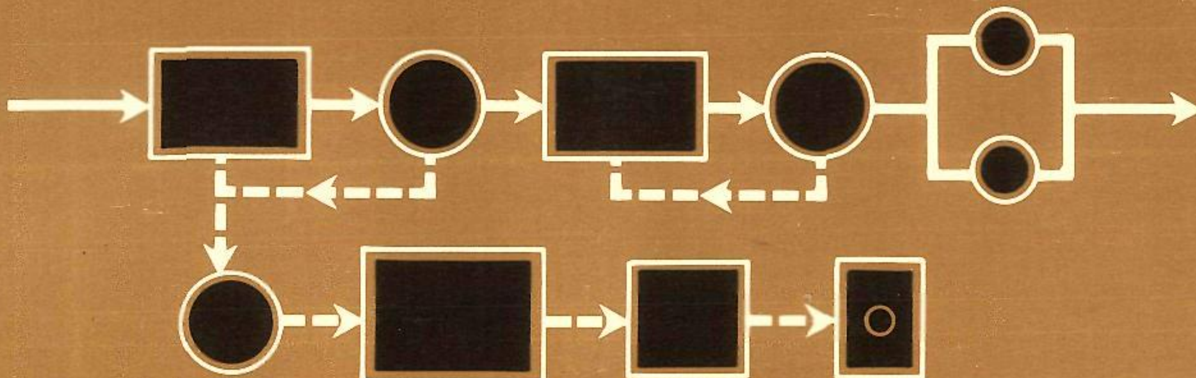
FITCHBURG PILOT PLANT REPORT

COMMONWEALTH OF MASSACHUSETTS

WATER RESOURCES COMMISSION

DIVISION OF WATER POLLUTION CONTROL

RESEARCH PROJECT 70-02



MARCH 1971

CAMP DRESSER & McKEE INC.

CONSULTING ENGINEERS

CAMP DRESSER & McKEE
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CONSULTING ENGINEERS

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September 1, 1971

Mr. Thomas C. McMahon, Director
Division of Water Pollution Control
Water Resources Commission
Department of Natural Resources
100 Cambridge Street
Boston, Massachusetts 02202

Fitchburg Pilot Plant Study
Final Report - Research Project 70-02
CDM 448-3-RT

Dear Mr. McMahon:

In accordance with the contract agreement between the Commonwealth of Massachusetts, Division of Water Pollution Control and Camp Dresser & McKee Inc., dated August 18, 1969, we have conducted studies at a pilot plant facility established at the existing Fitchburg wastewater treatment plant. This study was to investigate the effectiveness and efficiency of a two-stage activated sludge system to remove carbonaceous and nitrogeneous demanding material from Fitchburg wastewaters.

This report contains the results of our studies.

Very truly yours,

CAMP DRESSER & McKEE Inc.

Charles A. Parthum

Charles A. Parthum
Senior Vice President

COMMONWEALTH OF MASSACHUSETTS
CHARLES A. PARTHUM No. 7907
REGISTERED PROFESSIONAL ENGINEER

TABLE OF CONTENTS

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CAMP DRESSER & McKEE Inc.
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TABLE OF CONTENTS
(Continued)

LIST OF TABLES

LIST OF FIGURES

FITCHBURG PILOT PLANT REPORT

CHAPTER ONE

INTRODUCTION

General

In 1967, Camp, Dresser & McKee was engaged by the City of Fitchburg to make an engineering investigation to determine a plan for the effective treatment of wastewaters from the municipality, several large water consuming industries, the City and the surrounding Towns of Ashburnham, Lunenburg and Westminster. The basic recommendations of the study entitled, *Report on Comprehensive Plan for Domestic and Industrial Wastewater Disposal,* dated August, 1968, concluded that two wastewater treatment plants would most effectively and efficiently treat the municipal and industrial wastewaters from the area. A proposed municipal wastewater treatment facility would be located in East Fitchburg, adjacent to the municipal airport, and would treat the wastewaters from most of the City of Fitchburg, the Town of Lunenburg, and various industries in the City of Fitchburg. The existing municipal plant would be abandoned. The initial design capacity of this plant is expected to be approximately 12.4 million gallons per day (mgd), of which about 20 percent will be industrial wastewaters.

A proposed West Fitchburg wastewater treatment facility would be located on an abandoned lake bed adjacent to the Weyerhaueser Company, Paper Mill No. 7 in West Fitchburg. This treatment plant would be constructed to serve portions of West Fitchburg, the Town of Westminster and two major paper industries: the Weyerhaeuser Company, Paper Division and the Fitchburg Paper Company, a division of Litton industries. The plant, designed to treat approximately 15 mgd, was originally proposed to include flocculation and primary sedimentation for the industrial wastewaters, and conventional activated sludge for the further treatment of all wastewaters. Subsequent changes in the design loadings expected at the plant and in the methodology of activated carbon systems have resulted in the design of an activated carbon system for the treatment of the wastewaters from West Fitchburg in place of the proposed activated sludge system. However, no change was made in the pretreatment of the wastes prior to treatment in the activated carbon system.

During our study of the Nashua River, analyses of river water samples did not establish a definite relationship between the water quality of the river and available phosphorus and nitrogen because of limited data. We were able, however, to establish that a significant portion of the carbonaceous and nitrogenous Biochemical Oxygen Demand (BOD) must be removed from discharges to the Nashua River in order to meet a Class "C" stream classification. A computer model of the river was developed and a modified oxygen sag analysis was used to determine loadings which could be accepted from each of the Fitchburg treatment facilities and still maintain river standards during critical low flow periods.

Adequate removal of carbonaceous oxygen demanding material can be accomplished by conventional activated sludge or any of its modifications, such as a completely mixed system. Removal of nitrogenous oxygen demanding material can be accomplished either by removing the ammonia by stripping or by oxidizing it into nitrate. After considering a number of possible processes, we recommended that the City construct a two-stage activated sludge plant for the treatment of wastewaters at the East Fitchburg treatment facility. This plant was designed on the basis of results from this pilot plant and will result in the maximum amount of carbonaceous oxygen removal and will also oxidize the nitrogenous oxygen demanding material in the second stage aeration basin.

Pilot Plant Objectives

On August 17, 1969, Camp, Dresser & McKee signed a contract with the Massachusetts Division of Water Pollution Control to conduct a Research and Demonstration Grant to further investigate the concepts of the two-stage activated sludge system and to develop certain design criteria for the East Fitchburg wastewater treatment plant. The basic objectives of the pilot plant study were as follows:

1. Construct and operate a two-stage activated sludge pilot plant with an average capacity of 15-20 gallons per minute (gpm) located at the existing Fitchburg Sewage Treatment Plant.
2. Provide a suitable representative waste expected at the East Fitchburg wastewater treatment facility for the pilot plant study by utilizing wastewaters from the existing sewage treatment plant and obtaining those from the major paper industry by pumping to the pilot plant site.
3. Develop a specialized activated sludge for (a) the

removal of carbonaceous material and (b) the oxidation of ammonia (NH_3) to nitrate (NO_3^-) in order to achieve the highest possible degree of removal of oxygen demanding material from the wastewaters.

4. Obtain information on the settleability of the sludges developed in the two aeration systems of the pilot facility.
5. Study of removal of suspended solids (SS) from *the second stage effluent in granular filters.*
6. Study nitrate reduction in granular filters by the addition of a carbon source.
7. Study the reduction of phosphates (PO_4^-) by the addition of chemicals to the first aeration stage.
8. Investigate the waste sludge characteristics as they pertain to sludge thickening; air flotation and gravity thickening.
9. Investigate the waste sludge characteristics as they pertain to the filterability of the sludge.
10. Investigate the possibility of centrifugation of *the waste sludge.*
11. Evaluate sludge incineration and high rate oxidation of the sludge.

The pilot plant at Fitchburg had a two-fold purpose — *Research and Demonstration.* In addition to the research aspects of the project, as outlined above, the project sought to demonstrate the feasibility of the two-stage activated sludge system for the oxidation of carbonaceous and nitrogenous organic bearing materials. In determining the feasibility of this system, valuable data was collected which was utilized to determine the design criteria for the East Fitchburg wastewater treatment facility. The processes were modified so that design criteria could be established on aeration time, oxygen uptake of the mixed liquors, clarifier operation and various sludge characteristics such as thickening, dewatering and final disposal.

Initially this study was conducted with wastes from the City of Fitchburg and the Falulah Paper Company. *In July of 1970, the Falulah Paper Company* ceased manufacturing paper in Fitchburg. This significantly affected the results of the pilot study in certain areas, as discussed in this report.

Acknowledgements

This study was funded under a contract with the Commonwealth of Massachusetts, Water Resources Commission, Division of Water Pollution Control. This Research Project No. 70-02 was under the direction of Charles A. Parthum, Senior Vice President, and Alan E. Rimer, Project Engineer. Warren W. Terrell had direct responsibility for the operation and maintenance of the pilot plant and Norton G. True was supervisor of the laboratory personnel and facilities.

Special thanks is extended to Mr. Jack Elwood and the staff of the Division of Water Pollution Control for their assistance and guidance throughout the course of this investigation and to Mr. George Lanides Commissioner of Public Works, Fitchburg, Massachusetts and to the staff at the Fitchburg Sewage Treatment Plant for the many hours of help rendered during this study.

CHAPTER TWO

SUMMARY, CONCLUSIONS AND EAST FITCHBURG WASTEWATER TREATMENT PLANT DESIGN CRITERIA

Summary and Conclusions

The operation of the Fitchburg Pilot Plant resulted in several conclusions and findings which are noted below. A more detailed discussion of each of these points is presented in the appropriate chapter.

1. The municipal sewage tributary to the existing Fitchburg treatment plant was relatively weak due to large amounts of infiltration. The average BOD, suspended solids and ammonia were 134, 109 and 11.6 milligrams/liter (mg/l) respectively.
2. When the Falulah Paper Company was operating, the wastes delivered to the pilot plant had a moderately high BOD and COD (Chemical Oxygen Demand), an average pH of 6.4 and a high suspended solids content. Plain settling by upflow clarification was a very effective method for removing the suspended solids.
3. The two-stage activated sludge process proved to be a satisfactory method for removing BOD, COD, suspended solids and for the oxidation of ammonia nitrogen. It was found that the second stage system *not only removed the ammonia, but also provided additional removal (polishing effect) of BOD, COD and suspended solids.*
4. The sludge formed in the second stage aeration system was generally light and fluffy in nature and hence required a low overflow rate (hydraulic loading rate) in the second stage clarifier to insure proper settling.
5. The average oxygen uptake rate of the first and second stage mixed liquor micro-organisms was measured at about 35 and 16 mg/l per hour, respectively.
6. The variation of the oxygen uptake rate in the first stage mixed liquor varied considerably over the course of a day and with the characteristics of the incoming sewage. The second stage mixed liquor oxygen uptake rate was relatively constant throughout a 24-hour period.
7. In order to maintain a viable nitrifying sludge, the pH of the second stage mixed liquor had to be maintained between 8.0 and 8.4. It was also determined that the activated sludge in the second stage could be maintained if the pH was adjusted in the first stage aeration basin so that the resulting pH of the second stage mixed liquor was approximately 7.7.
8. The ability of the nitrifying sludge to oxidize ammonia to nitrate was significantly affected by the *temperature of the wastewater. The nitrifying sludge* could not be established during the winter months. The nitrifying sludge could be established more rapidly if the aeration tank was seeded with sludge which was already nitrifying.
9. The use of sodium hydroxide (NaOH) was preferred over the use of sodium carbonate (Na_2CO_3) for pH adjustment in the second stage mixed liquor. The chemical costs of NaOH and Na_2CO_3 were 30 and 50 dollars per million gallons respectively of sewage treated.
10. The Specific Growth Rate Constant, which is defined as the rate at which the nitrifying bacteria oxidize the ammonia (NH_3), ranged from 0.5 to 0.1 mg NH_3/mg MLVSS/day (milligrams of ammonia oxidized per mg of mixed liquor volatile suspended solids per day).
11. The Oxygen Utilization Constant varied from 2.0 to 11.0 mg O_2/mg NH_3 removed/day (milligrams oxygen consumed per milligram of ammonia oxidized). This parameter was inversely proportional to the mixed liquor temperature. At low temperatures the nitrifying bacteria required more oxygen to oxidize the same amount of ammonia than at a higher temperature.
12. *The occurrence of rainfall significantly affected* the performance of the treatment plant in oxidizing the ammonia. The loss in efficiency was probably caused by the decreased cell residence time due to hydraulic overloading of the aeration systems and a marked decrease in ammonia concentrations in the incoming waste.
13. The operation of a nitrification treatment plant must be closely monitored as the system is easily upset, resulting in a decrease in the ability of the plant to satisfactorily oxidize ammonia.
14. Though results were quite erratic, satisfactory denitrification, that is conversion of nitrate to elemental nitrogen, was accomplished in granular filters using methanol (CH_3 OH) as a carbon source for the denitrifying bacteria.
15. Partial removal of phosphates was accomplished by adding sodium aluminate ($Na_2Al_2O_4$) to the first stage mixed liquor. The maximum removal achieved at the pilot plant was about 84 percent.
16. The addition of sodium aluminate tended to reduce the first stage sludge volume index and increase the concentration of the first stage return sludge.
17. Gravity thickening of the waste activated sludge yielded a thickened sludge with a concentration averaging 2.7 percent.
18. *Flotation thickening was quite successful in* concentrating the waste activated sludge from the

pilot plant. Normally the sludge would thicken from 0.6 percent to approximately 5.0 percent. By using a polymer, an additional 1 to 2 percent thickening was achieved.

19. The thickened sludge was readily filtered on a leaf test apparatus. The total solids content of the filter cake produced ranged from 18.5 to 29.6 percent.

20. Wet oxidation of the waste activated sludge showed that the COD of the waste activated sludge was reduced 25 percent and the inflow solids were reduced by 60 percent.

21. Centrifugation produced a sludge cake with an optimum total solids of 36.1 percent.

22. Filtration of second stage effluent through granular filters produced an effluent which averaged 5 to 6 mg/l of suspended solids with a turbidity of 3 to 4 JTU's (Jackson Turbidity Units).

23. Optimum suspended solids removal in the granular filters occurred at a hydraulic loading of 1.9 gpm/sq ft.

This research and demonstration project showed conclusively that a two-stage activated sludge sewage treatment process is a feasible method for abating pollution in the Nashua River from municipal and certain industrial wastes produced in the City of Fitchburg.

Extrapolations For East Fitchburg Wastewater Treatment Plant Design Criteria

Aeration: Through the course of the project the aeration time in each unit was varied according to raw sewage flow. The design of the headbox permitted the maintenance of any preset flow rate. At the design flow of 15 gpm the average detention time in each aeration basin was 4.0 hours except that in August, 1970, the volume of the first stage aeration basin was reduced to give a detention time of 2½ hours at 15 gpm.

Aeration time in an activated sludge system is always an important design criteria. Approximately half-way through the project, it was decided to design the East Fitchburg sewage treatment plant for a first stage detention time of approximately 2 hours, based on the experience at the pilot plant to that time. It was decided that if the opportunity presented itself, the detention time in the pilot plant first stage aeration basin would be decreased also. This opportunity occurred on the 5th of August, when the partition in the first stage tank ruptured, requiring that the tank be repaired. Accordingly, the partition was repaired, but in a position which provided 2½ hours detention time at a flow rate of 15 gpm. The data indicated that the decrease in aeration time did not significantly alter the performance of the process and if anything, the BOD removed was somewhat higher with the shorter aeration time (See *Chapter Six*).

To adequately size aerators for the proposed East Fitchburg treatment plant, oxygen uptake studies were conducted on each of the mixed liquors. The first set of tests, described in *Chapter Six*, measured not only the maximum oxygen uptake rate, but also the time required for the mixed liquor to reach the endogenous respiration state. The second set of tests was used to determine the actual uptake conditions in the pilot plant aeration tanks.

The oxygen uptake studies also indicated that the oxygen demand is significantly higher in the first stage than in the second stage. This is due to the fact that much more energy is expended in oxiziding the carbonaceous BOD than that of the nitrogeneous BOD. The mechanical aerators in the proposed facility reflect the higher energy requirements of the first stage. A total of 400 and 360 horsepower were necessary for aerating the first and second stage systems, respectively.

pH Control: Several findings were made regarding the operation of the second stage aeration system which had a bearing on the design of the plant. pH control is necessary not only in the startup period, but also on a continuing basis. Several researchers[1,2,3] have indicated in the literature, that the optimum growth rate of the nitrifying bacteria may occur around a pH of 8.4. However, in these investigations pH control generally could be eliminated once the nitrifying sludge was formed. This was not the case at Fitchburg and it is thought that there was some toxic material in the waste which inhibited the growth of the nitrifiers, making it necessary to continuously adjust the pH to a range between 7.8 and 8.5, even in the warmest weather.

It was found that the use of sodium hydroxide (NaOH) was superior for adjusting the pH than the use of sodium carbonate (Na_2CO_3) as there was less problem with solution freeze-up and handling.

It was further found that the nitrification process could not be started up during the winter months, which is due to the fact that the growth rate of the nitrifying organisms is inversely proportional to temperature. This failure to start up during cold weather months may mean that upon completion of the proposed sewage treatment plant, the second stage process will have to be set in operation under favorable climatic conditions.

It was also determined that the nitrification process can be easily upset if close control of the process is not maintained. It appears that dilution of the incoming ammonia may tend to reduce the performance of the process and that at times, when the pH control is relatively erratic, the nitrification performance was also erratic. For a more complete discussion of the findings regarding nitrification, refer to *Chapter Six.*

Clarifiers: Operational data from the pilot plant clarifiers was more difficult to use for scale-up purposes. This problem is usually true in pilot studies and lies in the fact that small clarifiers tend to be upset quite easily. Generally speaking, it was noted that the second stage sludge was quite light and fluffy in nature. Adequate settling was achieved at low overflow rates, 300 to 400 gallons per day per square foot (gpd/sq ft). Filtered BOD and COD tests indicated that often times a poor final effluent was due to overflow rates above 400 gpd/sq ft.

The two sludges formed in the two-stage activated sludge process are quite different due to the nature of the organisms present in each tank. The micro-organisms in the first stage system are characteristic of a conventional activated sludge plant. That is, they are generally quite dense and settle rapidly. The micro-organisms in the second stage are far fewer in number and are characterized by their fluffiness or light density. This lighter density created settling problems which were overcome by using an overflow rate of about 300 - 400 gpd/sq ft, based on maximum day flow. The final clarifiers in the proposed wastewater treatment plant have been designed for 1,000 gpd/sq ft at a flow equal to about 1.3 times the 1990 average day flow. This is a higher overflow rate than used in the pilot plant, but it must be kept in mind that the performance of small clarifiers is erratic and is easily upset.

Phosphate Removal: Tests using sodium aluminate showed that the removal of phosphorus was inconsistent. The best phosphorus removal was on the order of 80 percent and occurred at a molar aluminum to phosphate ratio (i.e. Al/P) of approximately 1.7. Much of the literature indicates that a molar Al/P ratio of 1.2 to 1.3 is adequate for complete removal of phosphorus.

As it is not presently known if phosphate removal will be required at the proposed treatment plant on a full time basis, and as the removal itself was inconsistent using aluminate, various provisions have been made for phosphate removal. Equipment has been provided at the new treatment facility. Continuing tests will be conducted at the full scale plant.

The proposed sludge handling at the East Sewage Treatment Plant accounts for a major part of the capital investment. The pilot plant study investigated the most feasible methods of sludge handling. All tests were run on waste first stage activated sludge, for at no time during the pilot plant operation was sludge intentionally wasted from the second stage system. In the proposed plant second stage activated sludge will only be wasted occasionally.

Sludge Handling and Treatment: During the study no significant attempt was made to investigate the effect of the return sludge rate on sewage treatment performance except to insure that adequate return sludge was available to maintain the proper mixed liquor suspended solids (MLSS). This was largely due to the inability to adequately adjust the sludge pump systems. Throughout most of the study the sludge recirculation rate ranged from 20 to 40 percent of the average sewage flow.

Since all the sludge tests were run at various periods during the study, changes in other parameters such as flow, aeration time, sodium aluminate feed, etc., had a noticeable effect on the sludge characteristics and subsequently its treatment.

Both air flotation and gravity thickening were studied in the pilot plant. The air flotation thickener had a net area of 1.0 square foot. The gravity thickener was fabricated from a 55-gallon drum and had a full length sight window. These studies paralleled the proposed operation at the East Fitchburg treatment plant and revealed the significant effect certain process modifications could have on the plant. (See *Chapter Eight*).

For example, the data indicated that air flotation thickening was a feasible and acceptable method for sludge thickening at Fitchburg. With the addition of polymers to enhance flotation thickening, an additional 2 percent concentration of total solids was normally achieved.

After thickening, the waste activated sludge will be dewatered by vacuum filtration. Accordingly, tests were made in conjunction with the thickening to determine the filterability of the waste sludge. Dewatering by centrifugation was also studied. Centrifugation tests were run at the Bird Machine Company's laboratory in Walpole, Massachusetts.

The leaf test simulates operations of a vacuum filter. Leaf tests on samples of thickened sludge indicated that this sludge was readily dewatered by vacuum filtration. The filter cake from the test ranged from 18.5 to 29.6 percent total solids. The cake had all the properties of a good filter cake in that it was readily discharged from the screen. The leaf tests were run at operating conditions normally associated with regular vacuum filter operation.

CHAPTER THREE

PILOT PLANT DESCRIPTION

General

A pilot plant facility was constructed at the existing Fitchburg sewage treatment plant located adjacent to Crawford Road in Southeast Fitchburg. The existing laboratory was renovated, and an area near the headworks was graded for the pilot units. The pilot plant was designed to accept wastewater from the Falulah Paper Company at a rate of approximately 2 to 5 gpm and from the municipality at a rate of approximately 10 to 20 gpm.

The pilot plant consisted of four basic units: (1) the headworks, including the raw sewage pumps and headbox, (2) the clarifiers for the wastewater from Falulah, (3) the two stage activated sludge system, and (4) the 6-in diameter pilot filters. A schematic of the pilot plant is illustrated in *Figure 1*. *Table 1* lists all the physical dimensions and design parameters of the various units.

Pilot Plant Facility

Headworks: The pilot plant headworks consisted of two units: the raw sewage pumps, and a headbox for approximating the daily sewage flow variation. The municipal sewage was pumped from the grit channel of the sewage treatment plant by means of two submersible close coupled 1½-in pumps each with a capacity to handle approximately 18 gpm. When both pumps operated in parallel, it was possible to obtain a flow of about 25 gpm (See *Figure 2*). These pumps posed significant operational difficulties throughout the study. They plugged easily, even though they had an open impeller design, and when clogged with rags, would generally destroy the pump seals which protected the motor from moisture. Each pump motor was rewound several times.

In October of 1970, it was decided to use these pumps as standby only, and accordingly, a paper sizing pump (purchased from the Falulah Paper Company) was installed. This pump was located in a newly constructed dry pit and had the capacity of handling much larger solids, which reduced the maintenance of the pump to a minimum.

The sewage was pumped from the grit channel up to a headbox where provision was made to vary the flow according to the selected design criteria for aeration times, etc. The headbox consisted of an influent bay

TABLE 1—PILOT PLANT DIMENSIONS AND DESIGN PARAMETERS AT VARIOUS FLOWS

		Gallons Per Minute		
1st stage		10	15	20
Aeration Tank - Initial	Dec., 1969 to Aug., 1970			
Dimensions	6.0 ft × 8.9 ft × 9.0 ft			
Volume (gals)	3,600			
Detention Time (hours)		6	4	3
Aerators (numbers)	2			
Aeration Tank - Final	Aug., 1970 to End			
Dimensions	6.0 ft × 5.4 ft × 9.1 ft			
Volume (gals)	2,200			
Detention Time (hrs)		3.67	2.44	1.83
Aerators (number)	2			
Clarifier				
Diameter	6 ft			
Side Water Depth	8.25 ft			
Volume (gals)	1,740			
Surface Area (ft²)	28.2			
Surface Overflow Rate (gpd/ft²)		510	765	1,020
Detention Time (hrs)		2.9	1.9	1.45
2nd Stage				
Aeration Tank				
Dimensions	5.95 ft × 9 ft × 9 ft			
Volume (gals)	3,600			
Detention Time (hrs)		6	4	3
Aerators (number)	2			
BOD Loading				
Clarifier				
Diameter	9 ft			
Side Water Depth (ft)	8.25			
Volume (gals)	3,920			
Surface Area (ft²)	63.5			
Surface Overflow Rate (gpd/ft²)		227	340	453
Detention Time (hrs)		6.5	4.4	3.3
Falulah Settling Tanks				
Initial (Wading pools used alternately)				
Flow (gpm)	2.2			
Diameter (ft)	6			
Side Water Depth (in)	14			
Volume (gals)	246			
Surface Area (ft²)	28.2			
Surface Overflow Rate (gpd/ft²)	112			
Detention Time (hrs)	1.86			
Final (2 steel tanks used in series as upflow clarifiers)				
	Tank No. 1	*Tank No. 2*		
Flow (gpm)	2.2	2.2		
Diameter (ft)	3	3		
Side Water Depth (ft)	3.5	3.0		
Volume (gals)	185	158		
Surface Area (ft²)	7.1	7.1		
Surface Overflow Rate (gpd/ft²)	448	448		
Detention Time (hrs)	1.4	1.2		

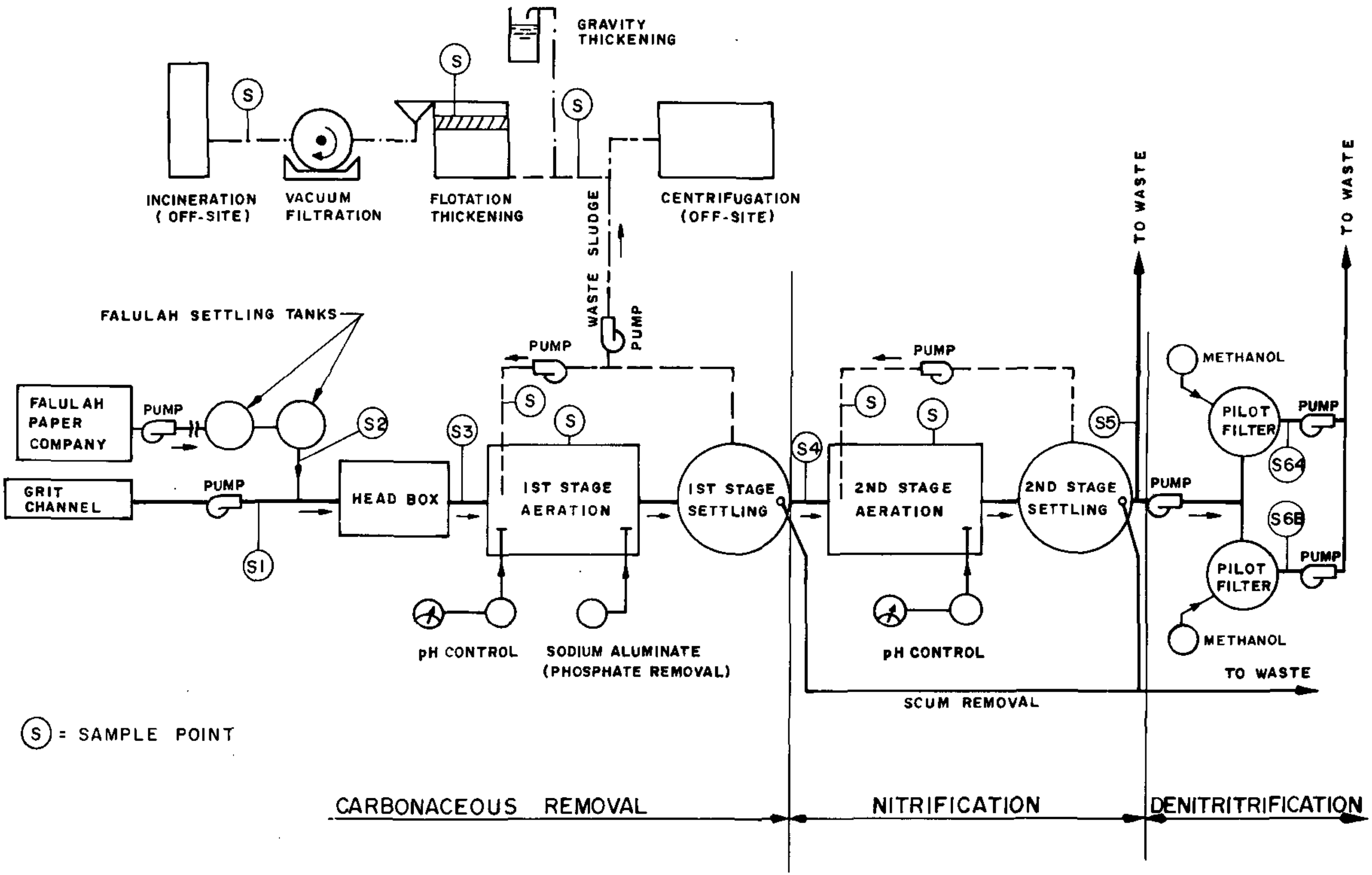

FIG. 1 SCHEMATIC FLOW DIAGRAM FITCHBURG PILOT PLANT

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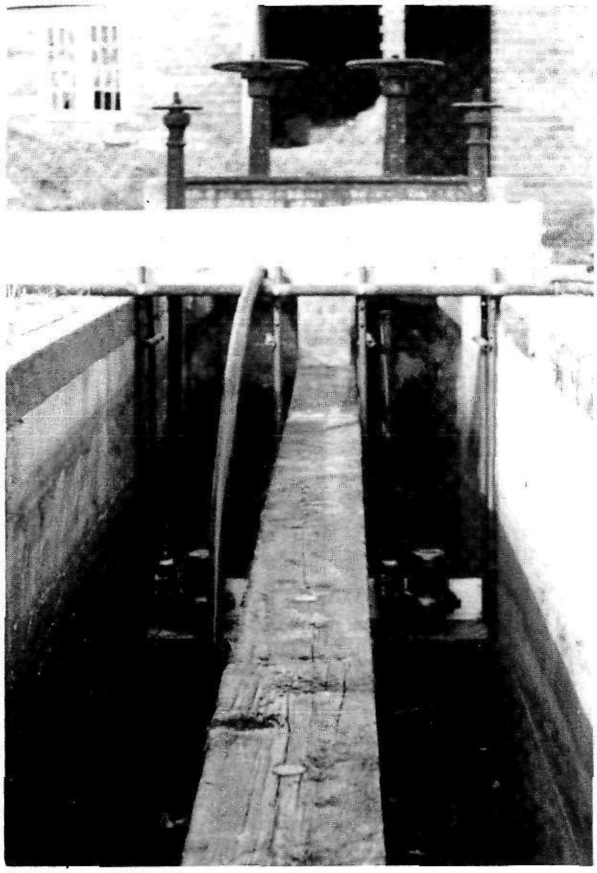


Figure 2. *Submersible Raw Sewage Pumps*

with an effluent weir which spilled into three control bays (See *Figure 3*). Each control bay drained to the pilot plant or to waste. The direction of flow, either to the plant or to the waste, was determined by the operation of automatic ball valves activated by electric timers. At the midpoint of the project, the automatic ball valves were deactivated and the variation of flow to the pilot plant depended on the variation in head in the grit channel. This resulted in a reasonable approximation of normal diurnal flow fluctuations, except during times of high flows to the plant when the head over the raw sewage pumps was high enough to significantly increase the flow to the pilot plant.

