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Study of Activated Sludge Separation by Dynamic Straining

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June 1978

STUDY OF ACTIVATED SLUDGE SEPARATION BY DYNAMIC STRAINING

by

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Contract No. 68-03-0427

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

As part of these activities, the study described herein presents a pilot-scale evaluation of the feasibility of replacing or supplementing conventional secondary gravity clarifiers in the activated sludge process with dynamic strainers equipped with ultrasonic transducers, in conjunction with sand filtration.

Francis T. Mayo, Director
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ABSTRACT

Pilot plant studies were conducted on domestic wastewater to determine the feasibility of replacing or augmenting conventional activated sludge gravitational clarifiers by dynamic straining. This work was a continuation of the successful program accomplished under EPA Contract No. 68-03-0102. In the prior program, two dynamic strainers in series were employed. In this program, less expensive techniques for polishing the primary strainer effluent were investigated.

Phase I covered pilot operations with the strainer in the aeration tank of an activated sludge plant producing a nitrified effluent. Phase II involved a non-nitrified effluent. In both phases, upflow and downflow sand filtration, settling, and flocculation-settling of the strainer effluent were investigated.

Phase I flows were low but correlated well with the previous studies of strainer operating variables. Strainer effluent averaged 35 mg/l suspended solids with mixed liquor suspended solids (MLSS) of 6800 mg/l. The upflow and downflow sand filters, operating on strainer effluent, produced effluents of 8 and 3 mg/l suspended solids, respectively.

Phase II, which called for high flows and high BOD loadings, was plagued with an intense growth of filamentous microorganisms, foaming, and development of a "syrupy" mixed liquor. Proper strainer throughputs could not be maintained. Flow rates were not reproducible and did not correlate with prior work.

A special Phase III program extended the effort and determined that the equipment was functioning properly. However, maximum achievable flows were still disappointing and could not be correlated with the prior study. These findings cast doubt on the ability of the strainer to achieve economically significant throughputs in a variety of process situations.

This report was submitted in fulfillment of EPA Contract No. 68-03-0427 by the FMC Corporation, Environmental Equipment Division, under the sponsorship of the U.S. Environmental Protection Agency. This report covers experimental work conducted during the period of May - December 1974.

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ACKNOWLEDGEMENTS

The support of the project by the Municipal Environmental Research Laboratory (MERL), Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio, and the assistance of the Project Officer, Mr. Richard C. Brenner, are acknowledged with sincere thanks. The efforts of Mr. Robert P.G. Bowker of MERL, who assisted in the review of this report, are also acknowledged.

SECTION 1

INTRODUCTION

The treatment capacity of an activated sludge plant is most often limited by the secondary clarifier. As the volumetric BOD loading increases, the MLSS concentration under aeration must be gradually increased to maintain the organic (F/M) loading within the desired operating range. However, an increase in MLSS concentration leads to a proportional increase in mass (solids) loading on the secondary clarifier. At some point, the solids loading on the secondary clarifier will begin to exceed the sludge thickening capability of that unit, necessitating a reduction in MLSS level and resulting in a higher than desired F/M loading. This in turn may result in decreased removal of soluble organics and poor biomass settling characteristics. Poor sludge settling characteristics can also result from a predominantly filamentous sludge, even though this type of sludge can yield efficient soluble BOD removal. These problems suggest that a better method of liquid/solids separation would result in greater treatment plant capacity and reliability.

Pilot plant studies (1) have indicated that straining, which is not dependent on the settleability of the solids involved, could be used as an alternative or supplement to gravitational settling to separate activated sludge solids. FMC Corporation has been investigating the process of straining for about 7 yr. The dynamic strainer, which evolved from this work about 4 yr ago, has been used for several different applications. For low suspended solids conditions, it was tested on municipal treatment plant and aerated lagoon effluents. The strainer has also been used to strain the mixed liquor resulting from the treatment of cheese whey. This represented an application of a high suspended solids condition.

Beginning in November, 1972, under sponsorship of the U.S. Environmental Protection Agency, an initial contract, No. 68-03-0102, entitled "Replacement of Activated Sludge Secondary Clarifiers by Dynamic Straining" was awarded to FMC Corporation to investigate the use of straining to separate activated sludge solids (1). The results of this study indicated that commercially acceptable specific flow rates of up to 8 $l/sec/m^2$ of filtering surface (12 gpm/ft^2) could be obtained using a nominally rated 10-μ stainless steel micromesh fabric with a MLSS concentration of 6500 mg/l.

During the above study, a secondary strainer was evaluated for reducing the concentration of suspended solids in the primary strainer effluent. The primary strainer effluent contained an average of 46 mg/l suspended solids over 1 mo of non-steady state operation. These solids were reduced to an average of 23 mg/l by the secondary strainer without additional flocculation or chemical treatment. Even though the secondary strainer was capable of producing an effluent of acceptable quality, the relatively small amount of solids passing through the primary strainer indicated that other less costly methods of clarification of the primary strainer effluent might be applicable. This potential improvement in process economics led to further pilot plant investigations and subsequent generation of this report under EPA Contract No. 68-03-0427.

The study consisted of two phases; Phase I - steady state operation of the strainer in activated sludge which was producing a nitrified effluent, and Phase II - steady state operation of the strainer in activated sludge which was not producing a nitrified effluent, i.e., a system with a high BOD loading. During both phases, the strainer effluent suspended solids were characterized as to concentration, volatile fraction, particle size, physical appearance, etc. Several additional means of removing the residual colloidal and suspended solids were examined. These included upflow sand filtration, downflow sand filtration (coal over sand), gravitational settling, and flocculation followed by gravitational settling.

SECTION 2

CONCLUSIONS

1. Dynamic straining is indicated to be a technically feasible process to replace or augment conventional activated sludge gravitational clarifiers. A reasonably firm data base, however, exists only for low throughput applications, where low specific flow rates of 1.4 - 2.7 l/sec/m^2 (2-4 gpm/ft^2) require a limited number of strainers (1 or 2 units) with plant flows below 3785 m^3/day (1 mgd). Under these flow conditions, suspended solids removals of 99 percent can be achieved with strainers operating in mixed liquor with MLSS levels in the range of 6000-7000 mg/l.

2. Further treatment of the strainer effluent by upflow or downflow sand filtration or chemical or autoflocculation-settling will achieve final effluent suspended solids below 10 mg/l.

3. The data are inconclusive on the maximum flow rates achievable with the strainer and the ability of the equipment to sustain high specific flow rates. Operating set points from prior equipment characterization studies (1) are reproducible at low specific flow rates of 1.4 - 2.7 l/sec/m^2 (2-4 gpm/ft^2) and can be sustained in long term operations.

4. Set point conditions for the more economically significant specific flow rates of 6-8 l/sec/m^2 (9-12 gpm/ft^2) have not been determined to be reproducible or capable of being sustained in long term operations.

5. The above specific flow rate restriction would require about three times the number of strainers for a particular application than believed necessary from the prior studies. This more than offsets any economic advantages gained by replacing secondary strainers for polishing primary strainer effluent with sand filters or flocculator-clarifiers. Under these conditions, the strainer cannot economically or operationally compete with conventional approaches to hydraulic and biological upgrading. The low-flow applications, where the strainer may be competitive, probably so seriously limit the market that continued development expense does not seem justified. Even if higher specific flow rates could be achieved, the principle market is still only in the vicinity of 3785 m^3/day (1 mgd).

6. Although there are many interesting technical applications for the strainer (control of bulking, upgrading, etc.), the current state-of-the-art does not warrant attempts to develop comprehensive cost estimates

for this report. Preliminary cost estimates were presented in the report of the initial feasibility study, EPA Contract No. 68-03-0102.

SECTION 3

RECOMMENDATIONS

1. In view of the conclusions discussed in Section 2, it is recommended that development work on the strainer for direct mixed liquor straining be terminated.

2. If satisfactory cases can be made for other possible strainer applications, consideration should be given to further work and the cost/benefit of that work in light of total development cost. This would include engineering, prototype construction and testing, and tooling for production.

SECTION 4

DESCRIPTION OF EQUIPMENT

The dynamic strainer unit used in this study consists basically of four parts as shown in Figure 1: the supporting drum basket, the micromesh fabric, the ultrasonic cleaning transducer, and the drive unit. A sketch of the dynamic strainer installation utilized on this project is shown in Figure 2. Photographs of the strainer and sand filter installations are presented in Figures 3 and 4, respectively.

The 0.61-m (2-ft) diameter by 0.61-m (2-ft) high inner expanded metal drum basket supports the strainer fabric while allowing the liquid to pass through to the inside. The fabric was resistance welded to the expanded metal backing and sealed against leaks by a silicone rubber based adhesive. Only one stainless steel fabric was used in this study. The cloth specifications are: nominal micron rating 10, absolute micron, rating 15-18, nominal mesh count (openings/inch, warp x shoot) 850 x 155, and wire diameter in inches (warp x shoot) 0.0012/0.004. The fabric is designated Robusta Reverse Dutch Weave and is supplied by Kressilk Products, Inc., Monterey Park, California. The cloth was determined to give superior performance in the previously performed contract.

The ultrasonic transducer is located inside the basket and mounted on the stationary axle. The power for this unit is supplied by an ultrasonic generator located remotely in a control cabinet. The transducer is exposed to the full vertical length of the cloth. The ultrasonic energy excites the fabric and sheds the solids back into the liquid reservoir. The cloth is completely cleaned each revolution as the basket rotates past the stationary transducer. This cleaning method is very simple, economical, and reliable.

The basket and strainer fabric are rotated by a 2.2-kw (3-hp) electric motor attached to a variable speed drive unit. This unit provides a maximum rpm of 180 and a minimum rpm of 30. The rotational effect of the strainer also helps to keep the fabric free of solids buildup.

The strainer unit is supported by brackets made of angle iron mounted on top of the activated sludge aeration basin. The strainer is connected to the effluent piping with the use of a WECO Air-O-Union seal. This allows the strainer to be installed without draining the tank. The seal is then inflated to 42,000-56,000 kgf/m^2 (60-80 psig) to secure the strainer outlet pipe. The wastewater flow passes through the fabric and discharges through the outlet pipe to a standpipe outside the tank. The standpipe maintains a water level in the strainer sufficient to keep the ultrasonic unit submerged, allowing effective cleaning of the fabric.

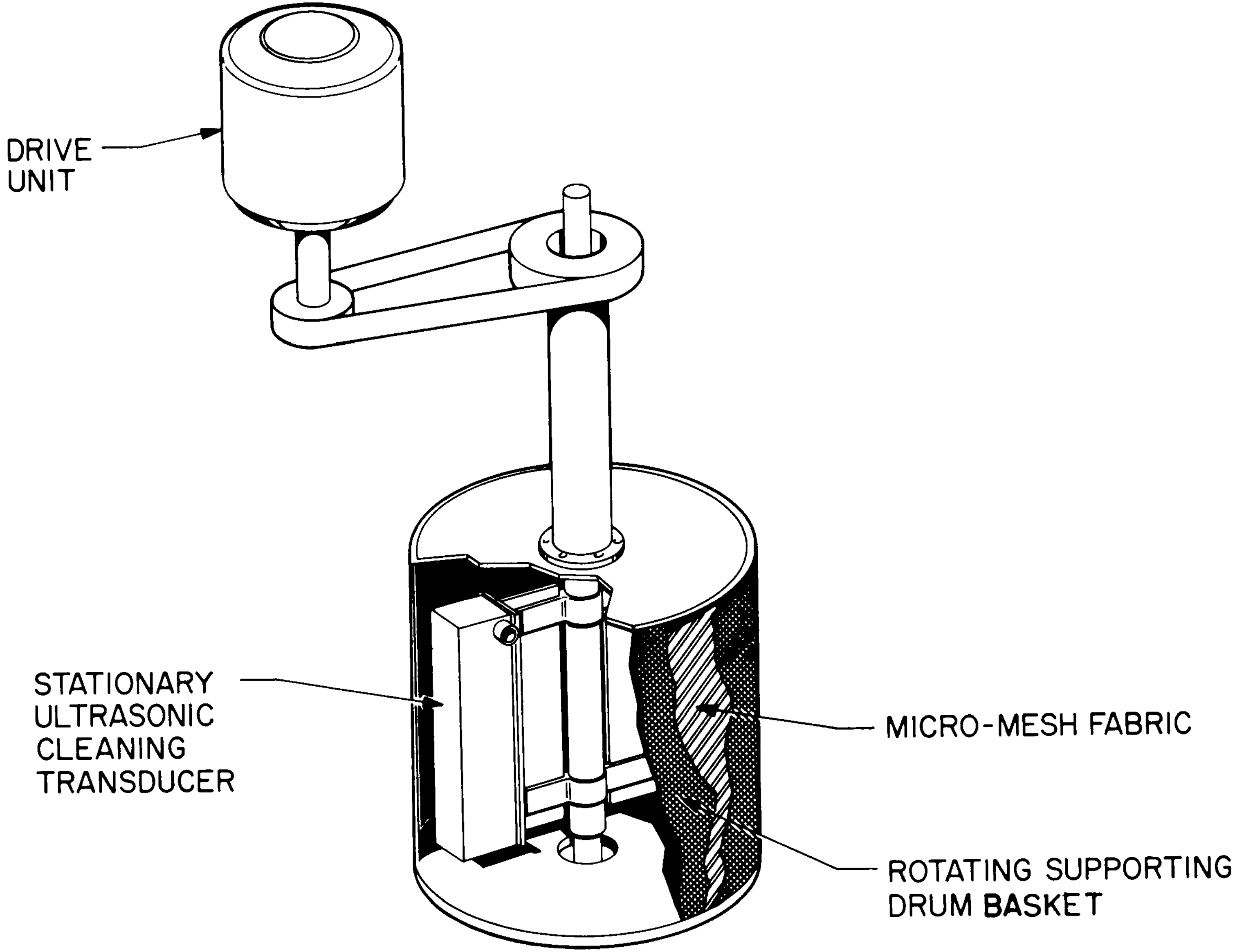


Figure 1. Dynamic strainer unit.

