Boucher and Evans (7) reported 50 - 90% removal efficiency was found to be greater as the feed suspended solids concentration increased. Hudson (8) studied the removal of partially decomposed organic solids by metal screen strainers and found them to be very effective, but subject to clogging. It was indicated that backwashing efficiency could be increased by the use of chlorine or ultra-violet radiation. Evans (9) has also reported that 70% incidental removal of coliform bacteria has occurred during micro-straining operations, by surface adsorption on particles removed by the strainer. Actual field tests (10, 11) on the straining of river water by the Fram self-cleaning strainer has confirmed that its present design is capable of handling massive contaminant slugs during erratic river flow periods.

Based on results obtained by the FWPCA at Pomona, California, on secondary effluent (12) considerable concern has been expressed that a diatomaceous earth filter for such an application has serious functional drawbacks: premature clogging ofthe filter; insufficient reduction in effluent turbidity and high raw material requirements. Using both a vacuum filter and a pressure filter, a number of filter-aids were evaluated at various flow rates and body-feed concentrations. Eighty-five percent reduction in turbidity was accomplished at flow rates of 0.53 to 1.0 gpm/ft^2 using Celite 545, Celite 503, and Hyflo Super-Cel grades of diatomaceous earth. The only information regarding organic removal was the statement that a 21 percent chemical oxygen demand decrease was found using Celite 545 at a flow rate of 0.52 gpm/ft^2.

It is well known (1, 2, 3, 4) that the amount of body feed, as well as type of contaminant, is very important in diatomaceous earth filtration when applied to municipal water systems. The AWWA Task Group report, "Diatomite Filters for Municipal Use", February 1965, pinpoints many of the problems associated with diatomaceous earth filters. On the other hand, the problem of concern here is quite different from that of potable water production or swimming pool clarification. It is within the scope of this proposal to use diatomaceous earth as both a mechanical strainer and chemical absorber without regard to absolute turbidity reduction. Primary consideration would be given to B.O.D. removal.

Effective use of diatomaceous earth has been made in the treatment of laundry wastes (5, 6) utilizing automatic backwash and precoat cycles. The experience developed in these instances is quite relevant to the storm sewer situation. Spade (6) listed typical results showing B.O.D. reductions near 90% and a reduction in suspended solids, for example, from 220 to 12 mg/l. The characteristics of the laundry wastes reported are similar in B.O.D. and suspended solid levels to what might be found in a combined sewer outfall.

C. Statement of the Problem

The purpose of this study was to conduct a feasibility investigation to determine the relative effectiveness of the self-cleaning strainer - filter concept in treating combined sewer overflows. The variables involved in this solids separation concept were investigated and the difficulties to be expected in a prototype design were considered.

Analysis of a typical combined sewer overflow in Providence, Rhode Island, was carried out in conjunction with this project.

II. Experimental Program and Procedures

The program was divided into three separate parts conducted concurrently whenever feasible: (1) Analysis of sewer overflow: (2) Self-cleaning strainer effectiveness; (3) Self-cleaning filter effectiveness.

A. Outfall Analysis

The primary purpose for including the analytical study of a combined sewer overflow was to determine the level of contamination that could be expected in the Providence area. This data was used in the preparation of samples for the laboratory evaluation of the proposed strainer-filter concept. It was anticipated that undue delays in the experimental program would occur if the study was restricted to a study of actual overflow samples.

The correlation of rainfall with overflow was attempted using data collected by the State of Rhode Island Water Pollution Branch at a site one air mile from the drainage area contributing to the selected site overflow.

In cooperation with the City of Providence, Rhode Island, an overflow site on the Woonasquatucket River was selected for study. A 54-inch sewer feeds into a 60-inch semi-circular open top channel prior to discharge into the river.

Following visual observation of sewer overflow during two storm events, the following sampling procedure was used throughout the program:

1. Sampling was performed manually. Whenever rain fell in the drainage area, a technician was dispatched to the overflow site.

2. Whenever flow was detected visually, sampling was started.

3. Samples were taken at fifteen minute intervals during the first two hours of flow, thereafter at 30 minute intervals for two hours. Additional samples were taken as dictated by the particular overflow event.

4. Samples taken for analysis were discrete in nature, not composites over each time interval and were taken in two quantities.

    a. Two-gallon sample taken with a one-gallon pail.
    b. One-gallon sample taken with a one pint wide mouth cup.

5. Samples were brought to the analytical laboratory within six hours of the initial sampling time. The following analyses were performed immediately: B.O.D., C.O.D., settleable solids, suspended solids, coliform count and dissolved oxygen level. Total and volatile solids determinations were performed within 18 hours after sample collection.

6. All analyses were performed in accordance with the Twelfth Edition of "Standard Methods for the Examination of Water and Wastewater".

B. Self-Cleaning Strainer

This program was divided into two sections: (1) experiments with strainer screen in the configuration of a flat sheet; (2) experiments with a working model of the Fram self-cleaning strainer.

1. Flat Sheet Testing

This test procedure is based on the premise that a relationship exists between the rate of accumulation of a solid material on a screen and its ability to remove the same material in a continuous cleaning system without blinding off, or the development of an excessive pressure drop across the screen.

Flat sheet samples were prepared using the following procedure with a mold described in Figure 1. Two gaskets 1/8" thick are molded from plastisol. One side of each is painted with plastisol. One is put back in the mold painted side up; the screen sample is placed on this and the other gasket is placed with the painted side making contact with the screen. A piece of 1/8" aluminum 3-1/4" in diameter is placed on this gasket with a 300 gram weight put on top for compression. It is then put in the oven for cure. Cure time in all cases is 8 - 10 minutes at 300°F.

The samples were tested in a fixture as shown in Figure 2, in the mode illustrated in Figure 3. Various screens were tested with the same contaminant at identical flow rates and solids concentration. Time-pressure readings were taken until the pressure drop across the screen reached 19 psig.

2. Model Self-Cleaning Strainer

The strainer used in this study is shown in Figure 4. The schematic drawing in Figure 5 illustrates how the unit functions. This model has a screen area of 40 square inches available for flow and filtration. The housing is constructed of plexiglass and is limited to an internal working pressure of 15 psig. Maximum rated flow of the unit is 15 gallons per minute.

The flat sheet testing procedure was used to screen those wire screens considered suitable for use in the model unit.

C. Self-Cleaning Filter

This part of the study was divided into two sections: (1) a 0.1 square foot filter area test system designed and built by the Johns-Manville Company; (2) adaptation of the model strainer into a vacuum filtration mode.

Cross-Section of a Circular Mold
For Flat Sheet Tester

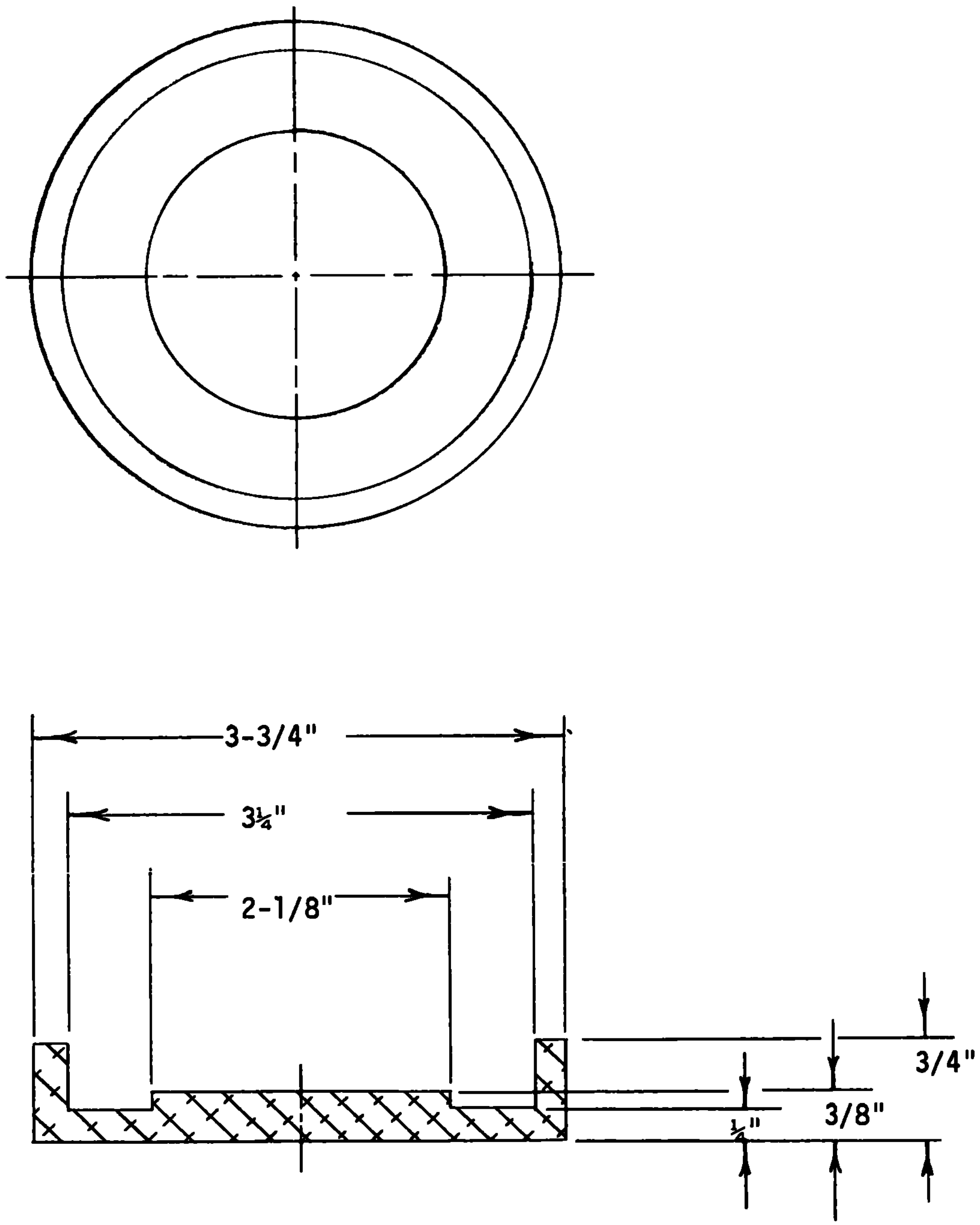
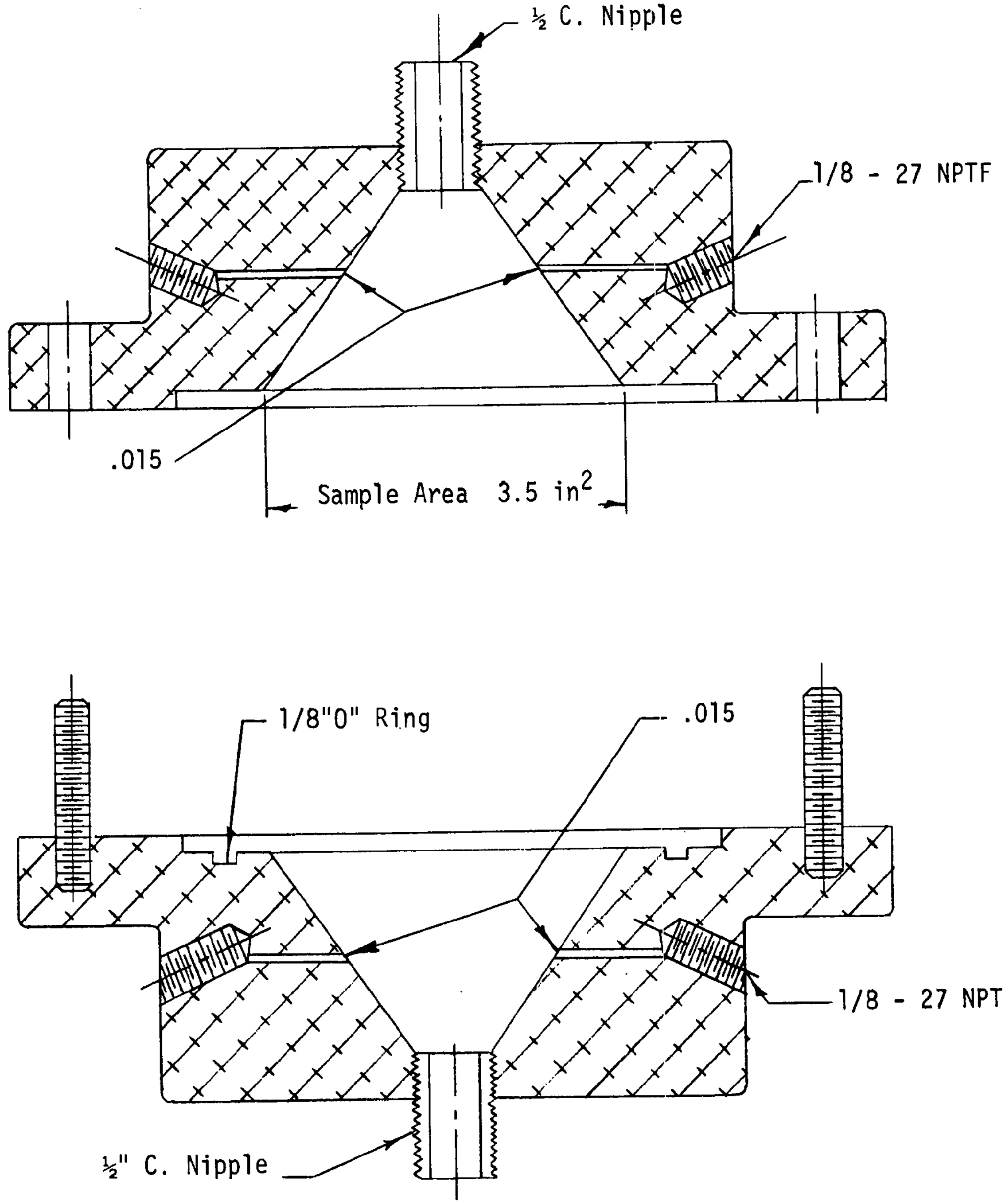