Falulah Paper Company Settling Tanks: The facilities for the pretreatment of the Falulah Paper Company waste were located at the pilot plant. It was necessary to settle the wastewaters from Falulah prior to discharge to the activated sludge system because of the very high suspended solids which were present in the wastewater.

Initially, two 6-ft diameter by 14-in side water depth "swimming pools" were used for gravity settling of the waste. The water was pumped to these settling basins from the mill, approximately 2,500 feet away, through a 1¼-in plastic pipe. Although the overflow rate of these clarifiers was sufficient (100-200 gpd/sq ft) there was little capacity for sludge storage. A significant amount of settled fiber and clay was noticed passing over the effluent weir of the clarifiers.

To alleviate this situation, the Falulah Paper Company provided us with two 3-ft diameter tanks which were modified to serve as primary clarifiers

The units were set up to operate in series as upflow clarifiers and the waste was discharged to the pilot plant headbox at a constant flow rate. The tanks were 4.0 and 3.5 feet deep, respectively, and provided adequate sludge storage. Consequently, the effluent from this unit was far superior to the effluent from the "swimming pool" clarifiers.

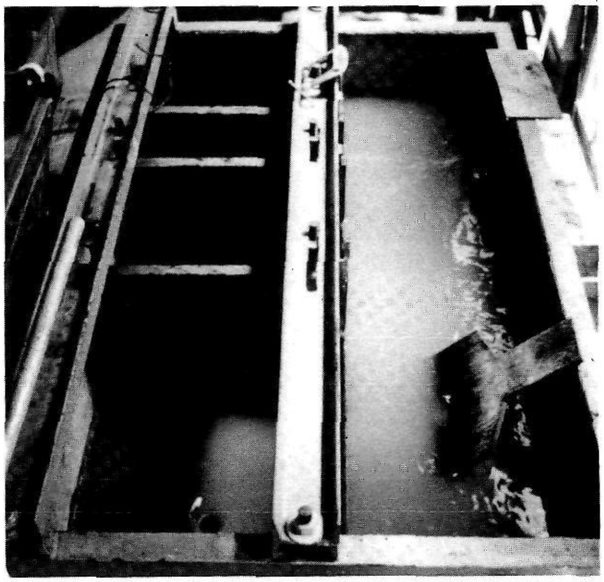


Figure 3. *Headbox for Diurnal Flow Variation*

Two-Stage Activated Sludge System: Another major group of units at the pilot plant consisted ot the two-stage activated sludge treatment system. The aeration basins were arranged in such a way as to provide for various detention times. Aeration was accomplished by means of diffusers which were supplied air by two compressors.

In the first stage, where carbonaceous BOD was oxidized, the aeration time initially was 4 hours at a flow of 15 gpm without sludge recirculation. Subsequently, this detention time was reduced to about 2½ hours. After aeration the mixed liquor flowed to the first stage clarifier where separation of the solids was achieved. This sludge was then recirculated back to the influent end of the first stage aeration basin. Although the first stage was used primarily for carbonaceous BOD removal, experiments were also carried out to ascertain the feasibility of phosphate removal by the addition of salts of aluminum in the first stage.

The effluent from the first stage clarifier flowed to the second stage aeration basin where the detention time was held at 4 hours, based on a flow rate of 15 gpm throughout the study. In this aeration system ammonia nitrogen (NH_3) was oxidized to nitrate-nitrogen (NO_3). To achieve this the pH had to be elevated to 8.4± by the addition of either NaOH or Na_2CO_3. As in the first stage, solids separation was accomplished in the second stage clarifier. Sludge was returned to the influent end of the second stage aeration basin.

Both treatment systems were prefabricated package sewage treatment plants manufactured by the Davco Company of Thomasville, Georgia. Generally speaking, the units were adequate for this pilot plant, but required initial and continual modifications to serve the varied needs of the study. The most significant operational problem encountered was the inadequacy of the sludge recirculation system. The airlift pumps operated very erratically and pumped too much or too little sludge. Closer control was required than that these units were design for. A sludge return system utilizing a positive displacement screw pump was therefore constructed. Provisions for better control of sludge wasting were also made at the same time.

In the clarifiers scum was collected from the top of the clarifier and returned to the aeration tank by means of an airlift system. This soon proved inadequate as the scum concentration continually built up in the aeration basin. A scum removal unit, which consisted of a 55-gallon drum, piped so as to permit removal of scum to waste, was therefore constructed. The underflow was discharged to the second stage aeration basin. Scum collected on the second stage clarifier was piped directly to waste. (See *Figure 4*).

Other equipment associated with the activated sludge system included the gravity and air flotation thickeners, which are described in *Chapter Eight*.

Pilot Filters: Other major units at the pilot plant consisted of two 6-in diameter pilot filters, which were housed in the basement of the existing Administration Building. These pilot filters serve a two-fold purpose; to study the removal of suspended solids in granular filters, and to investigate the denitrification of the treated waste by biological means. The effluent from the second stage clarifier was pumped to a distribution header on the filters. Each filter was equipped with a pressure regulator and pump which insured a constant flow through the filter regardless of the headloss occurring in the filter at any particular time. Adjacent to each filter was a manometer board for re-

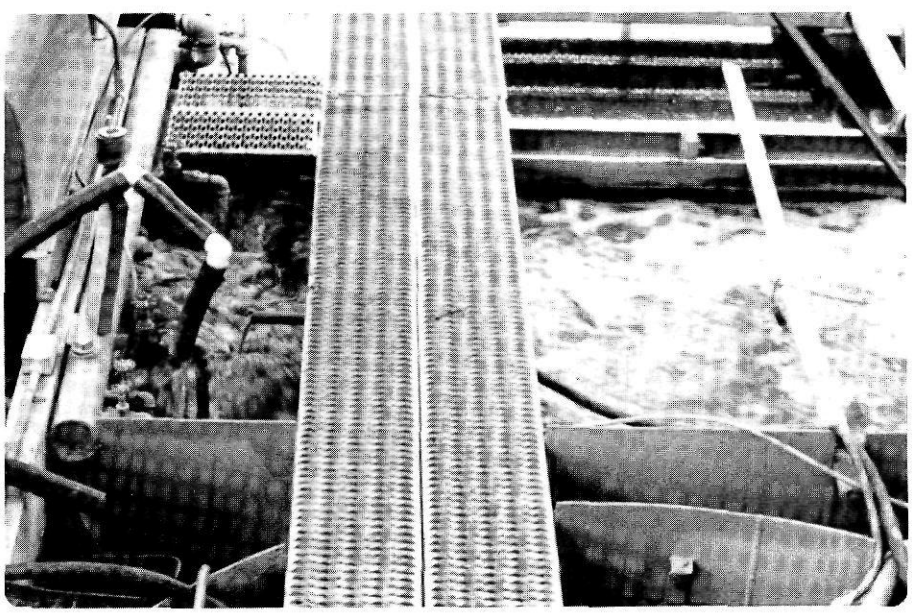


Figure 4. *Two-Stage Activated Sludge Pilot Plant (first stage)*

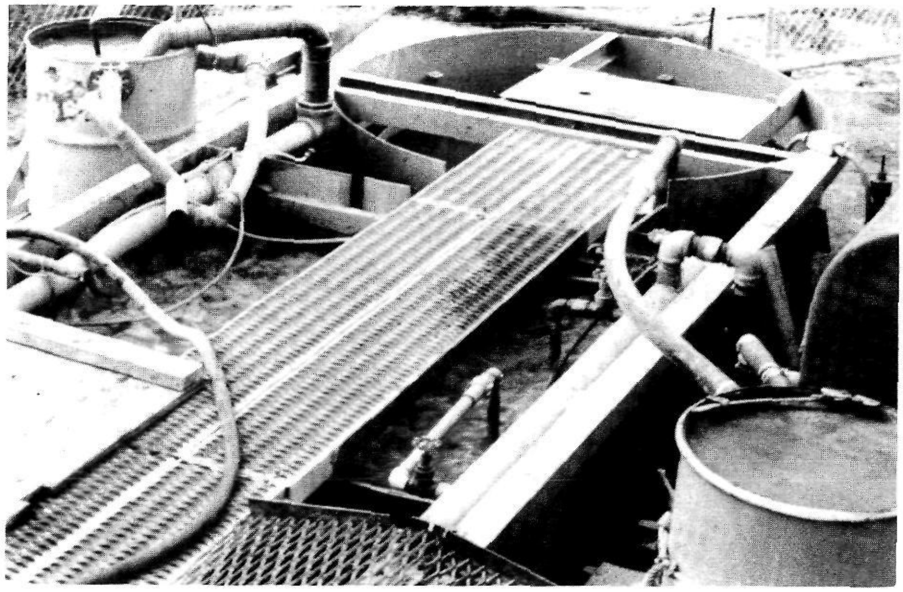


Figure 4. *Two-Stage Activated Sludge Pilot Plant (second stage)*

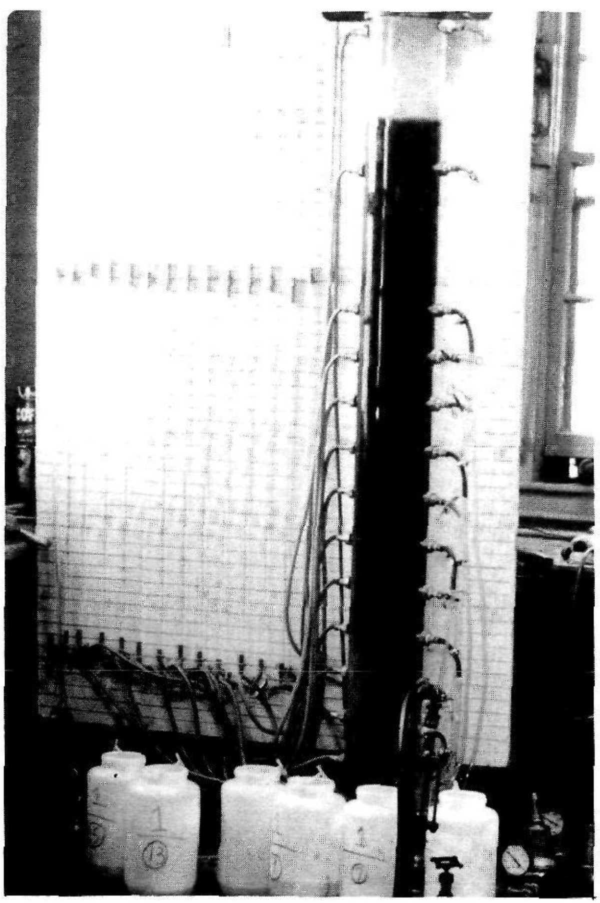


Figure 5. *Pilot Filter (during backwash operation)*

cording headlosses through the filter, and numerous sample taps on each side of the filter. A diagram of the filter apparatus is illustrated in *Figure 5*.

Initially, backwashing of the filter was accomplished using city water from a hydrant adjacent to the building. Because of residual chlorine in the city's water supply, this practice was discontinued in order to encourage the growth of the denitrifying bacteria. A backwashing facility was designed which utilized filter effluent stored for the purpose. With the installation of this system, denitrification was instituted rapidly.

Laboratory Facility

Upon completion of design of the pilot plant facility, a determination of the analyses to be run at the pilot plant predicated the selection of the laboratory equipment and supplies. The laboratory area in the existing Administration Building at the sewage treatment plant was utilized and consisted of three rooms with ample counter and storage space which required some modifications. Additional electrical power was brought in, the existing fume hood and blower systems were modified, some minor plumbing for laboratory apparatus was required, and the entire area was cleaned and painted. After these modifications the laboratory was equipped to run all necessary analyses to completely monitor the operation of the pilot plant.

Analyses and tests at an activated sludge pilot plant fall into two categories: tests for control of operation, and tests to document plant performance. Tests for the control of operation included: settleable solids, suspended solids, volatile suspended solids and sludge volume index (SVI) of the mixed liquor, as well as temperature, pH and dissolved oxygen (DO). This was done on both stages of aeration at regular intervals (See *Table 2*). When some of these tests were eliminated, the efficiency of the plant decreased in a short period of time, indicating the need for constant monitoring.

TABLE 2—PILOT PLANT ANALYSES AND MEASUREMENTS

Test or Analysis	Every 2 hrs*	Every 4 hrs*	Daily	Intermittently throughout the Study
FOR CONTROL				
1. Flows; Influent and Return Sludge	X			
2. pH		X		
3. Temperature		X		
4. DO 1st and 2nd Stages		X		
5. Settleable Solids, 1st and 2nd Stages		X	X	
6. MLSS, MLVSS† 1st and 2nd Stages		X		
FOR PERFORMANCE††				
1. Solids (T.S., T.V.S., S.S., V.S.S.)			X	
2. BOD (5-day, 20° C)			X	
3. COD			X	
4. Copper (Cu)				X
5. Nitrogen (TKN, NH_3, NO_2, NO_3)			X	
6. Phosphate (PO_4)			X	X
7. pH			X	
8. Turbidity			X	
9. Hexane Soluble (Grease)				X
10. Chlorides				X
11. Chlorine Demand				X
12. Coliform Bacteria				X
13. Alkalinity				X

* 24 hours a day, 7 days a week
† On a composite sample
†† On composite samples of raw sewage, Falulah waste, combined influent, 1st and 2nd stage effluent

Analyses and testing for efficiency (as indicated in *Table 2*) were conducted on daily composite samples taken at different points throughout the pilot plant and indicated the removal rates or decreases in concentration through the two-stage system either as a whole or each stage separately. Removal of 5-day BOD, COD, suspended solids, total solids, phosphates (PO_4), grease, oil, and other special components of the influent waste were determined for both stages. A complete nitrogen analysis (TKN, NH_3, NO_2, NO_3) of the second stage aeration system was also routinely conducted.

Along with the daily analyses for both control and efficiency, other special tests were performed at different periods throughout the project. Tests for alkalinity, chlorides (Cl), coliform bacteria, and copper (Cu) in the influent waste were performed periodically. Bench scale testing was performed and is discussed herein.

All analyses were carried out using the procedures and apparatus in accordance with *Standard Methods for the Examination of Water and Wastewater,* 12th Edition, and all results calculated and recorded as per the same reference.

Sampling and Operational Data Collection

The collection of wastewater samples is often as important as the analysis of the sample itself. Without the proper sampling procedure and frequency of sampling, laboratory results may be misleading. A representative type of sample is the integrated or composite sample which indicates the character of the wastewater over a period of time. The composite sample is made by taking grab samples at equally spaced intervals over a period of time.

For this study, grab samples were taken every hour and added to a 24-hour composite. Samples were taken at the following sample points:

1. Raw sewage at the headbox to the first stage;
2. Falulah waste at the headbox just before mixing with the new sewage;
3. Combined influent waste, a mixture of the Falulah waste and raw sewage;
4. The effluent from the first stage clarifier;
5. The effluent from the second stage clarifier at point of discharge to the main drain of the pilot plant; and
6. The discharge from the pilot filters.

These sample points are indicated on *Figure 1*.

When Falulah Paper Company shut down, only four sample points were used. Those being the raw sewage (1), first (4) and second stage (5) effluents and the pilot filter discharge (6). From daily composite samples at these various points, the overall treatment or individual stages of treatment were analyzed.

Samples of activated sludge and recirculated sludge were taken from each stage and composited for solids analyses.

During the study all sampling was done manually by Camp, Dresser & McKee and City of Fitchburg personnel, although an automatic system was tried. The manual sampling insured that the pilot plant was watched closely. The sample size collected was such that 24 equal samples yielded approximately 1 gallon of composite. Samples were kept refrigerated at 3-5° C to inhibit bacterial growth, but no preservatives were added.

Initially it was felt that a more automated method of sampling could be installed at the pilot plant, for it was desired to simplify sampling as much as possible and still collect a representative sample. The system designed involved the use of electric timers which actuated a sampling pump and solenoid valves. The unit was designed to collect a constant volume of sample every 15 minutes.

The system did not function properly. Although the timer and the sampling pump worked adequately, the solenoid valves continually clogged. Solids in the waste accumulated on the bronze valve seat and when the valve closed, the particles of waste left a small opening which then allowed sample water to pass continuously through the valve.

If such a system were to be built again, it is recommended that:

1. Solenoid valves be used on sample sources which have little or no suspended solids.
2. Washing machine valves be used to handle wastes with a large amount of solids in place of the solenoid valves.
3. The sampling pump be located below the liquid level of the point to be sampled, which would eliminate the need for priming.
4. The automatic timers be chosen to allow the solenoid valve to be opened for a short time (fractions of a second) rather than many seconds.

As important as proper sampling procedures were the methods provided for recording results and observations and the arrangement of data forms. Operational data was recorded on a daily log sheet. Pertinent data from these log sheets was averaged and re-recorded on a weekly data sheet of laboratory analysis. Samples of these forms are illustrated in Appendix I. In addition to the data forms, a detailed pilot plant diary was maintained and a biweekly "progress report" written.

CHAPTER FOUR

WASTEWATER CHARACTERISTICS

Municipal Wastes

The municipal wastewaters from the City of Fitchburg are a combination of domestic sewage and industrial wastes. There are many small industries in Fitchburg which discharge a wide variety of wastes into the municipal sewerage system. In most cases the individual quantity is small, but the total amount is significant. Qualitatively, however, the wastewater is quite weak due to large amounts of infiltration, which enter the old, partially combined sewer system, especially after rainfall. In fact, during the course of this study there was one point along the main trunk line sewer near South Street where water from the Nashua River entered the sewer system directly. The break has since been repaired.

As the Fitchburg sewerage system is combined, it was considered reasonable to assume that rainfall would [illegible] effect on the pollutional strength of the raw waste. Analyzing the influent concentrations of BOD, COD, suspended solids and ammonia in the raw wastewater, it was determined that the maximum dilution occurred one to two days after a rainfall. However, the fluctuation of concentrations between wet and dry periods was not particularly large, which may be due in fact to the infiltration into the sewerage system during dry weather.

A comparison of overall averages, averages during dry periods, and averages during wet periods for various parameters is illustrated in *Table 3*. A "dry period" is defined as a day following a day with zero rainfall, and a "wet period" is defined as a day following a day with rainfall.

TABLE 3—EFFECT OF RAINFALL ON STRENGTH OF MUNICIPAL WASTEWATER

	BOD mg/l	COD mg/l	Suspended Solids (mg/l)	Ammonia mg/l
Average Value	134	294	109	11.6
Average Value During Dry Periods	140	300	113	11.8
Average Value During Wet Periods	107	266	83	10.7

Industrial Wastes

The only major industrial waste treated during this study originated from the Falulah Paper Company, which originally intended to discharge its wastes, after primary treatment, to the proposed East Fitchburg wastewater treatment facility, although at the time of the study they discharged directly to the Nashua River. Falulah contributed wastewater to the pilot plant until July 2, 1970, after which the mill closed permanently. The data collected during this period served as a good benchmark to ascertain the effect of such an industrial wastewater on the operation of the plant.

The flow from Falulah was relatively constant from Monday through Friday with no flow on Saturday and Sunday. Qualitatively, the raw Falulah waste had a moderately high BOD and COD, an average pH of about 6.4, and a very high suspended solids content prior to primary settling. The pH was quite alkaline during periods of washdown. Primary settling removed a large percentage of the suspended solids as previously described in *Chapter Three*.

Table 4 indicates average analyses of the Falulah Paper Company wastewaters after settling. The two periods shown indicate the operation of the "swimming pool" and then the upflow clarifiers. For comparison purposes, data for the raw sewage and combined waste (raw and Falulah) are presented. The data for BOD are not included because of the limited number of observations available for certain periods.

TABLE 4—AVERAGE LABORATORY ANALYSIS OF PILOT PLANT WASTEWATERS — 1970

	Falulah Waste		Raw Sewage		Combined Value (mg/l)	
	2/2/70 - 4/2/70[1]	4/3/70 - 6/26/70[2]	2/2 - 4/2	4/3 - 6/26	2/2 - 4/2	4/3 - 6/26
COD	370	160	200	250	240	250
SS	220	70	65	90	110	110
VSS	160	30	55	80	85	85

[1] Settling basins consisted of two 6-ft diameter × 1-ft SWD "swimming pools" in parallel

[2] Settling basins consisted of two 3-ft diameter × 3.5-ft SWD upflow clarifiers in series

CHAPTER FIVE

PLANT PERFORMANCE

First and Second Stage Aeration System Efficiency

A measure of the operational efficiency of an activated sludge plant can be derived by studying such parameters as BOD and COD removal, although these factors may not be the sole criteria for determining the performance of the plant. Analysis of various parameters are presented to illustrate the effectiveness of the pilot plant to function under varying loading conditions. The period extending from April 22 to November 20, 1970, was used for reporting data herein, as it was during this period that the operation of the pilot plant was relatively constant.

Figure 6 illustrates the daily variation of three parameters in the first stage of the pilot plant, namely: aeration time, MLVSS and the percent BOD removed. By examining the curve of first stage detention time, one can readily see the marked effect of changing the aeration tank volume. The movable partition ruptured on August 5, 1970 and at that time was moved to allow a detention time of 2.4 hours at an average raw sewage flow of 15 gpm. Prior to that time the detention time was approximately 4 hours at the same sewage flow.

It is interesting to note that in the first stage mixed liquor there was no significant change in the volatile suspended solids operating level before or after changing the partition. The variation in the MLVSS shown is probably due to the amount of daily sludge wasting. The curve illustrating the BOD removal indicates that reducing the detention time resulted in a slightly better removal of BOD. It appears that a detention time of 4 to 5 hours yielded a BOD removal between 70 and 80 percent, while the detention period of 2 to 4 hours resulted in a BOD removal of between 80 and 90 percent.

The additional percentage of BOD removed in the second stage portion of the pilot plant was not significantly greater than that removed in the first stage systems. Often times, in fact, the final effluent BOD was greater than the effluent BOD from the first stage. The cause of this phenomenon was due to poor settling in the second stage clarifier, which was a result of the very light sludge formed in the second stage aeration system. The inefficiency of the second stage clarifier is discussed in detail herein.

Clarifier Performance

Figure 7 indirectly shows the effect of the poor settling in the second stage system. Illustrated in this figure are the final effluent concentrations of BOD, COD, filtered BOD and filtered COD. Note that a "filtered" BOD and COD was one where the effluent sample was first filtered through a No. 4 filter paper, which removed any residual suspended matter. That portion of the BOD and COD associated with the suspended solids was thus removed.

It is felt that in the properly designed prototype plant, the final clarifiers would produce an effluent BOD and COD which would probably approach the results shown by the filtered test and would probably lie within the shaded area on *Figure 7*. For example, 90 percent of the time the pilot plant produced an effluent BOD and COD equal to or less than 39 and 83 mg/l, respectively. A prototype plant might be expected to produce an effluent BOD and COD of 24 and 57 mg/l, respectively, 90 percent of the time. These figures represent the filtered analyses illustrated on *Figure 7*.

Figure 8 illustrates the suspended solids removal in the pilot plant from April 22 to November 20, 1970. The curve indicates that 90 percent of the time the first stage effluent suspended solids were equal to or less than 57 mg/l and that 90 percent of the time the second stage effluent suspended solids were equal to or less than 47 mg/l. Although it would appear that the lower suspended solids in the second stage effluent should have resulted in an overall reduction of BOD and COD through the second stage, in fact, the sludge that carried over contained a sufficient amount of BOD to affect the results.

The overflow rates for the first and second stage clarifiers are shown in *Figure 9*. The overflow rate is a parameter denoting the hydraulic loading of a clarifier based on raw sewage flow with units of gallons/day/square foot of surface area (gpd/ft^2). Studying this figure in conjunction with *Figure 8* leads to the conclusion that in the first stage effluent, suspended solids of 57 mg/l occurred when the overflow rate was equal to or less than 920 gpd/ft^2. In the final plant effluent the suspended solids equal to or less than 47 mg/l occurred when the overflow rate was 405 gpd/ft^2.