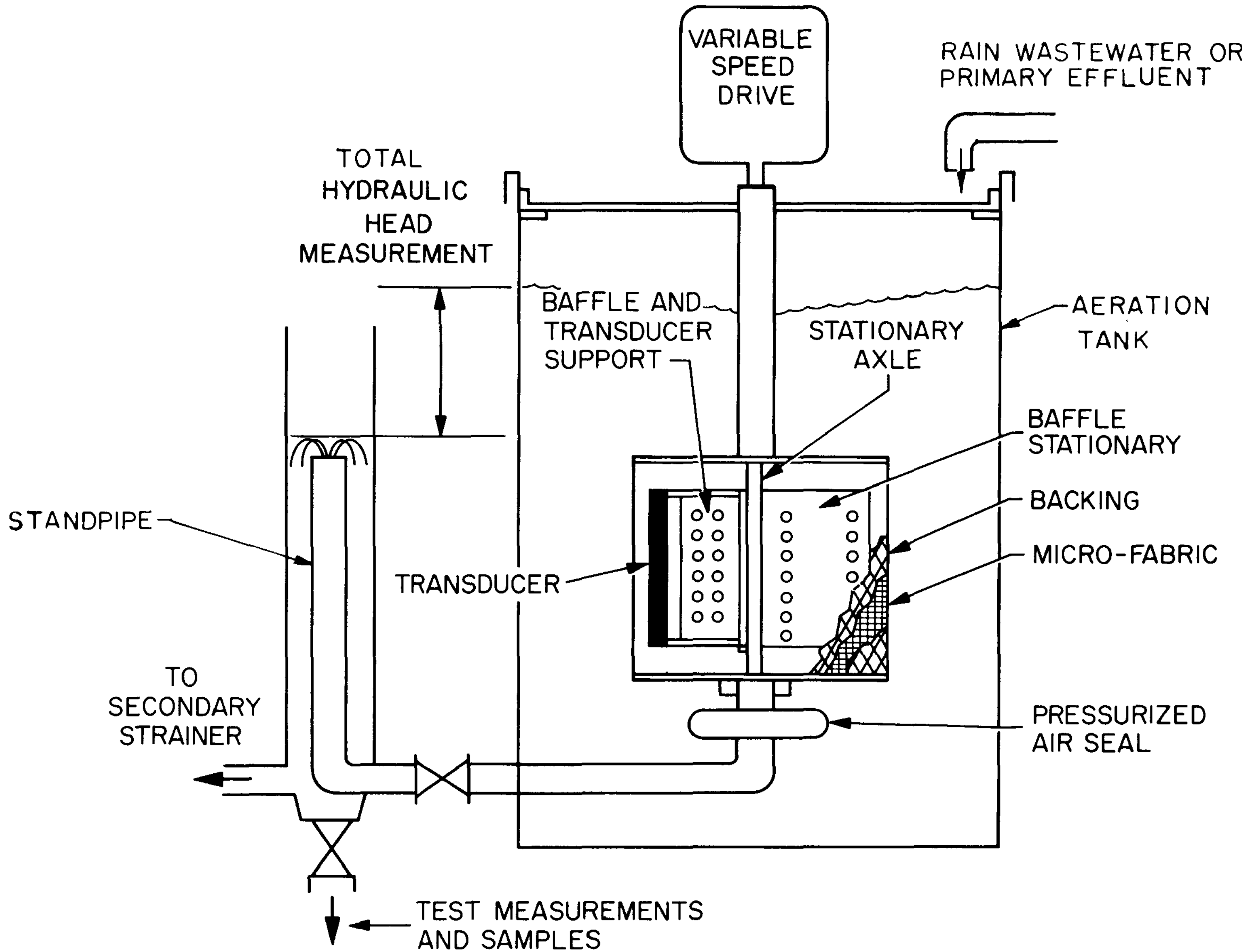
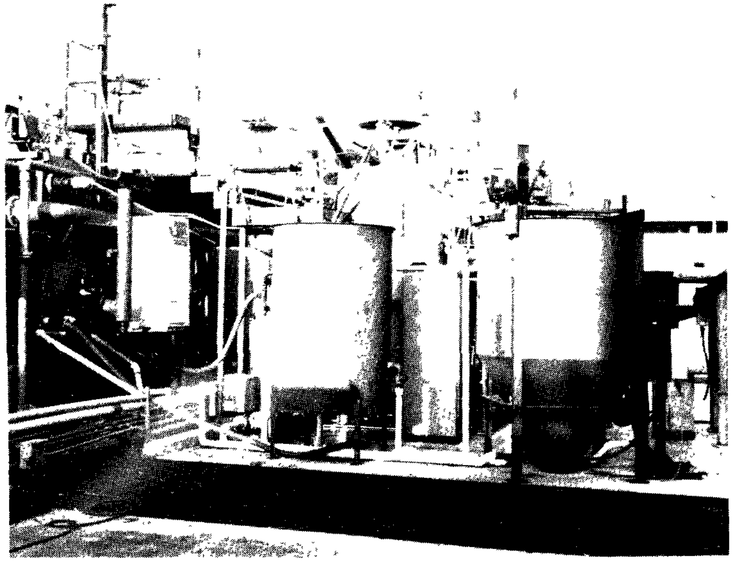
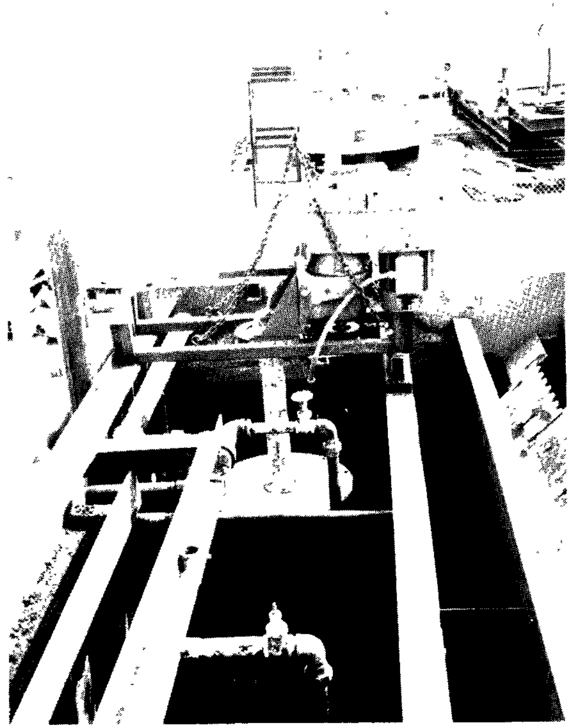


Figure 2. Dynamic strainer installation.

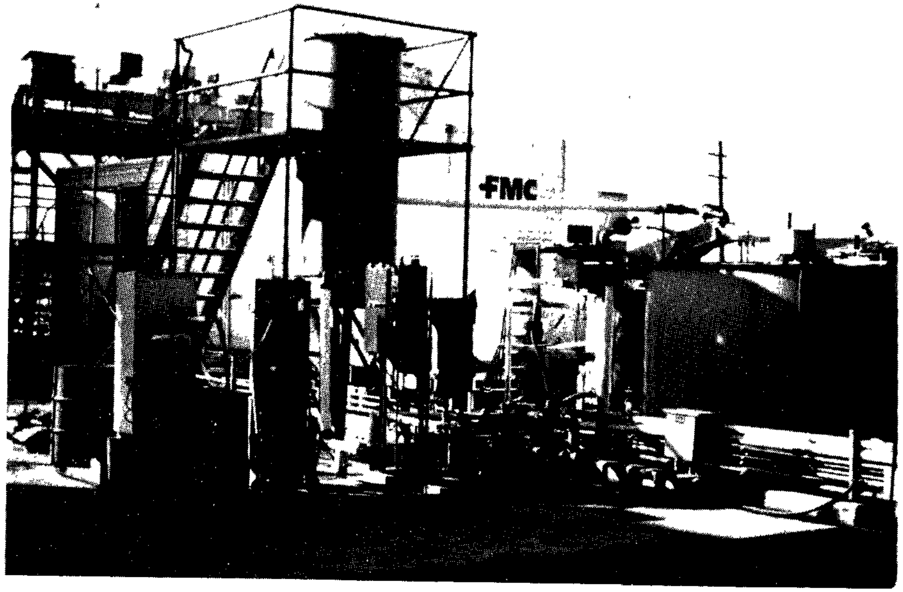


Standpipe on left is from the strainer and is on the side of the aeration tank. A sampler is next to it.

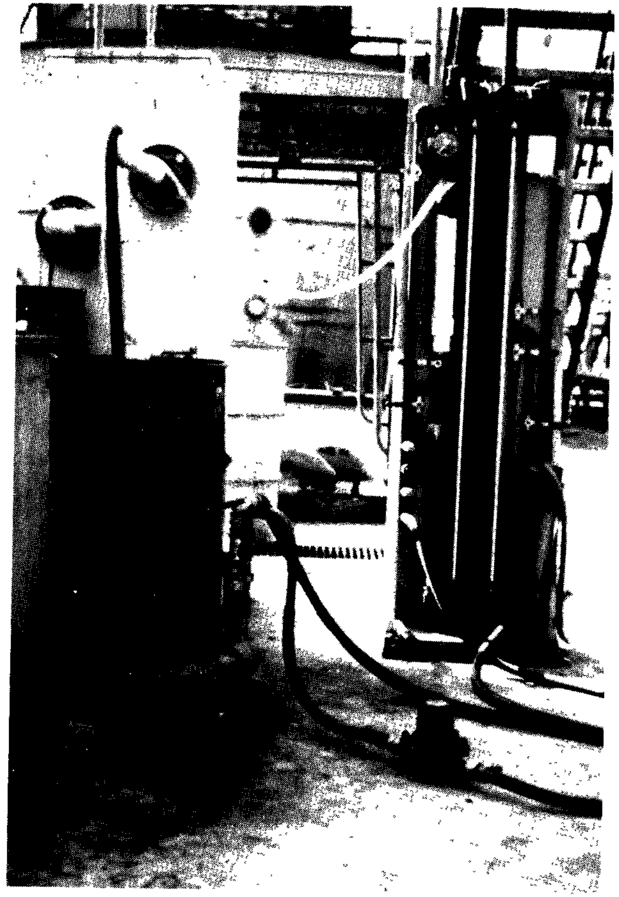


Primary strainer in place in aeration tank.

Figure 3. Strainer photographs.



UPFLOW SAND FILTER



DOWNFLOW SAND FILTER

Figure 4. Sand filters photographs.

An FMC SL-144 modified, complete-mix, activated sludge package treatment plant was used for this study. The package plant was supplied with municipal wastewater obtained in continuous supply from an interceptor sewer. The wastewater was screened and comminuted prior to entering the primary clarifier. The primary clarifier had a volume of 9.8 m^3 (347 ft^3 or 2600 gal) and a surface area of 5.9 m^2 (63.6 ft^2). The primary clarified effluent was then pumped into a 15.1-m^3 (535-ft^3 or 4000-gal) aeration tank. The primary strainer was placed directly in the mixed liquor at one end of the aeration tank opposite one of three influent ports. The effluent from the primary strainer was fed by gravity through a 90-degree, V-notch weir to an effluent holding tank with a volume of approximately 2.1 m^3 (75.4 ft^3 or 564 gal). The contents of this tank were continually circulated through an FMC sampler to obtain a 24-hr composite sample of primary strainer effluent. Primary strainer effluent from the holding tank was used as a feed stream for the upflow and downflow sand filters and the gravity settling column.

The dual media (coal over sand) downflow filter was manufactured by Neptune Microfloc, Inc. The unit was a plastic column pilot scale filter with an inner diameter of 0.11 m (4.5 in.), a height of 1.3 m (51 in.), and a surface area of 0.01 m^2 (0.11 ft^2).

The downflow filter was supplied by Neptune with 0.23 m (9 in.) of their MS-6 sand and 0.53 m (21 in.) of their MS-4 anthracite. The MS-6 sand had an effective size of 0.46 mm, a uniformity coefficient of 1.5, and a specific gravity of 2.6. The MS-4 anthracite had an effective size of 1.0-1.1 mm, a uniformity coefficient of 1.7 or less, and a specific gravity of 1.6. No support media was required below the sand since a screen over the discharge outlet kept the sand from leaving the filter.

The unit, as shown in Figure 4, included a differential pressure indicator, an effluent pressure regulator and bypass valve, an effluent flow meter, and piping to allow for both backwashing and surface washing of the filter. All washing was done manually as required. The filter flow rate could be varied from zero flow to 6.8 l/sec/m^2 (10 gpm/ft^2). The filter was normally operated at a flow rate of 3.4 l/sec/m^2 (5 gpm/ft^2) or less.

The upflow sand filter utilized was an FMC Corporation Model USF-3. The filter was 0.92 m (3 ft) in diameter and 2.4 m (8 ft) high with a surface area of 2.2 m^2 (7.1 ft^2). The filter media consisted of 0.92-m (3 ft) of filter sand supported by three, 0.1-m (4-in.) layers of gravel.

The upflow filter sand consisted of 98 percent natural silica sand which was spherical in shape, with all flat and crushed particles removed. The effective size was 1.15 to 1.25 mm with a uniformity coefficient of 1.50 to 1.60 and a specific gravity of 2.60 to 2.65. By weight, 95 percent of the particles passed a No. 8 U.S. standard sieve and 100 percent were retained by a No. 20 U.S. standard sieve. The support gravel consisted of hard, rounded, natural granite, free from flat or elongated pieces. The bottom layer consisted of 19 to 38 mm (0.75 to 1.5 in.) gravel followed by a layer of 6 to 12 mm (0.25 to 0.5 in.) gravel and a layer of 3 to 6 mm

(0.125 to 0.25 in.) gravel.

The upflow filter employed a flow rate of 2.0 l/sec/m^2 (3 gpm/ft^2) under normal filtering conditions. The feed pump had a capacity of 80 l/min (21 gpm) at a 6.3-m (20-ft) head. The feed pump was powered by a 1750-rpm, 1.5-hp motor. The filter was washed at the rate of 12.2 l/sec/m^2 (18 gpm/ft^2). The wash pump had a capacity of 485 l/min (128 gpm) at a 11.3-m (37-ft) head. The wash pump was powered by a 2600-rpm, 2-hp motor. During the wash cycle, the wash water flow was directed over a weir and carried to a separate point of discharge. The filter was equipped with proper instrumentation so that the wash cycle could be initiated automatically by either back pressure or by a timer, as well as by manual control. Variable speed pumps were used for the influent raw sewage, upflow sand filter, and downflow sand filter feeds.

Three FMC Corporation samplers were utilized on the project. These samplers collected daily composite samples of strainer effluent, downflow sand filter effluent, and upflow sand filter effluent. The samplers were set to collect a sample every 15 min. Samples of influent sewage were obtained by manually compositing a sample over the 8-hr work day. No samples were collected during the weekend. A flow diagram for the experimental setup is shown in Figure 5.

Large-scale settling studies were periodically performed during the course of the study. These were done using a 3.1-m (10-ft) high by 0.095-m (7.5-in.) I.D. plastic column as shown in Figure 6. The column was filled during test runs to a height of 2.4-m (8-ft) which corresponds to a volume of 68.5 l (18.1 gal). Sampling outlets were located every 0.3-m (1-ft), although most samples were taken at a depth of 1.4-m (4-ft).

Laboratory-scale flocculation and settling studies were conducted using a Phipps & Bird 6-place multiple stirrer. The studies were performed in 1-liter beakers. After flocculant addition to the strainer effluent, the solution was allowed to react for 15.5 min, followed by a 30 min settling period. Samples for analysis were then removed by siphoning. The flocculants examined were ferric chloride, alum, and two polyelectrolytes; one anionic and one cationic. The flocculants were studied at dosage levels of 0.5, 1.0, 1.5, 2.0 and 3.0 mg/l (as Fe, Al, and polyelectrolyte).

Photomicrographs of the activated sludge were taken daily during most of the project. Studies of the suspended solids passing through the strainer were also conducted utilizing a microscope equipped with an ocular micrometer and a Levy hemacytometer chamber with double Neubauer ruling. Using these two devices, estimates of particle size were made.

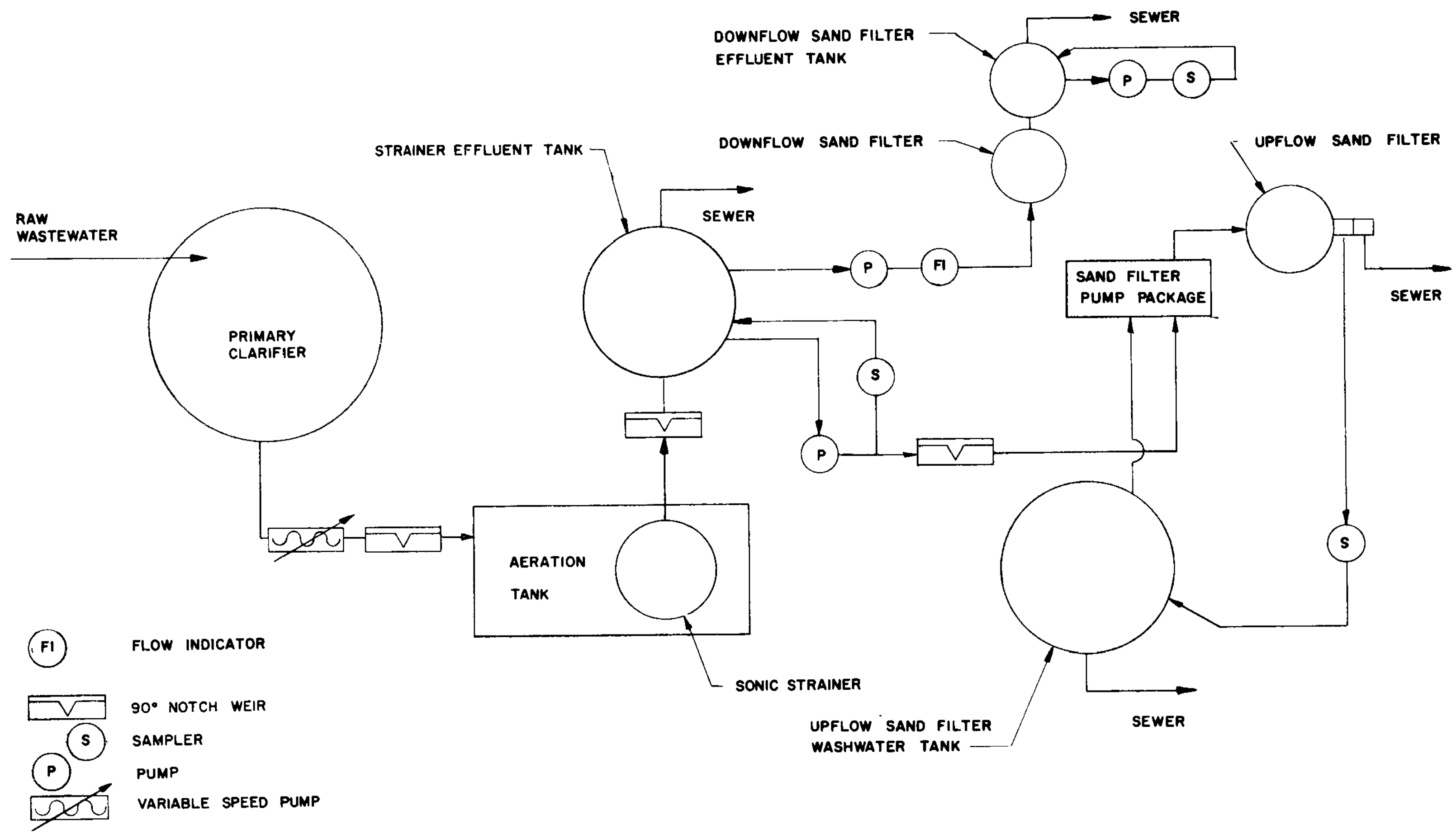


Figure 5. Dynamic straining-filtration flow diagram.