Figure 1

FLAT SHEET TEST FIXTURE



SCALE = FULL

Figure 2

SYSTEM SCHEMATIC FLOW DIAGRAM FOR FLAT SHEET TESTING

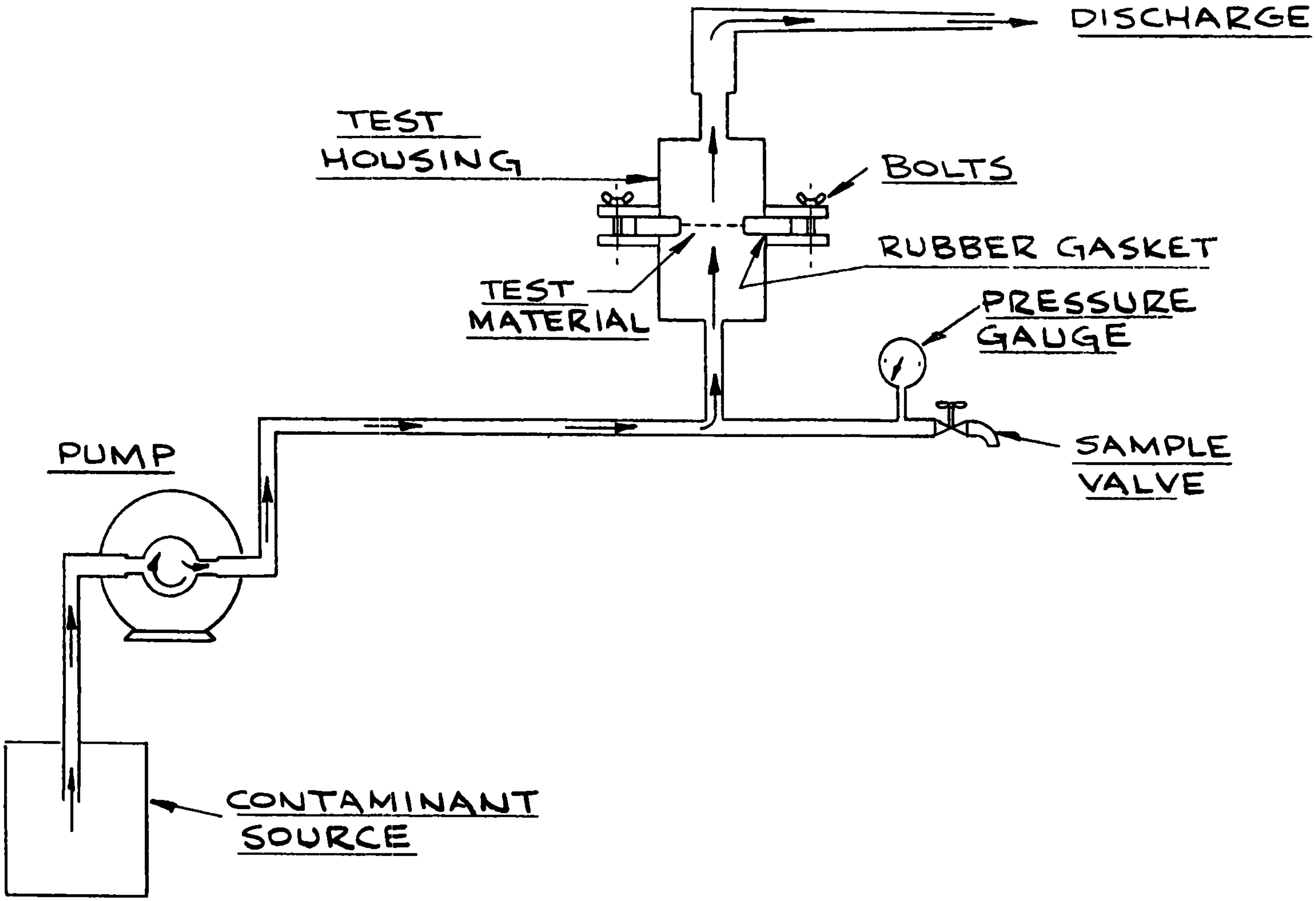
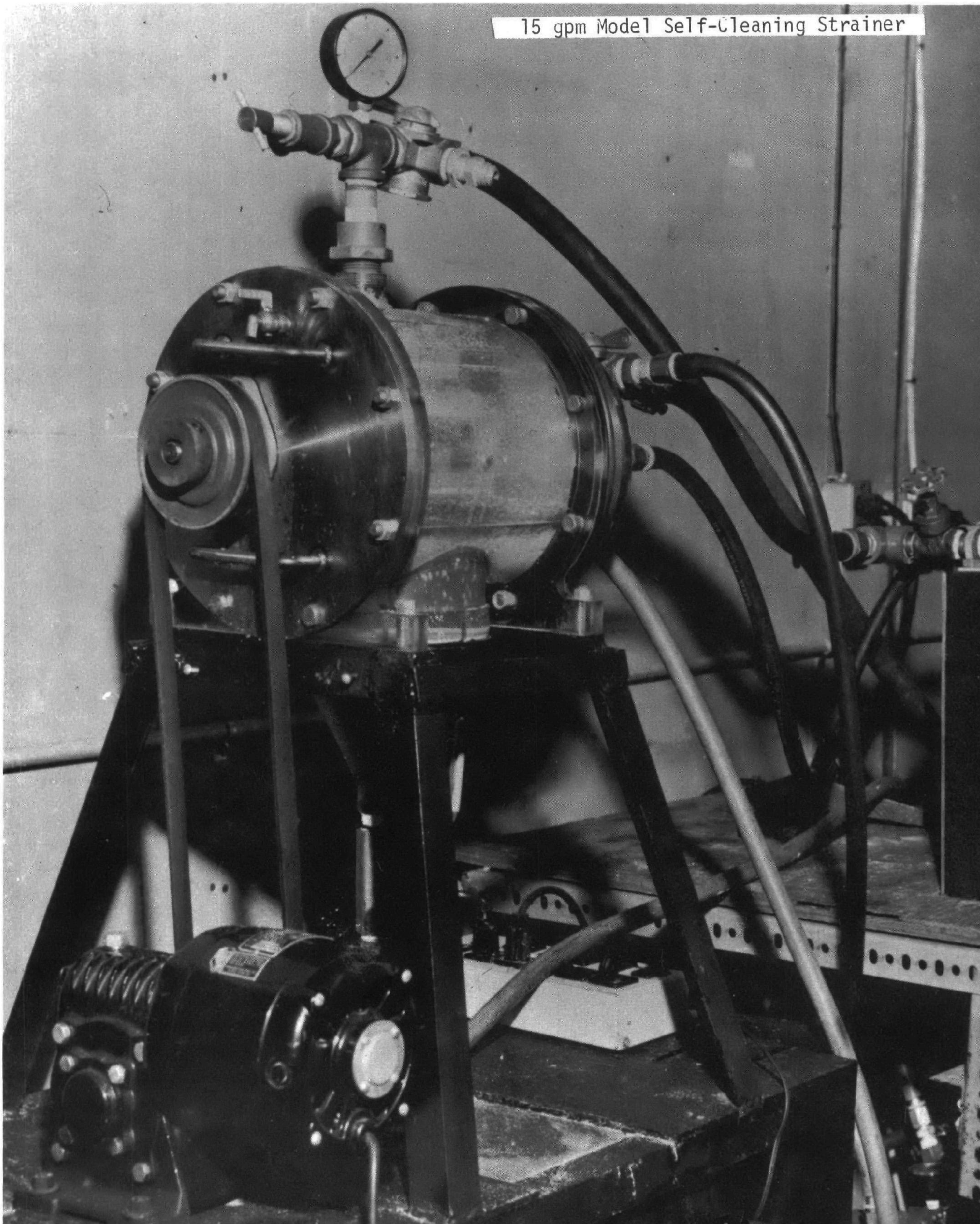


FIG. 3



15 gpm Model Self-Cleaning Strainer

Figure 4

Schematic Diagram Of

Model Self-Cleaning Strainer

A Inlet.

B Flow Control Deflector Baffle.