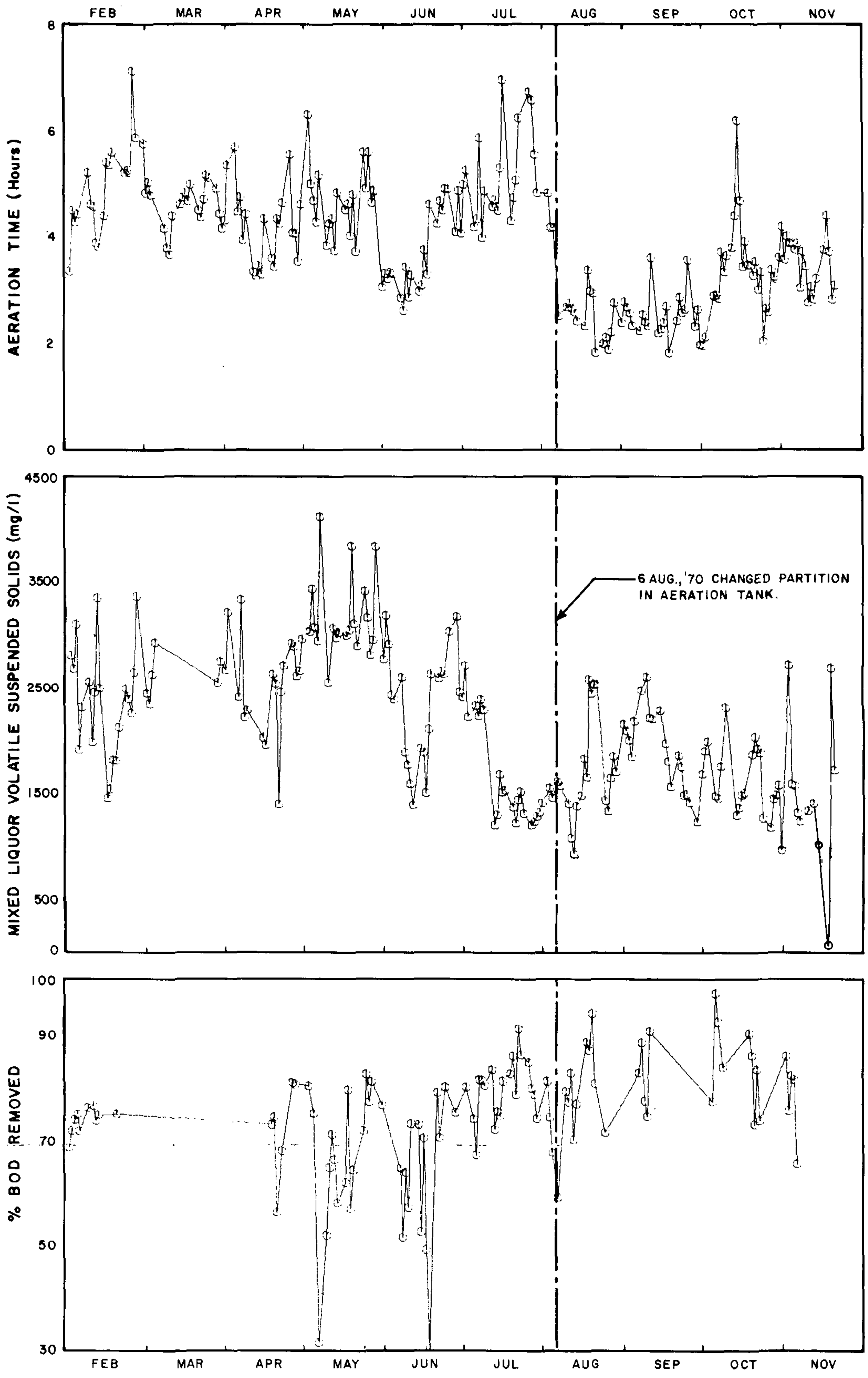


FIG. 6 DAILY VARIATION OF IST STAGE % BOD REMOVED, MLVSS AND AERATION TIME

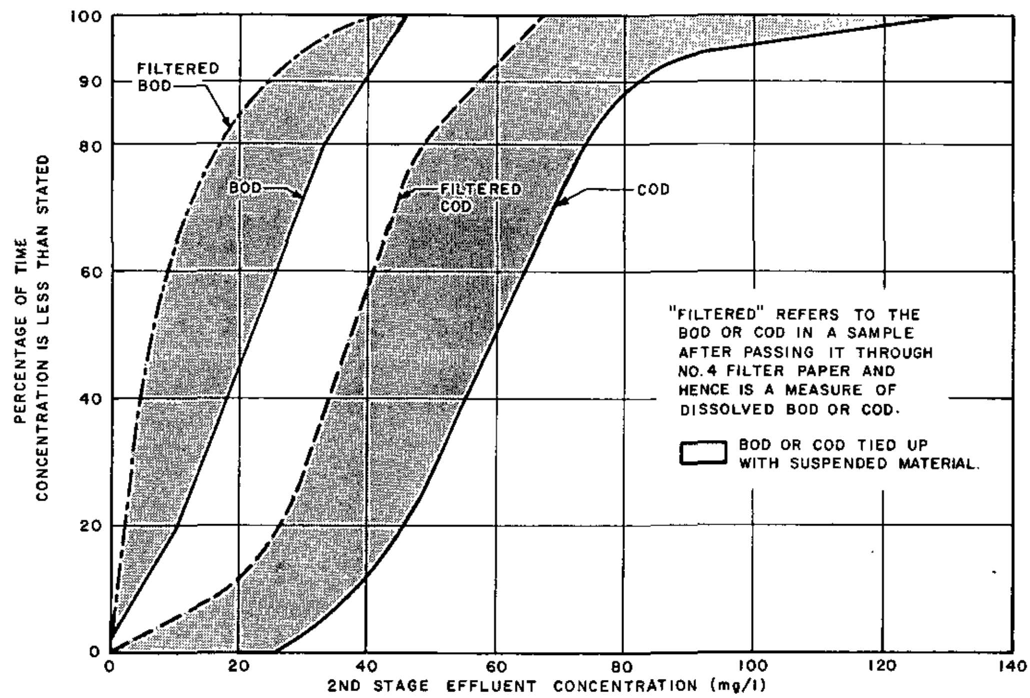


FIG. 7 PILOT PLANT RESULTS 22 APR. TO 20 NOV., 1970
BOD COD

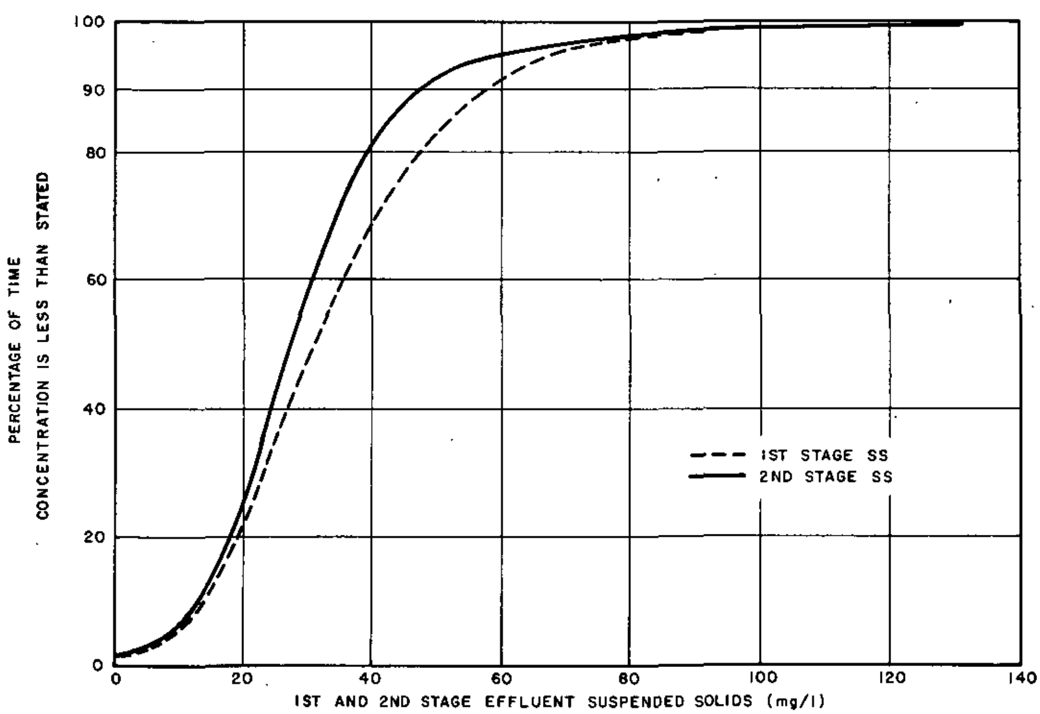


FIG. 8 PILOT PLANT RESULTS 22 APR. TO 20 NOV., 1970
EFFLUENT SUSPENDED SOLIDS

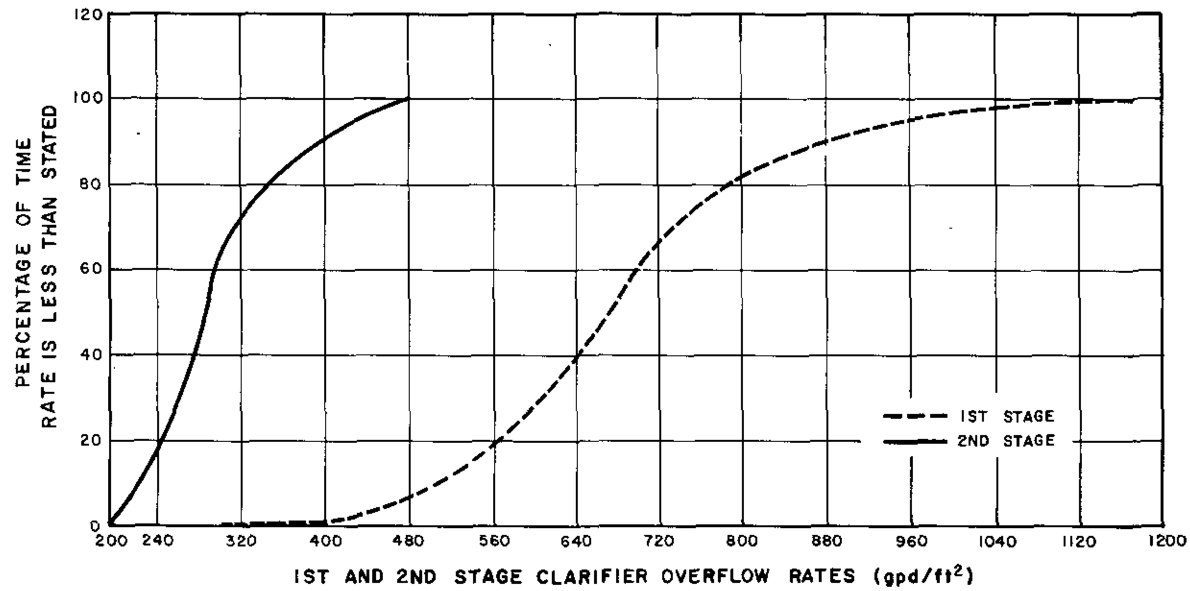


FIG. 9 PILOT PLANT DATA 22 APR. TO 20 NOV., 1970
CLARIFIER OVERFLOW RATE

It is significant that in order to achieve a 10 mg/l reduction in the final effluent suspended solids (i.e. first stage suspended solids - second stage suspended solids = reduction in suspended solids 57 - 47 = 10 mg/l) the overflow rate had to be decreased from 920 to 405 gpd/ft^2. The nitrifying activated sludge was difficult to settle, but because of the size of the pilot plant clarifiers, the overflow rate had to be less than that in a corresponding prototype second stage clarifier since the pilot unit is much more easily upset.

Ammonia and Phosphorus Removal

Figure 10 indicates the ability of the pilot plant to oxidize ammonia. The second stage effluent ammonia and TKN (total Kjeldahl nitrogen) were equal to or less than 4.3 and 9.5 mg/l respectively, 90 percent of the time. Average effluent ammonia and Kjeldahl nitrogens were equal to approximately 0.5 and 4.0 mg/l respectively.

Figure 10 also indicates the organic nitrogen which is the shaded area encompassed by the NH_3 and TKN curves. On the average, the organic nitrogen in the effluent was approximately 3.5 mg/l. A more complete discussion of the operation of the second stage is included in *Chapter Six*.

In general, phosphorus removal averaged 50 percent with a peak of 84 percent when aluminate was added. A discussion of phosphorus removal is included in *Chapter Seven*.

Grease Removal

Grease in sewage can be removed in an activated sludge process through biological assimilation and sedimentation. The scum at the pilot plant was continuously removed from each clarifier. The first stage scum was pumped to a scum barrel and there trapped. The underflow continued to the second stage aeration tank. Scum was periodically removed from this barrel. There was a much smaller volume of scum in the second stage so it was pumped to the baffled end of the chlorination chamber where it was trapped and removed by hand occasionally.

Figure 11 illustrates the grease removal at the pilot plant for the period April 22 to November 20, 1970. The combined influent concentration of grease as measured by the Hexanol-soluble test was equal to or less than 42 mg/l 90 percent of the time. The two stage process produced an effluent with 10 mg/l or less of grease 90 percent of the time.

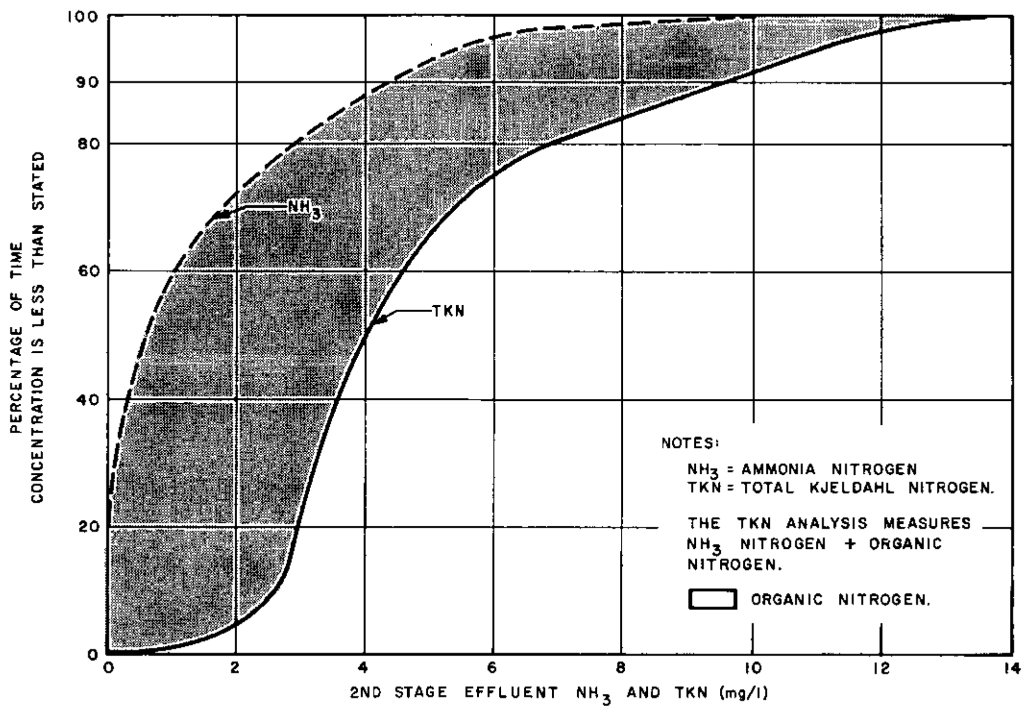


FIG. 10 PILOT PLANT RESULTS 22 APR. TO 20 NOV., 1970
SECOND STAGE EFFLUENT NH_3 AND TKN

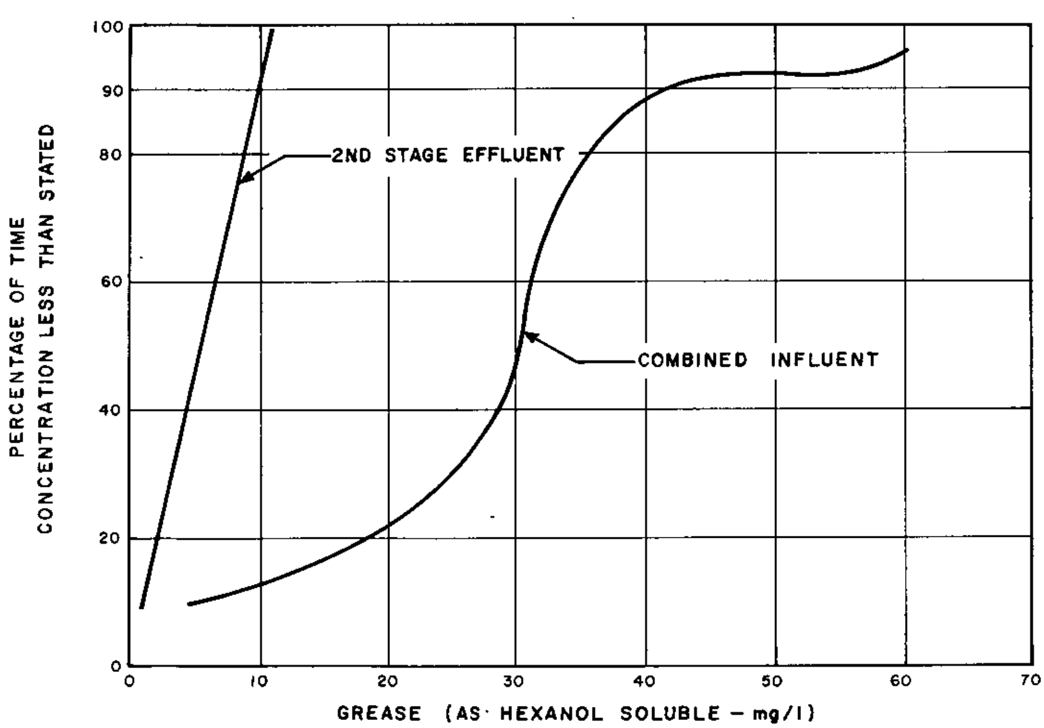


FIG. 11 PILOT PLANT RESULTS 22 APR. TO 20 NOV., 1970
GREASE REMOVAL

Summary

Figure 12 illustrates the major operational periods experienced during the pilot plant and can also be used to assist in the interpretation of the various pilot plant data.

Table 5 summarizes the operational performance of the pilot plant from April 22, 1970 to November 20, 1970 and also the percentage of time that 50 and 90 percent removal of the particular parameters was equalled or exceeded.

In Appendix II the results of all analyses made at the pilot plant are shown.

TABLE 5 — PLANT PERFORMANCE SUMMARY MEASURED AT SECOND STAGE EFFLUENT

April 22, 1970 - November 20, 1970[1]

Parameter	90% Time Effluent was (mg/l)	50% Time Effluent was (mg/l)	90% Removal or Better Occurred — % of time (mg/l)	90% Removal Effluent was — (mg/l)	50% Removal or Better Occurred — % of Time	50% Removal Effluent was — (mg/l)
BOD	40.0	22.0	20	12.0	90	39.0
BOD (filtered)[2]	24.0	6.0	74	14.0	100	42.0
COD	85.0	60.0	6	34.0	88	80.0
COD (filtered)[3]	58.0	38.0	23	28.0	100	67.0
SS	49.0	27.0	7	10.0	89	46.0
VSS	36.0	19.0	18	9.0	93	39.0
NH_3	4.5	0.7	44	0.4	67	1.5
TKN	9.5	4.2	4	1.8	92	10.0
NO_3	4.3	8.3	N/A[4]	N/A	N/A	N/A
Turbidity[5]	42.0	17.0	2	5.0	67	24.0

[1] It was during this period that pilot plant operation was relatively constant and free of start-up problems.

[2] Filtered BOD's not run daily as were regular BOD's.

[3] Filtered COD's not run daily.

[4] N/A = Not Applicable.

[5] Jackson Turbidity Units.

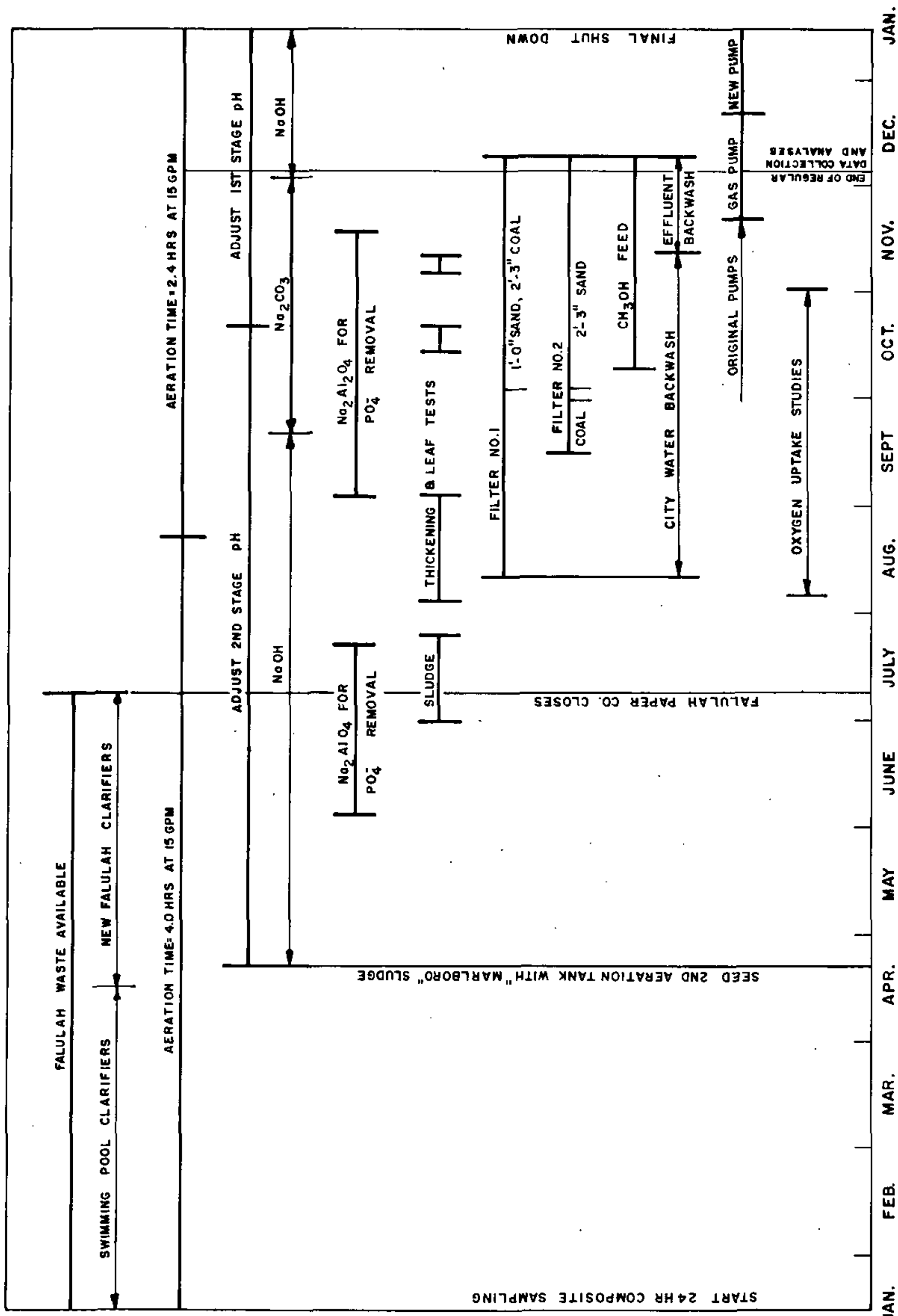


FIG. 12 MAJOR OPERATIONAL PERIODS FITCHBURG PILOT PLANT

CHAPTER SIX

NITRIFICATION

Theory of Nitrification

Removal of nitrogenous oxygen demanding material in a conventional single stage activated sludge wastewater treatment plant may be an inefficient and generally unreliable process while removal of carbonaceous oxygen demanding material is readily accomplished. In a plant designed to remove the nitrogenous oxygen demanding material, the ammonia is oxidized to nitrite and nitrates in the process. The process of conversion of the nitrogenous material is accomplished by autotrophic bacteria of the genera *Nitrosomonas* and *Nitrobacter*. The organism *Nitrosomonas* convert ammonia to nitrite.

REACTION:

$$2NH_4^{+1} + 3O_2 \rightarrow 2NO_2^{-1} + 2H_2O + 4H^{+1}$$

The organism *Nitrobacter* converts nitrite to nitrate.

REACTION: $2NO_2^{-1} + O_2 \rightarrow 2NO_3^{-1}$

In most situations, oxidation of ammonia to nitrite, mediated by *Nitrosomonas*, is generally much slower than that of oxidation of the carbonaceous material by the heterotrophic organisms. Thus the oxidation of ammonia is the rate limiting step and in order to maintain a nitrifying flora in a conventional activated sludge system, it is necessary that the overall sludge growth rate be less than the growth rate of the nitrifying organisms or these organisms will be lost with the excess sludge. In order to maintain this condition, the organic loading to the aeration basins must be kept low. This generally requires long aeration times (such as in an extended aeration system).

The aeration time required for nitrification can be reduced by using a two-stage process in which two separate sludges are developed. In the first stage aeration basin the bulk of the carbonaceous oxygen demanding material is removed, where aeration times are from 2 to 3 hours, based on influent waste flow, and the mixed liquor suspended solids (MLSS) ranges from 2,000 to 3,000 mg/l. In the second stage aeration basin the sludge growth rate should be comparatively low as the rate of growth is controlled largely by the growth rate of the nitrifying organisms. A 3 to 4 hour aeration period is adequate for complete nitrification, based on influent flow, with a MLSS concentration of 1,000 to 2,000 mg/l.

Dividing the activated sludge system in this manner with specialized flora in the two individual stages has the advantage of reducing the total aeration time. More stable performance is also obtained. Growth of the nitrifying organisms is inhibited by a number of constituents in the wastewater, including cyanide, various forms of chromium and copper. Copper may have had this effect on the nitrifying systems, but could not be proven.

Based on the pilot plant experience, it is expected that a full scale treatment plant will substantially convert the ammonia to nitrites and nitrates during most of the year, particularly in those periods when stream flow is lowest and the higher degree of treatment is needed.

Nitrification Startup

Researchers have shown that among the items which must be controlled to achieve consistent nitrification in an activated sludge plant are temperature, pH, dissolved oxygen, influent BOD, and the sludge retention time, referred to as sludge age.[1,2,3] Sludge age can be defined mathematically as the mass of mixed liquor volatile suspended solids under aeration divided by the amount of volatile suspended solids lost, either through wasting sludge or through solids carryover in the clarifier effluent.

During the initial start-up of the pilot plant, a great deal of trouble was experienced in developing a nitrifying flora. It was difficult to retain sludge in the system because of clarifier upsets and the waste temperature was low, 44 to 50°F during February and March.

To overcome the problems of sludge retention and waste temperature, flow into the second stage was reduced to 6 gpm, resulting in a 10-hour aeration time. By doing this, it was hoped that the ambient air surrounding the tank and the longer detention time would cause a general rise in the waste temperature. At the same time, pH adjustment of the second stage was instituted using sodium hydroxide, for the literature indicated that the optimum growth rate of nitrifiers occurred in the pH range from 8.2 to 8.5.[1] A pH controller permitted the maintenance of a pH of 8.4± .2. At this time it was also felt that the nitrifying population was quite low. Accordingly, a known source of nitrifying sludge was obtained from the Marlboro Pilot

Plant which was being run for the Commonwealth of Massachusetts under a Research and Demonstration Project. In the week following the seeding of the second stage aeration basin, the weather turned warm and the raw waste temperature increased about 6° F. This was still not sufficient to insure adequate nitrification and so bench scale studies were conducted to determine the proper combination variables which would yield complete nitrification.

Bench Scale Nitrification Studies

In order to determine the factors which resulted in incomplete nitrification in the pilot plant during the startup, three bench scale pilot plants were run in the laboratory. It was reasoned that if during February and March of 1970 nitrification could not be initiated under warm controlled laboratory conditions, there was little chance to achieve nitrification at the pilot plant where conditions varied widely.

Physically, each unit consisted of a 5-gallon glass carboy with air supplied first by means of a laboratory pump and later from the blowers at the pilot plant. At 6-hour intervals, the air was shut off and the sludge allowed to settle for 30 minutes in each unit. Two liters of effluent were then siphoned off and replaced with two liters from a composite sample of first stage effluent collected from the pilot plant on the previous day. At each 6-hour interval, the pH, temperature and dissolved oxygen of the bench unit effluent were recorded and a sample was composited for ammonia and nitrate analyses.

Because temperature, pH, and the type of bacteria were known to be important factors in nitrification, these parameters were closely watched and varied in the bench units. Each unit was fed the same quantity of first stage effluent from the pilot plant. In Units No. 2 and 3, the pH of the first stage effluent and the mixed liquor was maintained at 8.5 using sodium hydroxide (NaOH). The temperature of each unit was maintained at about room temperature (70° F), and the air supplied was approximately constant and equal for each unit. Units No. 1 and 2 contained sludge obtained directly from the second stage of the pilot plant and Unit No. 3 contained sludge obtained from a process known to be giving satisfactory nitrification (i.e., Marlboro Pilot Plant). Also, 20 mg/l of ammonia chloride was added to Unit No. 3 to make up for the low concentration of ammonia in the raw sewage due to the infiltration during this testing period. (At the time it was suspected that the concentration of ammonia was so low that it might be a limiting parameter.)

The data and results of the bench scale studies are indicated in *Table 6*. Several conclusions may be drawn from this data. First, a comparison of the pilot

TABLE 6 — SUMMARY - BENCH SCALE NITRIFICATION STUDIES

OPERATING CONDITIONS

Unit	Feed	pH Adjusted to 8.5	Ammonia Added	Type of Sludge
Pilot Plant - 2nd Stage	Pilot Plant - 1st Stage Effluent	No	No	Pilot Plant - 2nd Stage
Bench Unit No. 1	Pilot Plant - 1st Stage Effluent	No	No	Pilot Plant - 2nd Stage
Bench Unit No. 2	Pilot Plant - 1st Stage Effluent	Yes	No	Pilot Plant - 2nd Stage
Bench Unit No. 3	Pilot Plant - 1st Stage Effluent	Yes	Yes	Nitrifying Sludge

OPERATING RESULTS

	Temperature (F°)		pH		Ammonia Removal (%)	
Unit	Average	Standard Deviation	Average*	Standard Deviation		Standard
Pilot Plant - 2nd Stage	48	1.5	6.8	0.2	4.5	9.0
Bench Unit No. 1	74	2.8	6.0	0.7	69	25
Bench Unit No. 2	73	2.9	7.2	0.4	78	36
Bench Unit No. 3	72	3.0	6.9	0.7	76	25

* The values of pH for Bench Units 1, 2 and 3 were recorded 6 hours after adjusting to 8.5, thus the averages are somewhat below this figure.

plant and Bench Unit No. 1 indicates that nitrification is greater at higher temperatures. A comparison between Bench Unit No. 1 and Bench Unit No. 2 reveals that at higher values of pH there is a greater degree of nitrification. A comparison between Bench Unit No. 2 and Bench Unit No. 3 indicates that the quantity of influent ammonia is not a significant factor in achieving nitrification and also that non-nitrifying sludge may develop into nitrifying sludge under the proper conditions of temperature and pH.

Results of these tests assisted us in determining how to subsequently operate the pilot plant to obtain nitrification.

Pilot Plant Nitrification

Conditions which define good nitrification have arbitrarily been assumed to be those periods when the average removal of ammonia exceeded 90 percent and/or the effluent ammonia was normally less than 1 mg/l. Operating periods of poor nitrification were characterized by variable detention times, pH, and mixed liquor solids. The shaded areas of *Figure 13* indicate periods of good nitrification, based on these criteria. On August 6, 1970, the partition in the first stage aeration tank was changed, thereby reducing the first stage aeration time which in turn caused a decrease in nitrification in the second stage. The data indicates a decrease of first stage MLVSS from 1600 to 900 mg/l in the four days after replacement of the partition, with a subsequent drop in nitrification. Due to high solids carryover from the first stage, the second stage flora had been predominantly carbonaceous and at this point little nitrifying bacteria remained.

Referring to *Figure 13*, one sees that the first period or poor nitrification occurred with a condition of rapidly decreasing first stage MLVSS. In the first period of nitrification the first stage MLVSS were changing but slowly and were relatively constant at 3000 mg/l. The next period of good nitrification occurred under a condition of low first stage MLVSS. However, in this period the solids were quite constant only varying from 1200 to 1600 mg/l. The pH was controlled accurately and the temperature was warm. This period of good nitrification was then interrupted because of the rupture of the partition in the first stage aeration tank and a subsequent loss of the first stage sludge. *Table 7* shows the operating conditions for period of good and poor nitrification.

TABLE 7 — PERIODS OF NITRIFICATION

	2nd Stage MLVSS mg/l		2nd Stage pH		2nd Stage Det. Time hours		2nd Stage Sludge Age days	
	Average	Std Dev	Average	Std Dev	Average	Std Dev	Average	Std Dev
Periods of Good Nitrification[1]								
4/27/70 - 5/29/70	835 Increasing	141	7.9 Variable but steady	0.5	4.0-5.0	0.7	11.2	8.1
7/7/70 - 8/3/70	715	245	9.0	2.8	4.5-7.0	3.2	11.5	10.0
8/25/70 - 9/28/70	1,020 Quite variable	218	8.0	0.3	4.0-4.5	0.7	11.6	8.6
10/7/70 - 11/16/70	896	140	7.9	0.3	4.5-7.0	1.1	9.8	5.9
Periods of Poor Nitrification[2]								
6/1/70 - 7/6/70	859 Quite variable	192	8.1 Erratic	0.5	3.0-5.0	0.8	9.8	9.0
8/4/70 - 8/24/70	1,041 Erratic	146	8.5 Erratic	0.4	3.0-5.0 Decreasing	0.6	13.2	5.7
9/29/70 - 10/6/70	788	112	7.8	0.4	3.0-6.0 Increasing	0.7	2.3	1.1

[1] 90% NH_3 Removed or $<$ 1 mg/l NH_3 in Effluent

[2] 90% NH_3 Not Removed or $>$ 1 mg/l NH_3 in Effluent

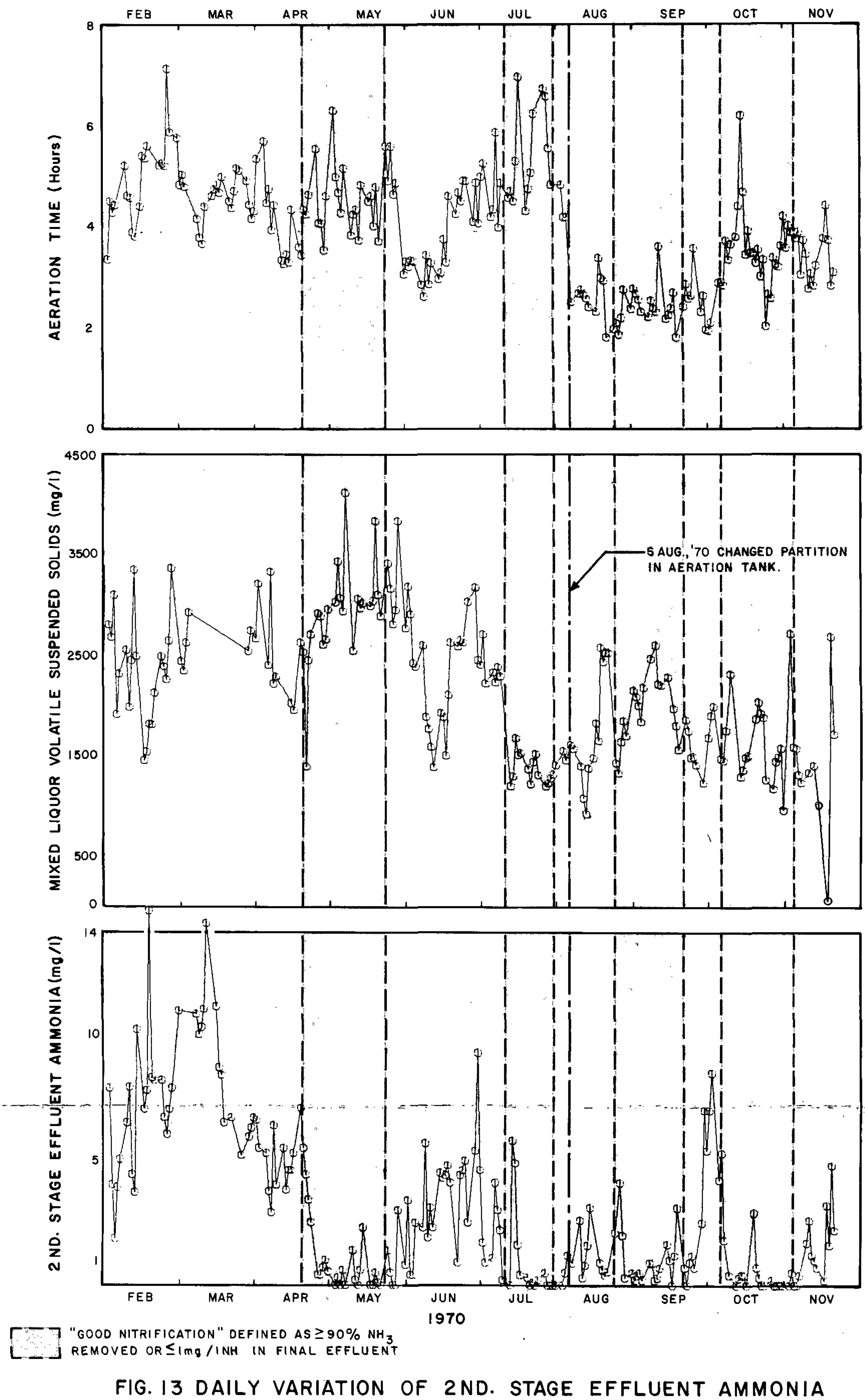


FIG. 13 DAILY VARIATION OF 2ND. STAGE EFFLUENT AMMONIA 1ST. STAGE MLVSS AND 1ST. STAGE AERATION TIME

Figure 14 compares the second stage effluent ammonia for good periods of nitrification against the percent occurrence in time for a particular effluent ammonia value. This figure illustrates that an effluent ammonia of equal to or less than 1 mg/l can be expected about 80 percent of the time and that 90 percent of the time the effluent ammonia would be 2.4 mg/l or less with an average influent ammonia of about 11.0 mg/l. Also plotted is a curve showing the overall average of nitrification in the entire pilot plant period since feeding the tanks with activated sludge from the Marlboro Pilot Plant. This curve includes both good and bad periods of nitrification.