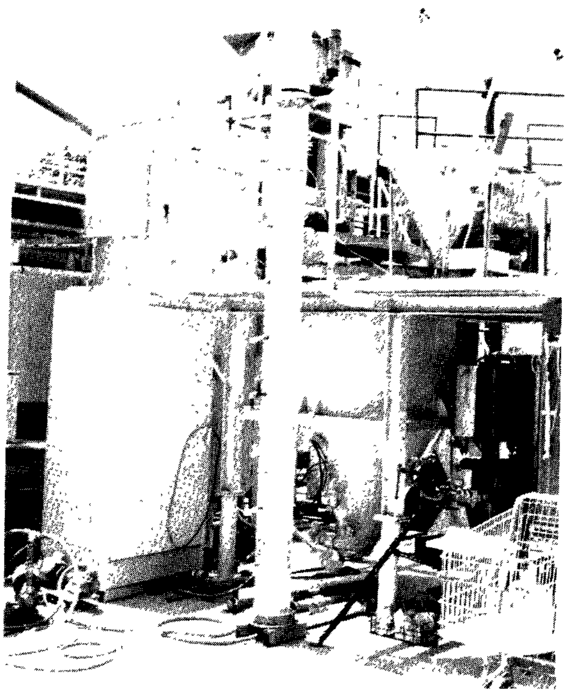


Figure 6. Photograph of settling column test set-up.

SECTION 5

DESCRIPTION OF OPERATION

Equipment acquisition and installation was completed by the end of March 1974. The plant, however, was put in operation at the beginning of March 1974 while equipment installation was being completed. The aeration tank was filled with 15.7 m^3 (4160 gal) of primary settled sewage, and aeration was started. On March 13, the MLSS level had reached 1235 mg/l and flow through the strainer was initiated. The plant was then fed primary settled sewage on a continuous basis. Samples of mixed liquor and strainer effluent were taken daily, and several analyses were performed. This preliminary startup work was done using a 20-μ fabric on the strainer while waiting for the 10-μ fabric to arrive from the supplier. On May 14, the 10-μ fabric was installed on the strainer and process equipment shakedown continued. On May 28, the MLSS concentration had reached 6560 mg/l and Phase I of the study was started. Phase I consisted of continuous steady-state operation of the primary strainer under activated sludge system conditions necessary to achieve a nitrifying mixed liquor population. During Phase I, MLSS averaged 6820 mg/l, primary strainer effluent suspended solids averaged 34 mg/l, strainer effluent ammonia nitrogen averaged 0.5 mg/l, and influent flow averaged 90.5 m^3/day (23,900 gpd).

Phase I lasted for 5 wk. During this period of time, plant operation, system monitoring, and data collection were continuous. Samples were taken Monday through Friday with no samples being taken on weekends. As previously mentioned, composite samples were taken of primary clarifier effluent, primary strainer effluent, downflow sand filter effluent, and upflow sand filter effluent. In addition to these, grab samples were taken daily of mixed liquor (strainer influent) and periodically of the sand filter wash water from both sand filters. A list of the analyses performed on each sample is given in Table 1. All analytical work was performed in accordance with the procedures and methods detailed in "Standard Methods of the Examination of Water and Wastewater", Thirteenth Edition, Washington, D.C. (1971). Various mechanical and operational data were also recorded daily, as shown in Table 2.

During Phase I operation, primary strainer effluent was continuously fed into both filters for the 5 wk test period. Bench scale studies on the primary strainer effluent solids were conducted periodically.

TABLE 1. SAMPLING AND ANALYSIS SUMMARY

SAMPLE NUMBER	LOCATION	TYPE
1	Primary Effluent	Composite (8 hr)
2	Mixed Liquor	Grab
3	Primary Strainer Effluent	Composite (24 hr)
4	Downflow Filter Effluent	Composite (24 hr)
5	Upflow Filter Effluent	Composite (24 hr)

SAMPLE	pH	TSS	VSS	TOC	SOC	COD	BOD_5	SETTLED SOLIDS	TURBIDITY	NH_3-N	NO_3-N	DO
1	x	x	x	x	x	y	y			z		
2	x	x	x					x				z
3	x	x	x	x	x	y	y		x	z	z	
4	x	x	x	x	x	y	y		x	z		
5	x	x	x	x	x	y	y		x	z		

x - Daily, Monday through Friday
y - Monday, Wednesday, Friday
z - Occasionally

TABLE 2. OPERATIONAL DATA OBTAINED

PARAMETER	LOCATION
Liquid Flow	Primary Effluent, Primary Strainer Effluent, Sand Filter Influents
Air Flow	To Aeration Tank
Strainer Speed	Primary Strainer
Hydraulic Head	Primary Strainer
Sonic Generator Amps	Primary Strainer
Sand Filter Head	Downflow Filter, Upflow Filter
Sand Filter Wash Cycle	Downflow Filter, Upflow Filter

Strainer effluent solids were examined for their settling characteristics using the 0.095-m (7.5-in.) diameter plastic settling column. Effluent was pumped into the column to a depth of 2.4 m (8 ft) and mixed well. Samples for suspended solids analysis were withdrawn from the column at a depth of 1.2 m (4 ft). Samples were taken at 1 min, 3 min, 5 min, and every

5 min thereafter for a period of at least 1 hr. Settling characteristics after flocculation were determined by flocculating multiple 1-liter samples of strainer effluent using ferric chloride, alum, Betz 1190 (a cationic polymer), and Betz 1130 (an anionic polymer). The flocculant was added to the strainer effluent and mixed for 30 sec at 100 rpm, 15 min at 60 rpm, and then allowed to settle for 30 min. Samples of the supernatant were then withdrawn for suspended solids analysis.

Photomicrograph techniques were used during Phase I to evaluate the type and size of primary strainer effluent suspended solids. The size of the particles was measured using an ocular micrometer. The length and width measurements were then used to calculate the mean and median length, width, and area of the particles.

Upon completion of Phase I, the test equipment was slightly modified in order to handle the increased loading and hydraulic flow for Phase II. Phase II was intended to demonstrate continuous steady-state operation of the primary strainer and sand filters at hydraulic loading, detention time, and MLSS levels which would preclude development of a nitrifying mixed liquor. Phase II was started on July 8, 1974.

Shortly after beginning work on Phase II, a noticeable change occurred in the influent sewage. The sewage on many days had the strong odor of hydrocarbons and on other days the odor and foaming characteristics of laundry waste. The apparent effect of the combined wastes on the mixed liquor was to produce a vast amount of filamentous microorganisms, which in turn produced a polysaccharide slime. This caused the mixed liquor to be very stringy and have the consistency of a light syrup. On numerous occasions, the mixed liquor foamed severely during the day as shown in Figure 7. The major effect of foaming was to cause a drastic decrease

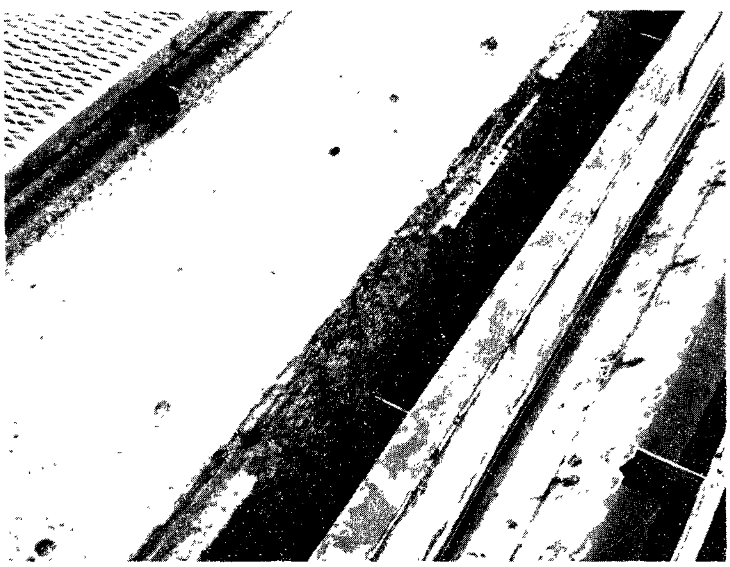


Figure 7. Photograph of mixed liquor surface during severe foaming conditions.

in the primary strainer flow rate. Maximum flow rates through the strainer during this time were 1.1 - 2.2 $l/sec/m^2$ (1.6 - 3.2 gpm/ft^2). Various methods (chlorination, reduced air, dilution) were tried to rid the system of the filamentous material. None of the methods tried had the desired effect except complete draining of the aeration tank. During September and October, the mixed liquor appeared to change back to more normal characteristics with a decrease in the amount of filamentous organisms present. Flow rates through the primary strainer increased; however, the high flow rates that were achieved during the previous study (1) could not be attained.

Phase II work was suspended and, during November and early December, a special Phase III study was initiated to try to elucidate the cause of the poor strainer flow rates. Work on Phase III was completed on December 4, 1974.

SECTION 6

DISCUSSION OF RESULTS

The operating capability of the dynamic strainer in terms of specific flow rate and suspended solids removal is dependent upon several parameters. These parameters include the nominal pore size and weave of the filter fabric, suspended solids concentration of the liquor being strained, the rotational speed of the strainer, the hydraulic head across the strainer, and the morphological characteristics of the biomass. These parameters and their effect on the performance of the dynamic strainer are detailed in the previous contract report (1).

The ultimate feasibility of using a dynamic strainer to either replace the final gravitational clarifier in an activated sludge system, or in conjunction with the final clarifier to handle periods of peak flows at possibly higher MLSS, will depend upon the consistent performance of the strainer in a variety of conditions. The strainer suspended solids removal efficiency must be high enough so that the effluent will be of sufficient quality to meet existing discharge requirements or be capable of further treatment to meet such requirements.

Two conditions under which different biomass characteristics develop and in which the strainer could potentially be applied to are: (1) activated sludge mixed liquor developed under low BOD loading rates where nitrification would occur, and (2) activated sludge mixed liquor developed under high BOD loading rates where nitrification would not occur. The suspended solids passing through the strainer filter fabric for these two conditions would most likely require different means to remove them from the final plant effluent. The following Phase I and II studies discussed in this section were undertaken to evaluate strainer operation with these two types of biomasses. As previously mentioned, the Phase III strainer flow rate investigative work was initiated in an attempt to elucidate causitive factors of the severe sludge bulking conditions encountered in Phase II.

PHASE I - ACTIVATED SLUDGE DEVELOPED UNDER LOW LOADING CONDITIONS

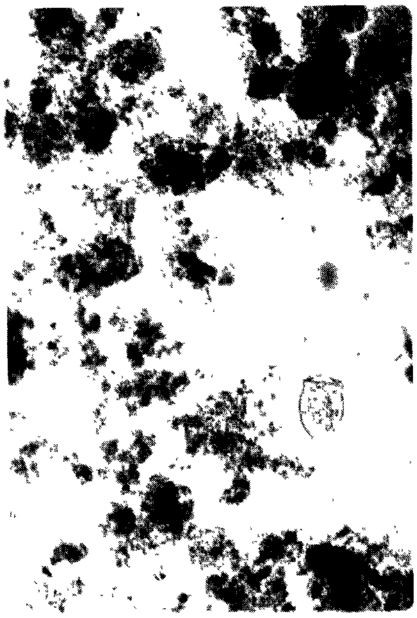
During Phase I (May 28 - July 3, 1974), the activated sludge system was operated such that a nitrifying mixed liquor was produced. The average organic (F/M) loading during this phase was 0.22 kg BOD_5/day/kg MLVSS with a cell retention time of 10 days, and the average flow rate to the plant was 92 m^3/day (24,300 gpd). Influent and effluent ammonia nitrogen averaged 16 and 0.5 mg/l, respectively. Several tests for nitrate nitrogen performed during this phase of the study indicated that nitrification was occurring in the aeration tank. MLSS averaged 6800 mg/l, and the strainer effluent averaged 35 mg/l suspended solids. Other average values for operational data were a strainer speed of 73 rpm (458 ft/min), a total hydraulic head of 16.5 cm (6.5 in.), and a total strainer flow rate of 63.9 l/min (16.9 gpm). Using an effective filtering area of 0.59 m^2 (6.4 ft^2), this flow corresponds to a specific flow rate of 1.8 l/sec/m^2 (2.6 gpm/ft^2). No attempt was made during this phase to maximize flow rate through the strainer.

The daily operation of the strainer was essentially trouble-free. All mechanical parts of the strainer system as well as the other parts of the test set-up operated properly. On several occasions, the activated sludge mixed liquor developed foaming problems such as shown previously in Figure 7. This primarily occurred toward the end of Phase I. These minor operational problems did not interfere with the collection of daily samples and operating data during this phase. Mixed liquor dissolved oxygen levels were maintained at an average of 1.5 mg/l, and air flow to the aeration tank was 82 kg/hr (180 lb/hr).

Daily microscopic observation of the mixed liquor during this period showed it to be composed of large, dense sludge particles and many forms of protozoan life. On most days, amoebae, free-swimming ciliates, flagellates, stalked ciliates, rotifers, and occasionally nematodes could be found. Stalked ciliates, primarily Vorticella sp., were the predominant microorganism. Filamentous organisms were present in minor amounts during most of this testing phase; however, they gradually increased in number toward the end of Phase I (Figure 8).

As evident in Figures 9, 10, and 11, the treatment system operated very well during Phase I. Secondary system BOD_5, COD, and suspended solids removals averaged 96 percent, 83 percent, and 79 percent, respectively. The average suspended solids concentration in the strainer effluent was 35 mg/l with a MLSS of 6800 mg/l (equivalent to a strainer solids removal efficiency of 99.5 percent). A complete tabulation of the operational data is presented in the Appendix.

Microscopic observation of the solids passing through the strainer indicated many of the particles which passed the filter fabric were protozoan life forms. The most common type was the free-swimming ciliate Trachelophyllum sp. These protozoa average 40.5 μ in length and are approximately 10 μ wide. Other types of microorganisms commonly observed were the small bits and pieces of activated sludge floc as seen in Figure 12. Measurement of the particles was performed microscopically using an ocular micrometer. Table 3 lists the results of these measurements. On only one day, June 14, 1974, did the strainer effluent used for particle analysis show a large discrepancy with other tests during Phase I. The photomicrograph for that date in Figure 12 indicates the particles had probably post-flocculated after passing through the strainer. For all seven tests, the average median area, length and width of the particles was 864 μ^2, 35 μ and 23 μ, respectively. Of the particles passing the strainer, 80 percent of them measured less than 64 μ long and 40 μ wide. These data would tend to indicate that the particles passing through the filter fabric fell close to the absolute size of the openings in the filter fabric, i.e., 15-18 μ.



MIXED LIQUOR 5-20-74 100X

MIXED LIQUOR 5-21-74 100X

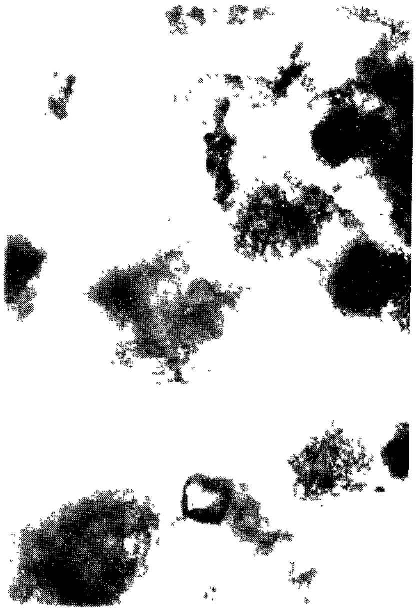
MIXED LIQUOR 5-22-74 100X

MIXED LIQUOR 6-20-74 100X

Figure 8. Photomicrographs of mixed liquor.

MIXED LIQUOR 7-1-74 100X

MIXED LIQUOR 7-10-74 100X



MIXED LIQUOR 7-31-74 100X

MIXED LIQUOR 8-1-74 100X

Figure 8 (continued).