C. Backwash Nozzle.

D. Cartridge Screen.

E. Bottom Sump Area Where Heavy Contaminants Are Stored Between Blow-downs.

F. Bottom Blow-down Connection For Removal Of Heavy Contaminants.

G. Upper Sump Area Where Lightweight Contaminants Are Stored Between Blow-downs.

H. Upper Blow-down Connection For Removal Of Lightweight Contaminants.

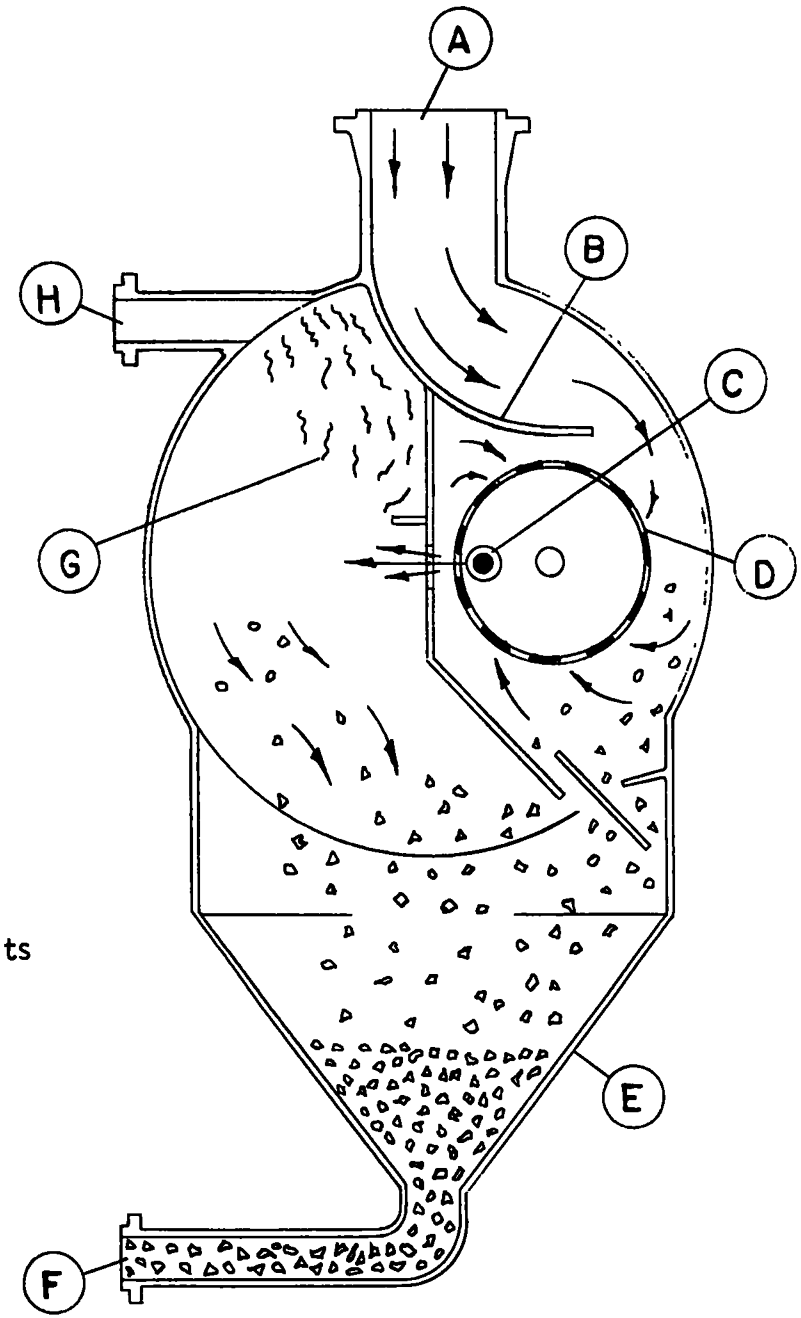


Figure 5

1. Johns-Manville System (13, 14)

This unit simulates the function of an equal area on the surface of a full-sized rotary vacuum precoat filter drum. The system is schematically outlined in Figure 6. During the course of each revolution, the filter drum passes through submergence, drying and residue removal phases; and the small filter test leaf is capable of such sequential operation on a timed basis.

This part of the experimental program was outlined as follows:

a. Preliminary screening

(1) Selection of representative samples of a diatomaceous earth.
(2) Selection of suitable septa.
(3) Selection of a suitable synthetic contaminant solution.

b. Filter performance studies using:

(1) Three diatomaceous earth sizes
(2) Three diatomaceous earth slurry feed rates
(3) Various contaminant concentrations
(4) Various flow rates
(5) Various septa

c. Filter performance with chemical treatment or additional filter aids

(1) Activated carbon
(2) Ion exchange
(3) Flocculating agents

III. Experimental Results

A. Selection of Synthetic Contaminant

The data obtained during the first two storm events sampled was used to establish the following minimum characteristics:

(1) B.O.D. - 125 mg/l; (2) C.O.D. - 400 mg/l; (3) Suspended Solids - 250 mg/l; (4) Settleable Solids - 2

Based on prior experience, a biodigestable dog food (Burgerbits) was selected as a suitable approximation to the chemical composition of human solid waste products. Various concentrations of the dog food were tested to determine how well the above noted values could be attained without the necessity of using some additional material. Twenty liter samples were prepared by blending the proper amount of dog food with one liter of water for 15 minutes, followed by one hour of aeration and dilution to 20 liters with tap water. At a concentration of 0.4 gm/l the following average values were obtained:

JOHNS-MANVILLE DIATOMATEOUS EARTH FILTER TEST SYSTEM

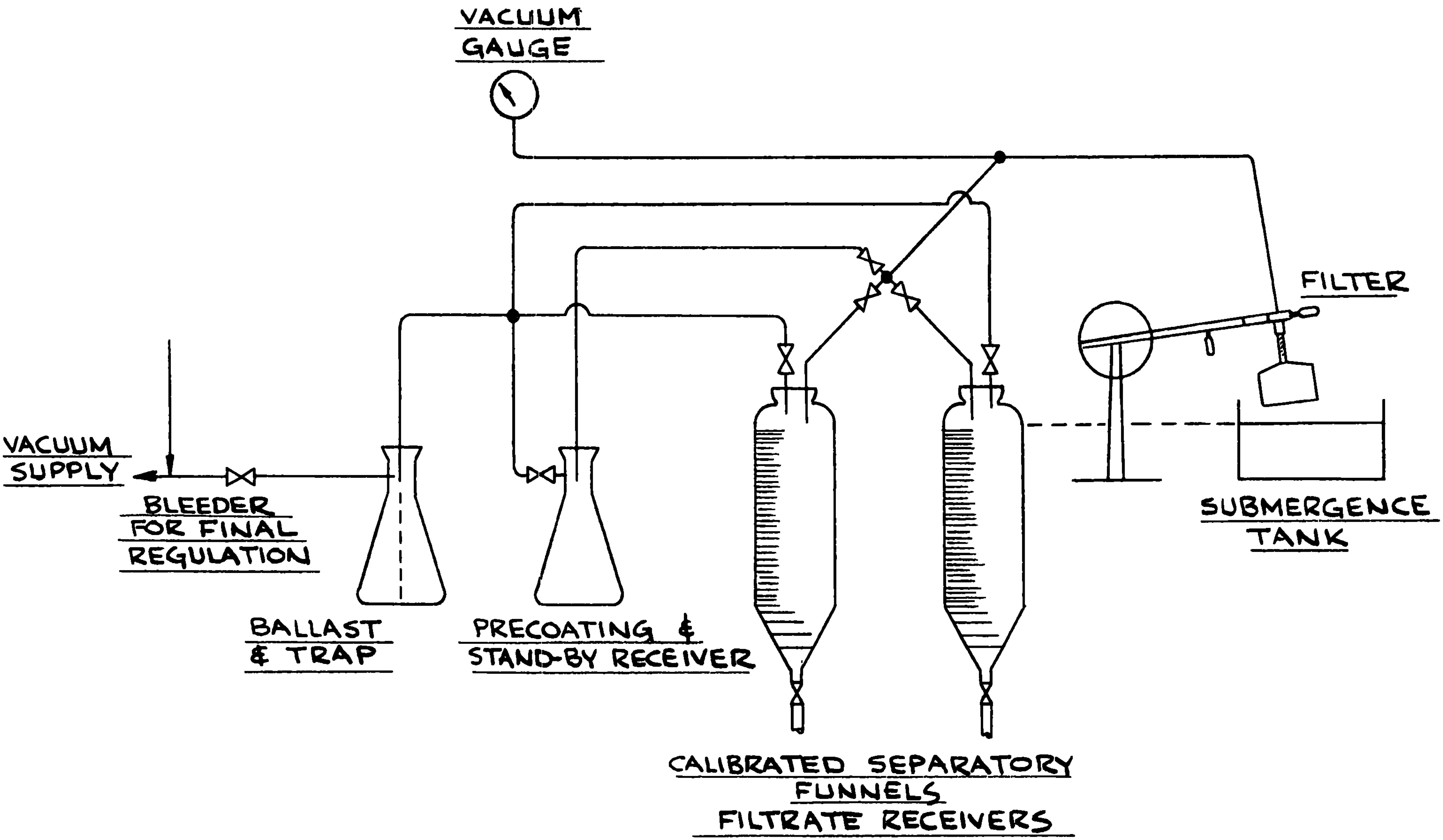


Figure 6

(1) B.O.D. - 172 mg/l; (2) C.O.D. - 433 mg/l; (3) Suspended Solids - 264 mg/l; (4) Settleable Solids - 2.1

It should be noted that since the Fram self-cleaning strainer operates with forced flow, particle size reduction of human feces occurs in the feed pump. The settling rate of the blended dog food and mechanically ground fresh human feces were found to be essentially the same. Since the density of the two materials are essentially the same, then the average particle size and distribution were considered to be essentially the same, based on Stokes Law.

Typical single values obtained when evaluating the dog food characteristics at various concentration levels are shown in Table (a) in the Appendix. The values obtained clearly show that reproducible properties of the resulting solution were readily achieved well within the normal variations of the analytical methods. The blending time was found to be the most important variable.

B. Outfall Analysis

The first complete outfall analysis was performed on samples taken January 30, 1968, and the results are shown in Table 1. A second overflow was sampled and analyzed on February 2, 1968, and these results are shown in Table II. There is a distinct difference between the two sets of samples which is probably due to the historical events in the sewer system. Prior to the January 30, event, there hadn't been any significant rain or overflow for fifteen days. High density solids, such as sand, coffee grounds, etc., could have accumulated along the sewer lines between January 15 and January 30 and were flushed out with the high flow rates on the 30th. The first sample taken on January 30 had a very large quantity of readily settleable coffee grounds, etc. On the other hand, the February 2 samples showed little or no readily settleable material such as coffee grounds, in addition to the fact that the total amount of settleable solids was significantly less at the first flushing. On January 14-15, 1968, the recorded rainfall between 10 PM and 6 AM was 1.20 inches, which resulted in rapid and complete flushing of the sewer system. The system was quiet for fifteen days before the first sampling, versus only two days before the second overflow sampling.

As a guide for the evaluation of straining or settling, the first set of samples was analyzed twice to determine the effect of twelve hour settling. The results are shown in Table III. The difference appears to be significant only with samples containing abnormally high settleable solids.

On March 17, 1968, a record amount of rainfall caused considerable flooding of the Woonasquatucket River and washed out a foot bridge at the Sheridan Street combined overflow sewer, used for sampling in this project. Due to the hazardous nature of the area during and after the storm, no samples were taken for analysis.

TABLE I - SHERIDAN STREET OVERFLOW SAMPLES - JANUARY 30, 1968

Sample No.	Time Interval Previous Sample	B.O.D. mg/l	C.O.D. mg/l	Settleable Solids ml/l	Suspended Solids mg/l	Volatile Solids mg/l	Total Solids mg/l	Coliform MPN	D.O. mg/l
1	-	440	1243	35.0	968	3200	4000	11,000,000	-
2	2 hrs.	150	428	6.5	310	400	1600	2,400,000	8.8
3	0.5 hrs.	90	317	2.0	172	125	1000	240,000	9.9
4	0.5 hrs.	76	214	2.0	110	400	800	2,400,000	10.9
5	0.5 hrs.	80	222	2.2	80	200	400	11,000,000	10.7
6	2.0 hrs.	22	113	1.2	76	200	200	11,000,000	12.0
7	12.0 hrs.	400	531	3.0	400	800	2800	4,600,000	7.3
8	0.5 hrs.	300	562	4.0	310	1000	2000	11,000,000	7.5

January 30, 1968 - Rainfall - 0.40 inches

TABLE II - SHERIDAN STREET OVERFLOW SAMPLES - FEBRUARY 2, 1968

Sample No.	Time Interval	B.O.D.	C.O.D.	Settleable	Suspended	Volatile	Total	Coliform
1	-	65	380	3.0	162	2800	3600	750,000
2	0.5 hrs.	60	373	3.5	190	800	2800	1,500,000
3	0.5 hrs.	38	-	2.3	200	400	2000	2,400,000
4	0.5 hrs.	78	264	0.8	106	1200	2400	430,000
5	0.5 hrs.	60	217	1.3	74	800	1600	240,000

February 2, 1968 - Rainfall - 0.28 inches

TABLE III - SHERIDAN STREET OVERFLOW SAMPLES - JANUARY 30, 1968 - EFFECT OF 12-HOUR SETTLING

Sample No.	B.O.D.		Settleable Solids
	Supernatant	Blended	
1	175	440	35.0
2	130	150	6.5
3	70	90	2.0
4	62	76	2.0
5	70	80	2.2
6	18	22	1.2
7	310	400	3.0
8	275	300	4.0

During April, two significant overflows were sampled and analyzed. Table IV lists the data obtained in samples taken April 15, 1968. It is significant that the greatest organic load occurred after the first flush (Sample 3). At 3:17 P.M., a heavy flow of human waste and toilet tissue was observed in the first four inches of water, just after Sample No. 5 was taken. This condition lasted for approximately 20 seconds and could not be adequately sampled; therefore, it is not included in the tabulated results shown in Table IV. Table V lists the data obtained in samples taken April 24, 1968.