Effect of Rainfall on Nitrification

Because of the nature of the combined sewer system in Fitchburg, the occurrence of rainstorms often affected the treatment at the pilot plant. *Figure 15* illustrates several rainstorms with the rainfall accumulations deposited noted. Also shown is the second stage aeration time and the percent NH_3 removed. It is believed that two factors account for the decrease in nitrification efficiency after rainstorms. The first is assumed to be the limiting amount of ammonia caused by dilution of the waste. The second is the decrease in aeration detention time (thus sludge age). The literature on nitrification indicates that the growth rate of nitrifying bacteria are not affected until such time as the influent ammonia drops below one part per million.[4] It is assumed, therefore, that the loss in nitrification was not caused by dilution but because of the decrease in aeration time resulting from the relatively high flows coming into the pilot plant.

It was noted that for several days after a rainstorm the water level in the grit channel was consistently higher than during dry weather periods and the pumps lifted more sewage into the pilot plant because of the higher head over them. As the cell residence time was decreased due to the higher flow, the nitrifying bacteria had insufficient opportunity to feed upon the influent ammonia and the sludge age was decreased.

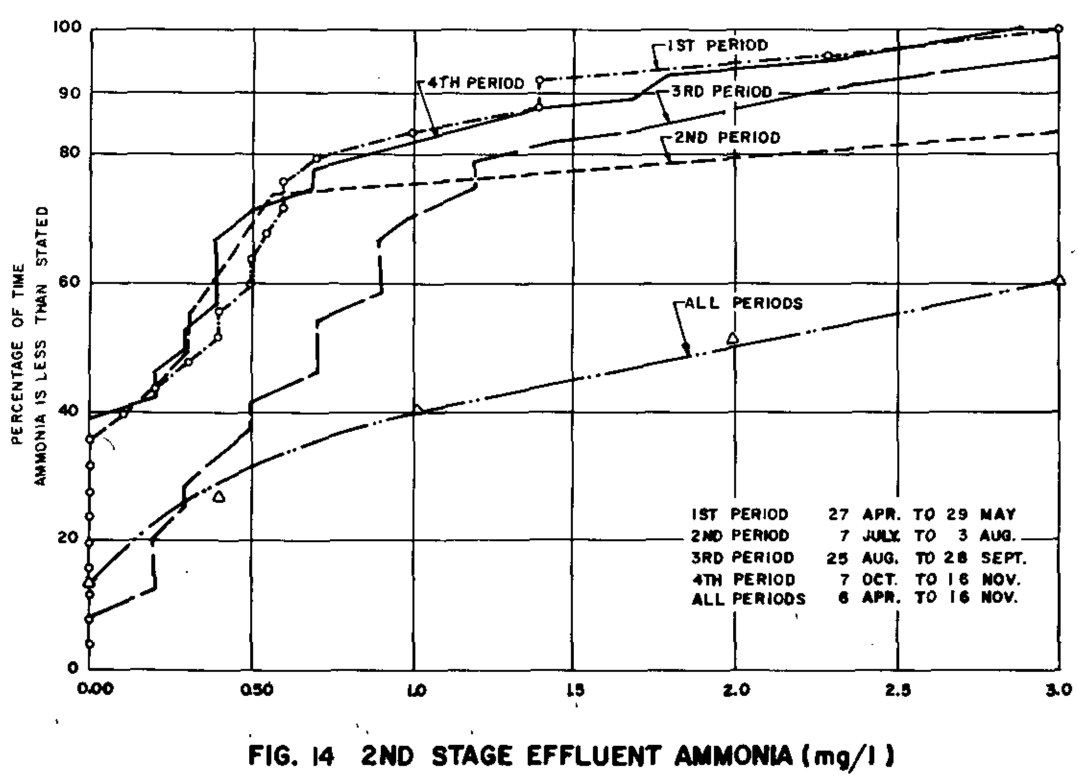
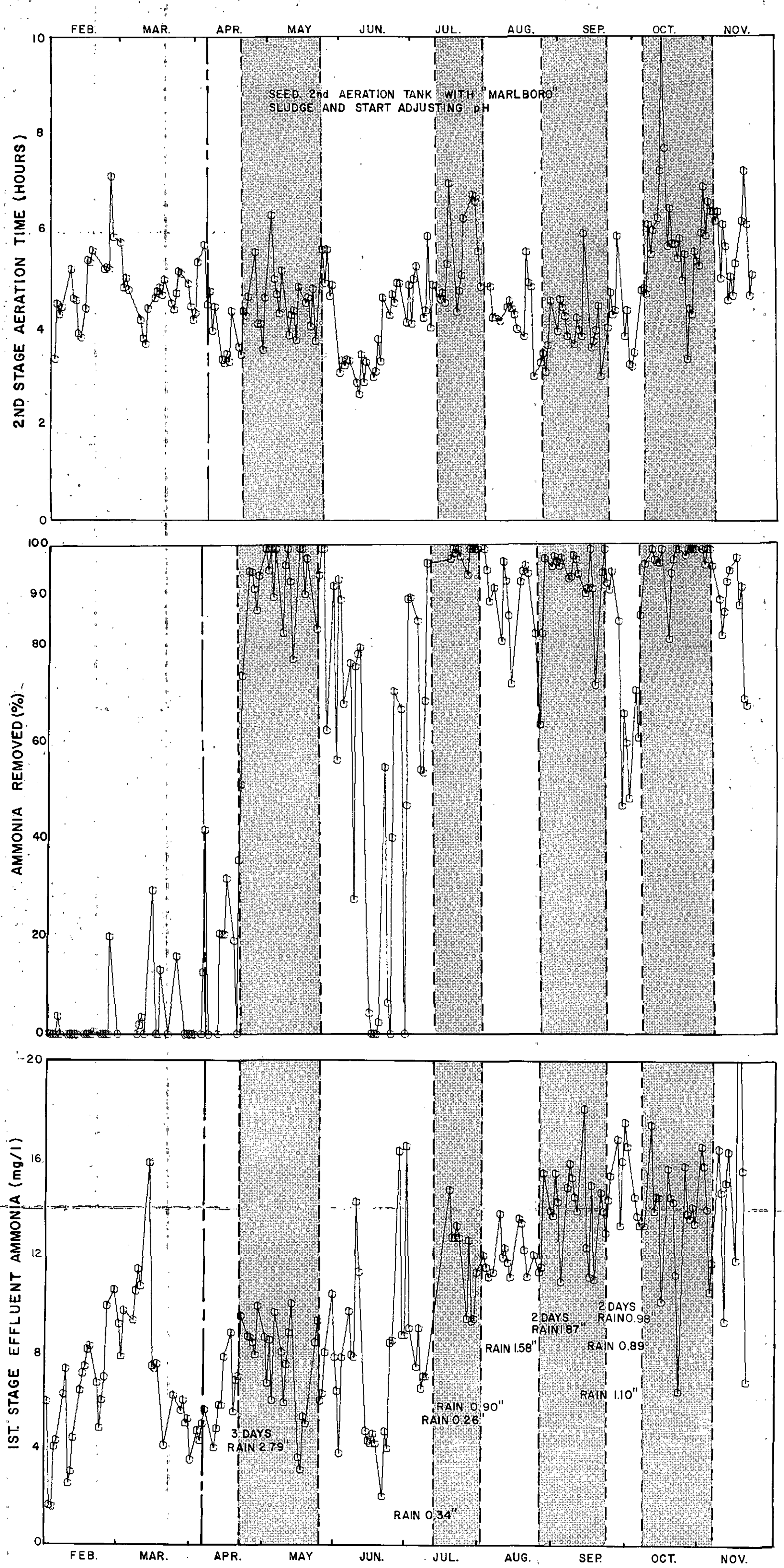


FIG. 14 2ND STAGE EFFLUENT AMMONIA (mg/l)



"GOOD NITRIFICATION" DEFINED AS ≥ 90% NH_3 REMOVED

Effect of Process Upsets on Nitrification

The problems of instituting nitrification have been described and the data indicates that the nitrification process yields an effluent of low ammonia content and high nitrates when the two-stage process is functioning properly. In November of 1970, it was decided to turn over operation of the pilot plant to city personnel. The purpose was two-fold: (1) to gain additional information on nitrification in the cold weather, and (2) to keep the plant running as it was anticipated that an operator's training school would be started in February of 1971 utilizing this facility. Maintenance of the process would eliminate the problem of reseeding the tanks in early February which had been unsuccessful the year before.

To insure that the pilot plant ran more smoothly, a new raw sewage pump was installed and the sludge recirculation systems were rebuilt. It was assumed this would insure more constant flows and eliminate problems due to plugging in all the pumps. In the process of constructing these facilities, the flow to the pilot plant was very erratic and for several days there was no flow for periods of up to one day. At one point a large amount of floating sludge appeared in the first stage clarifier and flushed over into the second stage. The first stage sludge was completely lost at this time. Nitrification in the second stage fell to zero.

Upon the return of more favorable flow conditions and close monitoring of the system, nitrification did not return. In fact, a situation similar to the winter of 1970 occurred, when in fact, the ammonia concentration in the second stage effluent was consistently greater than the ammonia concentration in the raw sewage. This was probably due to the hydrolysis of organic nitrogen to ammonia through the process. By mid-December, the first stage MLSS had returned to an acceptable level, but no nitrification developed in the second stage. By the first week of January in 1971, with still no nitrification, the pilot plant was shut down without collecting any cold weather data and the training school program opening was moved to May, 1971.

Use of Chemicals

pH adjustment of the second stage was accomplished by the addition of chemicals to the mixed liquor. Two chemicals, sodium hydroxide (NaOH) and sodium carbonate (Na_2CO_3) were utilized to determine which resulted in the most efficient and economical means of pH adjustment.

During the period that NaOH was added to the second stage mixed liquor, the average pH was 8.2 and the total cost of the chemical was approximately $30 per million gallons of sewage treated. When Na_2CO_3 was added to the second stage mixed liquor, the average pH was 7.8 with an approximate cost of about $50 per million gallons.

Specific Growth Rate Studies

The Specific Growth Rate Constant (U) for nitrification is defined as the milligrams per liter of nitrogen oxidized per milligram of MLVSS per day.[4] This value in effect defines the rate at which the nitrifying bacteria are oxidizing the ammonia in the waste. *Figure 16* shows the variation of the Specific Growth Rate Constant throughout the course of the pilot plant. The shaded areas signifies those times when there was good nitrification in the pilot plant (good nitrification being defined as greater than 90 percent removal of ammonia or less than 1 mg/l ammonia in the second stage effluent). The specific growth rate varies considerably, as would be expected.

In the first period of good nitrification, the growth rate averaged 0.05 and was generally decreasing. During this period sodium hydroxide (NaOH) was being fed for pH control and the pH in the second stage during this period generally decreased from a high of 9.0 to a low of 7.0. This probably accounts for the decrease in the growth rate. Upon the return to a higher pH value (evidenced in the second shaded area) a higher, though quite variable specific growth rate was attained with an average of approximately 0.1 mg NH_3 oxidized 1 mg MLVSS/day.

In the third shaded area the growth rate averaged 0.09 and generally increased with calendar time. It may be significant to note that this increase started upon the changeover from sodium hydroxide (NaOH) to sodium carbonate (Na_2CO_3) for pH adjustment. The pH during this period averaged 7.8.

In the fourth period, the rate averaged 0.06 and the pH at this time averaged 7.6. However, at this time the sodium carbonate was being fed into the first stage aeration tank in an attempt to precipitate out metallic ions which were believed to be inhibiting nitrification.

A comparison of the specific growth rate constants in this study and a study done in Manassas, Virginia indicate that the growth rates as determined at Fitchburg are quite similar.[5] The Manassas study showed an average growth rate constant of 0.07 at 12°C and 0.1 at about 17°C and approximately 0.13 at 22°C. At the pilot plant at Marlboro, Massachusetts, Metcalf & Eddy[2] found the growth rate constant to be 0.18 at 20°C at an optimum pH of 8.4.

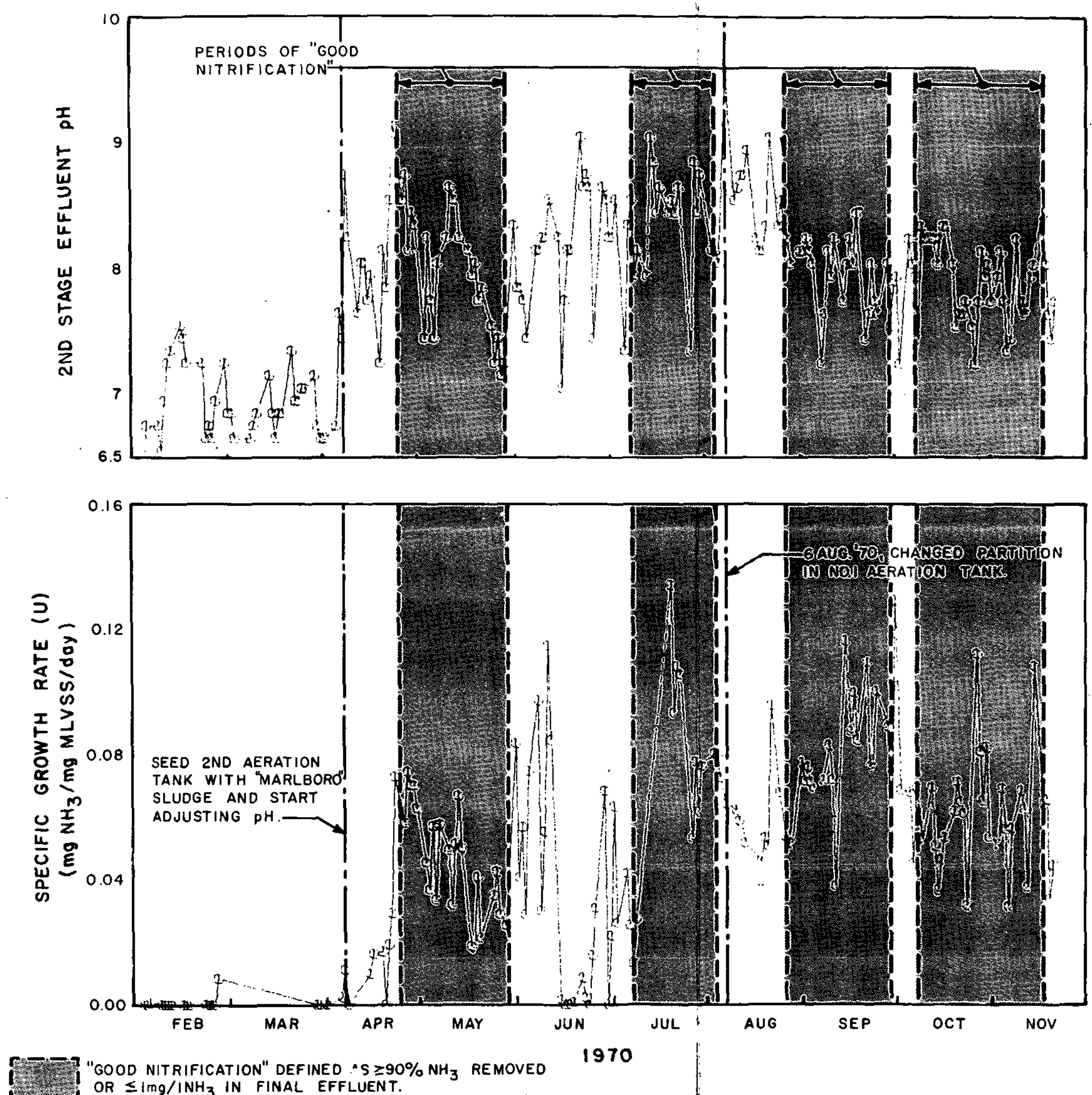


FIG.16 VARIATION OF SPECIFIC GROWTH RATE (U)

It is believed that the generally low values of the ammonia specific growth rate were caused by presence of certain toxic materials in the Fitchburg municipal sewage. The composition of these toxic materials are now known to be copper and steps are being taken to remove them from the waste. Other studies indicate that nitrification plants were run at volatile solids concentrations ranging from 800 to 6,000 mg/l. At Fitchburg the maximum MLVSS attained was around 1,500 mg/l. The average operating range of the MLVSS was from 700 to 1,100 mg/l.

The data shown on *Figure 16* indicates that for the wastewaters encountered at Fitchburg, no statistically viable relationship exists between mixed liquor pH and the specific growth rate. Yet experience at the facility indicates that pH adjustment of between 7.8 and 8.4 is required to insure oxidation of the ammonia down to 1.0 mg/l or less.

Oxygen Uptake Studies

Oxygen uptake studies were undertaken to determine the total oxygen requirements of both the first stage and second stage aeration system. The method employed consisted of obtaining a 5-gallon grab sample of mixed liquor from the first or second stage aeration tank and allowing the sludge to settle for approximately 30 minutes. The supernatant was then siphoned off. In the case of the first stage mixed liquor, a sample of raw sewage equal in volume to the supernatant was added to the settled sludge. In the case of the second stage mixed liquor, a sample of first stage effluent equal in volume to the supernatant was added to the settled sludge. Immediately upon mixing, the new sample was continuously aerated and, using the dissolved oxygen probe, rates of oxygen uptake were determined at various intervals until the endogenous phase was reached. The results of these tests are shown in *Figures 17* and *18*.

A simple statistical analysis of the data in *Figures 17* and *18* indicates approximate average rates of oxygen uptake of 35 mg/l/hour for the first stage and 16.5 mg/l/hour for the second stage. The data for the second stage is shown to be more closely grouped than that of the first stage. The smaller variability of this stage can probably be attributed to the fact that

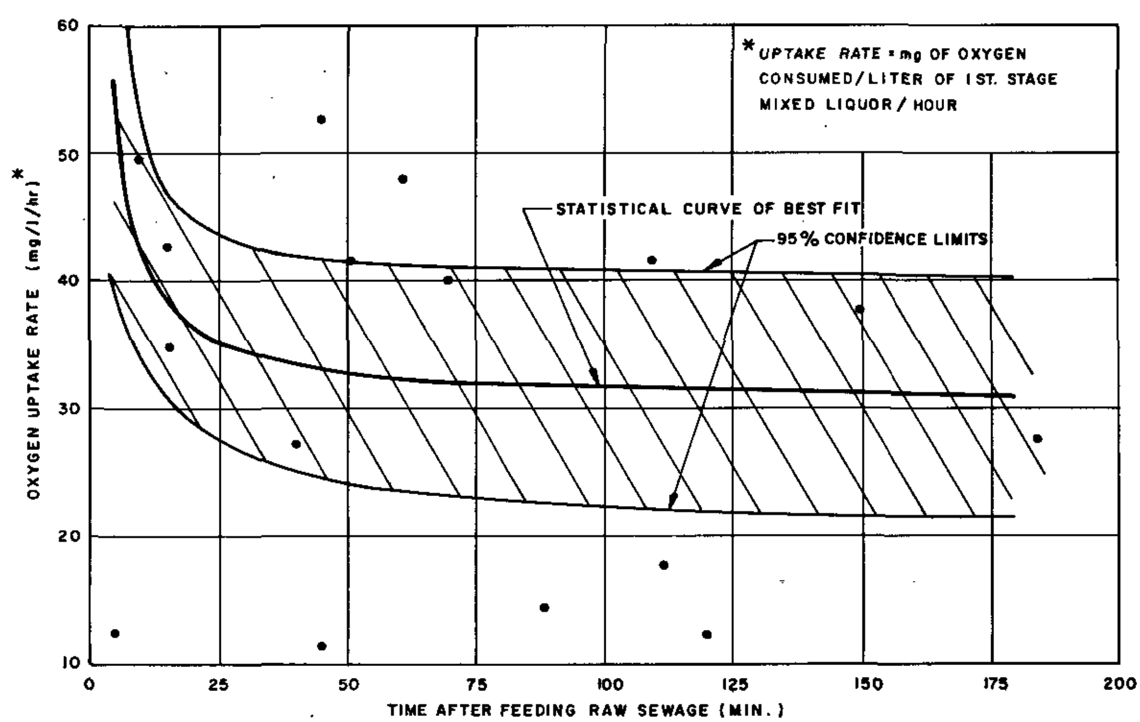


FIG. 17 OXYGEN UPTAKE RATES OF 1ST STAGE MIXED LIQUOR

the ammonia removal process occurring in the second stage was not as sensitive to changes in ammonia concentrations as the first stage system was to changes in BOD concentration. Also, in both stages, there was very little decrease in the oxygen uptake rates after about 60 minutes of detention time, indicating that the sample was beginning to approach the endogenous phase.

In order to determine how oxygen utilization varied during the day, uptake rates were determined for grab samples of mixed liquor at 2-hour intervals throughout a random 24-hour period. The results, shown in *Figure 19*, indicate that the oxygen utilization varied in proportion to the BOD load to the plant, as might be expected.

Oxygen Utilization Constant

Combining the data from the second stage oxygen uptake studies and the specific growth rate constant previously described, an estimate of the oxygen required for ammonia oxidation can be made. This value, computed by dividing the oxygen uptake rate by the specific growth rate constant, is known as the oxygen utilization constant in units of milligrams of oxygen per milligrams of ammonia oxidized. As both temperature and pH varied in the second stage aeration tank, the resulting constants were quite variable. However, at 72°F and at the pH between 8.0 and 8.6, *Table 8* illustrates that the average utilization rate was about 4.0. The theoretical value at 72°F is 4.57 milligrams of oxygen per milligrams NH_3 oxidized.

The effect of temperature is illustrated in *Figure 20*, where the oxygen utilization constant from controlled laboratory studies and from pilot plant operating data are shown. Generally speaking, as the temperature decreased, the oxygen utilization constant increased, which indicates that at colder temperatures the nitrifying organisms require more oxygen to oxidize the same amount of ammonia.

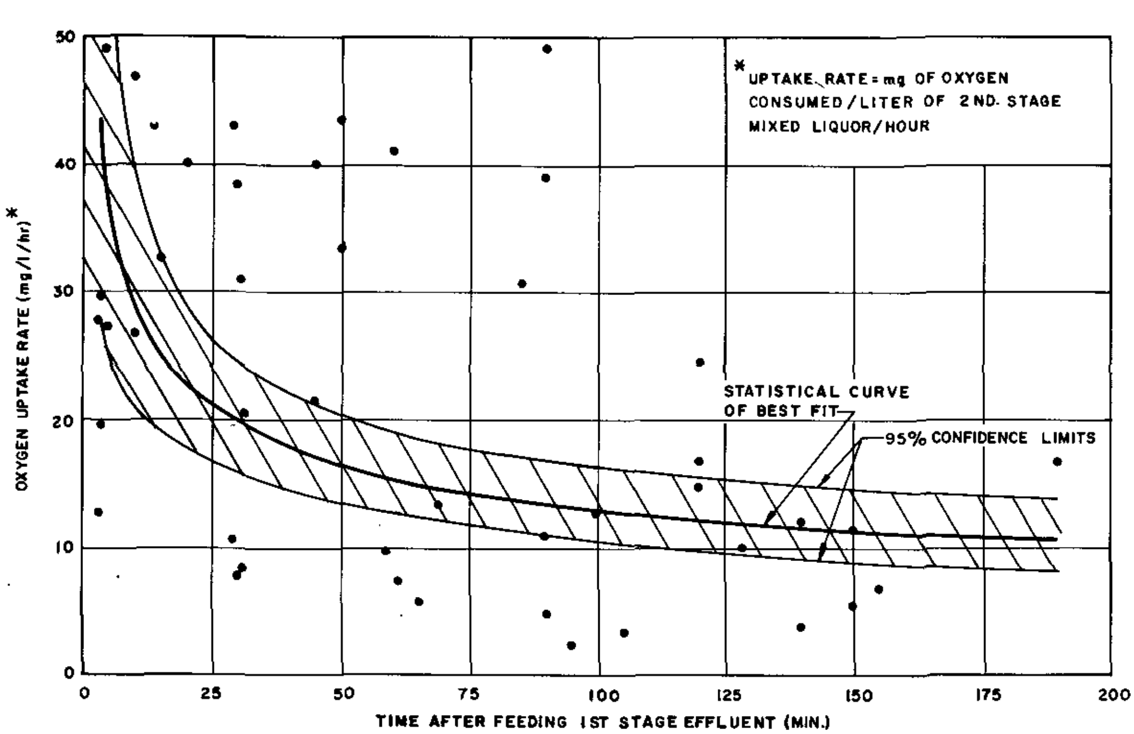


FIG. 18 OXYGEN UPTAKE RATES OF 2ND STAGE MIXED LIQUOR

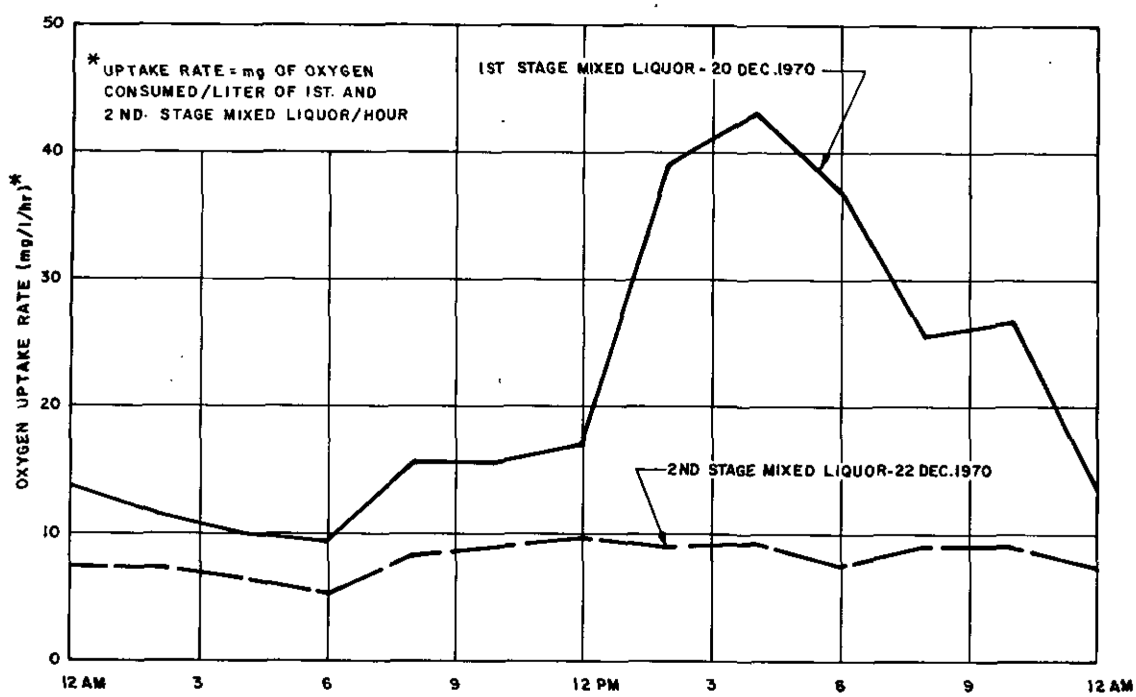


FIG. 19 DIURNAL VARIATION OF OXYGEN UPTAKE RATES OF 1ST & 2ND STAGE MIXED LIQUOR

TABLE 8 — OXYGEN UTILIZATION CONSTANTS

Date	Temp °F	pH	Oxygen Uptake Rate (O_2) (mg O_2/mg MLVSS/day)	Specific Growth Rate (U) (mg NH_3/mg MLVSS/day)	Oxygen Utilization Constant (O_2/U) (mg O_2/mg NH_3 oxidized)
8/11/70	72	8.6	.247	.059	4.19
8/26/70	72	8.3	.184	.054	3.41
8/31/70	72	8.1	.120	.078	1.54
9/10/70	69	7.9	.796	.072	11.05
9/14/70	69	7.7	.235	.116	2.02
9/23/70	72	8.0	.329	.078	4.21
9/28/70	65	8.0	.528	.089	5.93
10/9/70	67	8.3	.356	.053	6.72
10/12/70	65	8.2	.593	.070	8.46
10/16/70	64	8.3	.149	.054	2.76

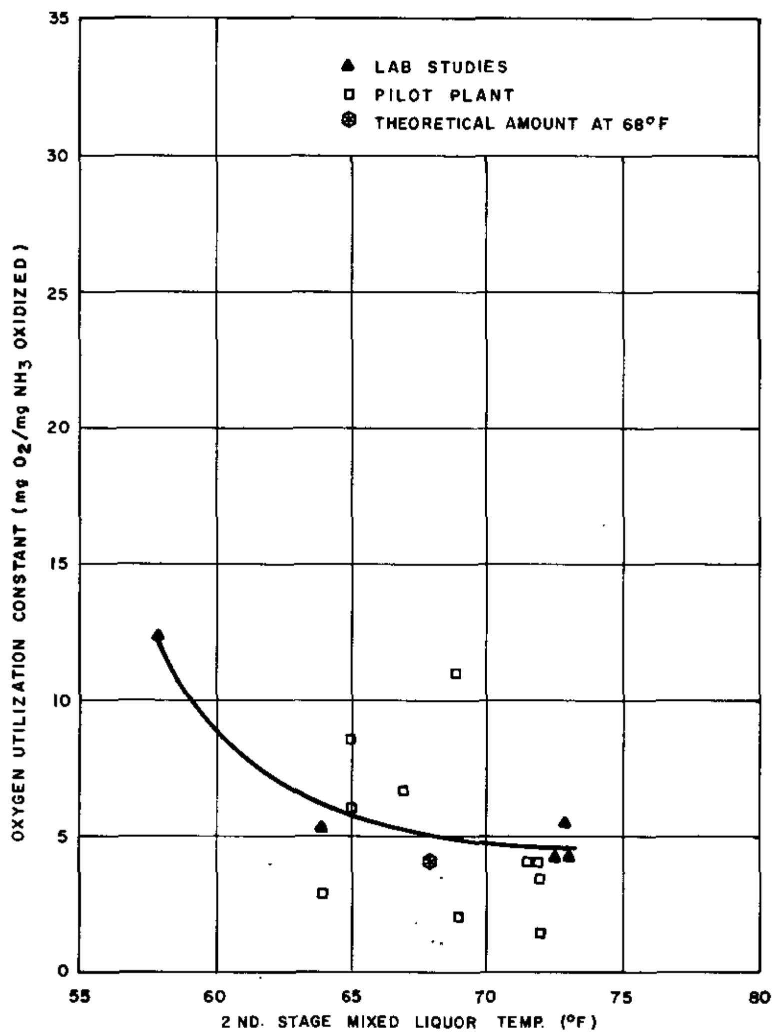


FIG. 20 EFFECT OF TEMPERATURE ON OXYGEN UTILIZATION CONSTANT OF AMMONIA

CHAPTER SEVEN

PHOSPHORUS REMOVAL

Phosphorus, in the form of phosphate (PO_4), like nitrate (NO_3), serves as a nutrient for plankton and aquatic weeds. Heavy fertilization, known as eutrophication, can stimulate the heavy growth of algae or weeds and eventually create a nuisance condition in lakes and rivers due to the decaying of dead organic matter. It is not easy to categorize the removal of phosphorus in an activated sludge plant for the actual reactions may be both biological and chemical in nature. The phosphates may be removed from the wastewater through chemical precipitation with multivalent metal ions. At Fitchburg, sodium aluminate ($Na_2Al_2O_4 \cdot 2H_2O$) was used for this purpose. The reaction of aluminum and the phosphorus is shown below:

$$Al^{+3} = Hn\,(PO_4)^{3-n} \rightarrow Al\,PO_4(S) + nH^{+1}$$

Theoretically, one mole of Al^{+3} is necessary to precipitate one mole of phosphorus as P. The reaction depends on the pH of the mixed liquor as the solubility of aluminate is insured at an elevated pH.