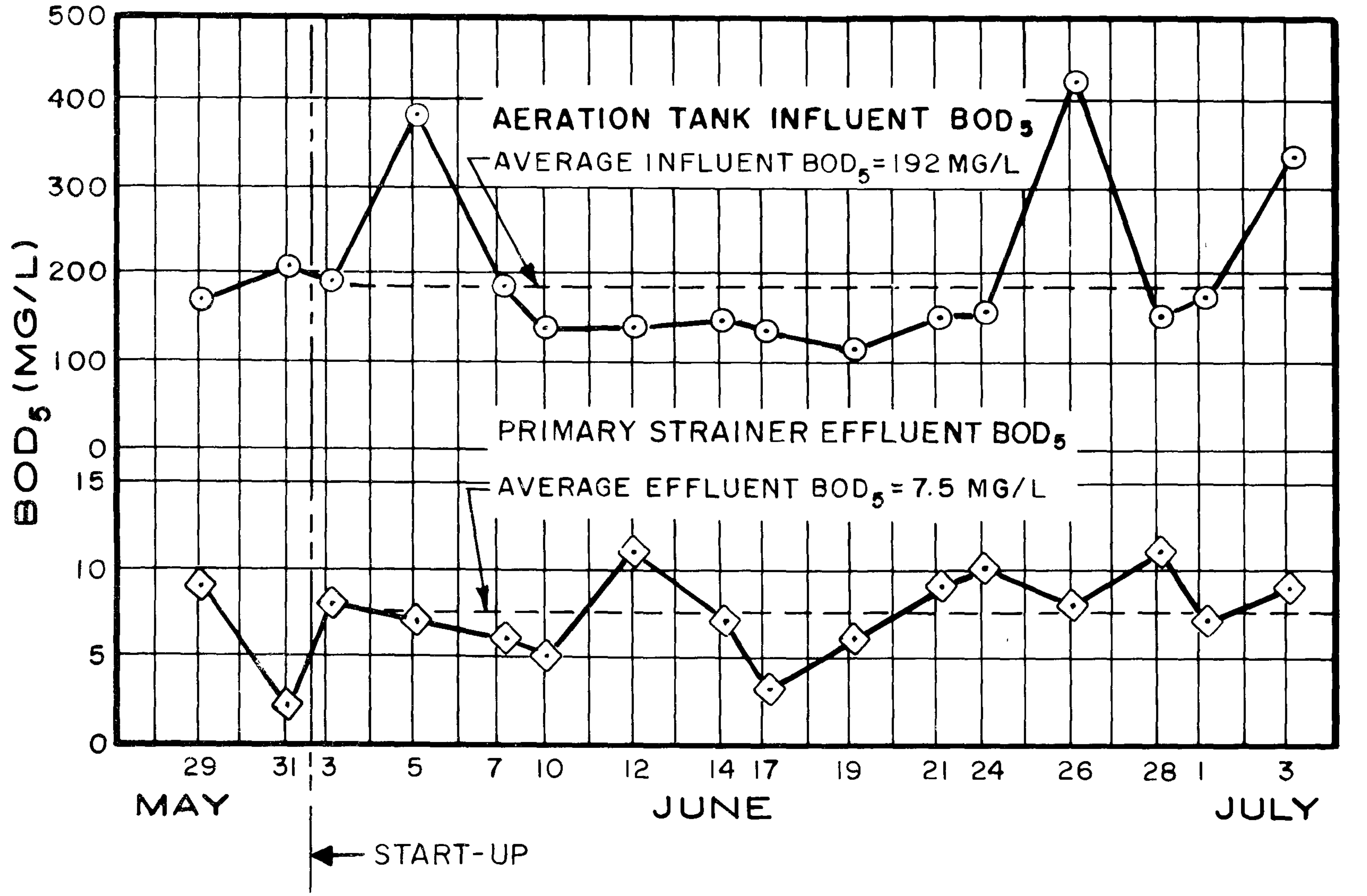


Figure 9. BOD_5 performance data - Phase I.

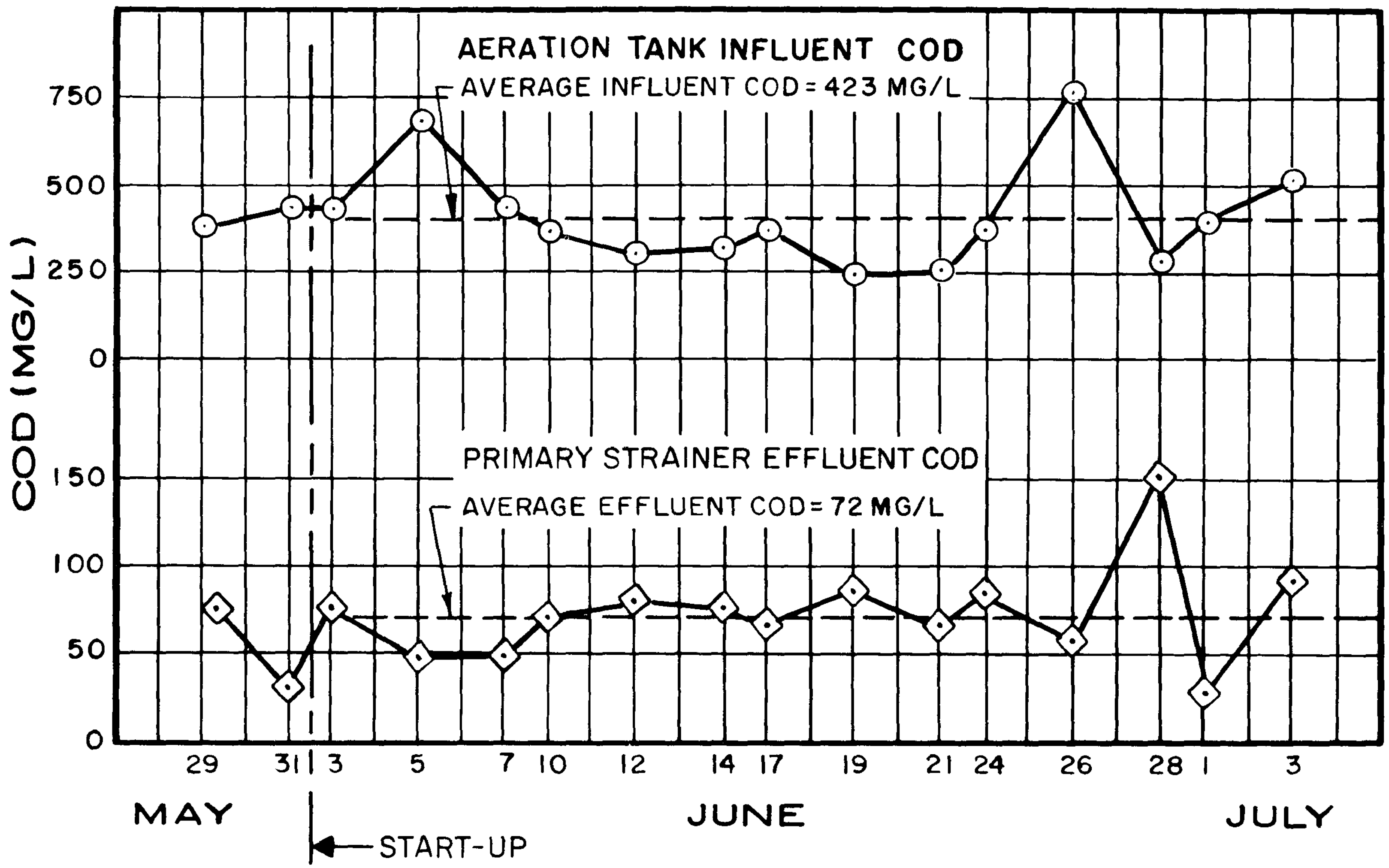


Figure 10. COD performance data - Phase I.

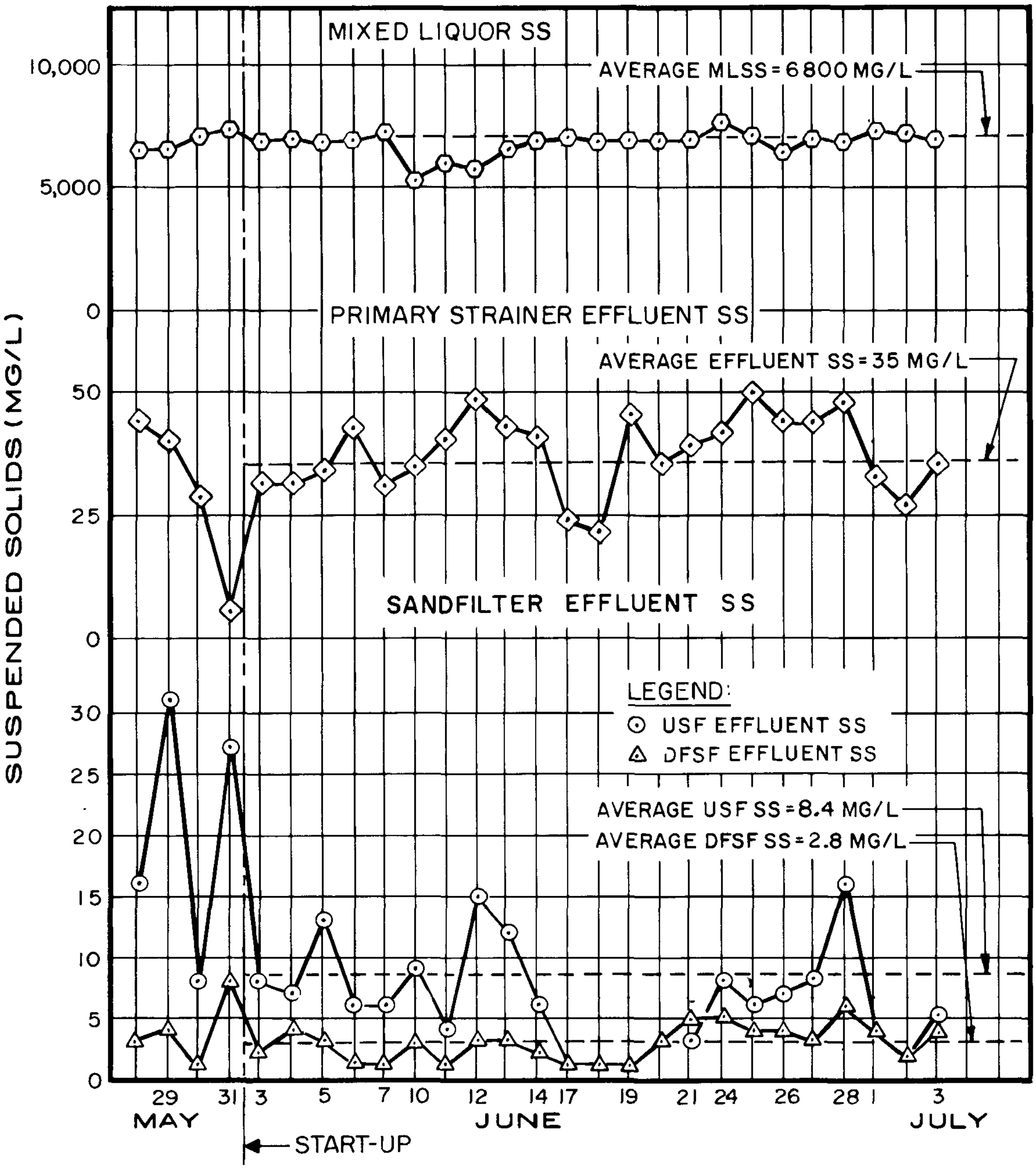
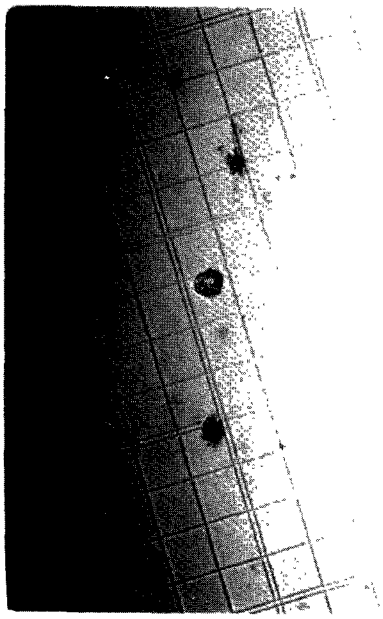
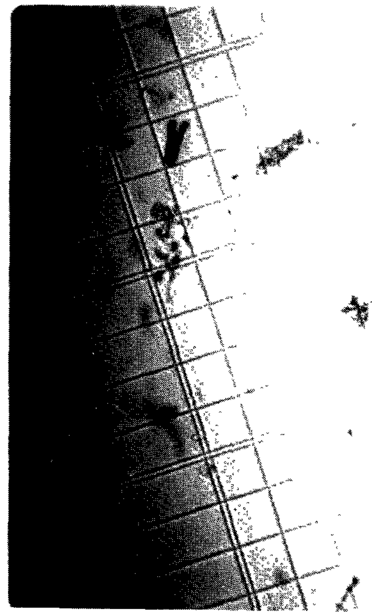


Figure 11. Suspended solids performance data - Phase I.

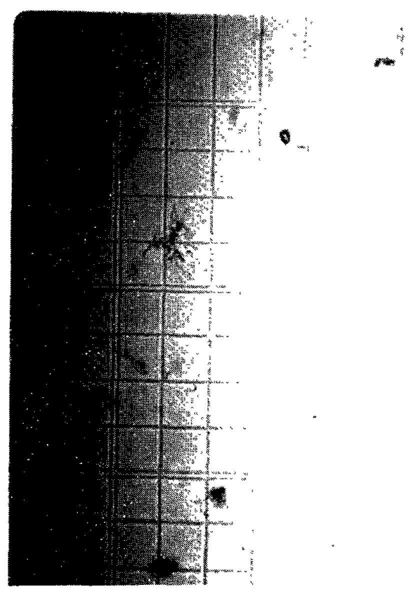


STRAINER EFFLUENT 5-29-74



STRAINER EFFLUENT 5-30-74

STRAINER EFFLUENT 6-14-74



STRAINER EFFLUENT 6-20-74

Figure 12. Photomicrographs of strainer effluent.

TABLE 3. PHASE I STRAINER EFFLUENT PARTICLE SIZE ANALYSES

	AREA (μ^2)			LENGTH (μ)			WIDTH (μ)		
DATE	MEAN	MEDIAN	RANGE	MEAN	MEDIAN	RANGE	MEAN	MEDIAN	RANGE
5-29	1401	744	124 - 8060	42	32	8 - 102	25	24	8 - 94
5-30	1194	682	62 - 9548	42	39	8 - 110	23	16	8 - 87
6-7	1088	527	62 - 9300	37	24	8 - 150	21	16	8 -118
6-11	1180	744	62 - 4340	39	32	8 - 94	24	24	8 - 63
6-14	5865	1488	62 - 62,000	72	39	8 - 394	44	32	8 -197
6-20	1240	930	62 - 4960	39	39	8 - 87	28	24	8 - 55
6-28	1179	930	62 - 11,160	39	39	8 - 142	24	24	8 - 80

Laboratory scale flocculation-settling tests performed during this phase of the study showed that the solids passing through the strainer can be decreased to 10 mg/l or less by combining either ferric chloride or alum addition with separate gravity clarification. Neither of the two polymers used, one anionic and one cationic, produced suspended solids values that were consistently 10 mg/l or less. The cationic polymer on one day did reduce the solids level to below 10 mg/l. The results of the laboratory scale flocculation-settling tests are given in Table 4. During these tests, a control sample of strainer effluent was subjected to the same test procedures, rapid mixing, slow mixing, and settling, but without a flocculating agent being added. The effluent remaining after settling only exhibited similar suspended solids concentrations as were found in the flocculated samples. This appears to indicate that the suspended solids passing through the strainer cloth are capable of auto-flocculation.