It should be noted that, in both instances, the flow rate was cyclic in nature. Although the rainfall during the sampling period was almost identical in both cases, it probably is a coincidence that a change in the flow pattern and waste occurred between Samples 5 and 6 both times.

TABLE IV - SHERIDAN STREET OVERFLOW SAMPLES - APRIL 15, 1968

Sample No.	Time Interval From Previous Sample	B.O.D. mg/l	Settleable Solids ml/l	Suspended Solids mg/l	Volatile Solids mg/l	Total Solids mg/l	Coliform MPN/ 100 ml	D.O. mg/l
1	Visual Start of Flow	126	2.5	30	65	295	2,400,000	7.8
2	15 minutes	75	0.9	5	55	255	750,000	7.2
3	15 minutes	90	7.5	220	80	240	930,000	6.7
4	15 minutes	110	3.0	90	40	230	930,000	7.2
5	30 minutes	46	0.5	30	35	140	240,000	7.1
6	30 minutes	120	0.25	80	150	300	4,600,000	7.6
7	30 minutes	65	negligible	40	45	170	430,000	7.8
8	30 minutes	18	negligible	10	20	110	430,000	7.8

Note:

(1) Total Rainfall from 8:10 A.M. to 3:00 P.M. = 0.42 inches
8:10 A.M. to 10:30 A.M. = 0.07 inches
10:30 A.M. to 3:00 P.M. = 0.35 inches

(2) Flow commenced at 1:45 P.M.

Flow rate at 1:50 P.M. = 1150 gal/min.
2:45 P.M. = 1600 gal/min.
3:45 P.M. = 400 gal/min.

TABLE V - SHERIDAN STREET OVERFLOW SAMPLES - APRIL 24, 1968

Sample No.	Time Interval From Previous Sample	B.O.D. mg/l	Settleable Solids ml/l	Suspended Solids mg/l	Volatile Solids mg/l	Total Solids mg/l	Coliform MPN/ 100 ml	D.O. mg/l
1	Visual Start of Flow	183	7.0	165	280	530	11,000,000	6.7
2	15 minutes	144	3.5	130	200	400	2,400,000	7.2
3	15 minutes	126	2.5	30	185	320	2,400,000	7.4
4	15 minutes	130	1.2	20	165	300	2,400,000	6.9
5	30 minutes	99	1.0	22	75	250	240,000	7.2
6	30 minutes	115	1.5	25	115	270	930,000	7.6
7	30 minutes	85	1.5	17	100	265	11,000,000	7.7
8	30 minutes	70	0.75	10	90	275	240,000	7.6

Note:

(1) Total Rainfall from 7:30 P.M. to 9:10 P.M. = 0.30 inches

(2) Flow commenced at 7:50 P.M. -- First Sample Taken 7:55 P.M.

Flow Rate at 8:00 P.M.=1900 gal/min.
8:45 P.M.= 900 gal/min.
9:30 P.M.=1440 gal/min.
10:15 P.M.=less than 50 gal/min.

From April 24, 1968, to November 12, 1968, there were no overflows observed at the test site. On a number of occasions during this time period there was rainfall equal to or greater than that which had previously caused overflows. This situation probably resulted from the flooding that occurred on March 17, 1968, and the construction work carried out in the vicinity of the overflow.

Visual observation of several overflows conclusively showed the presence of fresh human feces (larger than one-half inch) and whole pieces of toilet paper. Samples were collected using a wire-mesh screen with one quarter inch openings. Comparison of the suspended solids in the usual pail samples with those collected with the wire mesh, consistently showed a variation in particle size. Only when a sample was taken at the surface of the flowing stream did the maximum particle size obtained with the pail equal that found with the wire mesh strainer.

On April 1, 1968, a very brief overflow occurred at 8:15 A.M. Only one set of samples was taken; one with a one pint scoop, the second with a one gallon pail. The samples were simultaneously taken by two people at the same surface depth. The pail sample was found to have higher values for eacn variable tested.

	B.O.D.	C.O.D.	Suspended Solids	Total Solids	Volatile Solids	Settleable Solids
Scoop	190	444	315	580	350	3.25
Pail	210	495	825	1140	784	4.0

The eight samples shown in Tables IV and V above actually represent 16 samples. At each time period both a scoop and pail sample was taken for comparative analysis. The C.O.D. values are listed on page 19 in Table VI.

Although whole sections of toilet paper were noted in the overflow, the sampling technique used did not produce or yield any paper in the samples. A double sheet of toilet tissue weighs approximately 0.37 grams and would yield a C.O.D. value of approximately 19,400 mg/l.

TABLE VI - EFFECT OF SAMPLE SIZE ON OVERFLOW ANALYSIS

Sample No.	Sampler	C.O.D. April 15, 1968	C.O.D. April 24, 1968
1	scoop	244	372
1	pail	264	452
2	scoop	160	248
2	pail	180	300
3	scoop	192	256
3	pail	212	248
4	scoop	184	224
4	pail	284	270
5	scoop	120	212
5	pail	100	188
6	scoop	248	204
6	pail	212	232
7	scoop	136	172
7	pail	152	208
8	scoop	36	172
8	pail	45	180

C. Strainer Experiments

1. Flat Sheet Tests

The following wire screens were initially evaluated using the synthetic substrate at a concentration of 0.4 grams per liter and a flow rate of one gallon per minute: 50 x 250 mesh plain dutch weave; 25 x 25, 36 x 36, 60 x 60, 80 x 80, and 100 x 100 mesh square weaves.

The 50 x 250 mesh screen blinded off too rapidly to permit accurate visual measurement of the time-pressure relationship. Also, the solids became very tightly bound in the interstices of the screen and were not readily removed by backwashing. On the other hand, the 25 x 25 and 36 x 36 mesh square weave screens did not retain sufficient solids to reach the end point pressure of 20 psig even after 20 minutes.

A series of runs were performed with 60 x 60, 80 x 80, and 100 x 100 mesh square weave screens. Table VII contains data showing the relative time it took for each of the screens to reach a pressure of 19 psig at different blending times. The longer the blending time, the smaller the average particle size. These results showed that reproducible results could be obtained with the synthetic contaminant in terms of particle size and particle size distribution. It was quite obvious that the physical characteristics of the suspended solids could be controlled and varied by manipulation of mixing time and temperature.

TABLE VII - FLAT SHEET TEST RESULTS

Run No.	Wire Screen	Screen Openings Microns	Blend Time	Average Run Time
1263-19	100 x 100	150	5 min.	62 sec.
1263-16	100 x 100	150	5 min.	83 sec.
1263-17	100 x 100	150	5 min.	72 sec.
1263-20	100 x 100	150	10 min.	47 sec.
1263-24	60 x 60	230	5 min.	147 sec.
1263-25	60 x 60	230	5 min.	129 sec.
1263-36	80 x 80	190	10 min.	94 sec.
1263-42	80 x 80	190	10 min.	85 sec.

Each value is the average of five runs.

2. Model Self-Cleaning Strainer

a. Synthetic Strainer

The results obtained with the flat sheet samples were fairly reproducible and significantly different under varying conditions, but the analysis time was deemed too short for a suitable expanded program. The remainder of the project was carried out using the model strainer as described previously.

The initial short duration run used a 60 x 60 mesh square weave wire screen at a synthetic feed rate of 5.9 gallons per minute (0.4 grams per liter) and a clean water backwash of 2.2 gpm, with no sump discharge. The initial results are listed below in Table VIII. The influent values shown have been corrected for dilution caused by the clean water backwash.

TABLE VIII - INITIAL MODEL STRAINER RESULTS - 60 x 60 MESH, 230 MICRON OPENING

Sample	B.O.D.	C.O.D.	Suspended Solids	Total Solids	Volatile Solids
Influent	125	324	161	598	226
Effluent 1 min.	80	259	105	460	95
Effluent 3 min.	115	290	110	515	45
Effluent 5 min.	60	243	80	445	75
Effluent Composite	95	251	100	465	85

An attempt was made to establish a statistical program to evaluate the optimum combination of parameters (feed rate, backwash rate, drum speed, mesh size, etc.) on B.O.D. and suspended solids removal. The initial experimental results are shown in Table IX obtained with a 60 x 60 mesh screen with the synthetic substrate concentration at 0.4 grams per liter. Each value listed per run number represents a separate 50-gallon batch of synthetic substrate that was prepared.

TABLE IX - MODEL STRAINER RESULTS - 230 Micron
60 x 60 MESH - SYNTHETIC CONTAMINANT

Run No.	Percent Removal of Suspended Solids						Average
1	63	19	12	30	43	30	33
2	58	57	63	54	69	72	62
3	23	31	72	40	19	13	33
4	14	18	19	17	10	24	17
5	37	51	51	57	57	44	50
6	20	14	47	45	34	10	28
7	52	13	53	36	32	33	37
8	29	13	29	55	23	60	37

The raw data for these calculations are listed in Table (b) in the Appendix. The eight runs listed in Table IX were made at four different ratios of solution feed rate to backwash rate: drum speed constant at 8 rpm.

Run No.	Feed Rate	Backwash Rate
1, 2	6 gpm	2 gpm
3, 4	6 gpm	1 gpm
5, 6	5 gpm	2 gpm
7, 8	5 gpm	1 gpm

The primary objective of this experiment was to evaluate the effect of velocity across the screen on solids separation efficiency. The wide variation between runs made at identical conditions caused a re-examination of the experimental conditions. It was determined that improper metering of the synthetic suspension into the strainer resulted in widely fluctuating solids concentration in the influent material. The numbers calculated as shown in Table IX were based on an average inlet concentration and not, therefore, on the true value at any time. The effluent samples values as shown in the Appendix represent true values at that particular sampling time. Under more carefully controlled conditions a series of runs were performed using the synthetic substrate at various flow rates and backwash rates with three different size screens. The raw data is listed in Table (c) in the Appendix. The influent to the strainer was sampled at the same time as the effluent. During a 30-minute test cycle the influent varied 10 to 30 percent from the average values found with this particular synthetic substrate. Since actual field trials would entail at least this amount of variation no further changes were made in the test procedure. Table X on page 23 shows the calculated results for percent removal of suspended solids, B.O.D. and C.O.D. These values were calculated using the specific values obtained for each influent effluent pair of samples. The numbers shown in brackets were not used in calculating the averages. When the 100 x 100 mesh screen was used, the basket speed of rotation was doubled to prevent screen plugging.

TABLE X - MODEL STRAINER RESULTS - EFFECT OF MESH SIZE ON SOLIDS REMOVAL

				Average Percent Removal Data		
Run No.	Mesh Size	Inlet Flow Rate	Backwash Rate	Suspended Solids	B.O.D.	C.O.D.
1263-48	60 x 60	6	2	27	20	12.2
1263-49	60 x 60	6	2	28	10	7.1
1263-46	60 x 60	6	1	43	13	15.6
1263-47	60 x 60	6	1	33	14	12.8
1275-1	60 x 60	5	2	35	11	15.4
1275-2	60 x 60	5	2	32	-	17.2
1275-3	60 x 60	5	1	32	9	15.2
1275-4	60 x 60	5	1	31	-	18.9
1275-16	80 x 80	6	2	54	25	16.5
1275-15	80 x 80	6	2	61	-	21.5
1275-17	80 x 80	6	1	31	-	20.6
1275-22	80 x 80	5	2	57	12	17.8
1275-18	80 x 80	5	2	44	30	17.2
1275-24	80 x 80	5	1	37	-	16.0
1275-23	80 x 80	5	1	56	17	13.9
1263-44	100 x 100	6	2	43	25	16.9
1263-45	100 x 100	6	2	51	19	18.6
1275-6	100 x 100	6	2	70	22	(9.5)
1275-7	100 x 100	5	2	55	-	(5.3)
1275-8	100 x 100	5	2	58	19	19.2
1275-9	100 x 100	5	1	65	-	21.8
1275-10	100 x 100	5	1	52	9	17.0

(60, 80, 100 mesh = 230, 190, 150 microns respectively)

Notes:

1) Synthetic contaminant concentration - 0.4 gm/l

2) Normal drum speed - 8 rpm

Additionally, it should be noted that the 100 x 100 mesh screen could not be satisfactorily operated at 6/1 feed to backwash ratio. Excessive plugging of the screen occurred, causing a rapid increase in system pressure, which required frequent blowdowns. At the same flow ratio of 6/1, the 80 x 80 mesh screen also did not perform very well, only one value is listed in Table (X).

b. Sheridan Street Samples

Table XI lists the results obtained using four fifty-gallon composite samples taken at Sheridan Street. The samples were taken from the sanitary sewer line during a rain storm when overflow did not occur.