Due to side reactions involving the aluminum ion, specifically hydrolysis of Al^{+3}, it is necessary, even in closely controlled studies, to increase the aluminate dosage to such a point that the molar quantity of Al/P is slightly greater than 1.0. During this study the Al/P ratio ranged from 0.5 to 4.2.

TABLE 9 — PHOSPHORUS REMOVAL JAR TESTS WITH LIME

pH	$Ca(OH)_2$ (mg/l)	Settleable Solids 30 minutes (ml/l)	PO_4 Dissolved (as P) (mg/l)
9.2	61.9	11.0	24.8
9.4	75.0	11.0	20.2
9.6	97.0	12.0	19.2
9.8	119.0	12.0	17.2

Studies were conducted to determine the most efficient method of removing phosphorus from the pilot plant wastewater. Two primary methods of phosphate removal were utilized during the study. One series of tests utilized lime and polymers in the laboratory. The lime was added to the raw sewage in increasing dosages resulting in pH's of up to approximately 10.0. The second method utilized was in the full scale plant where sodium aluminate was added at the head end of the first stage aeration basin. Here the phosphate was flocculated and subsequently settled out in the first stage clarifier.

The laboratory studies were conducted over a period of several days at random periods throughout the project. *Table 9* indicates the results from one such run where lime was used. Adjustment of the pH to 9.8 resulted in the reduction of only 30 percent of the phosphorus and produced a good deal of sludge.

TABLE 10 — EFFECT OF SODIUM ALUMINATE ON PHOSPHORUS REMOVAL AND FIRST STAGE MIXED LIQUOR

Operating Period	Average Total Phosphorus Removal (%)	Average First Stage Return Sludge Suspended Solids (%)	Average First Stage Mixed Liquor Suspended Solids (mg/l)	Average First Stage Sludge Volume Index
February 2 - May 20, 1970 (No Aluminate) (Residual Alum from Falulah)	34.4	1.90	3,708	102
May 21 - July 3, 1970 (Aluminate Added)	50.2	1.68	3,531	82
July 4 - August 19, 1970 (No Aluminate)	15.2	0.73	2,090	85
August 20 - November 3, 1970 (Aluminate Added)	57.5	0.99	2,494	65

The effects of the addition of sodium aluminate to the first stage mixed liquor were studied in detail. Sodium aluminate was added in two periods of operation (May 21 through July 3 and August 19 through November 3). *Figure 21* illustrates that the first stage mixed liquor suspended solids, returned sludge suspendec solids and percent removal of phosphorus are all lower during periods when sodium aluminate was not added. The sludge volume index was significantly higher. Average values for the various operating periods are summarized in *Table 10*.

During the first operational period, the solids concentration was somewhat higher due to the fact that a daily program of sludge wasting had not been established and the Falulah Paper Company was discharging its wastewater to the plant. This had an effect on phosphate removal, as well as other parameters, because the wastewater normally had quite a high residual alum concentration, which probably helped to form a floc and remove a portion of the phosphates in the municipal wastewaters.

The increase in suspended solids concentration and the lower sludge volume index during the period when aluminate was added was due to the precipitated aluminum phosphate in the sludge. It should be noted that without sodium aluminate the average removal of total phosphorus in the first stage during the period when Falulah was not discharging to the plant was about 11 percent throughout the whole study, whereas the addition of the aluminate increased this removal to an average of 57.5 percent.

The performance of the first stage clarifier seemed to affect the concentration of phosphorus in the first stage effluent for the results indicate a significant correlation between suspended solids and total phosphorus in the first stage effluent. This phenomenon is illustrated in *Figure 22* which shows the importance of properly designed clarifiers when phosphorus is to be removed from a wastewater through precipitation with metal ions.

Figure 23 illustrates the relationship of the Al/P ratio and the precent removal of phosphorus in the first stage system. The peak removal of phosphorus was only 84 percent at an Al/P ratio of 1.7, far higher than would be expected theoretically. The average removal from the statistical line of best fit (regression line) was 63 percent at that dose.

The average influent concentration of total phosphorus (as P) during the study was 5.2 mg/l. Therefore, in terms of quantities, an Al/P ratio of 1 would require approximately 140 lbs of sodium aluminate per million gallons of wastewater and other Al/P ratios would be in proportion to that 140 lbs/mg.

Although the majority of phosphorus removal was accomplished in the first stage, the second stage did provide a polishing effect. Considering all operating periods, the first stage removed an average of 50.5 percent of the influent phosphorus and the second stage removed an additional 7.5 percent, which according to *Figure 24*, resulted in an average effluent phosphorus concentration of about 2.0 mg/l. The stream classification for the Nashua River limits the phosphorus in the effluent to a maximum of 0.5 mg/l, provided the plant effluent is the stream flow. It would appear that the required stream standard could not be met if the stream flow were very low. Provisions for a phosphate removal system have been made in the proposed East Fitchburg wastewater treatment facility.

In order to effectively dose the sodium aluminate, it was necessary to make a determination of the molar ratio of Al/P ratio and the percent removal of phosphate. Regression analyses indicated the phosphorus removal increased with increasing dosages of sodium aluminate, but that the increase in removal was not large enough to conclude that higher Al/P ratios experienced at the pilot plant resulted in increased removals of phosphorus.

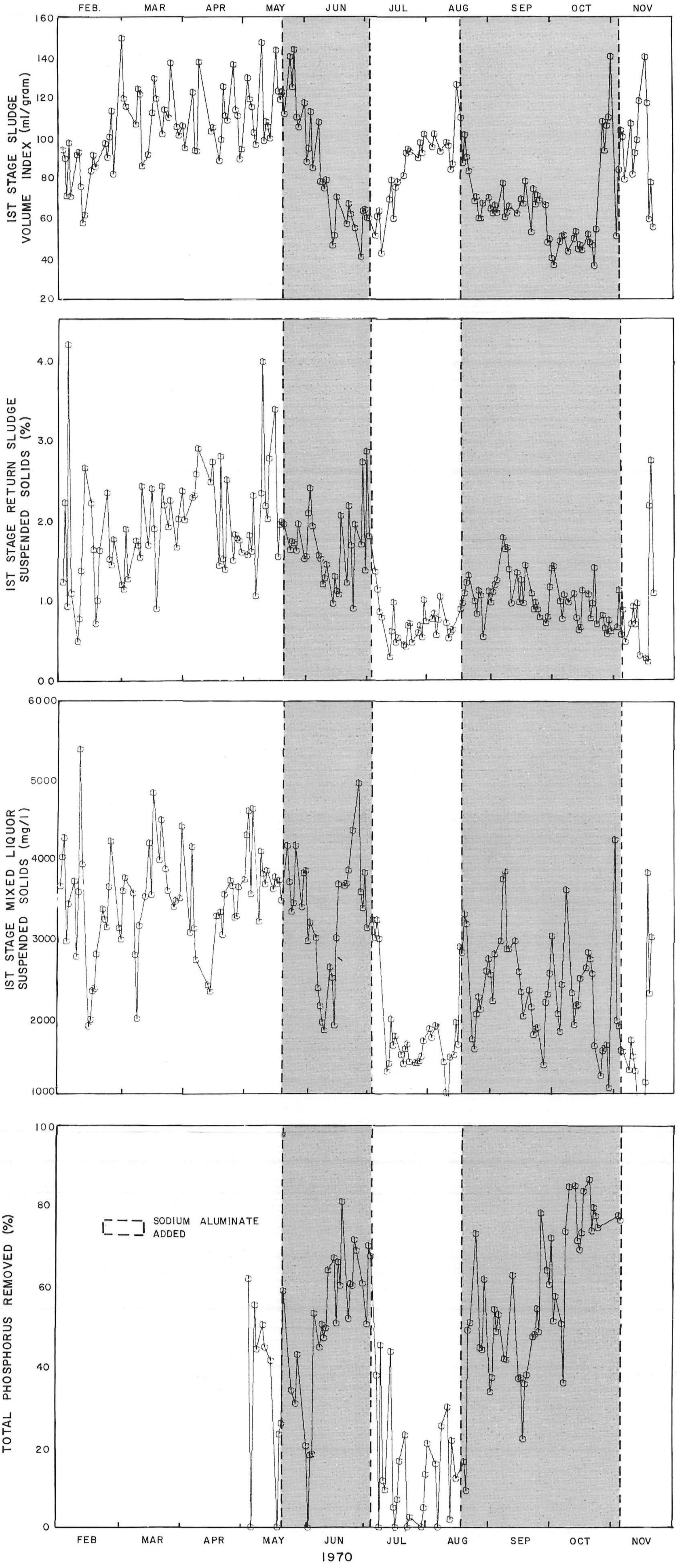


FIG. 21 EFFECT OF SODIUM ALUMINATE ON PHOSPHORUS REMOVAL AND SLUDGE SOLIDS

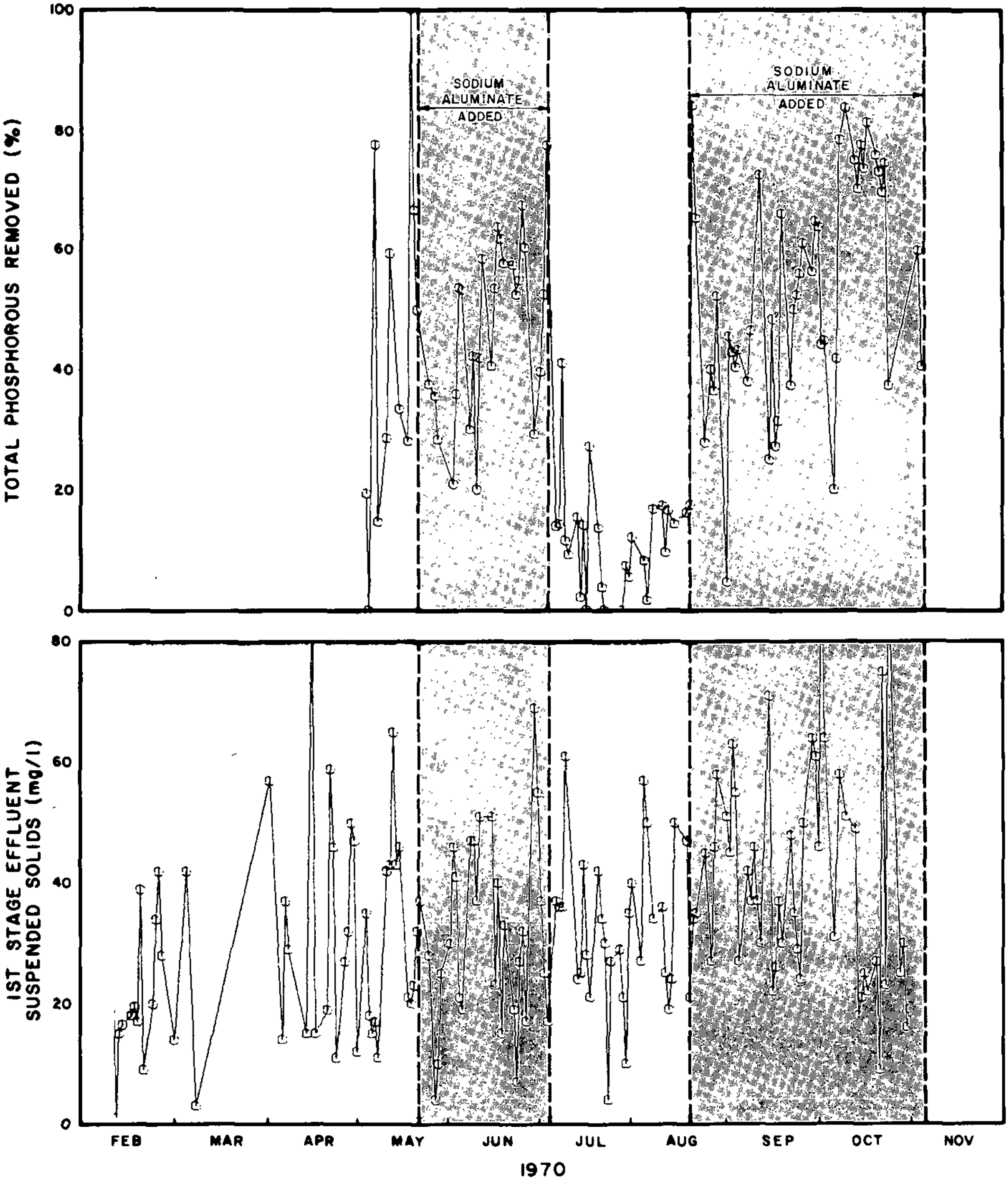


FIG. 22 EFFECT OF CLARIFIER OPERATION ON PHOSPHOROUS REMOVAL

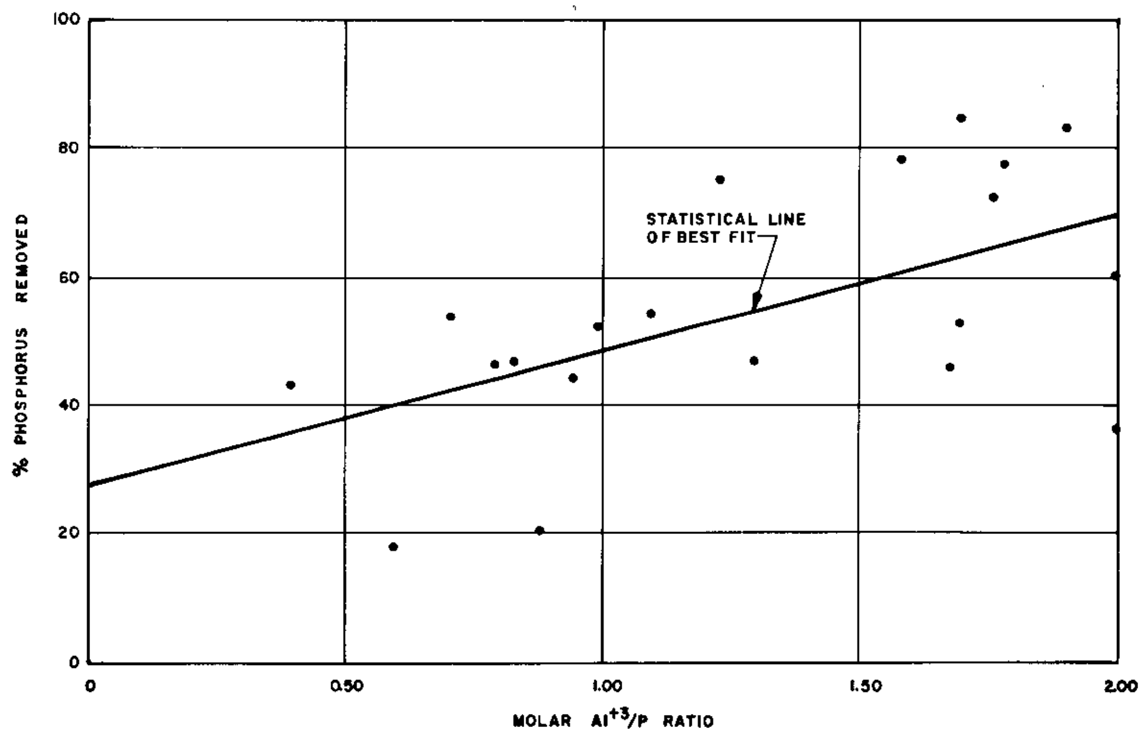


FIG. 23 EFFECT OF DOSAGE OF ALUMINUM ON PHOSPHORUS REMOVAL

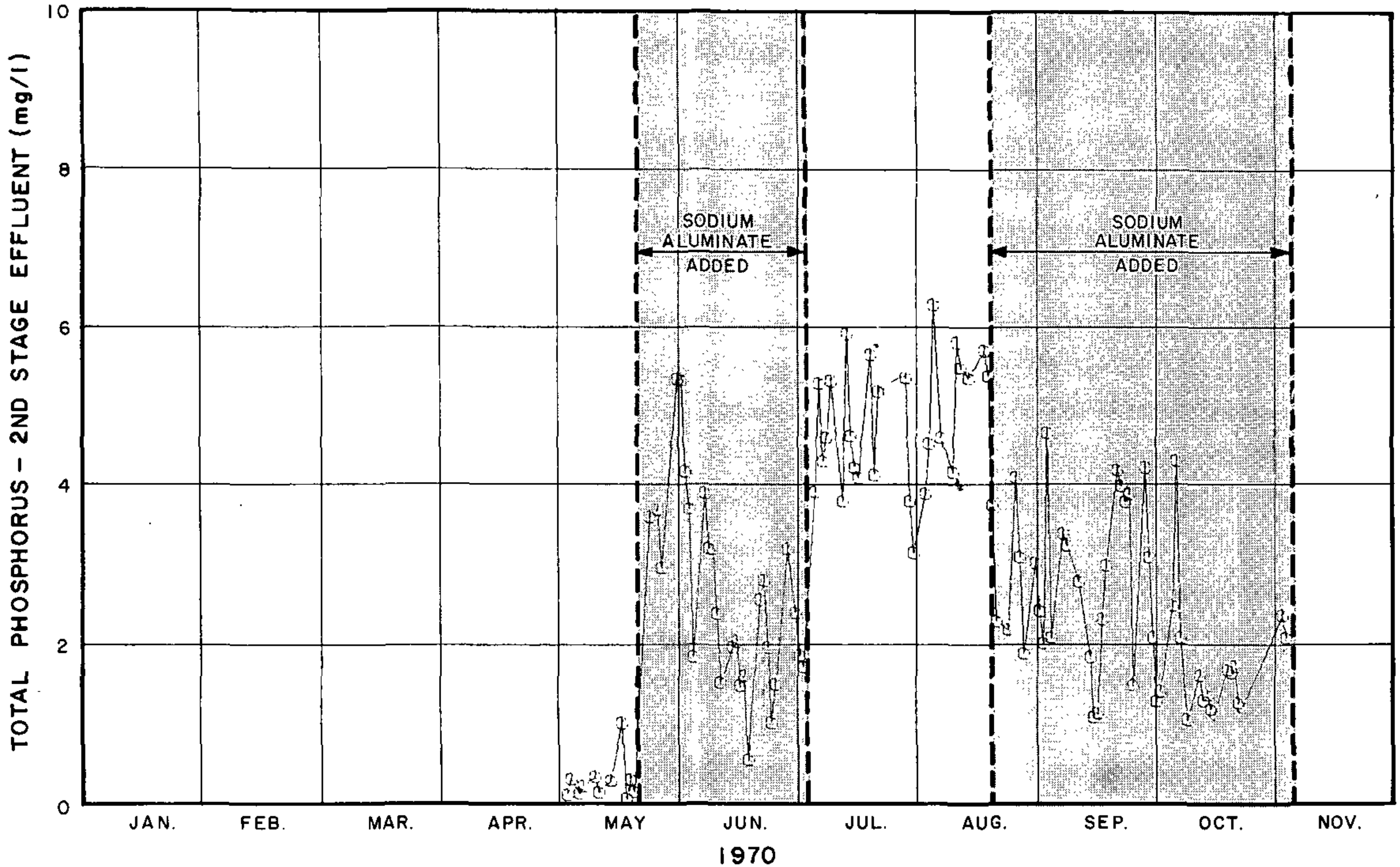


FIG. 24 EFFECT OF SODIUM ALUMINATE ON PHOSPHORUS CONCENTRATION

CHAPTER EIGHT

SLUDGE HANDLING

One of the areas of most interest in a pilot plant of this type was a study of the characteristics of the waste sludge and a prediction of how various treatment methods would satisfactorily dewater the sludge. In this study, gravity and air flotation thickening, vacuum filtration, centrifugation and wet oxidation were investigated.

Gravity Thickening

Gravity thickning is a simple operation which involves the settling of waste activated sludge with or without stirring and/or chemical conditioning. Since it is desired, within reasonable limits, to have the solids content of the thickened sludge as high as possible prior to vacuum filtration, gravity thickening of the waste sludge might be economical because of its inherent simplicity.

For activated sludge plants gravity thickeners are usually designed on the basis of a solids loading of about 8 lbs per day per square foot and a liquid loading of about 800 gpd per square foot. At these loadings it is usual to expect a thickened sludge concentration of approximately 2.5 percent.

In tests conducted at the pilot plant a 55-gallon drum was used for settling the sludge with neither stirring nor chemical conditioning. The results of the tests are shown in *Table 11*. The average increase in suspended solids concentration was about 0.9 percent, with thickened sludge concentrations averaging 2.74 percent. The high initial waste sludge concentration was due to the fact that Falulah was discharging wastewater with a significant amount of alum, which resulted in a more concentrated waste sludge than might normally be expected in a plant treating only domestic wastewater, as previously described. Although gravity thickening produced satisfactory results, other methods, such as flotation thickening were found to be more efficient.

Flotation Thickening

Flotation thickening involves the release of minute air bubbles into the sludge mixture. These bubbles become enmeshed with the sludge and lift the particles to the surface and thereby concentrate it. The minute air bubbles are produced by first saturating high-pressure (70-80 psi) water with air and then reducing the pressure to atmospheric pressure upon

TABLE 11 — GRAVITY THICKENING TESTS[1] [2]

Date	Time	Flow (gpm)	Raw Sludge Suspended Solids (%)	Thickened Sludge Suspended Solids (%)	Liquid Loading (gpd/sq ft)	Solids[3] Loading (lb/day/sq ft)
June 9, 1970	1000	0.50	1.59	1.95	267	36.2
June 12, 1970	1130	0.18	1.90	2.62	96	15.6
	1310	0.04	2.78	2.99	21	5.1
	1430	0.00	-	3.21	-	-
June 15, 1970	1030	0.15	1.17	2.27	80	8.0
	1230	0.30	1.51	3.00	160	20.6
	1430	0.00	-	3.49	-	-
June 16, 1970	0845	0.40	1.13	2.13	214	20.6
	1145	0.70	1.55	2.96	374	49.4

Notes:

[1] $Na_2Al_2O_4$ was being added to the first stage mixed liquor for phosphate removal during the period when gravity thickening tests were conducted.

[2] Supernatant was withdrawn continuously during gravity thickening tests.

[3] Based on suspended solids concentration of raw sludge.

mixing with the incoming sludge. The unit used at Fitchburg was a one square foot air-flotation thickener purchased from the Komline-Sanderson Company of Peapack, New Jersey. For our testing, the air saturated water flow was held constant at 2 gpm. As the thickener had one square foot of area, this was equivalent to 2 gpm/ft[2] and is approximately the same recycle per square foot used on full scale methods. This unit did not have automatic sludge drawoff and sludge had to be scraped manually from the surface with a paddle at about five minute intervals.

Two sludge thickening aids (polymers) were used in the studies, Primafloc C-7 and Nalco 636. In general, for each run made with a polymer, an additional run was made without the benefit of the polymer, at the same waste sludge flow. The operating variables in air flotation thickening included waste sludge flow, waste sludge suspended solids concentration, and the recycle ratio. The recycle ratio is defined as the waste sludge flow divided by the air saturated recycle water (2 gpm).

The benefit of the addition of polymers was often dramatic. When the polymer flow ceased, the thickener would run for a few minutes and then sludge particles would begin to appear in the under flow. Soon the unit would completely short-circuit and the influent sludge would be entirely diverted to the underflow with little or no thickening.

Figure 25 illustrates the effect of an increase of the polymer dose on the thickened sludge total solids, expressed as a percent. During these thickening tests the Falulah Paper Company was not operating nor was sodium aluminate being added to the first stage aeration tank. For the tests using Primafloc C-7, the average unthickened sludge concentration was 0.96 percent. For the runs using Nalco 636, the average sludge concentration was 0.88 percent.

The sludge characteristics during the study of the flotation thickener varied. When the Falulah Paper Company ceased operation, the waste activated sludge from the pilot plant attained the characteristics nor-

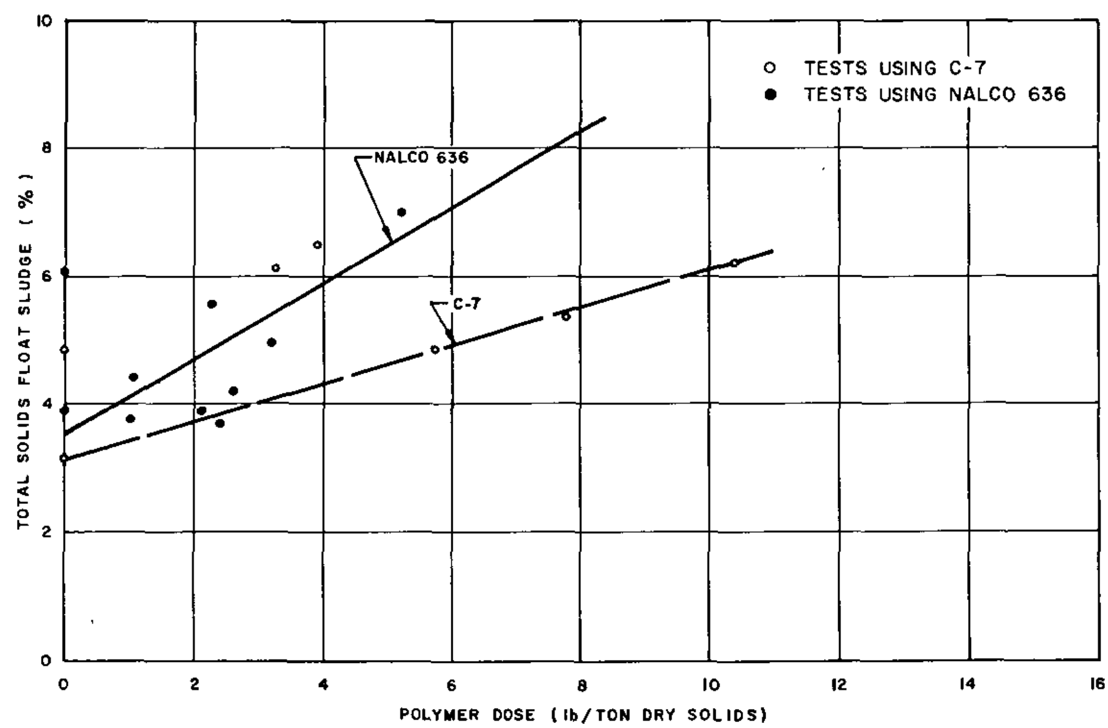


FIG. 25 EFFECT OF POLYMER DOSE ON SLUDGE THICKENING

mally expected with a domestic waste under aeration as the suspended solids concentration of the sludge ranged from 0.5 to 1.5 percent. On the average, the suspended solids concentration was 0.6 percent. On the other hand, when Falulah was discharging into the plant and sodium aluminate was being added to the first stage mixed liquor for phosphate removal, the waste sludge suspended solids ranged from 0.6 to 2.1 percent with an average value of 1.5 percent. When Falulah was not discharging into the plant but the sodium aluminate was still being added, the waste activated sludge suspended solids concentration ranged from 0.5 percent to 1.4 percent, with an average value of 0.9 percent.

The additional thickening, over and above that which initially occurred in the unit, ranged from 1.8 percent to 10.5 percent and it was not unusual to have additional thickening averaging 5 percent. This additional thickening probably occurred because the sludge mixture still had entrapped air bubbles which floated the sludge. In a prototype installation, such a phenomenon could result in a thicker sludge going to the vacuum filter and result in higher yields from the filter.

All sludge thickening tests, with the exception of two runs, were made using a Kenics mixer, manufactured by the Kenics Corporation, Danvers, Massachusetts. The unit was a one-inch diameter pipe with a special

Table 12 shows the operating conditions and parameters measured for all sludge thickening runs. As would be expected, during the period when Falulah contributed waste to the pilot plant, the unthickened waste sludge concentration was high, an average of 1.4 percent, and the thickened sludge averaged 6.3 percent. These values were just about the same as when polymers were added to the sludge which did not contain any Falulah waste.

Figure 26 illustrates the effect of sludge loading rate on sludge thickening. In general, when the waste sludge contained no polymers or sodium aluminate as the sludge loading rate (lbs/ft²/hr) increased from 1 to 2, the percent float of the sludge *dropped from 4.8 to 3.2 percent*. With the use of polymers or sodium aluminate, no such discernable trend was evident. The points do generally illustrate the downward trend in the yield of the thickener when the sludge loading rate was increased.

An interesting phenomenon was noted when thickened sludge was allowed to set for a period of from several hours to a day prior to leaf testing. A significant amount of additional thickening occurred.