Samples taken during the large-scale settling tests on the strainer effluent using the 0.095-m (7.5-in.) I.D. plastic column were analyzed for suspended solids and turbidity. It was assumed that the strainer effluent solids would settle as discrete particles, maintaining a relatively constant size, shape, density, and settling velocity. The particle size analyses and flocculation-settling studies indicated rather that the particles do not undergo true discrete settling but a modified form where some of the particles floc and agglomerate during settling. For each settling test conducted (without the addition of chemicals) in the large plastic column, a plot was made of the settling velocity in inches per minute versus the percent of the particles by weight remaining in the supernatant to determine the percent settling slower than a given clarifier overflow rate. The detailed procedure is given in reference (2). The average values obtained from six large-scale settling tests, shown in Table 5, were then plotted to obtain a single

TABLE 4. PHASE I BENCH SCALE FLOCCULATION STUDIES

DATE	INITIAL VALUES		FLOCCULANT DOSAGE	SUPERNATANT VALUES AFTER 30 MIN SETTLING									
				$FeCl_3$		ALUM		CATIONIC		ANIONIC		NO CHEMICAL ADDITION	
	SS (mg/l)	TURB. (JTU)	(mg/l as Fe, Al or Polymer)	SS (mg/l)	Turb. (JTU)	SS (mg/l)	Turb. (SS)	SS (mg/l)	Turb. (JTU)	SS (mg/l)	Turb. (JTU)	SS (mg/l)	Turb. (JTU)
6-19-74	22	8										12	5.2
			0.5	7	2.9	4	2.0	19	8.7	10	4.4		
			1.0	5	2.1	3	1.8	18	8.6	12	4.8		
			1.5	4	2.2	3	1.7	16	6.9	11	4.7		
			2.0	4	2.6	4	2.0	13	9.5	16	5.5		
			3.0	1	2.2	4	1.5	16	7.1	16	6.0		
6-27-74	46	19										10	4.4
			0.5	7	3.2	5	2.6	5	2.7	15	4.1		
			1.0	7	2.6	5	2.1	6	2.8	14	4.4		
			1.5	7	3.0	12	2.0	7	3.1	14	5.0		
			2.0	7	2.6	7	1.9	9	3.6	18	5.0		
			3.0	5	2.2	4	1.7	7	4.0	20	5.5		

representative settling curve (Figure 13). A theoretical discrete settling curve for a suspension having 500 mg/l suspended solids content was also plotted for reference. Determining the area under the curve from zero settling velocity to a selected clarifier overflow rate permits calculation of theoretical solids removal for various clarifier overflow rates. Percent suspended solids removal versus overflow rate is shown in Figure 14. To obtain a 90 percent reduction in strainer effluent suspended solids for the 53 mg/l concentration of the experimental sample, a low clarifier overflow rate of 14.7 $m^2/day/m^2$ (350 gpd/ft^2) would be needed under ideal conditions. Allowing for a 30 percent overdesign in clarifier overflow rate due to diurnal variation, an overflow rate of 10.3 $m^2/day/m^2$ (295 gpd/ft^2) would be indicated. To improve clarifier operation, flocculation with or without chemicals or mixing of the strainer effluent with mixed liquor are possible approaches.

TABLE 5. COMPOSITE SETTLING CURVE DATA

TIME (min)	SS (mg/l)	INITIAL SETTLING VELOCITY (in./min)	% SS REMAINING IN SUPERNATANT
0	53		
1	53	48	100
4	50	12	94.3
5	50	9.6	94.3
10	50	4.8	94.3
15	50	3.2	94.3
20	51	2.4	96.2
25	49	1.9	92.5
30	42	1.6	79.2
35	41	1.4	77.4
40	36	1.2	67.9
50	32	0.96	60.4
60	28	0.8	22.8

An alternative to either settling or flocculation followed by settling for the removal of strainer effluent suspended solids is sand filtration. Two sand filters were studied during this project: a small commercial FMC upflow sand filter with a design flow rate of 2.0 l/sec/m (3 gpm/ft) and a pilot-scale, dual-media downflow unit capable of accepting flows up to

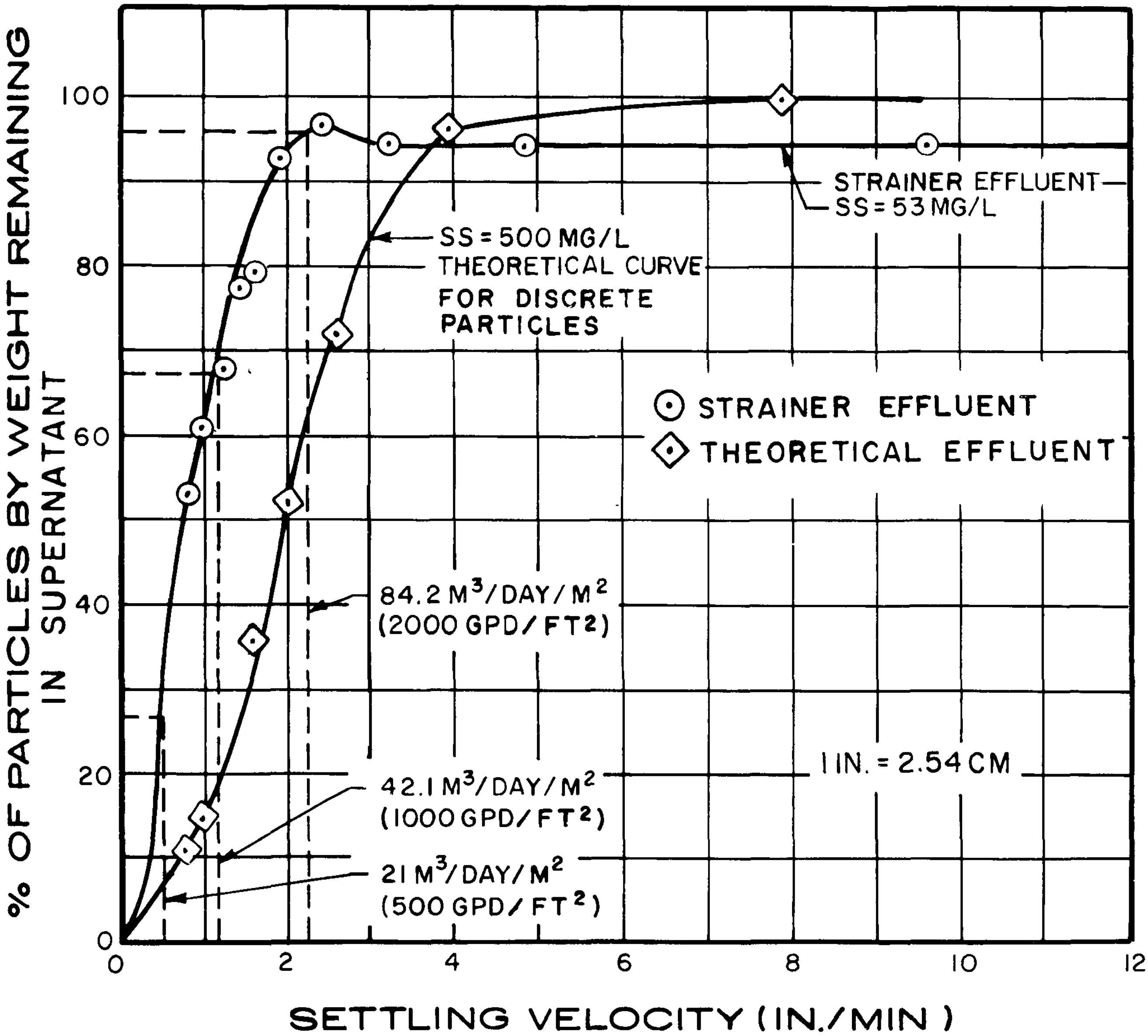


Figure 13. Composite settling curve for strainer effluent and discrete settling solids.

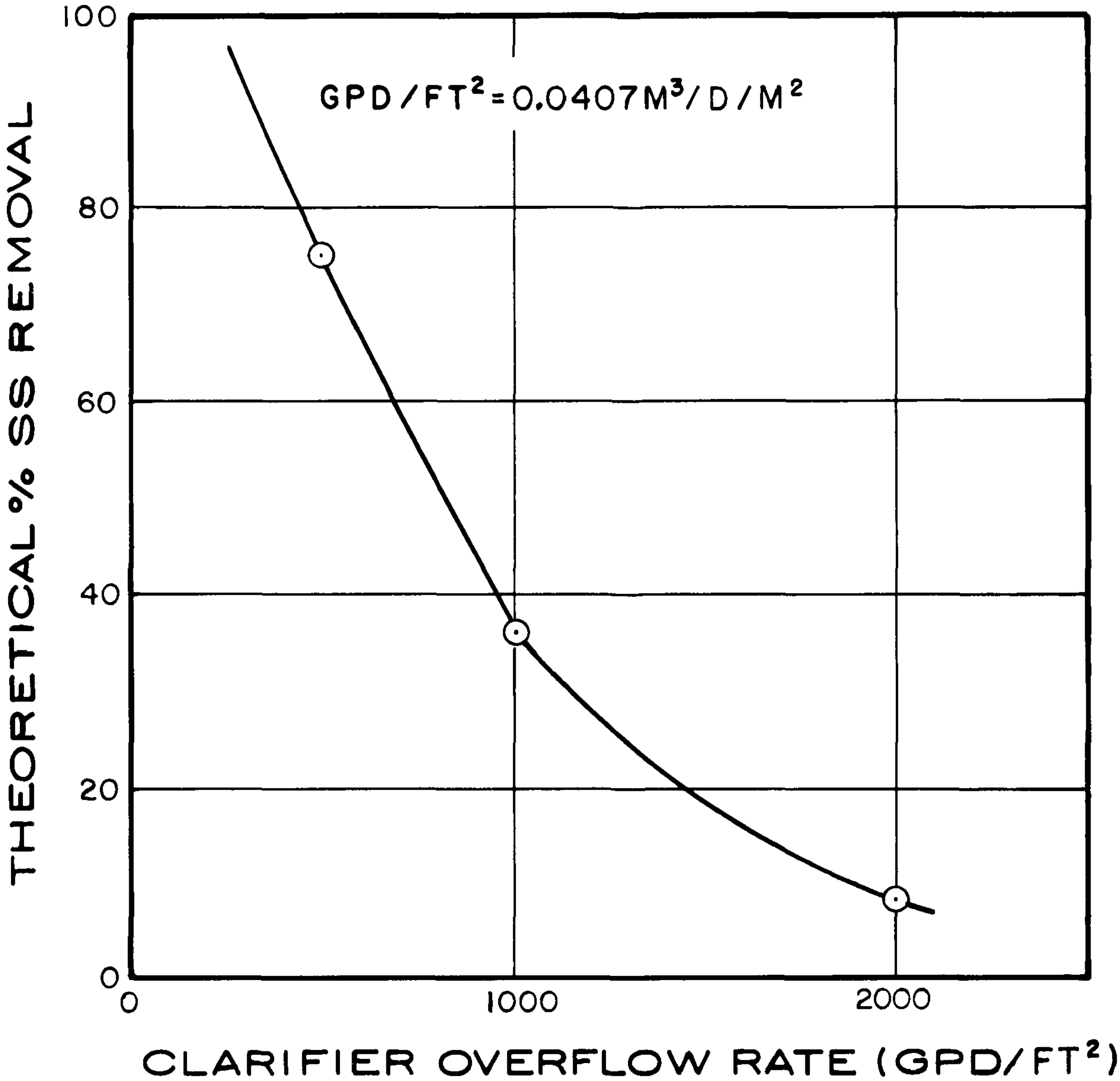


Figure 14. Theoretical strainer effluent suspended solids removal during subsequent gravity settling of strainer effluent.

6.8 $l/sec/m^2$ (10 gpm/ft^2). The upflow unit was consistently run at 2.0 $l/sec/m^2$ (3 gpm/ft^2), and the downflow unit was most often run at 3.4 $l/sec/m^2$ (5 gpm/ft^2). The flow to the downflow unit was held constant during the 8-hr work day. The downflow unit was backwashed daily at approximately 8:00 A.M. and again at 4:00 P.M. Backwashing was accomplished with clean water directed to the bottom of the unit for 10 min with surface washing for 6 min, both at a flow rate of 760 $l/min/m^2$ (18 gpm/ft^2). Pressure drop versus time data were obtained for various influent flow rates. These data are graphically presented in Figure 15 and indicate that the pressure loss across the filter increased linearly with time.

The upflow sand filter was operated at the standard design flow rate of 2.0 $l/sec/m^2$ (3 gpm/ft^2) on a 24-hr basis throughout Phase I. The filter was backwashed at least once a day, which was also a standard procedure. The frequency and duration of backwash in a 24-hr period were varied to study the effect on filter performance. During the backwash cycle, the flow through the filter was increased to 12.2 $l/sec/m^2$ (18 gpm/ft^2). The wash water was wasted to the sewer. From May 28 until June 10, the filter was backflushed once per day for a 20-min cycle. The on-stream filter effluent suspended solids during that time averaged 12 mg/l. It appeared as though a certain amount of channeling as well as some compaction of the sand was occurring using the once-a-day wash cycle as indicated by suspended solids breakthrough during the filter run. The wash frequency was then increased to three times per day, with the duration of each wash reduced to 10 min. This pattern of wash cycles was continued until the end of Phase I. The filter effluent suspended solids during this time averaged 7 mg/l. During the change from Phase I to Phase II, the backwash cycle was increased to four times per day for a duration of 5 min each. During this time, no improvement in the quality of the filter effluent was observed and the cycle was then returned to three times per day of 10 min duration each.

Figure 11 illustrates the suspended solids removal efficiencies of both the upflow and downflow sand filters. The average effluent suspended solids levels for the upflow and downflow filters were 8 mg/l and 3 mg/l, respectively.

PHASE II - ACTIVATED SLUDGE DEVELOPED UNDER HIGH LOADING CONDITIONS

Work on Phase II was started on July 5, 1974, immediately upon completion of Phase I. Phase II was intended to demonstrate the steady-state operation of the strainer in mixed liquor resulting from a process loading of approximately 0.40 kg BOD_5/day/kg MLSS and a cell retention time of 4 days. Influent flow to the strainer was set at 117 l/min (31 gpm) and the system allowed to adjust to the loading for about 1-wk.

During the 1-wk acclimation period, strainer flow rates were near the desired level. However, by the end of the 1-wk period, a definite change in the character of the mixed liquor was observed with a resultant decrease in strainer flow rate. The influent sewage began to have the odor of hydrocarbons, although no substantial increase in composite influent TOC, BOD_5, or COD was detected. At various other times, the influent sewage had the

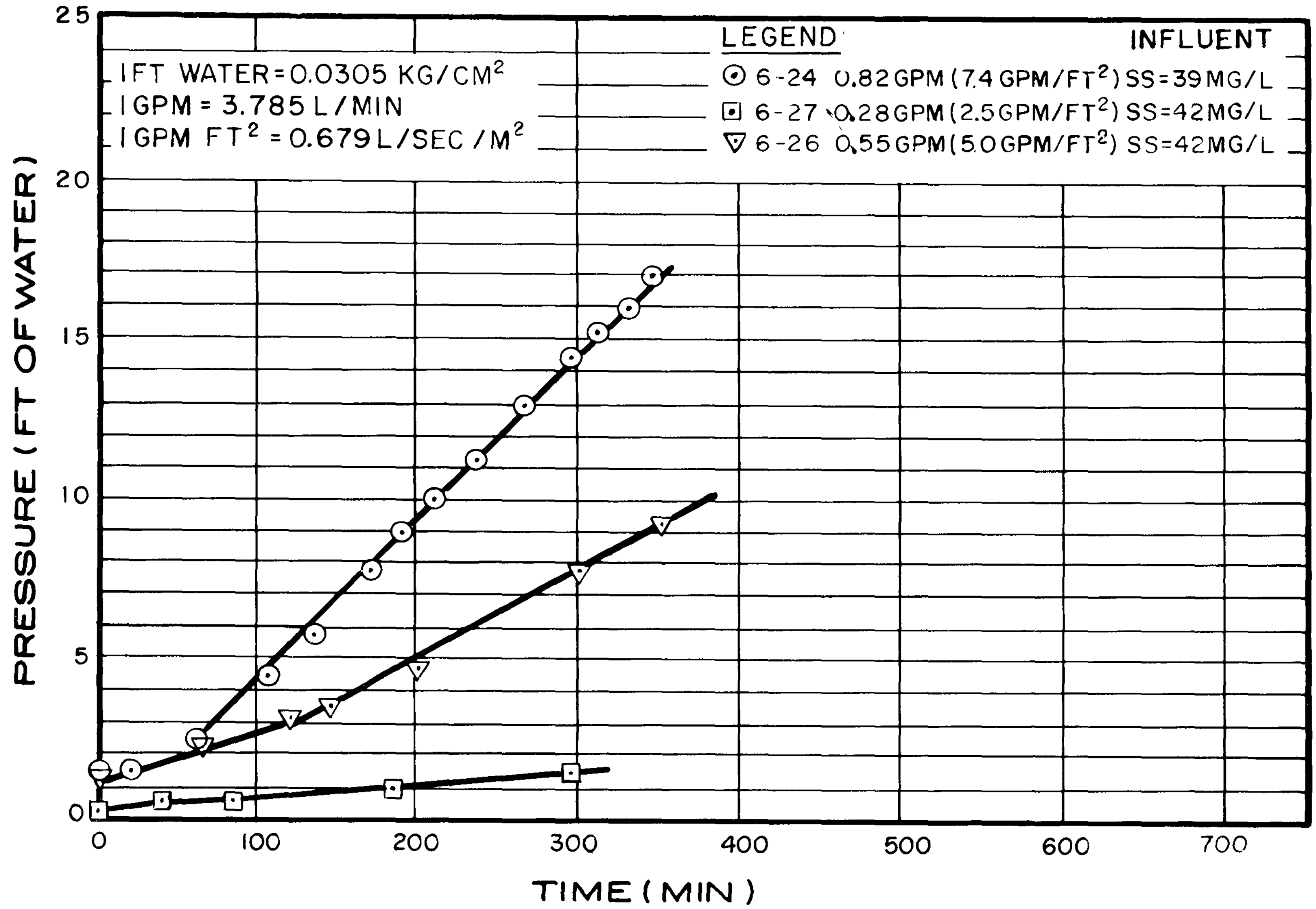


Figure 15. Downflow sand filtration pressure drop as a function of loading and run length.

odor of laundry wastes but again no substantial increase in oxidizable material in the sewage was observed.