This sampling was performed in June, 1968, two months after the disastrous spring flood. Prior to this date, the rainfall which occurred during this sampling has previously caused overflows. The samples were taken with a gasoline engine powered centrifugal pump rated at 80 gallons per minute.

These results were obtained at a flow rate of 5 gallons per minute, backwash rate of 1 gallon per minute, screen - 80 x 80 mesh (190μ) and the basket revolving at 8 revolutions per minute.

TABLE XI - MODEL STRAINER RESULTS - SHERIDAN STREET OVERFLOW SAMPLES
FLUX RATE - 18 GPM/FT.^{2}

Sample	B.O.D.	C.O.D.	Suspended Solids	Total Solids	Volatile Solids
1 Influent	65	188	1040	310	250
1 Effluent	50	168	620	305	225
2 Influent	67.5	196	920	-	-
2 Effluent	52.5	172	600	-	-
3 Influent	62.5	216	1000	290	230
3 Effluent	60	180	640	250	200
4 Influent	70	208	1000	-	-
4 Effluent	62.5	184	500	-	-
5 Influent	65	192	700	285	115
5 Effluent	60	180	480	260	120
6 Influent	80	200	680	-	-
6 Effluent	60	168	420	-	-

The coliform count on all samples was greater than 11,000,000. The settleable solids test was not performed since the sample had been passed through a pump three times prior to testing.

c. Mechanical Ability

One of the major concerns regarding the proposed system was the mechanical reliability of the strainer when operated semi-continuously on a stream containing a large amount of sewage solids. For this purpose the strainer was moved to the Bucklin Point Sewage Treatment Plant, East Providence, Rhode Island. This particular plant, operated by the State of Rhode Island, has only primary treatment and the influent contains a very high proportion of industrial waste, resulting in high dissolved organic concentrations. The treatment plant chemist estimated that at times seventy percent of the influent is industrial waste.

The influent for the strainer was taken at a point between grit removal and the sedimentation tanks. During the first six hours of operation, the pump suction line was not protected to exclude large objects which might slip by the bar screens. As a result, a number of times large pieces of paper and rags were pulled into the strainer housing and plugged the discharge dump valve. This resulted in a rapid increase in system pressure requiring a shut down to free the discharge part. This was not considered to be a real problem, since a full-scale unit would have at least two inch discharge line versus the three quarter of an inch dump valve on the model. This problem was eliminated by the installation of a perforated basket with one half inch holes around the intake.

The unit was operated for 83 hours on 15 separate days. Operating data was taken at 30 and/or 60 minute intervale during 77.5 of the 83 hours on 13 days. The specific nature of the results obtained in terms of percent removal of suspended solids, B.O.D., and C.O.D. are partially listed in Tables XII on page 26. The system was operated at an inlet flow rate of 7 gallons per minute with continuous solids discharge at a rate of two gallons per minute. The backwash nozzle was operated at two gallons per minute with strainer effluent as the backwashing fluid. There was absolutely no difficulty in operating the unit on the sewage solids. Plugging did not occur on either the 60 x 60 or 100 x 100 mesh screens used in the experiments.

TABLE XII - MODEL STRAINER RESULTS - BUCKLIN POINT SEWAGE TREATMENT PLANT INFLUENT 60 x 60 MESH SCREEN 230 MICRON OPENING

Running Time	Suspended Solids		B. O. D.		C. O. D.	
Total Hours	Influent	% Removal	Inf.	% Removal	Inf.	% Removal
0.5	315	25	245	8	812	19
1.5	140	43	205	24	444	21
3.0	90	45	200	18	456	10
4.5	60	83	183	4	467	14
6.5	110	50	160	63	689	7
18.0	130	23	210	14	468	16
19.0	180	19	165	7	652	3
20.0	185	48	213	25	576	13
21.0	305	65	243	14	644	6
22.0	150	33	210	4	580	15
23.0	150	40	260	16	508	15
28.0	100	70	160	16	657	1
31.0	55	18	168	11	664	13
38.0	465	69	310	22	796	37
41.0	310	72	330	27	816	40

FLUX RATE = 25 GPM/FT.^{2}

TABLE XIII - MODEL STRAINER RESULTS - BUCKLIN POINT SEWAGE TREATMENT PLANT INFLUENT 100 x 100 MESH SCREEN, 150 MICRON OPENING

Running Time	Suspended Solids		B.O.D.		C.O.D.	
Total Hours	Influent	% Removal	Inf.	% Removal	Inf.	% Removal
1.5	175	60	130	11	465	25
2.5	175	49	150	13	515	16
3.5	205	34	175	14	595	16
5.5	160	40	380	5	764	17
9.0	255	80	160	12	524	12
12.0	175	31	290	24	628	8
15.0	225	93	208	7	568	12
16.5	45	66	270	4	452	7
22.0	90	61	185	16	412	20
26.0	40	50	210	14	452	12
30.5	80	31	-	-	648	31

FLUX RATE = 25 GPM/FT.^{2}

Since it was known that industrial wastes are a major part of the influent received at the Bucklin Point Treatment Plant, analysis was carried out to determine the extent of dissolved organics present in the waste treated. A number of samples were analyzed as received, and also after filtration through a 0.45 micron membrane filter. Some typical results are shown in Table XIV below.

TABLE XIV - DISSOLVED ORGANIC CONCENTRATION IN BUCKLIN POINT INFLUENT

Sample No.	Suspended Solids	C.O.D. As Received	C.O.D. Filtered
86100	140	708	188
86103	170	844	196
86110	110	648	260
86113	490	836	304
87110	460	604	232
87103	210	560	196
87110	155	568	240
87113	250	728	200

The unit was moved to another municipal treatment plant in East Providence, R.I., which receives less industrial waste. Typical results obtained with a 60 x 60 mesh screen are listed in Tables (d) and (e) in the Appendix. The data in Table (d) were obtained when the influent to the strainer was taken upstream of the bar screens. Inlet flow was seven gallons per minute, backwash four gallons per minute and sump discharge at three gallons per minute. Again, it was not possible to operate the sump discharge ata lower flow rate without plugging the three quarter inch discharge line.

Table (e) data were obtained when the strainer influent was taken down stream of the bar screens. The operating conditions were maintained tne same as listed above.

No data were taken witn either an 80 x 80 or 100 x 100 mesh screen at this location (190, 150 Microns respectively).

d. Results with Fresh Solids

For the purpose of conparing the results obtained at the municipal treatment plants with those to be expected at an overflow site, raw sewage was collected from a sewer line containing only sanitary wastes. The sewage was collected in 55 gallon drums, using an eductor. Use of the vacuum system permitted collection without mechanical action or maceration of the solids. The solids were, therefore, presented to the system in the same physical state found at the overflow site analyzed.

The data obtained are listed in Table XV below. With this type of feed it was possible to operate the sump discharge rate at a much lower value than previously possible at the treatment plants. The backwash rate had to be maintained at a high value similar to the runs made at Bullock's Point noted above.

TABLE XV - MODEL STRAINER RESULTS - FRESH SEWAGE SOLIDS, 60 x 60 MESH SCREEN 230 Microns

Running Time	Suspended Solids		B.O.D.		C.O.D.	
Total Hours	Influent	Effluent	Influent	Effluent	Influent	Effluent
Inlet Flow - 7gpm		Effluent Flow - 5 gpm			Backwash - 4 gpm	
1	150	55	170	110	604	449
2	180	15	170	90	584	451
3	50	5	200	120	261	188
4	35	8	230	140	288	235
Inlet Flow - 7 gpm		Effluent Flow - 6.5 gpm			Backwash - 4 gpm	
5	20	5	90	60	174	140
6	68	28	115	65	334	240
7	28	12	95	55	337	321
8	50	20	145	80	358	305

D. Self-Cleaning Filter

1. Johns-Manville Test System

a. Screening Tests

The initial program was conducted with the 0.1 square foot filter area test system described above, that was designed and built by the Johns-Manville Company. Studies were carried out to determine which variables were important to the development of a standard test procedure.

Using the strainer effluent from the initial laboratory screening experiments, where the influent was 0.4 grams per liter of synthetic substrate, studies were made with the filter test leaf, Hyflo-Super Cel grade diatomaceous earth and Grade 2006 Polypropylene monofilament septa. These preliminary experiments were made to determine optimum submergence time (simulation of drum rotation speed) and optimum knife advance (simulation of residue removal phase). The analytical results are listed in Tables XVII and XVIII.

TABLE XVII - EFFECT OF SUBMERGENCE TIME ON FILTER PERFORMANCE

	C.O.D. (mg/l)		Suspended Solids (mg/l)	
Submergence Time	Influent	Effluent	Influent	Effluent
15 seconds	302	48	30	negligible
30 seconds	302	48	30	negligible
45 seconds	342	40	227	negligible
60 seconds	342	36	227	negligible

TABLE XVIII - EFFECT OF KNIFE ADVANCE ON FILTER PERFORMANCE

Knife Advance				
10 mil	302	48	30	negligible
20 mil	242	36	175	negligible
30 mil	242	32	175	negligible

It can be observed that the submergence time and knife advance thickness do not have to be critically controlled in order to obtain comparable effluent C.O.D. and effluent suspended solids levels on this synthetic substrate.

Based on the results shown in Tables XVII and XVIII, the following standard test procedure was adopted for the screening of six diatomaceous earth grades:

Precoat Slurry concentration - 6% Septum - Type 2006 Polypropylene
Volume of Slurry/addition - 300 mls, Final Cake Thickness - 1.50 in.
Vacuum Range - begin at 5, end at 20 in. Hg.
Operating Temp - 25 - 30°C, Filtering Vacuum - 20 in. Hg.
Submergence Time - 22 sec., Advance and Cake Removal - 8 sec.
Knife Advance - 0.020 inches

The six diatomaceous earth's are graded on a porosity scale of one to ten, where ten is the most porous. The results are tabulated in Table XIX below:

TABLE XIX - DIATOMITE EVALUATION WITH SYNTHETIC SUBSTRATE

J-M Diatomite Grade	Porosity	C.O.D. (mg/l) Influent	C.O.D. (mg/l) Effluent	Suspended Solids (mg/l) Influent	Suspended Solids (mg/l) Effluent
560	10	326	63	195	negligible
545	9	326	63	195	negligible
Hyflo Super Cel	5	326	40	195	negligible
512	4	216	44	175	negligible
Standard Super Cel	3	216	28	175	negligible
Filter Cel	1	216	36	175	negligible

It can be noted that the variations in porosity did not drastically change the effluent C.O.D. and suspended solids levels.

On the basis of the results from the initial screening, three diatomite grades were selected for further testing. Because of the small differences in removal levels, one grade was selected to represent each porosity range. They were Johns-Manville #545 (high porosity), Hyflo Super Cel (medium) and Standard Super Cel (low).

Continuing the studies further, another evaluation was carried out using the above three diatomite materials, the standard test procedure and two different influent substrates. Primary effluent was obtained from the Bucklin Point, East Providence, Rhode Island, municipal treatment facility. This effluent was used as is and also mixed 1:1 with 0.4 g/l dog food strainer effluent. Further, both these substrates were used in their unadulterated form and also with a 0.5 g/l Darco G-60 powered activated carbon treatment. The results of the tests employing these substrates and treatments are tabulated in Table XX.