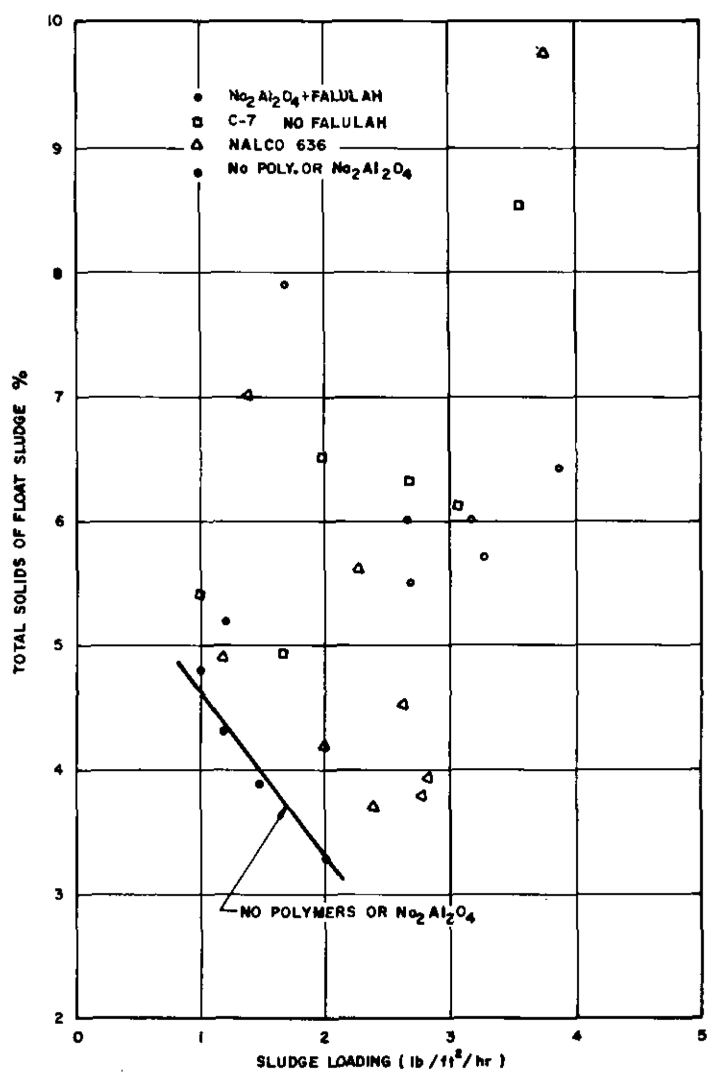


FIG. 26 EFFECT OF SLUDGE LOADING RATE ON SLUDGE THICKENING

helical partition, installed within it. The unit was designed to provide continuous mixing of any additive with the sludge prior to entering the thickening unit. *Figure 27* illustrates the results utilizing the static mixer to disperse the polymer. In general, it would appear that the use of the mixer reduced the percentage of total solids in the float sludge at an equivalent polymer dose. This may be due to the tortuous path the sludge must follow through the mixer with the subsequent shearing effect on the sludge. *Table 12*, however, illustrates that when the static mixer was not used, more chemicals, primarily $FeCl_3$, were needed to obtain a satisfactory yield in the leaf tests. It is our opinion that detailed studies should be conducted with this mixer for it may prove to be a valuable substitute for the complicated chemical mixing equipment employed prior to vacuum filtration.

Vacuum Filtration

The leaf test method may be used to determine the filterability of a sludge and should be a good measure of the effectiveness of a vacuum filter. Vacuum filter tests with a small prototype unit were not possible because sufficient waste activated sludge was not generated in a day to run even the smallest unit for more than one hour.

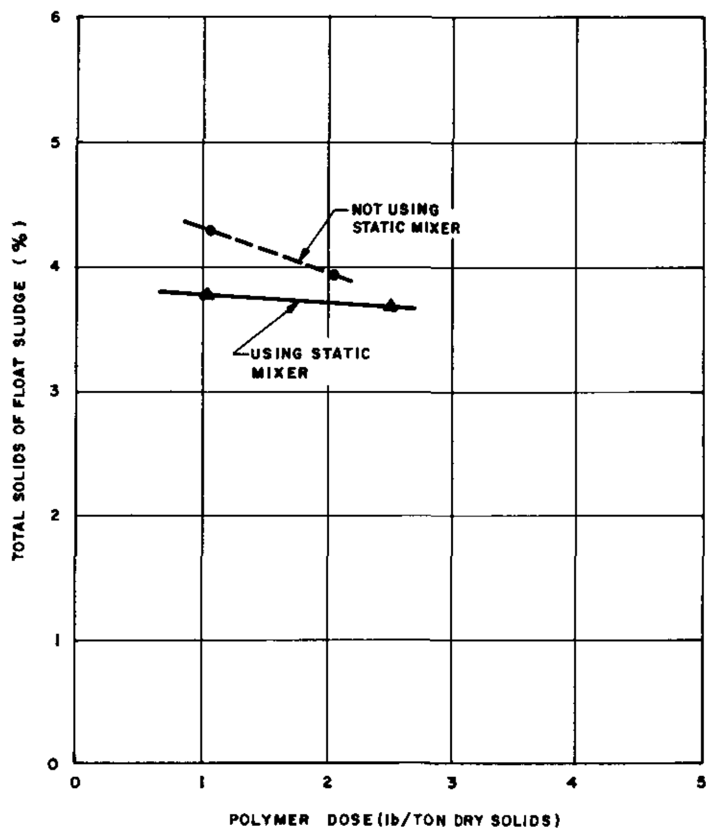


FIG. 27 EFFECT OF STATIC MIXER ON SLUDGE THICKENING

The leaf test apparatus was therefore employed and consisted of a circular polypropelene housing upon which was mounted a stainless steel screen. This screen, which had an effective area of 0.1 square feet is designed to approximate the actual surface found on a full scale coil vacuum filter. The test procedure consisted of submersing the leaf into a batch of thickened waste activated sludge, applying a vacuum, and then gently aggitating the apparatus in the sludge. The time of vacuum break was noted. All thickened sludge was conditioned with ferric chloride ($FeCl_3$) and hydrated lime ($CaOH_2$) in varying dosages. The chemical dosages used were the optimum dosage as determined by a series of Buchner funnel tests. All leaf tests used 25 percent submergence and a vacuum of between 13 and 13.6 inches of mercury. The variables in the leaf tests were "drum speed," in minutes per revolution, and the percent total solids of the thickened sludge.

Table 13 indicates that in all cases a properly conditioned thickened sludge could adequately be dewatered using the vacuum filter. The resulting cake had a percent total solids ranging from 18.5 to 29.6 percent. The cake was

TABLE 12. WASTE ACTIVATED SLUDGE HANDLING, CONDITIONS, AND RESULTS

FLOTATION THICKENING TESTS										LEAF TESTS												
			Polymer							TEST CONDITIONS						FILTER CAKE				FILTRATE		
Date	gpm	SS %	Name	mg/l	lb/ton	Float Sludge TS %	Sludge Loading lb/ft²/hr	Underflow SS mg/l	Remarks	Temp °F	pH	Fe Cl_3 % of Sld.	Ca $(OH)_2$ % of Sld.	Vacuum in. Hg	Drum Speed min/rev	Vacuum Break min-sec	TS %	Thickness in.	Yield lb/ft²/hr	pH	SS mg/l	Yield gal/ft²/hr
6-18-70	0.3	1.26		None		7.89	1.89	-	$Na_2Al_2O_4$ being fed to No. 1 aeration tank Falulah waste included			1.27	12.7	13	2	1-15	20.5		2.04			
												1.27	12.7	13.5	4	2-0	25.3		1.55			
												1.27	12.7		6	3-20	23.8		1.12		346	5.55
6-23-70	0.4	1.37		None		5.52	2.74	14	"		6.3	1.81	18.1	13	2	None	30.1				474	1.21
											6.3	1.81	18.1	13	4	None					885	6.76
											6.3	1.81	18.1	13	6	2-30	23.4				223	6.10
6-26-70	0.5	1.34		None		5.69	3.34	200	"		6.7	1.76	24.6	13	2	0-40	22.7	1/4	4.84	12.2	17	15.1
											6.7	1.76	24.6	13.3	4	3-0	24.1	1/4	2.55		232	8.40
											6.7	1.76	24.6	13.3	6	3-0	26.3	5/16	2.01	12.2	394	6.86
6-29-70	0.5	1.55		None		6.42	3.87	47	"		6.4	1.56	21.8	13.5	2	1-0	22.6	1/4	4.44		262	20.8
											6.4	1.56	21.8	13.5	4	1-45	25.6	5/16	3.74	12.05	276	11.0
											6.4	1.56	21.8	13.5	6	3-20	23.4	1/4	1.77	12.2	265	7.03
6-19-70	0.7	0.91		None		6.05	3.19		"			1.66	16.6	13.4		-	21.8	1/4	2.65		738	12.6
																None	22.6	1/4	1.14		717	6.91
																3-20	24.1	1/4	2.65		49	5.08
7-24-70	0.4	0.61		None		4.28	1.22		No $Na_2Al_2O_4$ or Falulah waste		6.5	9.34	46.5	13.5	4	1-45	24.2	5/16	4.9	12.1	72	14.3
											6.5	9.34	46.5	13.5	6	2-0	25.5	1/4	3.0		74	10.0
7-16-70	0.4	0.58		None		5.20	1.16		Sludge held 18 hrs thickened to 7.00%	68	6.4	9.60	28.2	13.2	2	0-52	29.5	1/4	6.85	12.2		
										68	6.4	9.60	28.2	13.2	4	1-37	21.9	1/4	3.80	12.2	495	8.5
										68	6.4	9.60	28.2	13.2	6	3-30	22.3	1/4	2.59	12.2	1,710	6.0
7-21-70	0.8					5.30			Sludge held in basin for several hours show a float TS = 7.55%		-	7.54	37.8	13.5	6	2-30	23.6	1/4	4.0	11.9		9.95
7-17-70	0.8	Testing Assume 0.25	C-7	9.7	7.75±	5.37	1.00±			64	6.2	9.32	28.0	13.8	4	1-45	22.0	5/16	4.37	12.0	124	14.5
										64	6.2	9.32	28.0	13.8	6	1-45	20.4	5/16	3.64	12.0	221	9.5
										64	6.2	9.32	28.0	13.8	8	2-20	23.9		2.18	12.0	241	8.4
7-17-70	0.8	0.25		None		4.77	1.00	Quite clear		66	6.6	10.5	31.5	13.8	4	1-25	22.9	1/4	4.6	12.0		12.1
										66	6.6	10.5	31.5	13.8	6	1-50	25.4	1/4	3.2	12.1	117	9.3
7-20-70	0.8	0.50	C-7	9.8	3.92	6.51	2.00	64		68	6.4	10.0	40.0	13.5	4	1-30	20.8	5/16	5.2	12.2		5.2
										68	6.4	10.0	40.0	13.5	6	2-46	20.3	3/8	4.1	12.1		4.1
										68	6.4	10.0	40.0		8	3-5	19.8		3.3	12.0		3.3
7-20-70	0.8	0.50		None		3.27	2.00		Sludge held several hours thickened to 6.73%													
7-15-70	0.6	0.56	C-7	16	5.72	4.91	1.68			68	6.4	10.2	40.8	13.5	4	2-10	24.3	5/16	5.4	12.2	231	11.5
										68	6.4	10.2	40.8	14.0	6	2-30	26.6	5/16	3.9	12.2	238	8.3
7-2-70	0.4	1.54	C-7	25	3.25	6.14	3.08			62	6.7	3.26	26.1	13.6	2	1-25	21.0	5/16	10.2	12.2		15.8
										62	6.7	3.26	26.1	13.6	4	2-5	22.8	3/8	6.3			11.2
										62	6.7	3.26	26.1	13.6	6	2-30	22.2	7/16	4.7			8.6
7-2-70	0.4	1.48		None					With secession of polymer feed, sludge would not thicken and was discharged in underflow													
7-1-70	0.45	1.21	C-7	63	10.4	6.26	2.72	Quite clear		67	6.9	1.60	30.4		2	1-10	23.5	1/4	9.2	12.2	392	14.3
										67	6.9	1.60	30.4		4	2-45	25.7	5/16	5.1	12.3	296	8.7
										67	6.9	1.60	30.4		6	2-15	24.5		2.8		454	5.7
6-29-70	0.45	1.62	C-7	106	47.0	8.46	3.64	68		62	6.4	2.36	18.9		2	1-25	21.9	3/16	3.03	12.3	405	11.5
										62	6.4	2.36	18.9		4	2-0	23.6	1/4	2.42	12.3	114	9.9
										62	6.4	2.36	18.9		6	2-15	24.4	1/4	1.76	12.3	69	6.4
7-23-70	0.8	0.57	Nalco 636	6.7	2.35	5.60	2.28	39		82	6.4	7.15	26.8	13.5	4	1-30	19.5	1/4	3.7	12.1	117	13.7
										82	6.4	7.15	26.8	13.4	6	1-45	21.1	3/8	3.2	12.1	62	1.64
7-30-70	0.5	0.47	Nalco 636	7.6	3.24	4.92	1.17	16	Sludge held 24 hours thickened to 11.6%	73	6.3	10.2	36.6	13.5	4	1-35	22.9	5/16	4.76	11.9		
										73	6.3			13.5	6	2-0	20.8	3/8	3.76	11.9		10.1
															8	2-30		5/16	2.68	12.0		7.25
7-30-70	0.5	0.62		None		3.94	1.55	36	Sludge held 24 hours thickened to 11.1%	77	6.3	10.1	50.7	13.5	4	1-50	24.3	1/4	4.42	11.8	226	15.0
										77	6.3	10.1	50.7	13.5	6	2-0	25.6	1/4	2.80	11.95	139	12.0
										77	6.3	10.1	50.7	13.5	8	2-30	22.2	7/16	3.82	11.9	95	10.4
8-4-70	0.5	0.81	Nalco 636	10.6	2.61	4.20	2.02	29		63	6.55	9.54	59.5	13.5	4	1-50	9.13	5/16	2.02	12.3	134	14.0
										63	6.55	9.54	59.5	13.5	6	2-0	7.57		0.98	12.3	148	10.2
						14.7			Sample of August 4, 1970, after being held 18 hours Leaf test data to right	70	6.45	6.13	13.6	13.5	6	2-15	20.3		4.65	12.2	211	8.60
7-30-70	0.5	0.57	Nalco 636	14.9	5.23	7.00	1.42	31	Sludge held 24 hours thickened to 15.9%	63	6.3	7.14	25.8	13.5	4	1-15	21.9	1/4	3.20	12.0		9.00
										63	6.3	7.14	25.8	13.5	6	1-45	18.5	3/8	2.74	12.0		7.95
										63	6.3	7.14	25.8	13.5	8	2-20	23.3	1/4	1.76	12.0		8.40
8-4-70	0.5	1.49	Nalco 636	25.2	16.9	11.9	3.72	54	Sludge held 18 hours thickened to 16.6%													
8-4-70	0.5	1.10		None		6.05	2.75	119	Conditioning after thickener with Nalco 636 produced a sludge which would not dewater. (Concentration 10-200 mg/l)													
						10.7			Sample of August 4, 1970, after being held 18 hours Leaf test data to right	68	6.3	6.55	18.7	13.5	4		20.2	1/2	6.40	12.2	318	13.9
										68	6.3	6.55	18.7	13.5	6	1-50	20.8	1/2	3.82	12.3	170	9.80
8-18-70	0.5	1.02	Nalco 636	5.7	1.12	4.36	2.65	80	Not using static mixer	-	-	6.87	45.8	13.5	4	2-15	23.8	5/16	5.28	-	-	-
										-	-	6.87	45.8	13.5	6	-	28.0	3/8	3.51	12.3	322	8.35
8-18-70	0.5	1.11	Nalco 636	5.7	1.03	3.79	2.78	292	Using static mixer	-	-	6.60	52.8	13.5	4	1-50	25.0	3/8	4.05	12.4	359	8.68
										-	-	6.60	52.8	13.5	6	2-36	28.8	3/8	4.41	12.4	237	10.5
8-18-70	0.5	1.14	Nalco 636	11.8	2.07	3.95	2.85	276	Not using static mixer	79	6.4	12.7	40.6	13.5	4	1-35	21.4	1/2	7.27	12.4	218	17.5
										79	6.4	12.7	40.6	13.5	6	2-06	22.0	-	5.48	12.0	220	13.6
8-18-70	0.5	0.95	Nalco 636	11.7	2.46	3.69	2.38	165	Using static mixer	79	-	8.13	54.2	13.5	4	2-10	26.2	-	4.96	12.4	405	7.61
										79	-	8.13	54.2	13.5	6	3-05	29.6	7/16	5.04	12.0	192	9.01
8-17-70		1.00		None				234		64	6.4	-	-	13.5	4	1-15	22.4	1/4	4.00	-	-	-
										64	6.4	-	-	13.5	6	1-40	23.5	3/8	3.33	12.2	449	9.26
										64	6.4	-	-	13.5	8	2-25	23.6	3/8	3.00	12.2	640	9.11
10-1-70	0.6	2.04		None		6.5	6.12	-	Sludge held 18 hours thickened to 8.7% Feeding $Na_2Al_2O_4$ into 1st aeration tank													
10-20-70	0.3	1.19		None		-	1.79	54	$Na_2Al_2O_4$ being fed to 1st aeration tank	58	6.9	-	-	13.5	4	1-50	22.6	-	4.10	11.7	350	7.35
										58	6.9	-	-	13.5	6	2-55	23.7	1/4	2.34	11.9	252	4.97
										58	6.9	-	-	13.5	8	3-15	26.3	1/4	2.04	-	58	8.61
11-2-70	1.2	0.96	Calgon 2630	19	3.96	5.54	5.76	148	$Na_2Al_2O_4$ being fed to 1st aeration tank	-	-	3.62	1.08	13.5	4	1-45	-	-	15.6	12.0	176	8.56
										-	-	3.62	1.08	13.5	6	2-05	-	-	2.04	-	188	6.62
										-	-	3.62	1.08	13.5	8	-	-	-	-	-	-	-

Notes: 1. All thickener runs were made with recycle flow = 2 gpm/ft². (Thickener area = 1 ft²)

2. All leaf tests used 25% submergence and at the drum speeds indicated (min/rev). The theoretical vacuum filtration and dewatering times are:

Min/rev	Filtration sec	Dewater sec
2	30	64
4	60	127
6	90	191
8	120	254

readily discharging from the leaf after dewatering and normally had a thickness of between ¼ and ½-in. The filter cake illustrates the average yield from the vacuum filter when various chemicals were utilized for phosphorus removal and conditioning prior to sludge thickening.

Considering the filtrates from all tests, it was found that the filtrate suspended solids ranged from a low of 17 mg/l to a high of 885 mg/l. The average suspended solids of the filtrate was on the order of 300 mg/l. The pH of the filtrate was always around 12.0.

TABLE 13 — RESULTS OF LEAF TESTS FOR VARIOUS OPERATING CONDITIONS

	Test Conditions of Sludge Thickening	Number of Tests	Average Total Solids of Cake (%)	Average Cake Yield lbs/ft²/hr
1.	No polymers No $Na_2Al_2O_4$[1]	8	24.1	3.87
2.	No polymers $Na_2Al_2O_4$ added Falulah included	5	24.0	2.54
3.	Polymer C-7 No $Na_2Al_2O_4$	6	22.8	5.54
4.	Polymer C-7 $Na_2Al_2O_4$ added	0	-	-
5.	Polymer-Nalco 636 No $Na_2Al_2O_4$	9	21.5	3.98
6.	Polymer-Nalco 636 $Na_2Al_2O_4$ added	0	-	-
2A.	No polymers $Na_2Al_2O_4$ added No Falulah	3	24.2	2.82

[1] $Na_2Al_2O_4$ was added to first stage for phosphorus removal.

Wet Oxidation

Laboratory tests were performed by Zimpro Inc., on the waste activated sludge to determine its suitability for wet oxidation as it was proposed to consider this process for the East Fitchburg wastewater treatment facility. Wet oxidation is a process which can accomplish varying degrees of organic matter destruction through the oxidation of sludge solids in an aqueous medium by applying heat and pressure.

Some of the advantages claimed for the process include:

1. flexibility in achieving any degree of oxidation,
2. flexibility in the type of sludge handled,
3. production of a small volume of oxidized material that settles rapidly, compacts well, dewaters easily (often without adding chemicals) is susceptible to biologic treatment, and offers few nuisance problems, and
4. operation in a small closed system.

Disadvantages that have been associated with the process include:

1. possible air pollution and odor problems,
2. the need for high quality supervision and frequent maintenance,
3. the necessity of having to recycle wet oxidation liquors back through the wastewater treatment process (this may represent a considerable organic load and the fine ash could plug sludge vacuum filter media), and
4. the cost of construction and operation.

The results of the tests by Zimpro, Inc., showed, using an intermediate oxidation process, that the insoluble volatile solids were reduced by 60.1 percent. However, the wet oxidation process was not considered for the plant because the cost of the system was found to be high when compared to the cost of other types of sludge disposal. The complete test report may be found in the Appendix.

Centrifugation

An alternate method of sludge dewatering investigated was centrifugation. In this process the sludge sample is subjected to high gravity forces, which has the effect of squeezing out the water. The tests were run on a sample of waste activated sludge (total solids = 0.90 percent) at the Bird Machine Company's laboratory in Walpole, Massachusetts. Runs made on the sludge without the use of polymers and at various loading rates produced a cake varying from 5.6 to 36.1 percent total solids.

The addition of a polymer (Dow Purifloc A-23) at a dosage rate of 0.495 lbs per ton of dry solids produced a sludge cake with a total solids ranging from 3.8 to 21.3 percent. The results of these tests appear to be inconsistent with the findings for the sludge without a polymer.

A second series of tests was completed in July, but Bird did not publish them. The complete report of the first series of the centrifuge tests can be found in the Appendix.

CHAPTER NINE

PILOT FILTERS

Studies were conducted at the pilot plant to determine the applicability of granular filters for the reduction of the nitrate, resulting from the two-stage activated sludge system, to nitrogen. In addition, studies were conducted to measure the efficiency of the filters to remove suspended solids from the effluent.

Two 6-in plexiglass columns, each 9 feet high were used in the studies. (The head over each filter was about 15 feet.) Filter No. 1 contained two feet of anthracite and one foot of filter sand. The anthracite had an effective size of 1.0 mm and a uniformily coefficient of 1.8. The filter sand had an effective size of 0.5 mm. The second column was filled with 2 feet of filter sand with an effective size of 0.5 mm. Each filter had its own pump system and rate controller device. The units were backwashed on a daily basis, first, using city water and later with filtered effluent.

Suspended Solids Removal

Each filter was run at three different flow rates. The majority of the runs, however, were at a flow of 0.5 gpm which is equivalent to a hydraulic loading of 1.9 gpm/sq ft of filter area. Initially each filter was run for one week at 1.9, 3.6 and 6.0 gpm/sq ft respectively. In subsequent weeks the flow averaged 1.9 gpm/sq ft as this loading resulted in the best suspended solids and turbidity removal.

Figure 28 illustrates the effect of hydraulic loading on the duration of individual filter runs. As one would expect, the duration of a filter run was dependent upon the hydraulic loading. Cessation of a filter run occurred when the headloss in the filter exceeded the height available on the manometer board or in any event, after an elapsed time of approximately 24

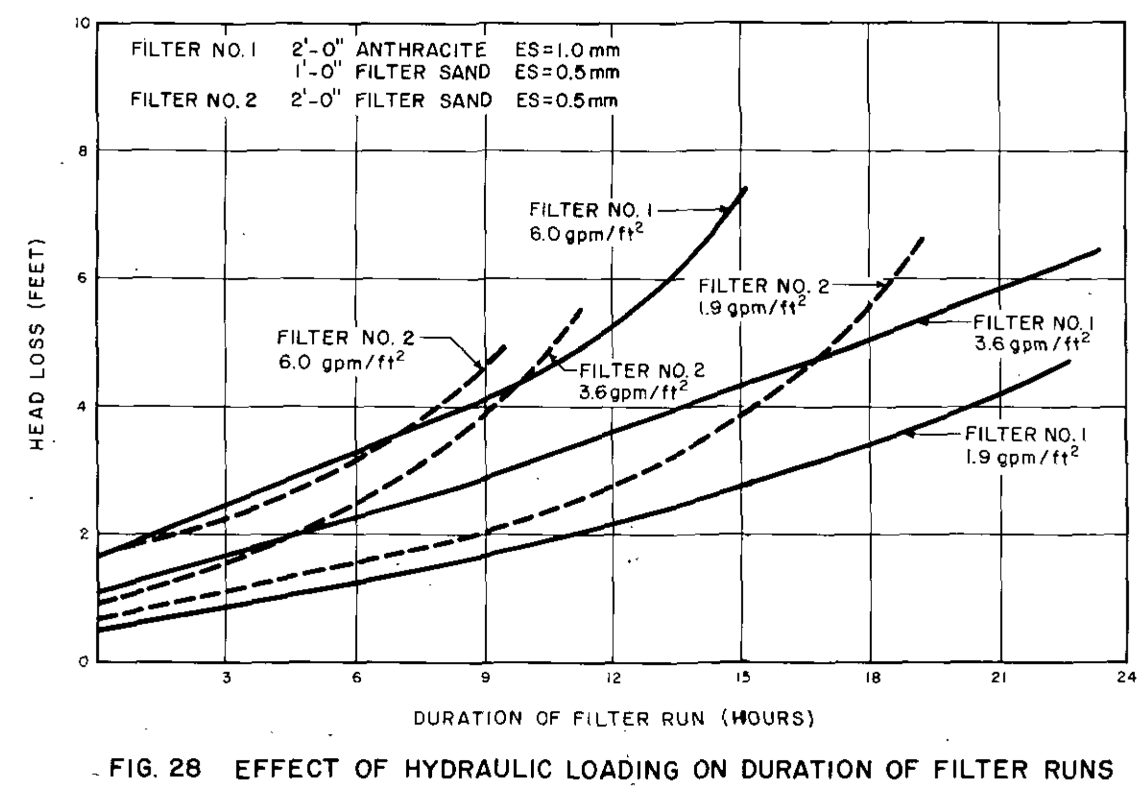


FIG. 28 EFFECT OF HYDRAULIC LOADING ON DURATION OF FILTER RUNS

hours. Backwashing of filters was done daily. It is significant to note (*Figure 28*), that the rate of increase of headloss was consistently higher for Filter No. 2 than the rate of increase for Filter No. 1. This may be attributable to the fact that Filter No. 2 had more than twice the height of filter sand than Filter No. 1.

The results of the pilot filter runs are shown in *Table 14*, and illustrate that as a tertiary treatment system, both filters significantly reduced suspended solids and turbidity from the feed water - treated second stage effluent from the pilot plant. The actual comparison of day to day operation of the pilot filters is shown on *Figures 29* and *30*. Inspection will indicate that as the feed suspended solids and turbidity increased or decreased, there was a similar rise or fall in the characteristics of the filter effluent. For Filter No. 1 the effluent suspended solids ranged from zero to about 16 mg/l and had an average value of 5.3 mg/l The very high values shown on *Figures 29* and *30* occurred at a time of very high flows in the pilot plant and also are due to a faulty sampling port. The normal range of effluent suspended solids for Filter No. 2 varied from zero to approximately 20 mg/l with an average concentration of 5.8 mg/l.

TABLE 14—RESULTS OF PILOT FILTER RUNS

Filter No.	Hydraulic Loading (gpm/ft²)	Average Effluent Suspended Solids (mg/l)	Effluent Turbidity (JTU's)	Time for Headloss to Reach 6-ft, 0-in (hrs)
1	1.9	5.3	3	25
1	3.6	11.1	6	22
1	6.0	8.5	7	13
2	1.9	5.8	4	19
2	3.6	15.0	8	12
2	6.0	9.2	8	10
2nd stage effluent	-	32.0	15	-

Figure 30 shows that turbidity, measured in Jackson Turbidity Units (JTU), of the feed water normally ranged from 10 to 30 JTUs with an average of 15 JTUs. The effluent from Filter No. 1 and No. 2 averaged 3 and 4 JTUs, respectively.

Generally the effluent produced from the pilot filters was clear, colorless and odorless. At times of best operation, the filter effluent could not be distinguished from tap water. Later in the project when methanol was being added for denitrification, the filter effluent exhibited a very light brown color.

Denitrification in Granular Filters

Subsequent to the study of the removal of suspended solids in the granular filters, the filters were run to promote the growth of denitrifying bacteria to accomplish denitrification. Methanol (CH_3OH) was fed to the filters to be utilized by the denitrifying bacteria, as a carbon source in the process of converting nitrate to nitrogen gas (reduction). That is:

$$2CH_3OH + 2NO_3 \rightarrow 2CO_2 + 4H_2O + N_2$$

As the denitrifying bacteria also reduced any dissolved oxygen in the wastewater, additional methanol was added to compensate for the dissolved oxygen in the feed water The empirical formula for the milligrams per liter of CH_3OH used during the pilot study was 2 (NO_3) + 0.8 (DO) where NO_3 is the nitrate nitrogen concentration and DO is the dissolved oxygen concentration of the influent wastewater. This formulation was developed by J. English at the Pomona advanced waste treatment research facility in Pomona, California.[6]

Instituting denitrification in the pilot filters was initially quite difficult. This was believed due to a high residual chlorine in the city's water supply, used for filter backwash, which killed the denitrifying bacteria each time the filters were backwashed. The methods used to dose methanol to the influent feed were originally inadequate and when nitrification began, it was very erratic.

In the first filter, which contained anthracite and sand, backwashing was a problem due to a cementing action of the anthracite grains caused by the biological slime. Even with a bed expansion of 70-100 percent during backwash, the large clumps were only partially broken up.

Filter No. 1 was placed in operation on September 25, 1970. Several days later, as shown on *Figure 31*, approximately 40 percent denitrification was achieved. Subsequently this dropped to zero and slowly climbed again until by the 10th of October a 40 percent level of removal had been achieved. By mid-October denitrification had fallen off again.

The daily denitrification results for Filter No. 1 are indicated in *Table 15*.