The aeration tank developed severe foaming problems as previously illustrated in the photograph of Figure 7. The foam and the mixed liquor were very stringy and had a "slimy" character. The mixed liquor at this time contained principally filamentous microorganisms. During the previous contract program, the strainer appeared to operate better with higher suspended solids removals and higher specific flow rates when the mixed liquor was filamentous in nature. It was theorized that the 10-μ cloth yielded better flow rates than the more open 20-μ cloth because the filaments could get more entangled in the 20-μ openings, partially blocking the area for flow through the strainer cloth. During the work on Phase II, the mixed liquor developed filamentous microorganisms to a much greater extent than had been seen previously. When the strainer, after being removed from the mixed liquor and washed off, was replaced into the mixed liquor, the desired flow rate could be maintained for a period of time. However, flow rates would gradually drop to practically zero after 1 to 8 hr of operation.

The type of filamentous microorganisms that developed during this study could have been different than those developed during the previous study. Because of the high concentration of these organisms, a fairly small fraction, which still comprised a large number of individual particles, could have been of small enough size to become entangled in the 10-μ cloth openings in much the same way it was theorized that the 20-μ cloth was blinded. However, a more likely explanation for the extreme reduction in strainer hydraulic capacity is the secretion by the organisms of excess amounts of extracellular, polysaccharide slime material. This could plug the cloth openings, cause excessive foaming, and create higher head losses through the strainer cloth.

During the remainder of July, in an effort to correct the flow problem, various combinations of strainer peripheral velocity and differential head did cause increases in flow rates. However, in all cases, the flow rates deteriorated with time.

On August 2, it was decided to waste most of the aeration tank contents in order to develop a diluted mixed liquor which was not as "slimy" or filamentous and would be more amenable to straining. On August 6, tests were conducted to determine maximum strainer flow rates. Flow rates of up to 7.4 l/sec/m^2 (10.9 gpm/ft^2) were obtained at a MLSS concentration of 2390 mg/l. The total hydraulic head was 27.9 cm (11 in.). The strainer controls were adjusted for operation at these flow rates. However, mechanical problems developed and testing was delayed for several days. By August 16, the mixed liquor was again extrememly filamentous and "slimy" with accompanying poor strainer flow rates. On August 19, the mixed liquor tank was completely drained and washed out and, on August 22, influent flow to the aeration tank was again started.

After restarting the flow to the strainer, flow rates of 3.8 l/sec/m^2 (5.6 gpm/ft^2) were obtained for several days at MLSS levels of 1635 to 5515 mg/l. The total hydraulic head ranged from 5.1 cm (2 in.) to 35.6 cm (14 in.)

By the beginning of September, the mixed liquor was again beginning to foam and the amount of filamentous organisms was increasing. Addition of calcium hypochlorite was initiated to control the amount of filamentous organisms. After adding chlorine for 2 days, the foaming of the mixed liquor stopped and the filaments were observed to decrease in length as well as in amount. The addition of chlorine was accompanied by the addition of ammonium sulfate to provide an additional nitrogen source. The nitrogen addition was done to make up for the losses in ammonia nitrogen caused by the chemical reactions of chlorine with ammonia nitrogen. Chlorine and nitrogen addition were continued until September 13.

Flow rates through the strainer, even after chlorine and nitrogen addition, did not meet the Phase II requirement for flow. Thus, the specified 0.40 F/M loading rate on the secondary system could not be maintained at the prevailing primary effluent BOD_5 concentration. The addition of beet molasses was started in order to increase the F/M ratio. The data collected during this part of the study are reported in the Appendix for the period September 17 until October 4.

The daily addition of 18.9 l (5 gal) of beet molasses to the mixed liquor added 16.3 kg BOD_5 (36 lb BOD_5) to the average 12.4 kg BOD_5 (27.3 lb BOD_5) supplied daily by the primary effluent. The average influent wastewater flow was 64.3 m^2/day (16,980 gpd). The average organic loading during molasses addition was 0.38 kg BOD_5/day/kg MLVSS. The strainer flow rate, because of the type of mixed liquor that was present, averaged 1.2 l/sec/m^2 (1.8 gpm/ft^2) at an average 22.6-cm (8.9-in.) total hydraulic head. The highest strainer flow rate recorded during this period was 2.2 l/sec/m^2 (3.2 gpm/ft^2) at a total hydraulic head of 22.9 cm (9 in.). Strainer suspended solids removals averaged 98 percent.

PHASE III - STRAINER FLOW RATE INVESTIGATIONS

During Phase I of this study, the strainer specific flow rate averaged 1.8 l/sec/m^2 (2.6 gpm/ft^2) at a total hydraulic head of 16.5 cm (6.5 in.) and a peripheral drum speed of 2.3 m/sec (7.5 ft/sec). The previous work (1) indicated this is the specific flow rate that would be expected for these equipment operating conditions. This specific flow rate was adequate to meet process requirements for the low-loading, nitrifying portion of the study based on analyses of settled sewage influent. The strainer operated consistently at these conditions, with only minor modifications during all of Phase I. The troublesome, foaming, viscous mixed liquor did not develop until the end of this portion of the experimental program when it was time to increase flow for Phase II. This subsection discusses the work that was done in an attempt to reach Phase II design conditions and to ensure that the flow problems were associated with the unusual mixed liquor process conditions and not the equipment.

Various tests conducted included checks of the sonic cleaning apparatus, tests of various combinations of head and peripheral velocity, experiments with different methods of attachment of the micro-mesh fabric to the strainer drum, operations with diluted and fresh mixed liquor, and chemical control.

On July 19, total head versus specific flow rate curves were determined for rotating speeds of 60, 90, and 120 rpm (equivalent to tip speeds of 1.9, 2.9, and 3.8 m/sec, respectively). These were then compared with data obtained during the previous contract at similar MLSS levels. The previous data indicated that a maximum specific flow rate of 8.1 l/sec/m^2 (12 gpm/ft^2) should have occurred at a speed of 120 rpm and a total head of 30.5 cm (12 in.). However, a maximum flow rate of 2.5 l/sec/m^2 (3.6 gpm/ft^2) at 120 rpm and 22.9 cm (9 in.), of total head was all that could be attained. The same test was repeated after allowing the mixed liquor to aerobically digest for several days at 3.8 m/sec and 4.8 m/sec (120 rpm and 150 rpm, respectively). The curves for this test are shown in Figure 16. The maximum specific flow rate for 120 rpm had increased to 3.1 l/sec/m^2 (4.5 gpm/ft^2) at a total head of 20.3 cm (8 in.) after the period of aerobic digestion. The maximum specific flow rate for 150 rpm could not be determined because the test set-up lacked the capability to pump sewage into the aeration tank at a rate greater than 145 l/min (38 gpm). However, the strainer flow rate obtained at 150 rpm was sufficient to operate the Phase II system at its design flow rate of 117 l/min (31 gpm). Therefore, the strainer was set to operate at 150 rpm and a total head of 31.8 cm (12.5 in.).

The strainer operated at this flow rate for approximately 24 hr at which time the fabric was torn loose from one of the panels by the increased peripheral drum speed. The strainer was repaired and placed back in the aeration tank. After 1 additional day of operation, the mixed liquor again began to change to a very filamentous, viscous nature and the strainer flow rate dropped off substantially.

All but 587 l (155 gal) were emptied from the aeration tank on August 2 and raw sewage flow was again started. By August 9, MLSS had reached 3000 mg/l and total head versus specific flow rate curves were again obtained for 1.9 and 3.8 m/sec (corresponding to strainer tip speeds of 60 and 120 rpm, respectively). These curves are shown in Figure 17. The specific flow rates obtained at both 60 and 120 rpm met the design requirements for Phase II work. The strainer was set to operate at 60-rpm for over a week-end period.

During the period of week-end operation, the strainer interior drum baffle broke loose and damaged the micro-mesh filter fabric. The baffle was replaced and a new panel of fabric was installed on the strainer. When the strainer was placed back into the aeration tank, a maximum specific flow rate of only 1.6 l/sec/m^2 (2.3 gpm/ft^2) could be obtained at either 60, 90, or 120 rpm due to the mixed liquor again changing to a very filamentous, viscous character.

On August 20, the entire contents of the aeration tank were wasted and the tank was cleaned. The strainer was put back in operation, and flow rates as high as 5.4 l/sec/m^2 (8.0 gpm/ft^2) were obtained during start-up operation, August 22 through August 27, at a total head of 27.9 cm (11 in.). On August 28, strainer specific flow rates again dropped below the design requirement for Phase II work. The addition of calcium hypochlorite and ammonium sulfate was then undertaken to try and remedy the problem of excessive filamentous growth. Although this increased the strainer flow

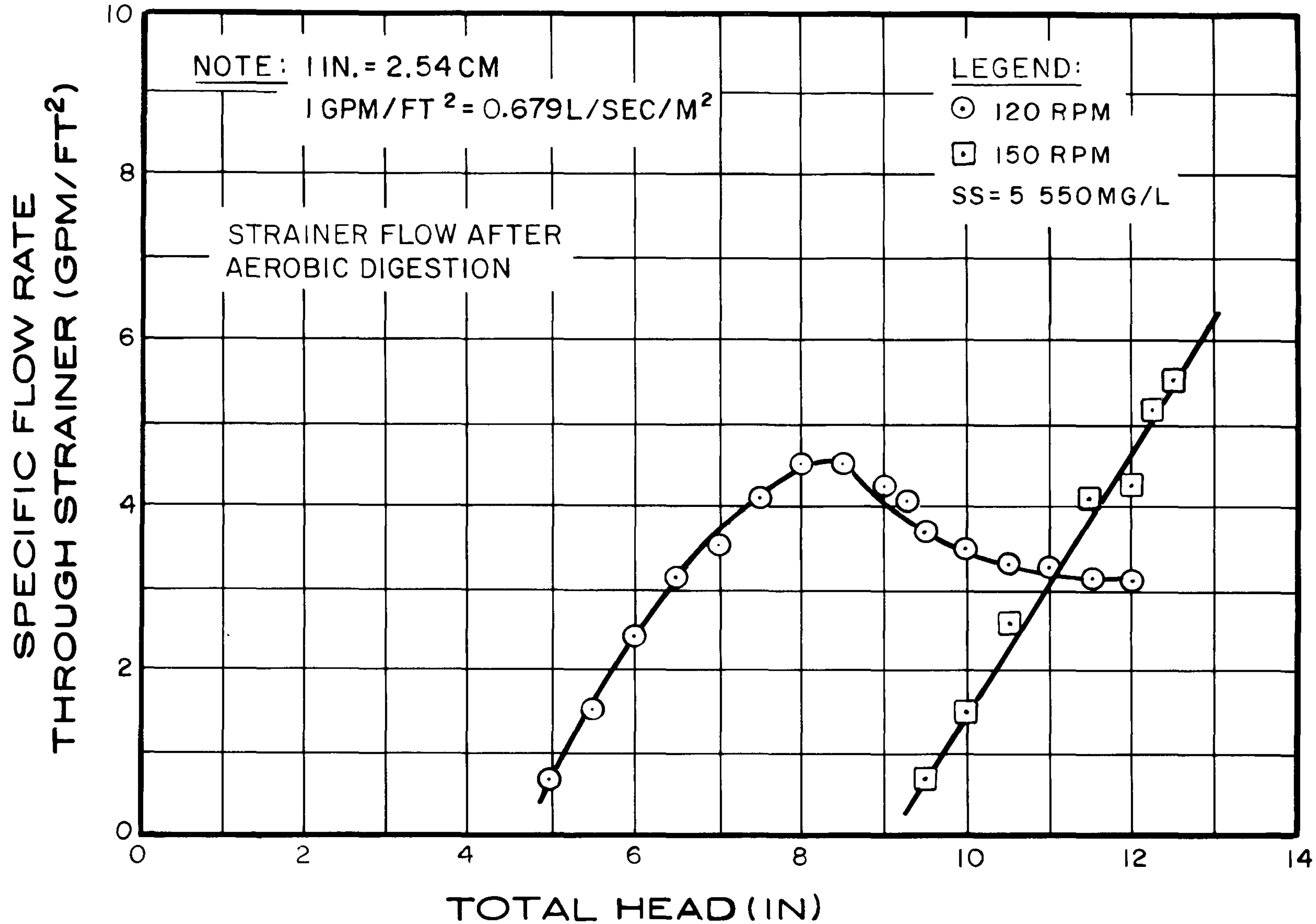


Figure 16. Specific flow rate as a function of total head - July 22, 1974.

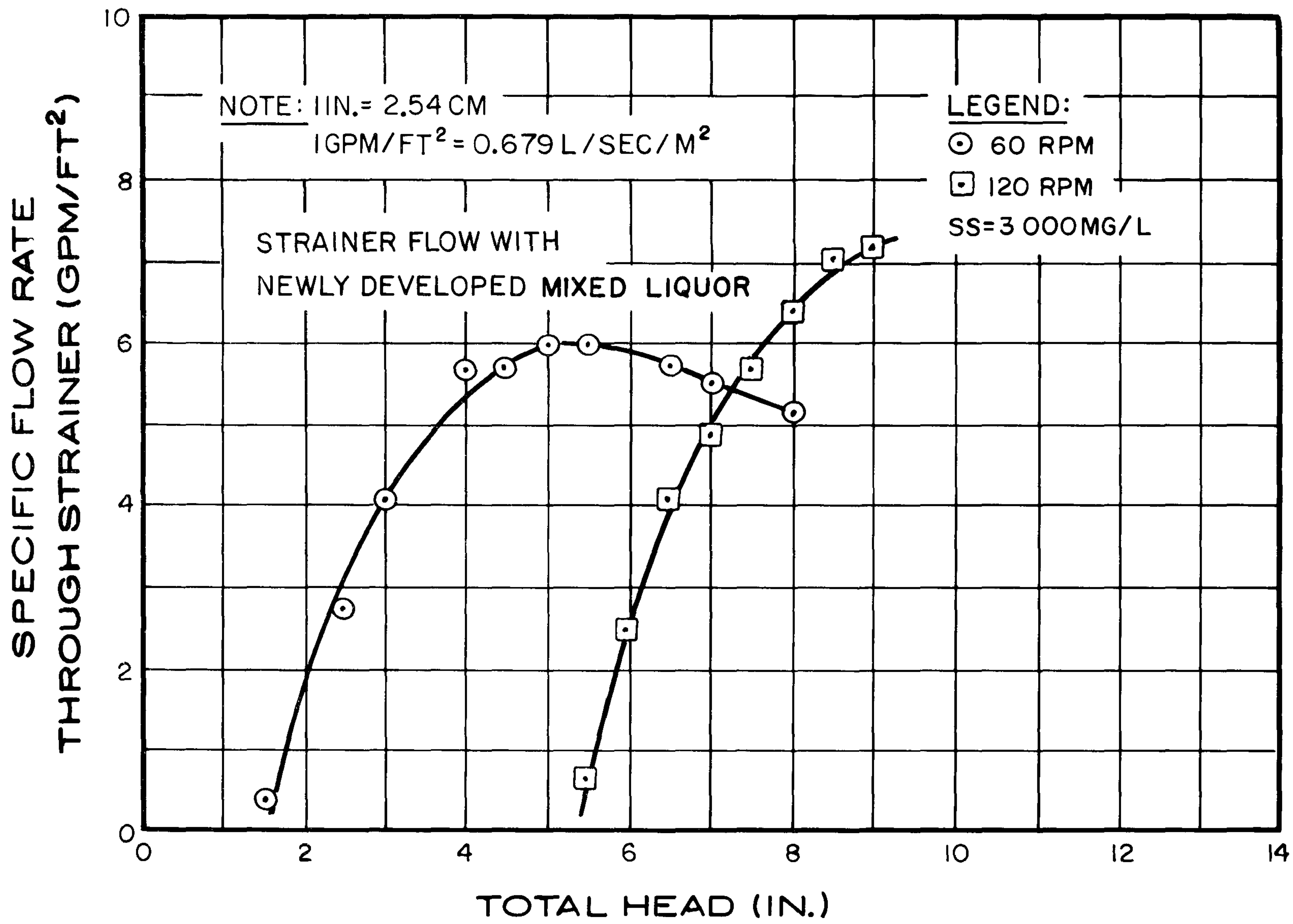


Figure 17. Specific flow rate as a function of total head - August 9, 1974.

rates somewhat, the design flow rate of 3.3 $l/sec/m^2$ (4.8 gpm/ft^2) could not be consistently obtained. Experimental work was suspended for the month of September, but sewage flow and chemical addition to the aeration tank were continued.