TABLE XX - EFFECT OF DIATOMITE TYPE ON FILTER EFFICIENCY

Sample Description	C.O.D. mg/l	C.O.D. % Red	B.O.D. mg/l	B.O.D. % Red	Coliform MPNx10^4	Coliform % Red	Total Solids mg/l	Total Solids % Red	Volatile Solids mg/l	Volatile Solids % Red
Bucklin Pt. - Inf.	501		260		1100		510		260	
B.P. - Eff. 545	432	13.8	230	11.5	43	96.1	385	24.5	190	26.9
B.P. - Eff. HSC	332	33.7	140	46.2	2.4	99.8	455	10.8	260	0
B.P.-Eff. SSC	228	54.5	175	32.7	0.04	99.9	425	16.7	275	0
B.P. (AC) Eff. 545	380	24.2	180	30.8	15	98.6	395	22.6	235	9.6
B.P. (AC) Eff. HSC	336	32.9	125	51.9	2.4	99.8	470	7.8	270	0
B.P. (AC) Eff. SSC	352	29.7	100	62.5	0.15	99.9	425	16.7	170	34.6
B.P.:S.E. - Inf.	383		210		460		485		260	
B.P.:S.E. - Eff. 545	244	36.3			93	79.8	270	44.3	130	50.0
B.P.:S.E.-Eff.HSC	240	37.3	155	26.2	4.6	99.0	410	15.5	235	9.6
B.P.:S.E.-Eff.SSC	228	40.5	90	57.1	0.23	99.9	445	8.3	280	0
B.P.:S.E. (AC) - Eff. 545	196	48.8	90	57.1	43	90.7	225	53.6	165	36.5
B.P.:S.E. (AC) - Eff. HSC	176	54.1	115	45.2	0.75	99.8	370	23.7	200	23.1
B.P.:S.E. (AC) - Eff. SSC	180	53.0	45	78.6	0.04	99.9	250	48.5	100	61.5

CODE:

B.P. - Bucklin Point Primary Effluent Sample.
B.P. - Eff. 545 - Sample after filtration through grade 545.
B.P. (AC) Eff. 545 - Sample after treatment with activated carbon and filtration through grade 545.
B.P.:S.E. - Inf. - A fifty-fifty mixture of Bucklin Point primary effluent and strainer effluent from synthetic substrate feed.
% Red - Percent Reduction

b. Filter Aid and Chemical Treatment Evaluation

(1) Activated Carbon Treatment

Continuing this study, the effect of diatomaceous earth filtration alone and aided by activated carbon was evaluated using three different composite samples of Sheridan Street overflow. This evaluation was performed according to the standard test procedure outlined in this report. Also, the activated carbon treatment was the same as that used previously, namely, 0.5 g/l Darco G-60 powered activated carbon.

The three influent samples were composites of (1) April 15, 1968, overflow Samples #1 through 8 as reported on Page16of this report, (2) April 24, 1968, overflow Samples #5 through 8 as reported on Page 17of this report. The results of this evaluation are tabulated in Table XXI.

(2) Polyelectrolyte Treatment

An initial screening of various polyelectrolyte flocculants was carried out employing nine different coagulants (3 each of anionic, cationic, and non ionic types) and 0.4 g/l dog food as substrate. Three dosage levels between 1.0 and 10.0 mg/l were tested with no visible coagulation noted. The nine possible cationic-anionic combinations were also evaluated at various dosage levels and visible coagulation was noted only with the following systems:

System	Cationic Polyelectrolyte	Anionic Polyelectrolyte
1	20 mg/l Calgon Cat-Floc	10 mg/l Dow Purifloc A-23
2	20 mg/l Dow Purifloc C-31	10 mg/l Dow Purifloc A-23
3	20 mg/l Alum	10 mg/l Dow Purifloc A-23

Primary effluent from the Bucklin Point, East Providence, Rhode Island municipal treatment facility was treated with the above three polyelectrolyte systems and then filtered through the three diatomaceous earth candidates previously selected. The filtration was carried out according to the standard test outlined above. The results of this "Diatomaceous Earth - Polyelectrolyte Study" are tabulated in Table XXII.

TABLE XXI - SHERIDAN STREET OVERFLOW - DIATOMACEOUS EARTH FILTRATION

Sample Description	C.O.D. mg/l	C.O.D. % Red	B.O.D. mg/l	B.O.D. % Red	Coliform $MPN x 10^4$	Coliform % Red	Total Solids mg/l	Total Solids % Red	Volatile Solids mg/l	Volatile Solids % Red
4/15/68-Inf.	127		62		460		250		145	
4/15/68-Eff.545	53	58.3	28	55	24	94.8	150	40.0	70	51.7
4/15/68-Eff.HSC	36	71.6			0.15	99.9	135	50.0	80	44.9
4/15/68-Eff.SSC	16	87.5	12	80	0.09	99.9	145	42.0	90	37.9
4/15/68-Eff.(AC)545	52	59.0	20	68	11	97.6	155	38.0	75	48.3
4/15/68-Eff.(AC)HSC	40	68.5	16	74	0.43	99.9	110	56.0	50	65.5
4/15/68-Eff.(AC)SSC	51	59.0			0.23	99.9	110	56.0	75	48.3
4/24/68(1-4)Inf.	158		75		1100		280		175	
4/24/68-Eff.545	92	41.8	50	33	24	97.8	165	41.0	85	51.5
4/24/68-Eff.HSC	64	59.5	30	60	0.43	99.9	100	64.4	50	71.5
4/24/68-Eff.SSC	40	74.8	16	79	0.04	99.8	60	78.5	35	80.0
4/24/68-Eff.(AC)545	68	57.0	26	65	15	98.6	215	23.2	135	22.8
4/24/68-Eff.(AC)HSC	48	69.6	18	76	2.4	99.7	155	44.7	80	54.3
4/24/68-Eff.(AC)SSC	60	62.0			0.09	99.9	120	57.2	80	54.3
4/24/68(5-8)-Inf.	109		55		43		210		125	
4/24/68 Eff.545	64	41.3	20	45	15	65.1	170	19.0	105	16.0
4/24/68 Eff.HSC	44	59.6	18	67	2.4	94.4	80	62.0	30	76.0
4/24/68 Eff.SSC	48	56.0			0.23	99.5	60	71.5	40	68.0
4/24/68-Eff.(AC)545	56	48.6	20	64	11	74.4	80	62.0	30	76.0
4/24/68-Eff.(AC)HSC	60	45.0	25	55	4.6	89.3	90	57.2	70	44.0
4/24/68-Eff.(AC)SSC	56	48.6	22	60	0.11	99.7	120	42.9	70	44.0

TABLE XXII - DIATOMACEOUS EARTH FILTRATION - BUCKLIN POINT PRIMARY EFFLUENT

Sample Description	C.O.D. mg/l	C.O.D. % Red	B.O.D. mg/l	B.O.D. % Red	Coliform mg/l	Coliform % Red	Total Solids mg/l	Total Solids % Red	Volatile Solids mg/l	Volatile Solids % Red
Inf. A	748		335		460		980		400	
Eff. A 545	428	42.8	305	8.9	93	79.8	495	49.5	265	33.8
Eff. A HSC	328	56.2			4.6	99.0	415	57.7	210	47.5
Eff. A SSC	124	83.4			0.23	99.9	265	73.0	185	53.8
Eff. $A_1$545	560	25.1	280	16.4	43	90.7	565	42.3	335	16.3
Eff. A_1HSC	568	24.1			2.4	99.5	160	83.7	85	78.8
Eff. A_1SSC	376	49.7			0.04	99.9	300	69.4	175	56.3
Eff. $A_2$545	500	33.2	190	43.2	15	96.7	520	46.9	310	22.5
Eff. A_2HSC	204	72.7			2.4	99.5	235	76.0	160	40.0
Eff. A_2SSC	240	67.9			0.15	99.9	300	69.4	175	56.3
Eff. $A_3$545	484	35.3	270	19.4	43	90.7	400	59.2	300	25.0
Eff. A_3HSC	448	40.0			0.75	99.8	440	55.1	275	31.3
Eff. A_3SSC	116	84.5			0.04	99.9	180	81.6	120	70.0

Code:

A_1, A_2, A_3 -- signify polyelectrolyte systems 1, 2, or 3 were used as described on Page 31

2. Self-Cleaning Strainer - Vacuum Modified

Although the proposal and contract did not specify working model evaluation of either a strainer or filter, changes were made in the strainer model to permit additional evaluation of filter aid filtration under vacuum filtration.

Initially, three runs were made under continuous flow conditions to evaluate three diatomite samples at the same load conditions. These initial results are presented in Table XXIII below at the following flow rates: (1) HSC at one liter per hour,(2) 545 at one gallon per hour, and (3) 560 at one liter per hour. The values listed as filtered effluent were obtained on the effluent samples after filtration through a 0.45 micron membrane filter.

TABLE XXIII - VACUUM MODIFIED FILTER RUNS WITH MODEL STRAINER

		C. O. D.		
Type	Running Time	Influent	Effluent	Filtered Effluent
HSC	8 hrs.	396	170	125
	16 hrs.	396	143	113
HSC	32 hrs.	554	131	97
545	4 hrs.	305	131	103
	8 hrs.	580	165	111
	16 hrs.	626	145	133
	20 hrs.	626	143	117
545	24 hrs.	288	80	66
	28 hrs.	288	92	74
560	8 hrs.	336	66	58
	16 hrs.	304	65	47
	24 hrs.	304	59	47

The results shown below were obtained using a constant body feed of five percent with the cake thickness gradually increasing from 1/64" to 3/32" during each run.

Flow Rate		Run Length	B.O.D.		C.O.D.		Coliform	
gpm/ft^2	Filter Aid	(Hrs)	In	Out	In	Out	In	Out
3.70	Hyflo Super Cel	0.5	85	35	240	74	4,600,000	43,000
4.10	Celite 545	0.5	68	32	133	70	2,400,000	430,000
1.85	Filter Cel	1.0	87	36	182	77	4,600,000	43,000

A second series of runs were made at a constantfilter aid drum thickness of 3/32 of an inch. In both instances the waste source was obtained from the influent at the Bullocks Point Treatment Plant in East Providence, Rhode Island, and was diluted with three parts of tap water.

Flow Rate gpm/ft^2	Filter Aid	Run Length (Hrs)	B.O.D. In	B.O.D. Out	C.O.D. In	C.O.D. Out	Coliform In	Coliform Out
3.70	545	0.5	110	42	282	98	4,600,000	240,000
3.70	HSC	0.5	90	38	253	86	11,000,000	750,000
0.92	Filter Cel	2.0	124	49	341	102	11,000,000	93,000

As a measure of potential efficiency, the samples taken during the runs shown above were filtered through 0.45 micron membrane filters. These results are shown in Table XXIV.

TABLE XXIV - DISSOLVED ORGANIC CONCENTRATION IN FILTERED EFFLUENT

Filter Aid	C.O.D. Effluent	C.O.D. Filtered Effluent
HSC-1	74	70
545-1	70	61
Filter Cel-1	77	63
HSC - 2	86	78
545 - 2	98	75
Filter Cel-2	102	98

Following the apparent success achieved in obtaining reasonable flow rates under adverse conditions, a number of extended runs were attempted at a fixed filter aid thickness of 3/32 of an inch using Hyflow Super Cel.

TABLE XXV - MODIFIED FILTER RUNS - HYFLOW SUPER CEL

Flow Rate gpm/ft^2	Run Length (Hrs)	B.O.D. In	B.O.D. Out	C.O.D. In	C.O.D. Out	Coliform In	Coliform Out
3.70	3	51	27.0	144	47	2,400,000	240,000
3.70	4	51	18.0	144	55		
1.54	4	51	17.5	144	75	2,400,000	93,000
1.23	4	51	16.0	144	63		
0.92	4	93	20	380	50	4,600,000	430,000
0.92	4	93	28	380	61		
0.92	4	93	14	380	85	4,600,000	430,000

Additional runs were performed but a very rapid fall off in flow rate was observed. In the space of 6 hours, in one instance, the flow dropped from 3.70 gpm/ft^2 to 0.123 gpm/ft^2 when operating at a fixed aid thickness.

IV. Discussion of Results

A. Site Analysis

Two significant factors were isolated concerning the characteristics of the overflows occurring at the particular site used for observation and analysis. The first, that during the periods of significant organic loadings that seventy to eighty percent of this load was represented by suspended solids larger than one sixteenth of an inch. This was caused by the presence of human feces (which had not been mechanically disintegrated) individual pieces of toilet and facial tissue (not individual fibers as found in the influent to most treatment plants), and kitchen wastes.