On October 14, 1970, Filter No. 2 was placed in operation and similar results occurred as denitrification was either low or non-existent in each column. (See *Table 16*)

The methanol supply was sufficient to overcome the dissolved oxygen in the waste and also to provide

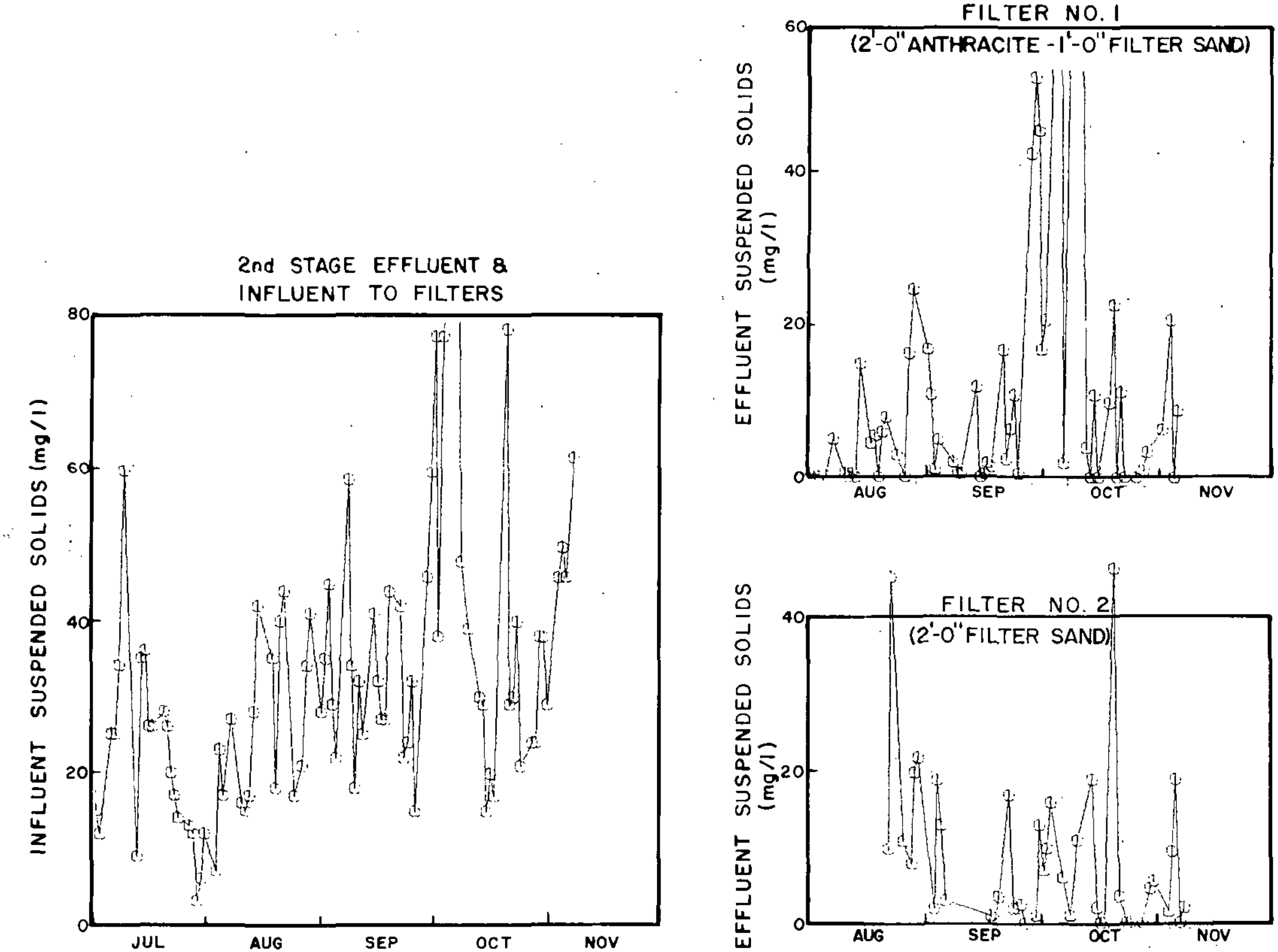


FIG. 29–SUSPENDED SOLIDS REMOVAL IN PILOT FILTERS

CAMP DRESSER & McKEE

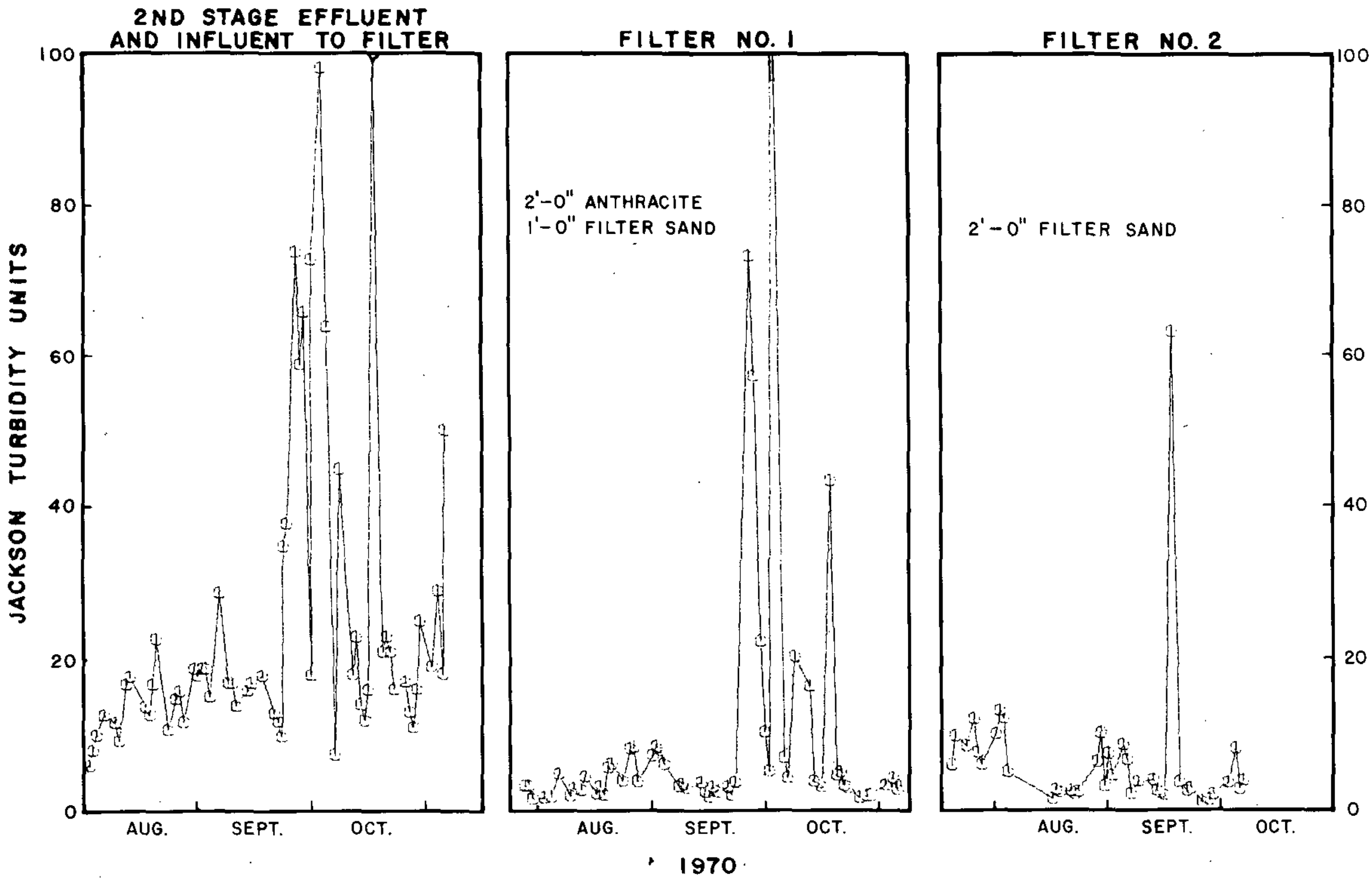


FIG. 30-TURBIDITY REMOVAL IN PILOT FILTERS

CAMP DRESSER & McKEE

TABLE 15 — DENITRIFICATION RESULTS FILTER NO. 1

ANTHRACITE AND SAND MEDIA

Date	Flow (gpm)	CH_3OH Dose (mg/l)	Influent NO_3 (mg/l)	Effluent NO_3 (mg/l)	NO_3 Removal (%)
9/24/70	.5	138	6.4	2.6	59
9/25/70	.5	-	4.0	8.9	0
9/28/70	.5	59	6.15	9.8	0
9/29/70	.5	-	3.0	2.0	33
9/30/70	.5	-	2.92	2.37	19
10/1/70	.5	-	3.1	-	-
10/2/70	.5	-	3.5	3.55	0
10/5/70	.5	-	3.37	3.24	4
10/6/70	.5	-	4.37	4.5	0
10/7/70	.5	-	-	-	-
10/9/70	.5	71	8.6	6.87	20
10/13/70	.5	67	7.63	4.63	39
10/14/70	.5	-	7.0	8.9	0
10/15/70	.5	-	-	-	-
10/16/70	.5	-	5.75	5.37	7
10/19/70	.5	48	4.12	4.25	0
10/20/70	.5	175	5.25	6.5	0
10/21/70	.5	121	4.12	5.5	0
10/22/70	.57	128	-	-	-
10/23/70	.5	155	3.5	3.5	0
10/26/70	.5	-	7.0	5.87	16
10/28/70	.55	220	5.9	3.8	36
10/29/70	.55	212	7.8	7.0	10
11/2/70	-	-	12.3	8.0	35
11/3/70	2.0	90	14.7	-	-
11/4/70	2.0	85	15.3	4.0	74
11/5/70	2.0	94	13.6	1.6	88
11/6/70	2.0	73	11.4	1.5	87
11/10/70	2.0	7	11.8	2.9	75
11/11/70	2.0	-	11.5	0.9	92
11/16/70	2.0	7	7.8	4.7	40
11/18/70	2.0	7	7.3	5.0	32
11/19/70	2.0	5	11.7	7.15	39
11/20/70	2.0	5	6.0	3.4	43

TABLE 16 — DENITRIFICATION RESULTS FILTER NO. 2

SAND MEDIA

Date	Flow (gpm)	CH_3OH Dose (mg/l)	Influent NO_3 (mg/l)	Effluent NO_3 (mg/l)	NO_3 Removal (%)
9/24/70	.5	138	6.4	-	-
9/25/70	.5	-	4.0	-	-
9/28/70	1.0	29	6.15	-	-
9/29/70	-	-	3.0	-	-
9/30/70	1.0	-	2.92	-	-
10/1/70	1.0	-	3.1	-	-
10/2/70	1.0	-	3.5	-	-
10/5/70	1.5	-	3.37	-	-
10/6/70	1.5	-	4.37	-	-
10/7/70	1.5	-	-	-	-
10/9/70	1.5	24	8.6	-	-
10/13/70	.5	75	7.63	-	-
10/14/70	.5	-	7.0	6.6	6
10/15/70	.5	-	-	-	-
10/16/70	.5	-	5.75	5.77	0
10/19/70	.5	48	4.12	5.5	0
10/20/70	.5	175	5.25	7.0	0
10/21/70	.5	-	4.12	-	-
10/22/70	.64	129	-	-	-
10/23/70	.5	141	3.5	2.75	21
10/26/70	.5	-	7.0	7.0	0
10/28/70	.57	187	5.9	5.0	15
10/29/70	.55	220	7.8	9.0	0
11/2/70	-	-	12.3	10.4	15
11/3/70	2.0	96	14.7	13.6	7
11/4/70	2.0	94	15.3	11.4	25
11/5/70	2.0	97	13.6	10.4	24
11/6/70	2.0	77	11.4	7.6	33
11/10/70	2.0	8	11.8	6.75	43
11/11/70	2.0	-	11.5	4.5	61
11/16/70	2.0	8	7.8	6.3	19
11/18/70	2.0	8	7.3	6.6	10
11/19/70	2.0	5	11.7	8.5	27
11/20/70	2.0	5	6.0	2.0	67

sufficient carbon sources for the denitrifying bacteria. In addition, throughout the initial operating period (through late October), an excess of methanol was fed to the columns. The excess feed was due to an error in the mixing preparation of the chemical.

In late October, it was determined that the city's municipal water supply, which was being used for backwashing operations, actually contained a chlorine residual of approximately 1.0 mg/l. As backwashing periods normally lasted 30 to 45 minutes, there was sufficient contact time to kill the denitrifying bacteria.

A backwashing system utilizing the abandoned Falulah upflow clarifiers for effluent storage tanks was established. The filtered effluent was stored in these tanks and backwash water pumped as needed. It is apparent from *Figure 31* that this procedure had an immediate effect on the growth of the denitrifying bacteria. Eight days after starting this backwash system, denitrification in Filter No. 1 had increased to almost 90 percent. Though erratic, it stayed between 75 and 90 percent for a period of 10 days, then dropped rapidly down to a level of approximately 30 percent, at which time the unit was shut down. Filter No. 2 showed a steady increase in denitrification, but the efficiency was not as good as in Filter No. 1. The results are shown in *Table 16*.

Though the data is variable, it has been shown that denitrification by using granular filters is possible. However, due to errors in feeding and an excess of methanol, no suitable conclusions can be drawn as to the relationship of methanol required per unit of nitrate removed.

Further testing was not possible because the pilot plant was shut down due to a loss of nitrification.

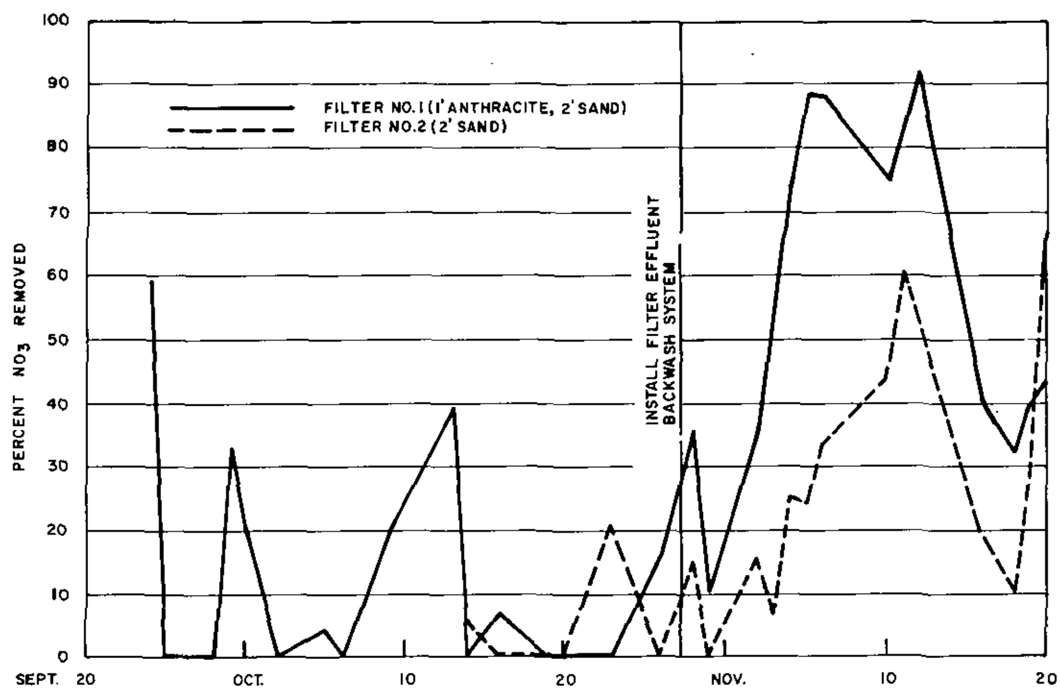


FIG. 31 DENITRIFICATION RESULTS

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6. English, J. N., *Nitrate Removal in Granular Activated Carbon and Sand Columns,* Preliminary Report, Pomona Advanced Waste Treatment Research Facility, Pomona, California, February, 1969.

Appendix I
PILOT PLANT DATA

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

OPERATING DATA

DATE 1970	RAIN FALL IN.	TEMPERATURE (F) AIR	COMB INF	1ST EFF	2ND EFF	AVG FLOW	1ST STAGE AERATION AVG DO MG/L	MLSS MG/L	MLVSS MG/L	SETT SOL ML/L	SVI ML/G	RET SLUDGE GPM	RSSS %	RSVSS %	WASTE SLUDGE GAL	PH
FEB 2		49	48	47	47	17.8	2.2	3870	2830	350	90	7.6	1.23	0.87	60	5.70
FEB 3	0.38		47	47	47	13.3	2.6	4230	2705	365	86	10.4	2.22	1.85	138	5.30
FEB 4	1.98	30	43	43	44	14.0	6.7	4470	3120	302	67	11.4	0.93	0.56	25	6.10
FEB 5		33	46	45	44	13.5	3.3	3190	1940	300	94	9.2	4.18	1.78	0	6.40
FEB 6	0.09							3650	2340	246	67		1.09	0.54		
FEB 9		51	49	48	48	11.5	3.2	3930	2580	346	88	10.8	0.49	0.32	74	6.60
FEB 10		49	47	48	47	13.0	2.5	3000	2010	268	89	8.7	0.77	0.52	0	6.40
FEB 11	1.98	44	44	44	46	13.1	5.7	3800	2480	275	72	12.1	1.37	0.85	0	6.40
FEB 12		36	45	45	46	15.4	5.7	5560	3370	302	54	9.3			233	7.00
FEB 13		36	46	45	45	15.7	7.1	4140	2520	242	58	8.8	2.65	1.54	445	7.00
FEB 15	0.18					13.6						7.0			0	
FEB 16	0.41	42	48	47	47	11.1	4.6	2144	1480	172	80	10.2	2.21	1.55		7.10
FEB 17		42	47	46	45	11.2	4.4	2226	1564	196	88	7.2	1.63	0.35	0	7.20
FEB 18		47	48	48	48	10.7	3.5	2578	1841	212	82	4.9	0.71	0.22	0	7.00
FEB 19								2608	1842				1.00	0.69		
FEB 20								3030	2150				1.62	1.10		
FEB 23		38	48	47	47	11.5	5.1	3584	2516	336	93	5.3				6.80
FEB 24		42	49	47	46	11.4	5.7	3456	2416	300	86	4.5	2.34	1.66	0	6.30
FEB 25		43				11.5	4.6	3360	2284	326	97	7.1	1.51	1.04	0	6.60
FEB 26		41	48	48	47	8.4	6.6	3860	2668	424	109	4.1	1.44	1.20		6.50
FEB 27		34	48	48	47	10.2	3.6	4424	3384	348	78	3.0	1.76	1.19		6.80
MAR 2		43	48	48	47	10.4	4.8			440		3.9				6.90
MAR 3		50	48	50	48	12.4	3.8	3350	2470	489	145	3.9	1.19	0.85	288	6.70
MAR 4		46	49	48	48	11.9	5.0	3208	2370	372	115	3.6	1.13	0.83	0	6.80
MAR 5		45	47	47	48	12.5	4.2	3810	2650	427	112	3.8	1.89	0.98		6.40
MAR 6	0.47							3970	2950				1.26	0.90		
MAR 9															110	
MAR 10		39	48	45	45	14.4		3780		390	103	3.8	1.74		0	6.40
MAR 11		43	48	46	46	15.8	2.4	3020		365	120	3.7	1.68		287	6.50
MAR 12		49				16.3	1.9	2235		264	118	3.5	1.53		215	6.80
MAR 13	0.03					13.6	1.9	3380		279	82	3.6	2.42			
MAR 16		51	50	49	49	13.0	1.7	3740		330	88	3.6	1.68		0	7.10
MAR 17		48	49	48	48	12.6	1.6			460		3.6			114	6.60
MAR 18		49	49	48	49	12.4	1.9	4400		479	108	3.5	2.39		108	6.50
MAR 19		53	50	49	50	12.8	2.6	3760		474	126	3.5	1.89		0	6.70
MAR 20		54	49	49	50	12.0	5.1	5020		582	115	3.2	0.89		0	6.70
MAR 23		47	48	47	47	13.3	2.6	4190		412	98	2.8	2.42		60	7.20
MAR 24	0.06	48	49	49	47	13.7	2.7	4690		518	110	3.1	2.18		90	6.70
MAR 25		49	48	49	48	12.7	3.1			550		2.4			75	6.90
MAR 26		48	48	49	48	11.6	2.4	4080		435	106	3.4	1.91		0	6.80
MAR 27	0.84	52	46	47	48	11.7	3.9	3810		510	133	2.5	2.24		0	7.00
MAR 30	0.49	55	49	52	48	12.2	3.5	3610	2570	368	101	2.7	1.64	1.19	0	7.00

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

OPERATING DATA

DATE	RAIN	-----TEMPERATURE (F)------				AVG	-----1ST STAGE AERATION-----									
1970	FALL IN.	AIR	COMB INF	1ST EFF	2ND EFF	FLOW	AVG DO MG/L	MLSS MG/L	MLVSS MG/L	SETT SOL ML/L	SVI ML/G	RET SLUDGE GPM	RSSS %	RSVSS %	WASTE SLUDGE GAL	PH
MAR 31		42	49	48	48	13.5	3.2	3690	2770	361	97	3.1	2.01	1.47	56	6.50
APR 1	0.26	56	50	50	49	14.4	2.5			403		3.1			0	6.60
APR 2	0.53	44	45	47	48	13.9	3.1	3720	2690	382	102	3.0	2.36	1.73	90	6.60
APR 3	1.98	46	44	44	45	11.2	5.0	4610	3230	422	91	2.6	2.00	1.41	0	6.50
APR 6		51	48	47	48	10.5	3.7			456		2.7			0	6.50
APR 7		50	47	47	47	13.4	2.5	3300	2430	394	119	2.6	2.28	1.68	60	6.40
APR 8		56	47	48	48	12.6	2.6	4360	3350	394	90	2.2	2.31	1.73	0	6.50
APR 9		62	50	50	50	15.2	2.6	3350	2240	302	90	2.4	2.57	1.88	69	6.40
APR 10		48	50	50	50	13.5	3.4	2960	2310	398	134	3.1	2.89	2.19	0	6.70
APR 13		61	52	51	51	17.9	4.4			368		2.5			213	7.00
APR 14		61	52	51	52	18.3	6.3			316		2.7			0	5.70
APR 15		56	52	52	52	17.3	5.1			313		2.8			129	6.80
APR 16		58	52	52	52	18.1	4.3	2650	2050	265	100	2.3	2.47	1.83	75	6.90
APR 17		58	52	52	51	13.8	3.7	2570	1980	262	101	7.6	2.72	2.12	55	7.30
APR 20		50	52	50	51	16.6	2.3	3500	2650	299	85	3.7	1.43	1.09	0	6.50
APR 21	0.27	48	52	52	51	17.4	2.7	3500	2560	336	96	3.4	2.79	1.94	0	6.50
APR 22	0.10	56	53	53	52	13.8	2.9	3550	1420	434	122	3.1	1.51	0.95	84	6.60
APR 23		49	53	52	52	14.1	2.5	3270	2480	352	107	3.6	1.38	1.04	102	6.80
APR 24	0.02	52	54	52	52	12.9	2.1	3770	2730	397	105	3.2	2.50	2.19	0	6.90
APR 27		73	53	55	55	10.8	2.7	3940	2940	525	133	3.6	1.49	1.09	0	7.00
APR 28		68	57	56	55	14.7	2.0	3870	2910	428	110	3.8	1.82	1.39	151	7.00
APR 29		60	56	56	56	14.7	2.7	3480	2630	375	107	3.8	1.77	1.32	114	6.90
APR 30		61	57	56	56	16.9	1.9	3500	2680	302	86	3.9	1.74	1.30	111	7.20
MAY 1		69	56	56	57	13.0	1.9	3860	2980	352	91	4.1	1.59	1.22	0	7.10
MAY 4	0.07	59	57	56	56	9.5	2.6	3950	3050	500	126	3.7	1.56	1.22	50	6.90
MAY 5		63	58	57	56	12.0	3.2	4500	3450	522	116	3.8	1.81	1.43	118	6.60
MAY 6	0.11	46	57	56	57	12.8	2.8	4800	3090	538	112	3.7	1.60	1.21	0	6.50
MAY 7		44	56	56	55	14.0	1.9	3770	2960	375	99	3.1	2.30	1.75	100	6.80
MAY 8		54	58	57	56	11.6	2.1	4830	4130	451	93	3.9	1.05	0.79	0	6.60
MAY 11	0.04	79	61	61	63	15.6	1.5	3430	2570	494	144	3.5	2.33	1.79	75	7.40
MAY 12		68	60	60	62	14.1	1.6	4300		410	95	3.5	3.96	3.31	75	7.30
MAY 13		65	61	60	61	13.8	1.6	4020	3080	421	104	3.1	2.17	1.69	75	7.20
MAY 14		57	60	60	60	16.0	1.3	3890	2990	398	102	3.9	2.01	1.54	75	7.40
MAY 15		56	60	60	60	12.4	1.6	4060	3040	392	96	3.8	2.76	2.36	75	7.20
MAY 18	1.06	52	56	57	58	13.3	2.4	3830	3010	538	140	3.8	3.37	2.99	75	6.60
MAY 19	1.41	53	58	57	57	13.0	5.0	3980	3060	477	119	3.6	1.53	1.18	75	6.20
MAY 20		62	62	57	57	14.9	5.2	3900	3850	451	115	3.4	1.94	1.46	75	6.50
MAY 21		61	62	60	60	12.5	3.6	3940	3120	471	119	3.6	1.97	1.01	75	6.70
MAY 22		69	62	60	60	16.1	2.8	3690	2910	401	108	3.3	1.95	1.52	75	6.80
MAY 25		53	57	56	57	10.7	2.3	4370	3430	600	137	3.5	1.62	1.27	80	6.90
MAY 26	0.08	62	59	60	59	12.2	1.7	3920	3180	478	121	3.3	1.73	1.40	99	6.50
MAY 27		63	61	61	60	10.7	2.4	3550	2830	500	140	3.5	1.70	0.88	96	6.20

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

OPERATING DATA

DATE	RAIN	-----TEMPERATURE (F)------				AVG	-----1ST STAGE AERATION-----									
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MAY 28		59	60	60	60	12.9	2.6	3660	2968	391	106	2.8	1.61	1.37	100	6.60
MAY 29		57	60	60	61	12.3	1.9	4370	3850	446	102	3.5	1.95	1.59	100	6.80
JUN 1		82	65	66	65	19.5	2.0	3610	2790	412	114	3.2	1.51	1.18	125	6.60
JUN 2		75	65	65	65	18.0	1.8	4030	3200	342	84	3.5	1.54	1.24	125	6.00
JUN 3		70	65	65	65	18.6	1.9	4060	2930	372	91	3.0	2.08	1.61	175	6.00
JUN 4	1.28	63	65	65	65	17.9	3.6	3190	2450	350	109	3.2	2.39	1.83	175	6.30
JUN 5		62	63	64	64	18.0	2.8	3420	2410	280	81	3.1	1.92		175	6.50
JUN 8		79	63	62	62	20.9	1.9	3230	2620	338	104	4.1	1.55	1.16	175	7.00
JUN 9		76	65	65	65	22.8	1.5	2610	1910	196	75	3.6	1.51	1.11	175	6.90
JUN 10		74	66	66	67	17.4	1.2	2390	1790	179	74	3.3	1.19	0.87	175	7.10
JUN 11		77	67	67	68	20.8	1.0	2190	1610	157	71	4.1	1.27	0.93	175	7.30
JUN 12		70	65	67	67	18.2	1.4	2090	1410	159	76	3.3	1.44	0.63	0	7.70
JUN 15		71	65	64	64	20.1	1.9	2870	1950	125	43	4.2	0.95	0.66	175	7.50
JUN 16		66	65	65	65	19.3	2.1	2740	1910	133	48	3.1	1.29	0.95	230	7.40
JUN 17		70	65	65	66	15.9	2.9	2150	1525	145	67	4.2	1.11	0.76	0	7.20
JUN 18	0.02	72	67	66	66	18.1	3.0	3230	2130			3.3	1.07	0.72	0	6.90
JUN 19	0.34	73	66	66	66	13.0	2.7	3890	2650			4.4	2.05	1.46	50	7.10
JUN 20	0.02														125	
JUN 21															130	
JUN 22			64	64	65	14.1	20.0	3870	2610	210	54	4.6	1.21	0.81	15	7.40
JUN 23		76	66	66	66	12.8	2.1	3900	2670	250	64	4.7	2.17	1.77	137	7.10
JUN 24		78	66	66	66	13.3	2.5	4060	2650	240	59	4.5	1.67	1.12	129	7.30
JUN 25		73	65	66	67	12.2	3.1			240		4.4	0.89	0.53	130	7.20
JUN 26		56	65	66	66	12.2	3.3	4556	3050	238	52	4.5	1.94	1.25	123	7.30
JUN 29		76	66	65	65	14.6	1.7	5140	3190	195	37	4.3	1.68	1.11	130	7.30
JUN 30	0.04	68	66	66	67	12.3	1.7	3790	2475	230	60	4.5	2.71	1.75	0	7.60
JUL 1	0.08	73	66	68	68	14.7	1.6	3588	2432	220	61	4.5	1.36	0.92	236	7.60
JUL 2	0.02	67	66	67	68	12.0	2.5	4032	2730	231	57	4.2	2.84	2.17	227	7.50
JUL 3			65	67	67	11.4	1.8	3350	2240	191	57	4.2	1.79	1.17	160	7.20
JUL 6		75	67	67	67	14.3	2.1	3450	2350	167	48	4.4	1.35	0.89	150	7.10
JUL 7		76	68	68	68	13.8	1.5	3230	2250	187	57	4.3	1.13	0.78	150	7.00
JUL 8		76	68	69	69	10.2	2.3	3450	2410	210	60	4.4	0.85	0.60	150	7.10
JUL 9		78	68	69	69	15.0	1.0	3220	2310	128	39	7.0	0.78	0.56	150	6.80
JUL 10		74	68	70	69	12.3	1.2			199		7.0			150	7.10
JUL 13	0.16	74	68	68	68	13.1	2.8	1580	1220	105	66	4.0	0.29	0.21	150	7.50
JUL 14		68	68	68	68	12.7	1.8	1685	1320	128	75	4.1	0.61	0.46	150	7.60
JUL 15		71	68	68	68	13.3	1.4	2230	1700	127	56	3.8	0.97	0.74	150	7.40
JUL 16	0.48	76	70	71	71	11.3	1.3	1904	1530	138	72	4.8	0.47	0.37	160	7.20
JUL 17		74	69	70	71	8.6	2.2	2020	1550	152	75	4.9	0.53	0.40		7.20
JUL 20		81	71	73	73	13.9	3.3	1790	1390	140	78	4.6	0.44	0.32	122	7.20
JUL 21		72	71	71	71	12.6	1.8	1676	1240	150	89	4.4	0.42	0.32	120	7.30
JUL 22		68	70	70	71	11.8	3.2	1860	1460	170	91	4.4	0.68	0.53	120	7.30