Total hydraulic head versus specific flow data were next obtained on October 7 and 8 and are listed in Table 6. The data show that the maximum flow rate attainable was 2.0 $l/sec/m^2$ (2.9 gpm/ft^2) at 120 rpm and a total head of 22.8 cm (9 in.). During the previous study, a flow rate of 3.5 $l/sec/m^2$ (5.1 gpm/ft^2) was obtained at the same head and MLSS level. When the results of the 120-rpm run on October 7 are compared with the 120-rpm run on October 8, it is evident that a problem existed with reproducibility of the strainer specific flow rates.

The results differ substantially in terms of maximum flow rate even though the data were obtained at the same MLSS level and only 1 day apart. The possibility that the sonic cleaning device was not properly operating, thus not thoroughly cleaning the strainer fabric, was suggested.

Tests were made to determine the condition and the cleaning ability of the sonic transducer located on the interior of the strainer drum. A piece of aluminum foil was placed over the outside of a panel which was located directly in front of the sonic transducer. This was done both with a piece of strainer fabric mounted on the panel between the transducer and the aluminum foil and without the strainer fabric mounted on the panel. In both cases, the characteristic pitting of the aluminum foil associated with good sonic transducer performance was observed. The transducer output was tested with the aluminum foil at currents of 2, 4, 6, and 8 amps. Only at the 2-amps setting was very little pitting of the aluminum foil seen. This would tend to indicate that the sonic cleaning device was functioning properly and, thus, cleaning the fabric adequately.

The strainer flow rate was also tested with the sonic transducer turned off. In this condition, cloth cleaning would be retarded and the effluent flow would stop. With a MLSS concentration of 3700 mg/l and the strainer operating at 120 rpm, the effluent flow decreased from 1.4 $l/sec/m^2$ (2 gpm/ft^2) to less than 0.07 $l/sec/m^2$ (0.1 gpm/ft^2) in approximately 5 min.

The method of strainer fabric attachment to the strainer panels was also examined. In the work done on the previous contract, the strainer fabric was wrapped around the outside of the strainer panels and held in place by an additional expanded metal covering wrapped around the fabric. All of the flow data reported for the previous contract were obtained using this form of fabric attachment. However, during the interim between contracts, a modification of the method of fabric attachment was developed to increase the life of the strainer fabric and allow for greater ease of attachment. The revised method consists of welding the strainer fabric to each individual strainer panel. This eliminates the need for the exterior expanded metal covering as well as allowing for rapid replacement of only one panel at a time should one become damaged.

Tests were conducted using the same method of fabric attachment as was

TABLE 6. PRIMARY STRAINER SPECIFIC FLOW RATES, MLSS = 6465 MG/L

OCTOBER 7, 1974				OCTOBER 8, 1974	
90 RPM		120 RPM		120 RPM	
TOTAL HEAD (in.)	SPECIFIC FLOW (gpm/ft²)	TOTAL HEAD (in.)	SPECIFIC FLOW (gpm/ft²)	TOTAL HEAD (in.)	SPECIFIC FLOW (gpm/ft²)
2.0	0.0	5.0	0.4	10.0	0.1
2.5	0.2	5.5	1.1	10.5	0.2
3.0	0.7	6.0	1.5	11.0	0.3
3.5	1.1	6.5	1.8	11.5	0.3
4.0	1.5	7.0	2.2	12.5	0.4
4.5	2.1	7.5	2.7	13.5	0.4
5.0	2.1	8.0	2.9	14.5	0.4
6.0	2.4	9.0	2.9	15.5	0.4
7.0	2.4	9.5	2.7		
8.0	2.6	11.0	2.4		
9.0	2.6	12.5	2.2		
10.0	2.4	14.0	2.1		
11.0	2.2	15.0	2.0		
13.0	2.1				
15.0	2.1				

used on the previous contract as well as another modification whereby the fabric was held in place by three 1/2-in. wide bands located at the top, middle, and bottom of the strainer drum. This latter method of attachment was used in previous work and yielded satisfactory flow rates. The data for these tests are tabulated in Table 7. The data indicate that the change to the welded panels did not adversely affect the specific flow rates and, in fact, may have improved the flow rates under the mixed liquor conditions which existed during much of the testing.

All tests conducted indicated that the strainer mechanical equipment was functioning properly. This indicated that the problem being encountered with respect to strainer specific flow rates was indeed due to the unusual mixed liquor process conditions. Since the activated sludge plant continued to develop a type of mixed liquor in which it was difficult to attain and hold the Phase II design flow rate of 117.3 l/min. (31 gpm), it was decided, in conjunction with the Project Officer to cease work on the contract at this point.

TABLE 7. PRIMARY STRAINER SPECIFIC FLOW RATES AS A FUNCTION OF METHOD OF FABRIC ATTACHMENT

EXPANDED METAL COVERING, MLSS = 5000 mg/l*		BANDED, MLSS = 3740 mg/l**		WELDED, MLSS = 3690 mg/l**	
120 RPM		120 RPM		120 RPM	
TOTAL HEAD (in.)	SPECIFIC FLOW (gpm/ft^2)	TOTAL HEAD (in.)	SPECIFIC FLOW (gpm/ft^2)	TOTAL FLOW (in.)	SPECIFIC FLOW (gpm/ft^2)
9.5	0.1	7.5	0.2	9.0	0.1
10.0	0.5	8.0	1.1	9.5	1.1
10.5	0.9	8.5	1.5	10.0	1.3
11.5	0.9	9.0	1.8	10.5	1.5
12.0	0.8	9.5	2.0	11.0	1.8
12.5	0.7	10.0	2.1	11.5	2.1
13.0	0.5	11.0	2.4	12.0	2.1
13.5	0.3	12.0	2.6	12.5	2.1
14.5	0.2	13.0	2.6		
		13.5	2.4		
		14.5	2.2		
		15.0	2.1		

* Effective Filter Area = 4.6 ft^2
** Effective Filter Area = 6.4 ft^2

REFERENCES

1. Joyce, M., Schultz, W., and Strom, A., "Replacement of Activated Sludge Secondary Clarifiers by Dynamic Straining," U.S. Environmental Protection Agency, Environmental Protection Technology Series Report No. EPA-670/2-75-045, Cincinnati, Ohio (May 1975).

2. Thackston, E.L., Eckenfelder, W.W., Editors, "Process Design in Water Quality Engineering - New Concepts and Developments," Chapter 3, Jenkins Publishing Company, New York, N.Y. (1972).

APPENDIX

TABLE A-1. MAY 1974 STRAINER PERFORMANCE DATA (PHASE I)

	SECONDARY INFLUENT					LOAD FACTOR		STRAINER EFFLUENT						MIXED LIQUOR			
Date	Q (gpd)	pH	SS/VSS (mg/l)	TOC/SOC (mg/l)	BOD/COD (mg/l)	mg BOD_5/day / mg MLVSS	NH_3-N (mg/l)	pH	SS/VSS (mg/l)	TOC/SOC (mg/l)	BOD_5/COD (mg/l)	NH_3-N (mg/l)	TURB. (JTU)	pH	SS/VSS (mg/l)	SVI* (ml/g)	DO (mg/l)
6														7.55	1375/1100	-	-
7														7.40	1420/1205	-	-
8														7.85	1490/1205	-	-
9														7.35	1735/1375	-	-
10														7.95	1735/1395	-	-
11																	
12																	
13	-	7.70	128/104	113/48	-	-	-							7.75	1610/1280	-	-
14																	
15	-	7.65	132/104	100/44	-	-	-	8.00	20/17	22/11	-	-		7.60	1690/1350	118	7.4
16	-	7.55	106/86	94/38	-	-	-	8.15	14/11	15/9	-	-	6.6	7.45	1935/1575	119	6.5
17	-	7.70	111/89	100/44	-	-	-	7.90	15/12	14/8	-	-	6.6	7.25	2735/2270	154	4.6
18	-							8.10	12/9	12/6	-	-	4.6				
19																	
20	24,420	7.70	126/100	96/39	/349		20	7.75	34/25	17/8	-	-	14.0	7.20	6590/5535	151	5.4
21	27,020	7.60	110/96	94/56	-		-	7.80	25/19	23/10	-	-	9.0	7.30	4760/4025	210	5.0
22	24,650	7.50	89/73	88/43	-		14	7.75	26/20	24/9	-	N.D.	9.0	7.05	3765/3165	Float	
23	25,110	7.65	119/101	100/47	-		12	7.80	17/14	18/10	-	4	8.4	7.05	3560/3025	152	
24	17,820	7.35	222/190	174/65	-		23	7.60	39/29	27/9	-	-	13.0	7.00	4520/3660	157	-
25	24,860													8.00	4300/3730	Float	4.2
26	23,110													7.20	5010/4320	Float	4.5
27	19,400													7.10	6120/5230	150	-
28	19,270	7.85	156/124	142/75	-	-	19	7.40	42/31	13/9	-	-	-	7.00	6560/5630	152	4.4
29	22,690	7.80	92/74	65/51	165/382	0.18	18	7.50	38/30	20/10	9/77	N.D.	13.0	6.90	6630/5650	151	-
30	20,270	7.20	110/88	85/38	-	-	18	7.60	27/19	13/6	-	N.D.	-	7.05	7110/6110	141	-
31	17,770	7.45	144/120	110/49	206/441	0.16	20	8.20	4/3	7/7	2/30	N.D.	8.5	7.15	7310/6160	137	-

N.D. = Non-detectable
* = Solids in cylinder floated instead of settled on some days.

TABLE A-2. MAY 1974 SAND FILTER PERFORMANCE DATA (PHASE I)

	DOWNFLOW COAL/SAND FILTER					UPFLOW SAND FILTER				
Date	pH	SS/VSS (mg/l)	TOC/SOC (mg/l)	BOD_5 (mg/l)	TURB. (JTU)	pH	SS/VSS (mg/l)	TOC/SOC (mg/l)	BOD_5 (mg/l)	TURB. (JTU)
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20	8.25	16/7	9/7	-	7.0	7.40	4/2	11/11	-	2.2
21	8.10	2/1	9/9	-	1.3	7.70	2/2	9/9	-	1.4
22	8.10	4/2	9/8	-	1.6	7.60	4/2	10/8	-	1.6
23	8.05	5/2	13/10	-	2.9	7.60	10/7	19/9	-	6.8
24	8.10	2/1	10/8	-	2.3	7.70	32/24	14/8	-	8.2
25										
26										
27										
28	8.00	3/1	9/9	-	1.3	7.25	16/13	11/7	-	6.2
29	8.10	4/2	7/6	-	1.8	7.80	31/22	40/6	7	8.7
30	8.15	1/1	7/4	-	1.5	7.75	8/4	11/7	-	4.3
31	7.75	8/7	8/8	2	3.5	7.60	27/21	14/6	7	8.1

TABLE A-3. JUNE 1974 STRAINER PERFORMANCE DATA (PHASE I)

	Secondary Influent					Load Factor		Strainer Effluent						Mixed Liquor			
Date	Q (gpd)	pH	SS/VSS (mg/l)	TOC/SOC (mg/l)	BOD/COD (mg/l)	mg BOD_5/day / mg MLVSS	NH_3-N (mg/l)	pH	SS/VSS (mg/l)	TOC/SOC (mg/l)	BOD_5/COD (mg/l)	NH_3-N (mg/l)	TURB. (JTU)	pH	SS/VSS (mg/l)	SVI* (ml/g)	DO (mg/l)
1	15,020																
2	17,106							7.80	33/23	13/8		2					
3	32,480	7.70	176/140	122/48	190/43	0.27	22	7.70	30/28	17/6	8/77	N.D.	9.3	-	-	-	-
4	28,320	7.69	88/68	69/29	-	-	16	8.08	30/23	14/5	-	N.D.	13	7.08	6810/5820	147	-
5	28,860	7.39	451/387	181/56	385/695	0.51	16	7.95	32/26	15/7	7/47	N.D.	18	7.10	6970/5940	143	1.6
6	27,810	7.30	132/112	139/52	-	-	19	8.00	41/33	18/5	-	N.D.	8	7.12	6880/5850	145	-
7	28,110	7.62		96/43	182/444	0.22	21	7.88	29/22	14/4	6/48	0.8	16	7.10	6880/5670	145	-
8	27,690												12	7.20	7200/6180	139	1.4
9	16,860							8.12	23/16	12/5	5/-	1					
10	23,940	7.82	115/93	83/31	138/373	0.18	17	8.10	33/24	15/5	5/71	N.D.	8.6				
11	27,270	7.65	103/86	95/38	-	-	17	7.80	38/29	16/8	-	N.D.	12	7.18	5350/4580	187	1.5
12	23,190	-	120/10.	86/36	141/313	0.18	17	7.70	47/35	18/5	11/80	N.D.	12	7.12	6070/5080	165	1.3
13	24,690	-	106/88	88/36	-	-	12	7.65	41/27	16/4	-	N.D.	16	7.10	5770/4910	Float	-
14	25,690	7.75	99/78	95/49	146/331	0.18	14	7.95	39/31	16/6	7/74	N.D.	15	7.10	6620/5570	Float	1.9
15	27,270												15	7.10	6900/5640	Float	1.4
16	29,150																
17	28,000	7.82	141/114	87/38	137/379	0.17	17	7.80	22/17	12/4	3/64	N.D.					
18	25,950	7.70	138/113	87/46	-	-	14	8.00	19/14	10/5	-	N.D.	8.7	7.19	7000/5970	Float	2.0
19	27,880	7.65	88/72	70/29	117/225	0.15	13	7.80	43/30	14/4	6/85	N.D.	7.2	7.15	6850/5830	Float	1.4
20	24,770	7.22	111/93	108/49	-	-	15	8.32	33/26	15/4	-	N.D.	14	7.05	6960/5960	Float	-
21	22,700	7.10	118/105	94/40	152/271	0.15	-	8.30	37/28	12/3	9/64	N.D.	13	7.05	6900/5850	Float	1.0
22	22,440												12	7.08	6990/5990	143	
23	22,650																
24	22,730	7.39	114/93	88/41	154/385	0.14	15	7.95	39/29	23/5	10/82	N.D.					
25	23,600	7.20	140/59	140/59	-	-	14	7.98	48/36	17/4	-	N.D.	17	7.12	7640/6420	131	
26	24,400	7.20	96/53	96/53	423/778	0.50	15	8.10	42/30	26/7	8/56	N.D.	18	7.20	7070/5980	Float	
27	21,270	7.40	95/50	95/50	-	-	12	7.85	42/35	27/16	-	2	14	7.18	6410/5450	Float	
28	24,270	7.15	88/53	88/53	150/303	0.17	14	7.95	46/35	20/5	11/150	N.D.	17	7.22	7130/6050	140	
29	20,770												17	7.30	6720/5770	Float	
30	23,860																

N.D. = Non-detectable
* = Solids in cylinder floated instead of settled on some days.