This result should not be surprising in view of what has been documented previously. As stated earlier, it had been found that the first flush in a combined sewer overflow system could contain a very high solids content as a result of settling during dry weather flow. This type of result was indeed verified by the January 30, 1968 samples. In contrast, the samples obtained on February 2, 1968, did not contain an appreciably higher solids content in the first flush as was found with the samples a few days earlier. The load contributed by material that had been settled in the lines naturally will be almost entirely suspended solids.

The physical characteristics of the solids obtained during the first flush should be and were found to be quite different from those samples later during an overflow. Bacterial action and particularly hydrolysis reactions create solids which are readily disintegrated during and by the turbulence created by the flow of water which sweeps them out of the sewer system. Soluble organic compounds which are produced by bacterial action in the settled sewage are continually removed by the water during dry-weather flow conditions, therefore, only insoluble or suspended organic solids are left behind waiting for the first rapid change in flow conditions.

After the first flush, the solids which reach the overflow are fresh solids, such that little or no time has elapsed for hydrolysis reactions to occur to any appreciable extent. This was verified by comparing the physical state of toilet paper at the overflow site with that found at the Bullock's Point Treatment Plant in East Providence, Rhode Island. One of the main influent sewer lines reaching this plant does not contain any pumping installations, so that any mechanical action on solids is entirely due to the hydraulic situation. Very careful examination of this particular stream showed practically no toilet tissue in discernable form. On the other hand, most of the overflows contained a great deal of whole pieces of toilet tissue.

The second most important factor determined relates to sampling methods for the collection of data on combined sewer overflows. The previous discussion points out that the characteristics of the suspended solids present in an overflow can change markedly with time. The vertical distribution of solids in the flowing stream changes with time for a particular flow rate. During the first flush most of the solids are below the surface, whereas most of the fresh solids are near the surface. The nature of the solids and their distribution across a cross section of flow would appear to preclude the usual type of automatic sampling device. Any system which uses a sampling tube approximately one-half inch in diameter cannot be expected to provide a suitable representative sample for analysis. Fresh solids and toilet paper which represent a very high load per unit volume are most certainly missed by most automatic sampling methods used to date.

Additionally, there are two conflicting factors to consider when evaluating the merits of a sampling system. First it is important to obtain the sample without mechanical action. Second, because of high flow rates a large sample should be taken in order to have any hope for a "representative" sample - which almost certainly implies the use of a pump. This project has only raised these two points - it has not solved them.

With regard to the exact load contributed to a receiving stream by an overflow, this paper can only provide a guideline. For an overflow in an area which is 80 percent (or greater) residential, the total load can be approximated by multiplying the total overflow volume by an average B.O.D. value of 120 mg/l.

B. Self-Cleaning Strainer Effectiveness

The flat sheet testing and analysis as described on Page 20, Table VII, statistically showed that: (1) the synthetic substrate could be reproducibly prepared; (2) the 80 x 80 and 100 x 100 mesh screens gave essentially the same result; (3) the 60 x 60 mesh screen would be significantly different at the 1 percent level from the 80 x 80 mesh screen in suspended solids removal, (60, 80, 100 mesh=230, 190, 150 microns, respectively).

The data in Table X, page 23, was statistically analyzed and it was shown that the influent flow rate to backwash flow rate ratio was not significant for those tested, when using the synthetic substrate. The result found with the flat sheet tester was also true with model strainer. No significant difference between the 80 x 80 and 100 x 100 mesh screens, but a definite statistical difference between the 60 x 60 and 80 x 80 mesh screens. While these particular results are specific for the synthetic substrate, they do relate to the results found with sewage plant influent, fresh sewage and actual stormwater overflow.

Of the four sources of sewage tested, the influent to the Bullock's Point Treatment Plant was the most difficult to treat. The data in Table e in the Appendix was calculated to show the percent suspended solids and C.O.D. removed. Additionally, the suspended solids C.O.D. was determined in the influent and effluent samples. Since the strainer is designed to remove only suspended matter, its efficiency was calculated on this basis in Table XXVI.

Data obtained in this project indicated that 90 percent of the B.O.D. found in the overflow discharges was exerted by suspended matter. On the other hand, the primary influent to the two nearby treatment plants have only 50-70 percent of the total B.O.D. present in suspended form. The last column in Table XXVI was calculated, therefore, on the basis of the C.O.D. exerted by the suspended solids retained by 0.45 micron membrane filter as follows for line 1 in the Table.

$$\% \text{ Removed} = \frac{(437-196) - (390-231)}{(437-196)} \times 100 = 33$$

These results are generally more in line with the suspended solids removal efficiency than the raw data indicated.

The most significant difference found between these results and those obtained with fresh solids was the ratio of effluent flow to sump discharge flow that was permissable. At the same inlet to backwash flow ratio, the inlet to effluent flow was 7/4 at Bullock's Point versus 7/6.5 with fresh solids.

Overall, the model strainer showed very consistent results with each type of waste under widely fluctuating conditions. The Bucklin Point data show that with the 60 x 60 mesh screen an average of 46 percent removal of suspended solids was accomplished over a 43 hour period when the level varied from 60 to 465 mg/l of suspended solids. The 100 x 100 mesh screen gave an average of 53 percent removal over a 34.5 hour operating period when the level varied from 40 to 255 mg/l of suspended solids.

TABLE XXVI - MODEL STRAINER RESULTS - BULLOCK'S POINT TREATMENT PLANT

60 x 60 MESH
(230 Microns)

Running Time	Suspended Solids		C. O. D.				
			Influent		Effluent		% Removed
Total Hours	Influent	% Removal	As Is	Filtered	As Is	Filtered	Filterable
0.5	85	35	437	196	390	231	33
1.5	510	45	768	208	574	208	35
3.0	260	56	621	216	510	225	30
4.5	90	48	504	225	480	255	20
6.0	80	32	482	235	394	223	30
11.0	440	52	525	124	414	118	26
15.0	1415	56		276	1430	267	
19.0	425	25	841	192	692	225	28
23.0	660	68	792	267	719	202	
27.0	345	29	790	204	545	225	45
31.0	255	47	625	186	525	186	23
35.0	205	59	655	290	498	222	25
39.0	165	43	600	225	514	223	22
43.0	235	60	666	263	490	218	32
47.0	175	29	545	167	467	218	34

C. Self-Cleaning Filter Effectiveness

The most obvious and straight-forward results are those that were obtained with the polyelectrolyte-ion exchange systems. It is quite clear that the fluctuating flows and concentrations make the use of such chemical pretreatment systems impractical with a diatomite system. Even with carefully controlled laboratory systems, the results were not sufficiently positive to encourage further work in this direction.

The trends visible in C.O.D. and B.O.D. reduction shown in Table XX suggest the use of low porosity diatomaceous earth for this type of application. Excellent reductions in coliform level were obtained, however, with all grades of diatomite. The results obtained with powdered activated carbon indicate its applicability only with the more porous diatomite. While this appears to be an anomaly, it is undoubtedly due to the resulting change in porosity of the filter cake due to the carbon. The standard Super Cel has, according to the manufacturer, 50 percent by weight of its particles seven microns or less. The Darco G-60 has 30 percent of its particles larger than 44 microns with the distribution between 44 and 7 microns unknown. The activated carbon, therefore, produces a more porous cake when mixed with SSC or HSC grades of diatomite.

The formula provided by the manufacturer suggests that at the operating conditions used to obtain the data in Table XXI, the cost of operating the system would be greater than $1.50 per 1000 gallons of water treated. The data shown on Pages 34 and 35 indicate that the costs could be lowered if the diatomite could be reused and it would not disintegrate with repeated usage.

V. References

1. Baumann, E.R; Cleasby, J.L; & LaFrenz, R.L. - A Theory of Diatomite Filtration. Journal AWWA, 54:1109 (September 1962).

2. Baumann, E.R; Cleasby, J.L; & Morgan, P.E. - Theoretical Aspects of Diatomite Filtration. Water and Sewage Works, 111:229, 290, 331 (1964).

3. Bell, G.R. Design Criteria for Diatomite Filters, Journal AWWA, 54:1241 (October 1962).

4. Baumann, E.R. & LaFrenz, R.L. Optimum Economical Design for Municipal Diatomite Filter Plant. Journal AWWA 55:48 (January 1963).

5. Eckenfelder, W.E. - Proceedings 21st Purdue Industrial Waste Conference, Lafayette, Indiana, 1964, p. 427.

6. Spade, J.F; Treatment Methods for Laundry Wastes, Water & Sewage Works, 109, 110 (1962).

7. Boucher, P.L; Evans, G.R. Micro-Straining - Description and Application, Water and Sewage Works, 1963.

8. Hudson, W., Performance of Wire Filter Cloth in Self-Cleaning Strainers - unpublished internal report - Fram Corporation, June 1966.

9. Evans, G.R; Treatment of Water Supplies by Micro-Straining, J. New Hampshire Water Works Association, December 1962.

10. Fram Self-Cleaning Strainer Field Test - Weldwood of Canada, Quenelle, British Columbia.
    Test Duration: Spring and Summer, 1966
    Operation: Straining of make-up water for paper board plant.
    Water Source: Raw river water.
    Contaminant: Small fish, dirt, and sediment.
    Screen Area: 350 in.^{2} 50 x 250 plain Dutch Weave.
    Test Flow: 200 GPM
    Contaminant Removal Efficiency: 100% 40 microns and larger.
    No clogging of screen experienced.

References (Continued)

11. Fram Self-Cleaning Strainer Field Test - Suntide Refining Company. Corpus Christi, Texas.
Test Duration: 1968 - 1969
Operation: Straining of cooling tower water.
Contaminant: Airborne dirt and algae.
Screen Area: 1,000 $in.^2$ 50 x 250 plain Dutch Weave
Test Flow: 750 GPM
Contaminant Removal Efficiency: 100% over 45 microns
No clogging of screen during test, to date.

12. Summary Report - Advanced Waste Treatment (WP-20-AWTR-19), 1968

13. Bell, G.R.; Hutto, F.B.; Analysis of Rotary Precoat Filter Operations - New Concepts, Chemical Engineering Progress 54:69 (1958)

14. Description of Johns-Manville Rotary Precoat Filter Test Leaf. Published by Johns-Manville Research Center, Manville, N.J.

VI Appendix

Table a

Synthetic Substrate Characteristics

Concentration gms/s	C.O.D. mg/l	Suspended Solids, mg/l	Settleable Solids, ml/l	B.O.D. mg/l
1.0	990	550	6	-
1.0	1085	563	5.8	-
1.0	1069	613	-	-
0.4	416	248	2.25	-
0.4	423	270	-	-
0.4	439	265	1.90	162
0.4	455	276	-	182

Table b

Raw Data For Table IX Calculated Results
Self-Cleaning Strainer - Synthetic Substrate
60 x 60 Mesh Square Weave Screen
Pore Size - 230 Microns

Run No.	Suspended Solids, mg/l Batch No. 1	2	3	4	5	6
1 - In	169	184	165	165	256	158
Out	63	150	145	115	125	110
2 - In	120	173	109	98	113	109
Out	50	75	40	45	35	30
3 - In	240	120	73	180	86	105
Out	185	25	20	105	70	90
4 - In	133	159	197	206	172	197
Out	115	130	160	170	155	150
5 - In	143	154	193	186	186	143
Out	90	75	95	80	80	80
6 - In	125	104	132	154	143	89
Out	100	90	70	85	95	80
7 - In	154	179	138	125	154	196
Out	105	155	65	80	105	130
8 - In	109	92	163	213	117	267
Out	75	80	100	95	90	105

Table c

Raw Data For Table X Calculated Results

Self-Cleaning Strainer - Synthetic Substrate

		Suspended Solids						B.O.D.						C.O.D.					
		Batch No.						Batch No.						Batch No.					
Run No.		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
1263-48	In	113	146	161	135	191	225	105	101	105	95	185	105	365	403	368	306	255	345
	Out	105	115	125	90	130	220	75	75	100	79	94	85	251	310	317	302	344	332
1263-49	In	176	165	143	139	169	176	94	86	79	101	117	113	327	351	375	246	378	381
	Out	125	135	90	115	110	110	65	70	50	100	110	110	328	328	312	320	333	352
1263-46	In	129	137	163	129	189	155	163	180	189	214	206	189	378	408	444	398	401	432
	Out	70	70	95	95	85	95	190	210	190	180	170	180	361	333	337	314	357	368
1263-47	In	172	176	193	193	228	193	189	189	190	240	206	189	357	396	373	388	432	388
	Out	145	65	140	130	170	170	180	180	189	190	180	150	337	302	341	356	349	345
1275-1	In	175	154	161	196	154	161	185	165	165	180	147	165	423	392	321	317	304	392
	Out	100	100	115	90	100	130	165	147	143	164	145	164	332	308	272	280	288	304
1275-2	In	129	125	132	143	172	132	170	175	221	150	132	129	258	349	338	361	417	358
	Out	90	95	70	90	120	95	168	164	145	135	130	125	300	284	300	316	300	284
1275-3	In	154	171	171	150	188	140	180	160	175	160	170	170	405	375	392	405	385	375
	Out	70	115	125	115	145	134	158	158	158	150	150	158	344	344	256	348	324	352
1275-4	In	191	224	204	196	175	280	-	-	-	-	-	-	418	452	448	418	392	395
	Out	140	155	125	160	180	170	-	-	-	-	-	-	336	336	336	328	336	340

Operating Sequence of Self Cleaning Strainer-Filter System

The proposed combined filtration/purification system contains a number of rather sophisticated parts. The function of each is outlined in the following operational sequence description. This review should be made with reference to the schematic drawing attached. As previously stated, the system is completely automatic. All components making up the system are commercially available. However, modifications may be necessary in some cases to adapt the particular components to the specific problem.

Power Supply

To use the proposed system, an adequate source of electricity is required. This will require the use of the public utility system and when required the construction of extension lines and transformers. For a test site demonstration, a portable engine-powered electrical generator would be rented to provide electrical power.

Influent Supply System

It is proposed that the overflow water be pumped from the supply source; in this case, the previously mentioned receiving basin. The suction hose, equipped with a large opening strainer screen, would be placed in the receiving basin. To prevent clogging by large debris such as tree limbs, timbers, rags, etc., the screen strainer would be surrounded by a large mesh or bar screen cage.

The influent pump, of a centrifugal type, provides the supply water to the self-cleaning strainer. Level controls placed in the basin reservoir activate the influent pump motor, and in turn, the remainder of the filtration equipment at a pre-selected level in the basin. As the water level declines to normal, the influent pump stops, thereby placing the remainder of the system on a standby status.

Self-Cleaning Strainer

The water would be pumped into the self-cleaning strainer, in the normal manner, in which the strainer screen support basket would be continuously rotating and backwashing the deposited solids of 50 microns or greater. As the differential pressure builds up across the strainer, the blowdown system would operate automatically and discharge collected solids to a portable receiving bin which may be removed from the test site and dumped at the municipal sanitary fill.

Flow Control Mechanism (Valves V1, V2 and V5)

The flow control valves, as shown, would be throttled by the pilot valve mechanism working off of the float level control in the self-cleaning filter unit. In other words, if the liquid level within the self-cleaning unit begins to rise above the desired level in the filter case, the discharge from the influent pump would be throttled. At the same time the discharge of the self-cleaning strainer would be throttled until such time as the effluent pump could withdraw the liquid as fast as it is being pumped into the unit. This balanced system would be established to maintain a constant liquid level in the self-cleaning filter unit downstream of the self-cleaning strainer.

Diatomaceous Earth Injector System

A small portion of the flow stream from the effluent side of the self-cleaning strainer would be continuously circulated through an open funnel arrangement on the suction side of the diatomaceous earth injection pump. The liquid level in the funnel system would be automatically controlled by the float mechanism operating Control Valve V-3. In this manner, the injection system would be ready at all times to receive injected portions of diatomaceous earth or activated carbon or any other type of filter aid or powdered chemical treatment. If a liquid chemical agent would be desirable, a Wallace-Tiernan type pump would have to be added.

Self-Cleaning Filter

As shown in the schematic diagram, the self-cleaning filter basket would be mounted on external bearings, which in this case, are not required to seal against any high pressure and are not required to maintain continuous rotation. The basket would be covered with any changeable type of filter cloth such as Dacron, Teflon, nylon or other conventional filter cloth materials which can be readily sealed at the ends of the support basket. The flow is directed into the filter body and the level controlled as previously discussed. As the contaminated liquid enters the filter housing, it will be drawn through the filter cloth when the liquid level reaches the float to open Valve 16. As there would be no filter aid now in contact with the filter cloth, the turbidity meter would sense a contaminated stream and the following sequence would then take place:

a. The turbidity meter sensing the contaminated stream would close Solenoid Valve V-7 and open Solenoid Valve V-8 to direct the flow back to the inlet side of the filter case.

b. Simultaneously with this operation, the signal from the turbidity meter would also actuate the vibrating system for the diatomaceous earth storage tank and open Valve V-4 to inject the precoat material into the diatomaceous earth injection system. This material would then be deposited on the filter cloth. The filtration unit would continue to bypass until such time as the filter precoat had been established on the filter cloth sufficiently to permit a clear effluent, at which time the Solenoid Valve V-8 would close and V-7 would open discharging a clean effluent, through the cnlorinator, to the water system. At the same time, the signal from the turbidity meter would cut off the vibrating hopper on the diatomaceous earth injection system and close Valve V-4.

<u>Self-Cleaning Filter Backwash Cycle</u>

When the contamination level builds up across the filter cloth in sufficient quantity, the suction pressure on the effluent pump will decrease. The effluent control switch S-1, in the suction line of this pump, will sense this condition and the following sequence will take place simultaneously:

a. The rotary drum filter cloth drive system will be automatically energized; rotating the basket through approximately 120° to expose a clean section of the cloth to again permit full flow.

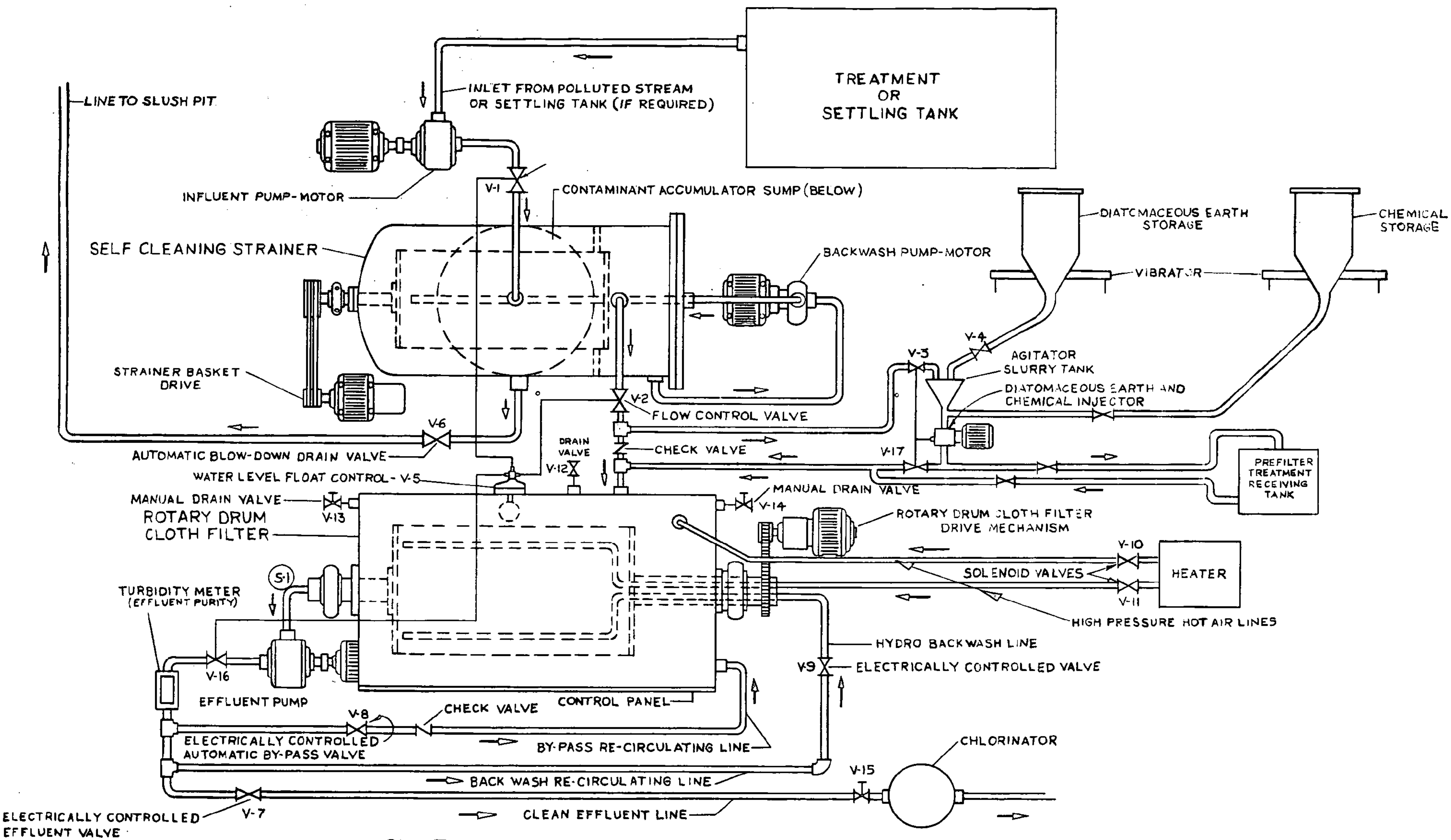
b. The high pressure nozzle will be energized, opening Vavle V-1, "ballooning" the cloth outward against the adjustable rubber scraper blade and directing the spent diatomaceous earth cake to the discharge conveyor. The spent material is conveyed to a portable receiving bin.

c. Following the scraper, Valve 9, actuated by the S-1 switch, opens to allow flow of high pressure water through the hydraulic nozzles to remove any remaining traces of contaminant from the cloth. The flow rate will immediately increase as the clean filter cloth is exposed to the liquid. The effluent contamination will increase causing tne turbidity meter to again energize the diatomaceous earth feeder for additional precoat and bypass back to the unfiltered side of the unit.

d. The backwash air stream will be directed through the nozzles (as in Step 7b) by closing Valve 10 on the heater-blower unit and opening Valve V-11. In normal operation (not backwash) the heater-blower unit will circulate a high-flow warm air stream through the upper portion of the filter cloth which is above the liquid level. The air flow will be in the outside-in direction to prevent the premature rupture of the filter cake.

Chlorinator

This would be a conventional device of the Wallace-Tiernan type or equivalent and would be employed to feed sufficient chlorine to maintain a desired residual chlorine content in the water effluent.



SYSTEM SCHEMATIC FLOW DIAGRAM

Table d

MODEL STRAINER RESULTS - BULLOCK'S POINT SEWAGE TREATMENT PLANT - 60 x 60 MESH SCREEN, 230 MICRON OPENING RAW INFLUENT, FLUX RATE 25 GPM/FT^2

Running Time	Suspended Solids		C. O. D.	
Total Hours	Influent	% Removal	Influent	Effluent
0.5	85	35	437	390
1.5	510	45	768	574
3.0	260	56	621	510
4.5	90	48	504	480
6.0	80	32	482	394
9.0	180	52	---	---
11.0	440	52	525	414
15.0	1415	56	---	---
19.0	425	25	841	692
23.0	660	68	792	719
27.0	345	29	790	545
31.0	255	47	625	525
35.0	205	59	655	498
39.0	165	43	600	514
43.0	235	60	666	490
47.0	175	29	545	467

Table e

MOUEL STRAINER RESULTS - BULLOCK'S POINT TREATMENT PLANT
60 x 60 MESH SCREEN, 230 MICRON OPENING, DOWNSTREAM OF
BAR SCREENS, 25 GPM/FT^2

Running Time	Suspended Solids		C. O. D.	
Total Hours	Influent	Effluent	Influent	Effluent
48	375	175	538	436
49	230	125	530	474
50	170	50	540	450
51	485	290	468	358
52	325	230	760	704
53	840	660	1504	852
54	425	120	1464	850
55	175	60	460	400
56	270	115	540	456