TABLE A-4. JUNE 1974 SAND FILTER PERFORMANCE DATA (PHASE I)

	DOWNFLOW COAL/SAND FILTER					UPFLOW SAND FILTER				
Date	pH	SS/VSS (mg/l)	TOC/SOC (mg/l)	BOD_5 (mg/l)	TURB. (JTU)	pH	SS/VSS (mg/l)	TOC/SOC (mg/l)	BOD_5 (mg/l)	TURB. (JTU)
1										
2	8.12	3/1	7/7	-	1.6	7.69	6/1	8/6	-	2.8
3	8.05	2/2	6/5	2	1.8	7.65	8/6	10/7	4	3.3
4	8.08	4/2	6/5	-	1.8	7.68	7/4	7/7	-	3.2
5	8.25	3/2	5/5	2	1.5	7.50	13/12	13/7	1	4.5
6	8.05	1/1	4/4	-	1.3	7.70	6/6	8/4	-	3.7
7	8.09	1/N.D.	4/4	4	1.3	7.73	6/6	8/7	2	3.3
8										
9	8.10	1/N.D.	8/3	1	1.8	7.80	4/3	5/3	-	3.0
10	8.19	3/N.D.	6/6	1	1.4	7.95	9/2	7/6	-	3.5
11	8.10	1/N.D.	7/6	-	1.3	7.70	4/2	7/7	-	2.4
12	8.30	3/1	6/6	2	1.6	7.90	15/10	8/8	5	5.0
13	8.20	3/1	5/5	-	1.9	7.75	12/8	9/4	-	5.0
14	8.35	2/2	6/5	1	1.5	8.00	6/5	8/6	1	3.0
15										
16										
17	8.09	1/N.D.	4/4	N.D.	1.3	7.75	1/N.D.	5/4	N.D.	1.2
18	8.10	1/N.D.	4/4	-	1.4	7.75	1/N.D.	4/4	-	1.3
19	8.25	1/N.D.	4/4	1	1.1	7.75	1/N.D.	4/4	1	1.5
20	8.18	3/3	4/4	-	1.4	7.75	3/1	3/3	-	1.4
21	8.25	5/2	4/4	3	2.1	7.60	3/2	4/4	3	1.7
22										
23										
24	8.29	5/4	7/7	2	2.7	7.85	8/7	7/4	3	4.3
25	8.25	4/3	6/4	-	1.7	7.78	6/5	5/4	-	2.4
26	8.25	4/2	8/5	2	1.8	7.72	7/4	6/4	3	2.5
27	8.39	3/3	4/4	-	1.7	7.72	8/6	7/3	-	3.0
28	8.01	6/4	13/4	4	2.4	7.70	16/12	11/4	7	6.2
29										
30										

TABLE A-5. JULY 1974 STRAINER PERFORMANCE DATA

	SECONDARY INFLUENT					LOAD FACTOR		STRAINER EFFLUENT						MIXED LIQUOR			
Date	Q (gpd)	pH	SS/VSS (mg/l)	TOC/SOC (mg/l)	BOD_5/COD (mg/l)	mg BOD_5/day / mg MLVSS	NH_3-N (mg/l)	pH	SS/VSS (mg/l)	TOC/SOC (mg/l)	BOD_5/COD (mg/l)	NH_3-N (mg/l)	TURB. (JTU)	pH	SS/VSS (mg/l)	SVI* (ml/g)	DO (mg/l)
1	27,710	7.20	284/218	96/30	174/412	.21	15	7.85	31/23	7/3	7/4	2	9.4	7.25	7230/6120	Float	1.7
2	18,600	7.52	88/71	50/18	-		14	7.80	25/18	9/4	-	3	7.6	7.42	7200/6160	139	
3	23,215	7.22	624/504	165/38	338/539	.36	-	7.85	33/23	13/6	9/89	3	10.0	7	6950/5960	144	1.6
4	23,690	7.35	135/113	83/19	-		10								6820/5750	147	
5																	
6	3,500					END OF PHASE I											
7	2,100																
8	17,440	7.25	122/94	102/54	207/413		16	7.95	41/30	15/7	11/-	N.D.	17.0	6.80	6970/5840	143	
9	28,270	7.20	134/110	132/87	-		15	7.70	64/49	24/8	-	N.D.	32	7.10	6180/5210	162	
10	30,190	7.10	126/107	94/52	165/-		13	7.70	47/36	14/5	12/-	N.D.	16	7.05	6070/5180	Float	
11	14,860	6.60	143/120	133/79	-		13	7.90	59/46	20/14	-	N.D.	23	7.00	5350/5090	187	
12	26,110	6.95	147/115	136/95	-		14	7.95	64/45	23/5	16/105	N.D.	23	7.15	6430/5510	156	
13	24,360																
14	24,940																
15	30,690	6.90	149/127	140/79	230/528		17	8.15	31/23	13/7		N.D.	8.5	7.10	6090/5120	164	
16	49,440	7.20	140/61	94/47	-		15	7.90	56/43	15/8		4	20.0	7.20	7090/6140	141	
17	13,690	7.30	126/102	84/40			17	7.95	17/13	11/4	-	N.D.	5.4	7.35	4910/4230	204	
18	13,440	7.10	123/98	98/56	-		15	8.20	21/13	11/4	-	N.D.	6.3	7.20	5600/4740	178	
19	<1,000	7.10	95/80	76/59	-		11	-	-	-	-	-	-	7.10	5730/4910	175	
22	0	-	-														
23	<1,000	6.75	115/93	110/65	-		-	-	-	-	-	-	-	5.35	5550/4650	180	
24	6,250	7.15	102/85	82/42	-		12	-	-	-	-	-		5.35	5640/4790	177	
25	<1,000	7.05	134/107	95/45	-		12	-	-	-	-	-	-	6.60	5060/4260	194	
26	45,190	7.00	174/134	99/50			13	-	-	-	-	-	-	7.25	3870/3210	215	
27	23,110						15	7.55	80/58	9/6		1	26	6.80	4110/3300	117	
28	0																
29	-	7.40	111/90	63/28			17	7.60	71/53	17/3		3	21	7.00	7190/5800		
30	-	7.10	112/91					7.70	50/37			2	13	7.23	5510/4500		
31	-	7.30	408/323				17	8.05	71/58			1	23	7.20	7740/6460		

N.D. = Non-detectable
* = Solids in cylinder floated instead of settled on some days.

TABLE A-6. JULY 1974 SAND FILTER PERFORMANCE DATA

	DOWNFLOW COAL/SAND FILTER					UPFLOW SAND FILTER				
Date	pH	SS/VSS (mg/l)	TOC/SOC (mg/l)	BOD_5 (mg/l)	TURB. (JTU)	pH	SS/VSS (mg/l)	TOC/SOC (mg/l)	BOD_5 (mg/l)	TURB. (mg/l)
1	8.20	4/3	5/3	3	2.0	7.75	4/3	4/3	3	1.7
2	8.10	2/1	3/3	-	1.4	7.80	3/2	4/4	-	1.3
3	8.00	4/2	6/6	2	1.7	7.90	5/3	6/5	2	2.7
4										
5										
6	-------------------End of Phase I ----------------------------------									
7										
8	8.20	3/2	14/5	1	2.3	7.70	2/2	10/7	2	1.5
9	8.10	8/6	10/9	-	3.5	7.70	11/8	10/10	-	4.3
10	8.15	6/3	10/5	-	2.6	7.70	9/5	6/6	-	4.0
11	8.20	7/5	6/6	-	3.0	7.70	11/9	11/7	-	4.5
12	8.10	5/2	5/5	3	2.4	7.60	12/10	9/7	6	7.6
13										
14										
15	8.10	6/3	6/6		2.7	7.65	9/5	9/7		4.3
16	8.10	4/4	7/6	-	3.2	7.65	7/5	8/8	-	4.3
17	8.00	2/2	4/4		1.4	7.65	3/3	3/3		1.3
18	8.20	3/2	6/6	-	1.2	7.60	3/3	4/4	-	1.3
19										
22										
23										
24										
25										
26	8.20	5/2	4/4		3.1	7.60	10/7	10/10		3.7
27										
28										
29	8.20	7/5	3/3		2.3	7.70	12/10	5/1		3.8
30	8.20	7/5		-	2.3	6.70	25/21		-	7.5
31	8.10	7/6			2.6	7.80	5/4			2.4

TABLE A-7. AUGUST 1974 STRAINER PERFORMANCE DATA

	SECONDARY INFLUENT					STRAINER EFFLUENT					MIXED LIQUOR			
Date	Q (gpd)	pH	SS/VSS (mg/1)	BOD_5/COD (mg/1)	NH_3-N (mg/1)	pH	SS/VSS (mg/1)	BOD_5/COD (mg/1)	NH_3-N (mg/1)	TURB. (JTU)	pH	SS/VSS (mg/1)	SVI (mg/1)	DO (mg/1)
1	42,520	7.50	116/93	-	16	8.00	26/17	-	N.D.	7.3	7.15	10,820/8920	92	1.2
2	44,360										7.20	10,660/8680	94	1.0
3	0													
4	0													
5	42,520	7.65	160/124	177/407	16	7.70	114/88	56/229	8	48	7.55	1,105/835	226	
6	44,360	7.55	147/114	-	12	7.45	147/121	-	4	54	7.35	2,390/1980	109	1.2
7	8,940	7.30	140/109	190/345	15	7.50	98/75	35/150	N.D.	-	7.20	3,840/3220	229	
8	1,250										7.40	3,700/3080	251	1.3
9	15,520													
10	29,780													1.6
11	0													1.6
12	0													
13	29,360	7.30	114/91	-	-	7.10	117/	-	24	-	7.80	1,960/1650	212	
14	10,610	7.20	157/103	-		8.00	42/30	-	N.D.	11	7.40	1,800/1550	178	2.0
15	2,510	7.80	124/79	-	-			-	-	-	6.80	3,150/ -	281	
16	6,480			-	-			-		-	7.30	4,390/3480	223	
17	10,440										7.30	3,430/2910	286	1.2
18	9,690													
19	0													1.0
20	0													
22	33,600	-	-	-	-	7.40	208/149	-	-	-	-	-	-	-
23	36,170	7.30	332/239	-	-						7.35	1,695/1340	118	
24	16,500													
25	17,170					7150	215/158	-	-	66	-	-	-	-
26	30,250	7.20	137/88	-	-	7.35	141/110	-	-	49	7.30	3,335/2680	99	1.1
27	30,830	7.20	217/165	-	-	7.30	196/145	-	-	70	7.20	4,550/3785	172	1.0
28	12,250	7.30	211/164	-	-	7.90	91/80	-	-	33	7.10	5,310/4415	173	
29	7,000	7.50	260/210	-	-	7.70	118/89	-	-	36	7.20	5,515/4625	170	
30	12,000	7.65	120/92	-	-	-	-	-	-	-	7.05	5,350/4530	181	
31	1,420													

N.D. = Non-detectable

TABLE A-8. AUGUST 1974 SAND FILTER PERFORMANCE DATA

Date	DOWNFLOW COAL/SAND FILTER			UPFLOW SAND FILTER		
	pH	SS/VSS (mg/l)	TURB. (JTU)	pH	SS/VSS (mg/l)	TURB. (JTU)
1	8.05	5/2	1.7	7.90	3/1	1.4
2						
3						
4						
5	-	-	-	7.55	16/10	8
6	7.65	62/51	22	7.40	59/48	24
7						
8						
9						
10						
11						
12						
13	7.50	15/-	8.5	7.20	24/-	11
14	7.20	5/5	2.4	7.80	6/6	2.6
15						
16						
17						
18						
19						
20						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						

TABLE A-9. SEPTEMBER 1974 STRAINER PERFORMANCE DATA

		SECONDARY INFLUENT				STRAINER EFFLUENT					MIXED LIQUOR			
Date	Q (gpd)	pH	SS/VSS (mg/1)	BOD_5/COD (mg/1)	NH_3-N (mg/1)	pH	SS/VSS (mg/1)	BOD_5/COD (mg/1)	NH_3-N (mg/1)	TURB. (JTU)	pH	SS/VSS (mg/1)	SVI (ml/g)	DO (mg/1)
1	4,083													
2	14,667					7.50	62/48	-	-	18				
3	13,920	7.90	190/141	-	-	8.00	40/24	-	-	16	7.30	3405/2720	285	
4	11,250	7.35	97/76	-	-	7.80	113/88	-	-	42	7.40	3745/3040	267	0.9
5	10,000	7.60	128/100	-	-	7.85	133/111	-	-	53	7.40	3945/3135	246	
6	16,420	7.65	96/83	-	-	7.80	118/85	-	-	47	7.35	3865/3065	248	1.0
7	23,000													
8	15,590													
9	28,250	7.85	165/127	-	-	7.85	100/68	-	-	33	7.35	4360/3450	72	1.2
10	15,080	6.65	129/101	-	-	7.90	141/105	-	-	53	7.35	6050/4750	137	
11	24,420	7.50	101/79	-	-	8.00	46/33	-	-	17	7.60	5090/4010	79	1.4
12	21,670	7.40	118/87	-	-	7.95	66/44	-	-	13	7.50	5830/4510	129	
13	12,000	7.25	115/91	-	-	7.50	127/93	-	-	42	7.40	5270/4140	169	
14	15,420													
15	13,170													
16	19,500	7.55	135/107	-	-	7.40	228/172	/368	-	86	7.35	5910/4640	162	1.0
17	29,000	7.25	131/105	/313	-	7.85	176/130	/293	-	45	7.45	5180/4090	168	
18	4,920	7.30	199/152	/370	-	7.60	152/120	/306	-	44	7.20	5440/4300	171	
19	28,000	9.20	144/109	/493	-	7.50	178/136	/363	-	50	7.45	5880/4780	164	1.7
20	21,330	7.35	129/99	/319	-	7.30	106/83	/205	-	40	7.10	6200/5090	160	
21	17,870													
22	15,500													
23	17,080	7.35	167/127	/351	-	7.65	134/102	/273	-	33	7.25	6970/5710	142	
24	13,250	7.00	460/266	/712	-	7.70	87/71	/165	-	31	7.20	5700/4620	175	1 4
25	13,000	7.05	118/94	/339	-	7.60	91/76	/235	22	30	6.95	5670/4500	176	
26	16,750	7.15	140/116	/386	4.4	7.60	90/73	/314	-	40	6.90	5300/4310	189	
27	13,080	7.30	278/188	/646	-	7.90	45/34	-	-	15	7.10	7000/5660	143	0.9
28	15,000													
29	15,083													
30	19,083	7.60	183/152	-	-	7.95	99/63	/196	12	30	7.40	6960/5750	144	

TABLE A-10. OCTOBER 1974 STRAINER AND SAND FILTER PERFORMANCE DATA

Date	SECONDARY INFLUENT					STRAINER EFFLUENT					MIXED LIQUOR		DOWNFLOW COAL/ SAND FILTER			UPFLOW SAND FILTER		
	Q (gpd)	pH	SS/VSS (mg/l)	COD	NH_3-N (mg/l)	pH	SS/VSS (mg/l)	COD	NH_3-N (mg/l)	TURB. (JTU)	pH	SS/VSS (mg/l)	pH	SS/VSS (mg/l)	TURB. (JTU)	pH	SS/VSS (mg/l)	TURB. (JTU)
1	22,020	7.00	94/78	428	20.6	7.70	74/61	170	N.D.	29	6.70	6845/5710	7.70	56/47	22	7.50	63/53	40
2	17,020	7.00	165/143	414	17	7.80	96/79	219	N.D.	42	6.80	6930/5880	7.70	70/55	32	7.50	63/46	53
3	27,690	7.50	111/85	364	17	7.65	70/59	163	-	32	6.85	6210/5240	7.75	86/75	47	7.35	76/67	48
4	21,440	7.20	127/108	384	-			-	-	-	6.95	6300/5300	-	-	-	-	-	-
5	22,360																	
6	26,070																	
7	5,440	7.60	108/84			7.75	172/130				7.40	6470/5400						
8	<1,000	7.35	155/108								7.50	6460/5460						
9	0										7.60	4930/4040						
10	3,100										7.70	5000/4100						
11	<1,000										8.00	4400/3610						
12	0																	
13																		
14	<1,000										8.15	3690/2490						
15	<1,000										7.95	3760/3020						
16	5,400										7.20	3540/2870						
17	5,100										7.15	3740/2990						
18	4,440					8.80	113/90				7.75	3700/2990						
19	3,940																	
20	5,360																	
21	0										7.45	1290/980						
22																		
23																		
24																		
25																		
26																		
27																		
28																		
29																		
30																		
31	1,000	7.60	136/97			7.90	98/67				7.80	328/248						

TABLE A-11. NOVEMBER-DECEMBER 1974 STRAINER PERFORMANCE DATA

	SECONDARY INFLUENT			STRAINER INFLUENT		MIXED LIQUOR	
Date	Q (gpd)	pH	SS/VSS (mg/l)	pH	SS/VSS (mg/l)	pH	SS/VSS (mg/l)
11-6	46,100	7.30	128/103	7.40	156/124	7.80	3650/3050
7	40,607	7.30	70/57	7.25	274/110	7.25	5540/4500
8	42,690	7.40	78/57	7.35	242/230	7.30	5510/4600
10	18,270						
11	16,290						
12	46,190	7.65	65/50	7.30	140/105	7.20	6890/5710
13	11,500					7.30	5635/4605
14	41,440					7.05	4130/3820
15	34,940					7.50	3020/2450
16	39,690						
17	28,020						
18	41,520					7.40	2395/1955
19	48,270					7.30	3260/2705
20	<1,000					7.25	1320/ -
21	0						
22	31,060						
23	25,020						
24	37,770						
25	37,020						
26	46,440						
27	39,940						
28	39,190						
29	37,770						
30	43,100						
12-2	<1,000			7.50	139/121	7.40	7760/6540
3	<1,000					7.10	2000/ -
4	<1,000			7.30	60/-	7.20	1470/ -