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

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JUL 23		78	72	72	72	9.6	1.7	1920	1540	173	90	4.8	0.71	0.57	125	7.70
JUL 24								1700	1330				0.47	0.37		
JUL 27	1.58	90	75	75	75	8.9	2.4	1690	1220	147	86	5.3	0.59	0.42	120	7.10
JUL 28		84	74	76	76	9.1	1.7	1690	1250	160	94	4.6	0.68	0.50	100	7.10
JUL 29	0.03	82	74	76	77	10.8	1.3	1710	1300	153	89	4.5	0.53	0.40	100	6.90
JUL 30		82	74	76	77	12.4	1.3	1770	1340	175	98	4.6	1.00	0.86	100	7.20
JUL 31								1960	1430				0.73	0.53		
AUG 3		83	74	74	74	12.4	2.4	2110	1570	195	92	4.7	0.76	0.57	120	7.60
AUG 4		73	72	73	73	14.3	0.7	2000	1480	198	99	4.9	0.83	0.63	120	7.30
AUG 5		62	72	71	72	14.3	1.8			205		5.4	0.56	0.39	200	7.30
AUG 6								2152	1630				0.75	0.56		
AUG 7		70	72	72	73	14.5	2.7	2130	1590	192	90	3.8	1.04	0.78	0	9.00
AUG 10		82	73	76	76	13.6	2.0	1700	1420	161	94	4.9	0.71	0.60	120	7.20
AUG 11		67	71	72	72	13.2	3.3	1320	1100	123	93	5.1	0.52	0.44	700	7.20
AUG 12	0.04	76	73	73	73	13.7	2.8	1108	950	90	81	4.4	0.60	0.50	0	7.10
AUG 13		84	73	74	74	14.1	2.0	1760	1400	148	84	4.7	0.63	0.50	0	7.30
AUG 14		78				15.1	1.2					4.4			75	7.10
AUG 15								1790	1500	221	123				78	
AUG 16								2190	1850						75	
AUG 17		79	73	74	74	15.7	0.4	1916	1672	205	106	4.5	0.88	0.73	25	7.30
AUG 18	0.22	71	72	73	73	10.8	0.9	3120	2600	264	84	4.3	0.96	0.78	90	7.50
AUG 19		72	72	72	73	12.2	0.6	3050	2460	301	98	3.7	1.08	0.86	75	7.20
AUG 20	0.06	68	70	72	72	12.4	1.2	3520	2550	308	87	4.3	1.21	0.92	150	7.40
AUG 21	0.39	72	72	73	73	20.0	1.5	3400	2550	274	80	4.3	1.30	0.97	150	7.30
AUG 24	0.96	70	69	68	68	18.3	1.4	1980	1450	130	65	4.2	0.98	0.71	125	7.50
AUG 25		69	81	71	71	17.3	1.6	1860	1350	126	67	4.4	0.82	0.61	120	7.50
AUG 26		74	71	72	72	19.4	1.8	2290	1660	131	57	4.3	1.11	0.82	120	7.50
AUG 27		72	73	73	73	16.5	0.6	2500	1870	143	57	4.1	1.05	0.73	120	7.10
AUG 28		67	72	72	72	13.2	1.1	2350	1720	152	64	4.1	0.53	0.47	120	7.40
AUG 31	0.17	69	71	72	72	15.3	1.6	2820	2170	190	67	3.3	1.10	0.85	150	7.50
SEP 1		57	70	69	69	13.1	2.0	2970	2110	184	61	4.6	0.96	0.70	150	7.90
SEP 2		70	68	67	67	13.6	2.2	2780	2020	166	59	4.3.	1.09	0.80	160	8.30
SEP 3		59	70	70	70	14.2	1.9	2450	1860	156	63	4.4	1.18	0.85	130	7.60
SEP 4	0.22	74	72	72	72	15.7	1.3	3030	2200	182	60	3.4	1.24	0.92	120	7.30
SEP 7		59	68	68	68	16.4	1.3	3190	2490	238	74	3.8	1.77	1.37	0	7.30
SEP 8		58	70	68	68	14.3	1.6	3950		228	57	3.9	1.62	1.26	150	7.10
SEP 9		56	69	68	68	15.2	0.9	4050	2620	244	60	4.0	1.64	1.21	225	7.70
SEP 10	0.11	67	70	69	69	15.7	1.4	3090	2230	195	63	4.2	1.37	1.01	125	7.70
SEP 11		64	70	70	69	10.1	2.0	3090	2220			3.8	0.95	0.70	300	7.10
SEP 14	0.02	48	68	67	67	16.7	1.5	3190	2300	190	59	4.0	1.33	0.98	210	
SEP 15	0.12	50	67	66	66	16.1	3.3			206		4.0	0.96		120	7.30
SEP 16	0.86	58	68	66	66	15.2	2.6	2810	1990	187	66	4.0	1.24	0.88	150	7.40

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

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DATE 1970	RAIN FALL IN.	TEMPERATURE (F) AIR	COMB INF	1ST EFF	2ND EFF	AVG FLOW	1ST STAGE AERATION AVG DO MG/L	MLSS MG/L	MLVSS MG/L	SETT SOL ML/L	SVI ML/G	RET SLUDGE GPM	RSSS %	RSVSS %	WASTE SLUDGE GAL	PH
SEP 17		59	69	68	67	13.5	3.1	2560	1820	165	64	4.3	0.95	0.69	263	
SEP 18	0.18	50	68	67	67	20.0	4.2	2260	1580	171	75	3.3	1.42	1.11	177	
SEP 21		75	67	67	67	15.0	2.3	2580	1880	130	50	4.0	1.07	0.80	176	7.00
SEP 22		80	71	71	71	12.7	3.0	2370	1770	170	71	4.1	0.87	0.65	175	7.20
SEP 23		78	71	72	72	14.1	3.4	2030	1500	130	64	3.2	0.96	0.71	175	7.20
SEP 24		70	70	70	70	13.8	4.1	2100	1510	144	68	3.8	0.87	0.64	175	7.30
SEP 25		74	70	71	71	10.2	4.0	2120	1430	140	66	3.6	0.77	0.53	275	7.70
SEP 28	0.18	56	65	65	65	15.7	2.6	1660	1250	106	63	4.0	0.70	0.52	175	7.80
SEP 29		51	66	66	65	13.8	3.2	2430		110	45	4.2	0.78		120	7.80
SEP 30		51	65	64	64	18.5	2.5	2530	1700	119	47	4.0	1.15	0.81	175	7.40
OCT 1	0.03	55	68	67	66	18.7	2.1	2790	1920	105	37	4.3	1.38	0.95	160	7.20
OCT 2		53	66	65	65	17.2	1.3	3250	2010	111	34	4.0	1.41	0.92	120	7.20
OCT 5		51	66	64	64	12.6	2.6	2290	1490	105	45	3.1	0.97	0.63	136	7.30
OCT 6		53	66	65	65	12.5	2.0	2070	1470	100	48	3.6	0.75	0.52	145	7.70
OCT 7		64	69	67	66	12.8	2.0	2650	1770	130	49	3.6	1.05	0.68	186	7.60
OCT 8		58	68	67	66	9.8	4.1			150		4.4			0	7.80
OCT 9		66	68	67	67	10.9	2.2	3820	2330	157	41	3.5	0.96	0.58	100	7.70
OCT 10						10.0	3.8					3.2			144	7.80
OCT 11							2.1			150		3.7			150	7.70
OCT 12		67	67	65	65	9.6	3.1	2550		121	47	2.8	1.07	0.67	150	7.50
OCT 13		65	67	66	66	8.3	4.8	2160	1310	110	50	4.0	0.77	0.48	102	7.80
OCT 14		64	67	67	67	5.9	6.1	2390	1380	101	42	3.5	0.62	0.39	140	7.80
OCT 15		65	67	67	67	7.8	5.8	2410	1500	107	44	3.6	0.65	0.39	132	8.00
OCT 16	0.81	51	65	64	64	10.6	4.7	2730	1520	114	41	3.5	1.11	0.67	150	8.20
OCT 17	0.08	40	65	64	64	9.3	6.1					3.2			0	8.50
OCT 18		56				10.5	2.6			145		3.1			150	
OCT 19		47	65	64	62	10.5	2.5	2860	1884	142	49	3.4	1.06	0.68	170	8.30
OCT 20		42	65	61	62	11.1	4.5	3050	2050	139	45	3.6	0.76	0.48	142	8.40
OCT 21		57	63	63	61	10.3	4.3	2970	1940	132	44	2.3	0.95	0.58	162	8.40
OCT 22	0.09	52	63	63	61	12.1	4.2	2790	1900	95	34	3.1	1.39	0.89	650	8.10
OCT 23	0.34	57	61	61	61	10.9	7.5	1900	1280	99	52	3.3	0.69	0.44	0	8.80
OCT 24	1.10	61	66	64	62	17.9	3.5			125		3.2			0	
OCT 25		52				13.7	3.7			105		3.2				7.70
OCT 26	0.05	45	62	62	62	14.1	4.8	1530	1190	161	105	3.1	0.80	0.58	200	8.10
OCT 27	0.02	37	62	61	60	10.8	4.2	1840	1460	167	90	3.6	0.64	0.49	180	8.90
OCT 28		39	61	60	59	11.2	5.1	1870	1500	193	103	3.1	0.57	0.45	180	9.30
OCT 29		39	62	61	60	11.4	4.5	1910	1590	205	107	3.1	0.74	0.61	200	9.00
OCT 30		41	62	60	59	10.1	5.5	1380	980	190	137	2.3	0.60	0.47	200	8.60
OCT 31		50				8.7	5.0			192		3.0			150	8.80
NOV 1			62	61	61	10.2	4.7			237		2.9			150	
NOV 2		46	60	59	59	9.1	5.0	4440	2730	216	48	2.6	0.65	0.45	192	9.10
NOV 3	0.10	52	63	62	62	9.4	3.1	2210	1600	180	81	3.2	1.11	0.87	138	8.40

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

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NOV 4		49	62	61	59	9.4	4.7	2140	1590	216	100	3.7	0.56	0.38	150	8.70
NOV 5	0.55	44	60	59	59	9.7	5.0	1840	1330	180	97	3.3	0.87	0.64	0	8.10
NOV 6	0.11	61	59	59	57	9.4	6.0	1830	1250	140	76	3.4	0.47	0.34	130	8.10
NOV 7						12.0						3.2			150	
NOV 8			61			9.8	4.1			150		3.3				8.70
NOV 9		42	59	57	56	10.6	2.0	1600	1350	167	104	3.3	0.69	0.58	150	8.80
NOV 10		44	60	59	58	13.2	1.7	1970		156	79	3.3	0.91		150	8.60
NOV 11	0.52	52	59	57	57	11.9	5.6	1770	1420	159	89	3.3	0.69	0.53	150	8.80
NOV 12	0.21	49	60	58	57	12.9	2.8	1590		153	96	3.6	0.95		150	9.00
NOV 13		45	61	58	57	11.3	1.5	1220	1030	141	115	2.9	0.30	0.22	144	8.90
NOV 16	0.39	37	59	58	57	9.7	2.6	1040	173	143	137	3.3	0.26	0.05	140	9.50
NOV 17		35	59	57	56	8.3	3.0	1450	220	166	114	3.3	0.22	0.18	0	8.50
NOV 18		36	60	58	58	9.8	2.2	4030	2700	230	57	3.1	2.16	1.70	280	8.40
NOV 19		42	60	58	56	12.9	1.6	2540	1730	191	75	3.1	2.72	2.32	150	8.80
NOV 20	0.39	46	56	56	56	11.8	2.1	3240		172	53	2.6	1.07		0	0.89

FITCHBURG, MASSACHUSETTS - PILOT PLANT STUDY

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

OPERATING DATA

DATE 1970	2ND STAGE AERATION AVG DO MG/L	MLSS MG/L	MLVSS MG/L	SETT SOL ML/L	SVI ML/G	RET SLUDGE GPM	RSSS %	RSVSS %	PH	NA2AL2O4 AS AL+++ MG/L	FILTER NO 1 -SAND & COAL- FLOW GPM	FILTER NO 1 CH3OH MG/L	FILTER NO 2 ----SAND----- FLOW GPM	FILTER NO 2 CH3OH MG/L
FEB 2	5.2	2180	1930	307	140	10.6	0.60	0.51	6.0					
FEB 3	5.4	1950	1580	245	125	87.0	1.81	1.86	5.6					
FEB 4	6.9	2320	2040	280	120	8.3	0.59	0.50	6.2					
FEB 5	6.6	1675	1380	279	166	19.3	1.09	0.90	6.7					
FEB 6		2210	1870	255	115		1.71	1.05						
FEB 9	6.7	2010	1645	238	118	8.3	0.01	0.01	6.7					
FEB 10	8.1	1420	1145	79	55	8.2	0.49	0.39	6.5					
FEB 11	7.9	1595	1372	178	111	8.8			6.9					
FEB 12	9.3	2380	1510	190	79	12.5			7.2					
FEB 13	9.6	1750	1450	200	114	19.5	0.63	0.28	7.3					
FEB 15						8.0								
FEB 16	9.3	1638	1362	222	135	8.0	1.16	0.95	7.5					
FEB 17	8.9	1390	1155	185	133	8.3	0.84	0.72	7.4					
FEB 18	8.6	944	772	97	102	5.9	0.22	0.19	7.2					
FEB 19		808	672				0.51	0.42						
FEB 20		774	660				0.24	0.20						
FEB 23	9.5	1468	1220	81	55	5.3	0.16	0.14	7.2					
FEB 24	9.2	1064	882	74	69	5.1	0.21	0.18	6.6					
FEB 25	9.2	736	504	77	104	4.9	0.16	0.13	6.7					
FEB 26	10.0	656	524	75	114	5.0	0.18	0.14	6.6					
FEB 27	9.3	1180	972	74	62	5.0	0.13	0.10	6.9					
MAR 2	9.9			67		4.8			7.2					
MAR 3	9.6	663	523	65	98	5.1	0.15	0.11	6.8					
MAR 4	9.6	640	492	70	109	4.9	0.15	0.11	6.8					
MAR 5	9.5	540	484	67	124	4.8	0.19	0.15	6.6					
MAR 6		530	496				0.13	0.11						
MAR 9														
MAR 10	8.5	804		86	106	4.8	0.47		6.6					
MAR 11	7.8	735		92	125	4.1	0.28		6.7					
MAR 12	6.6	558		92	164	4.9	0.43		6.8					
MAR 13	6.2	1320		77	58	4.8	0.27							
MAR 16	7.9	186		14	75	3.9	0.04		7.1					
MAR 17	7.6			49		4.9			6.8					
MAR 18	8.1	825		70	84	5.3	0.18		6.6					
MAR 19	8.0	665		71	106	6.4	0.99		6.8					
MAR 20	8.6	920		73	79	6.2	0.11		6.8					
MAR 23	9.3	650		35	53	5.9	0.13		7.3					
MAR 24	8.9	751		46	61	5.7	0.16		6.9					
MAR 25	8.7			52		5.5			6.9					
MAR 26	8.5	1290		56	43	5.4	0.20		7.0					
MAR 27	9.0	290		60	206	5.3	0.35		7.0					
MAR 30	9.8	920	510	53	57	5.0	0.23	0.12	7.1					

FITCHBURG, MASSACHUSETTS - PILOT PLANT STUDY

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

OPERATING DATA

DATE 1970	2ND STAGE AERATION AVG DO MG/L	MLSS MG/L	MLVSS MG/L	SETT SOL ML/L	SVI ML/G	RET SLUDGE GPM	RSSS %	RSVSS %	PH	NA2AL204 AS AL+++ MG/L	FILTER NO 1 -SAND & COAL- FLOW GPM	FILTER NO 1 CH3OH MG/L	FILTER NO 2 ----SAND----- FLOW GPM	FILTER NO 2 CH3OH MG/L
MAR 31	9.2	675	490	52	77	3.7	0.24	0.16	6.7					
APR 1	8.0			54		3.2			6.6					
APR 2	6.2	876	544	53	60	3.2	0.66	0.41	6.6					
APR 3	10.2	1055	640	62	58	3.7	0.21	0.12	6.6					
APR 6	9.9			100		1.7			6.7					
APR 7	9.0	1840	1190	123	66	6.5	0.58	0.36	7.6					
APR 8	10.9	1440	950	108	75	5.7	0.32	0.22	7.4					
APR 9	9.6	1200	675	89	74	5.6	0.26	0.15	8.7					
APR 10	9.5	1210	805	84	69	5.1	0.26	0.16	8.2					
APR 13	9.6			83		7.9			7.6					
APR 14	9.7			83		5.0			8.0					
APR 15	9.4			37		3.4			8.0					
APR 16	8.4	1270	864	102	80	6.3	0.15	0.09	7.7					
APR 17	7.9	1350	840	110	81	3.8	0.57	0.35	7.9					
APR 20	7.7	1175	667	78	66	1.8	0.39	0.22	7.2					
APR 21	8.0	1010	604	77	76	6.8	0.48	0.28	8.1					
APR 22	8.2	1195	700	95	79	5.2	0.25	0.15	7.8					
APR 23	6.2	1170	695	100	85	3.7	0.22	0.13	8.5					
APR 24	7.4	930	495	90	96	3.0	0.26	0.15	9.1					
APR 27	8.1	1090	612	93	85	2.4	0.26	0.14	8.5					
APR 28	6.6	1045	647	84	80	2.4	0.35	0.24	8.7					
APR 29	6.8	1045	645	89	85	2.3	0.43	0.25	8.1					
APR 30	6.5	1145	665	80	69	2.3	0.53	0.31	8.4					
MAY 1	6.4	1245	775	81	65	2.4	0.32	0.20	8.3					
MAY 4	7.0	1220	720	100	81	2.3	0.34	0.20	7.4					
MAY 5	7.3	1390	836	111	79	2.4	0.30	0.17	8.2					
MAY 6	7.1	1340	760	116	86	2.2	0.24	0.14	7.7					
MAY 7	5.6	1280	900	121	94	2.3	0.57	0.34	7.4					
MAY 8	7.0	1385	775	118	85	2.5	0.34	0.18	8.0					
MAY 11	3.8	1300	835	100	76	2.3	0.20	0.12	8.2					
MAY 12	3.4	1760	1010	104	59	2.4	0.66	0.38	8.6					
MAY 13	3.5	1345	805	108	80	2.4	0.69	0.40	8.5					
MAY 14	2.6	1355	785	97	71	2.4	0.85	0.50	8.5					
MAY 15	2.4	1520	760	109	71	2.3	0.79		8.2					
MAY 18	6.6	1610	1030	112	69	2.4	0.78	0.47	8.1					
MAY 19	6.8	1495	900	103	68	2.3	0.59		7.9					
MAY 20	5.1	1250	700	71	56	2.1	0.94	0.55	8.0					
MAY 21	4.7	1620	1145	97	59	2.3	0.53		7.7	0				
MAY 22	3.8	1440	1000	72	50	2.1	1.14	0.69	7.8	0				
MAY 25	6.3	1410	854	100	70	2.3	0.73	0.44	7.5					
MAY 26	5.2	1050	1010	103	98	2.4	0.47	0.28	7.2					
MAY 27	4.8	1450	890	125	86	2.4			7.4					

FITCHBURG, MASSACHUSETTS - PILOT PLANT STUDY

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

OPERATING DATA

DATE 1970	2ND STAGE AERATION AVG DO MG/L	MLSS MG/L	MLVSS MG/L	SETT SOL ML/L	SVI ML/G	RET SLUDGE GPM	RSSS %	RSVSS %	PH	NA2AL2O4 AS AL+++ MG/L	FILTER NO 1 -SAND & COAL- FLOW GPM	FILTER NO 1 -SAND & COAL- CH3OH MG/L	FILTER NO 2 ----SAND----- FLOW GPM	FILTER NO 2 ----SAND----- CH3OH MG/L
MAY 28	3.7			79		2.4	0.56	0.34	7.1	0				
MAY 29	4.8	1660	980	84	50	2.4	0.51	0.31	7.2					
JUN 1	3.4	1530	895	75	49	2.0	0.73	0.43	8.3					
JUN 2	2.6	1275	780	70	54	2.3	0.64	0.38	7.8					
JUN 3	2.7	1270	786	50	39	2.2	*****	0.34	7.8	10				
JUN 4	5.1	1420	850	73	51	2.3	*****	0.35	7.7	12				
JUN 5	3.5	916	510	38	41	2.4	0.71	*****	7.4	12				
JUN 8	2.9	925	635	92	99	2.3	0.61	0.44	8.1	9				
JUN 9	1.2	1075	670	46	42	2.4	0.70	0.43	8.1	13				
JUN 10	2.0	1160	740	48	41	2.4	0.78	0.49	8.2	15				
JUN 11	1.3	1260	805	57	45	2.4	0.83	0.30	8.2	20				
JUN 12	2.2	1260	775	68	53	2.3			8.5	43				
JUN 15	1.5	1490	974	78	52	2.4	0.94	0.61	8.2	22				
JUN 16	2.1	1510	970	81	53	2.3	0.76	0.51	7.0	31				
JUN 17	4.3	1510	1040	80	52	2.3	0.73	0.47	7.7	39				
JUN 18	4.0	1210	795			2.3	0.76	0.48	8.1	35				
JUN 19	2.8	1025	675			2.3	0.94	0.63	8.1					
JUN 20														
JUN 21														
JUN 22		984	720	47	47	2.4	0.81	0.52	9.0	39				
JUN 23	4.4	1090	700	50	45	2.4	1.01	0.74	8.6					
JUN 24	4.1	1110	662	80	72	2.4	1.23	1.15	8.7	39				
JUN 25	2.4	1520	1050	93	61	2.4	0.84	0.53	8.6	44				
JUN 26	1.8	1350	948	98	72	2.4	1.15	0.79	7.4	45				
JUN 29	1.9	1436	932	50	34	2.3	1.06	0.69	8.6	36				
JUN 30	1.0	1495	938	105	70	2.4	1.83	1.18	8.5	17				
JUL 1	1.9	1676	1092	108	64		1.13	0.72	8.2					
JUL 2	2.3	1644	1120	120	72	2.4	0.97	0.64	8.2	28				
JUL 3		1570	1420	122	77	2.4	1.20	0.79	8.5	40				
JUL 6	2.1	1350	857	87	64	2.2	1.69	1.18	7.3					
JUL 7	1.0	1620	1070	102	62	2.3	1.93	1.29	8.3					
JUL 8	0.8	1630	1090	110	67	2.3	0.56	0.37	8.5					
JUL 9	1.7	1580	1050	66	41	2.4	0.89	0.69	7.9					
JUL 10	1.8			97		2.4			8.1					
JUL 13	2.8	1100	799	78	70	2.3	0.33	0.22	7.9					
JUL 14	6.2	1095	790	93	84	2.2	0.62	0.42	9.0					
JUL 15	2.5	1195	822	60	50	2.2	0.75	0.50	8.8					
JUL 16	1.8	1320	965	84	63	2.6	0.53	0.36	8.4					
JUL 17	5.0	1210	835	76	62	2.1	0.48	0.32	8.6					
JUL 20	2.9	700	597	53	75	2.2	0.34	0.23	8.4					
JUL 21	3.7	1000	685	48	48	2.3	0.39	0.26	8.5					
JUL 22	4.4	810	550	61	75	2.3	0.45	0.30	8.4					

FITCHBURG, MASSACHUSETTS - PILOT PLANT STUDY

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

OPERATING DATA

DATE	2ND STAGE AERATION									NA2AL204	FILTER NO 1 -SAND & COAL-		FILTER NO 2 ----SAND-----	
1970	AVG DO MG/L	MLSS MG/L	MLVSS MG/L	SETT SOL ML/L	SVI ML/G	RET SLUDGE GPM	RSSS %	RSVSS %	PH	AS AL+++ MG/L	FLOW GPM	CH3OH MG/L	FLOW GPM	CH3OH MG/L
JUL 23	5.2	725	480	58	80	2.2	0.33	0.23	8.6					
JUL 24		740	488				0.32	0.21						
JUL 27	5.0	945	595	75	79	3.2	0.40	0.26	7.3					
JUL 28	4.6	900	590	80	88	2.2	0.55	0.35	8.8					
JUL 29	4.5	940	650	80	85	2.1	0.55	0.36	8.4		2.1			
JUL 30	4.3	850	610	81	95	2.1	1.40	1.03	8.7					
JUL 31		1120	728				0.57	0.37			2.0			
AUG 3	5.4	1140	740	92	80	2.6	0.96	0.63	8.1					
AUG 4	2.4	1230	785	99	80	2.4	1.07	0.70	8.1					
AUG 5	1.4	1280	780	105	82	2.9	0.72	0.45	8.0					
AUG 6		1560	1050				0.30	0.20						
AUG 7	1.2	1460	940	114	78	2.4	0.79	0.53	9.5					
AUG 10	1.1	1450	970	138	95	3.0	0.94	0.66	8.5		0.6			
AUG 11	2.0	1560	1041	150	96	3.4	0.59	0.40	8.6		0.6			
AUG 12	2.0	1560	1090	133	85	3.0	0.72	0.49	8.7		0.6			
AUG 13	0.5	1610	1100	125	77	2.9	0.59	0.40	8.7		0.6			
AUG 14	1.3					5.0			8.9		0.6			
AUG 15		1430	970	130	90									
AUG 16		1670	1170											
AUG 17	0.6	1800	1305	160	88	2.8	0.72	0.50	8.2					
AUG 18	1.1	1740	1190	125	71	3.2	0.75	0.53	8.1					
AUG 19	1.5	1640	1160	147	89	2.8	0.83	0.57	8.1	19				
AUG 20	1.1	1720	1150	142	82	3.2	0.78	0.53	8.3	20				
AUG 21	1.6	1390	880	125	89	3.0	1.48	1.02	9.0	8				
AUG 24	0.7	1530	1070	120	78	3.2	0.87	0.60	8.3	13				
AUG 25	1.2	1610	1010	116	72	3.2	0.71	0.48	8.5	15				
AUG 26	1.6	1630	1040	118	72	3.9	1.41	0.97	8.3	13				
AUG 27	1.0	1780	1210	140	78	4.9	0.67	0.46	8.2	16				
AUG 28	2.8	2330	1550	132	56	4.1	1.23	0.84	8.0	19				
AUG 31	2.4	1610	1050	127	78	3.9	1.03	0.70	8.1	22				
SEP 1	3.6	1560	980	122	78	3.2	0.50	0.32	8.1	32	1.5		1.5	
SEP 2	2.7	1650	1070	118	71	3.1	0.76	0.50	8.2	25	1.5		1.5	
SEP 3	3.0	1590	1090	122	76	3.1	0.97	0.65	8.1	25	1.5		1.5	
SEP 4	3.0	1540	970	123	79	3.2	0.85	0.54	8.0	24	1.5		1.5	
SEP 7	1.6	1870	1270	150	80	2.7	1.02	0.67	7.2	21				
SEP 8	2.2	2100		141	67	2.9	0.81	0.54	7.6	37				
SEP 9	2.4	1720	1100	141	81	3.2	0.97	0.53	8.1	29				
SEP 10	1.9	1780	1230	132	74	3.2	1.01	0.68	7.9	32				
SEP 11	3.9	1580	1390			3.2	0.52	0.35	8.2	50				
SEP 14	3.3	1460	940	120	82	3.1	0.85	0.55	7.7					
SEP 15	4.9			126		3.0	0.84	0.54	8.0	15				
SEP 16	4.0	1260	770	100	79	2.8	0.80	0.50	8.2					

FITCHBURG, MASSACHUSETTS - PILOT PLANT STUDY

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

OPERATING DATA

DATE 1970	2ND STAGE AERATION: AVG DO MG/L	MLSS MG/L	MLVSS MG/L	SETT SOL ML/L	SVI ML/G	RET SLUDGE GPM	RSSS %	RSVSS %	PH	NA2AL2O4 AS AL+++ MG/L	FILTER NO 1 -SAND & COAL- FLOW GPM	FILTER NO 1 CH3OH MG/L	FILTER NO 2 ----SAND----- FLOW GPM	FILTER NO 2 CH3OH MG/L
SEP 17	4.1	1220	740	100	81	2.8	1.09	0.69	8.0					
SEP 18	3.2	1230	745	100	81	2.9	0.52	0.33	8.4					
SEP 21	2.7	1140	760	97	85	3.2	0.72	0.46	7.4	23				
SEP 22	3.5	1390	920	94	67	3.2	0.57	0.15	7.6	21				
SEP 23	3.1	1350	864	100	74	3.1	0.64	0.40	8.0	21				
SEP 24	3.6	1050	720	93	88	3.3	0.53	0.34	7.7	45	0.5	12	0.5	12
SEP 25	4.5			93		3.0	0.32	0.20	7.6	42	0.5		0.5	
SEP 28	2.5	1550	1010	126	81	2.7	0.84	0.55	8.0	39	0.5	5	1.0	2
SEP 29	4.3	1320	880	90	68	2.5	0.50	0.33	7.5	50	0.5			
SEP 30	4.2	870	600	81	93	2.5	0.86	0.57	7.8	40	0.5		1.0	
OCT 1	2.7	1140	770	77	67	2.4	0.85	0.52	7.9	50	0.5		1.0	
OCT 2	2.6	1190	800	99	83	2.7	0.89	0.56	7.2	33	0.5		1.0	
OCT 5	6.0	1290	755	88	68	2.6	0.54	0.32	8.2		0.5		1.5	
OCT 6	4.5	1330	920	79	59	2.8	0.50	0.33	8.0	42	0.5		1.5	
OCT 7	4.4	1270	838	85	66	3.2	0.60	0.40	7.9	43	0.5		1.5	
OCT 8	4.8			90		3.3			7.4	60				
OCT 9	3.9	1650	1050	102	61	2.9	0.50	0.31	8.3	50	0.5	6	1.5	2
OCT 10	5.4					2.9			8.2	55				
OCT 11	2.3			90		3.0			8.2					
OCT 12	5.2	1530	960	88	57	3.5	0.50	0.30	8.2	56				
OCT 13	6.0	1410	885	76	53	2.3	0.42	0.27	8.2	66	0.5	6		
OCT 14	6.6	1410	905	91	64	2.8	0.40	0.25	8.0	66	0.5		0.5	
OCT 15	6.1	1560	941	96	61	3.0	0.54	0.32	8.2	52	0.5		0.5	
OCT 16	6.4	1290	800	93	72	2.7	0.46	0.28	8.3	40	0.5		0.5	
OCT 17	6.7					3.0			8.3	45				
OCT 18	2.8			100		3.2								
OCT 19	2.5	1410	859	95	67	2.5	0.49	0.30	8.0		0.5	3	0.5	3
OCT 20	5.5	1440	850	91	63	3.2	0.48	0.30	7.5	7	0.5	14	0.5	14
OCT 21	5.3	1470	880	87	59	2.2	0.79	0.48	7.6	7	0.5	9	0.5	
OCT 22	5.4	1420	886	91	64	3.2	0.57	0.36	7.6	6	0.5	10	0.6	10
OCT 23	7.6	1410	875	88	62	3.1	0.51	0.32	7.7	7	0.5	12	0.5	11
OCT 24	2.3			75		3.1				4				
OCT 25	3.8			85		3.4			7.5					
OCT 26	5.2	1455	778	94	64	3.2	0.70	0.43	7.2		0.5		0.5	
OCT 27	5.6	1230	728	88	71	2.3	0.84	0.51	7.7					
OCT 28	5.7	1420	925	87	61	3.3	0.39	0.25	8.1		0.5	17	0.5	15
OCT 29	5.1	1200	772	90	75	2.9	1.03	0.66	7.9		0.5	17	0.5	17
OCT 30	7.7	1320	1000	79	59	2.4	0.25	0.17	8.0					
OCT 31	7.2			67		2.9			7.7	37				
NOV 1	5.7			90		3.2								
NOV 2	7.6	2030	1170	76	37	3.6	0.26	0.15	7.9	27				
NOV 3	5.8	1370	825	72	52	3.4	1.04	0.61	8.1	31	0.5	35	0.5	30

FITCHBURG, MASSACHUSETTS - PILOT PLANT STUDY

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

OPERATING DATA

DATE 1970	2ND STAGE AERATION AVG DO MG/L	MLSS MG/L	MLVSS MG/L	SETT SOL ML/L	SVI ML/G	RET SLUDGE GPM	RSSS %	RSVSS %	PH	NA2AL2O4 AS AL+++ MG/L	FILTER NO 1 -SAND & COAL- FLOW GPM	FILTER NO 1 CH3OH MG/L	FILTER NO 2 ----SAND----- FLOW GPM	FILTER NO 2 CH3OH MG/L
NOV 4	6.0	1570	930	70	44	3.6	0.37	0.22	7.7		0.5	33	0.5	15
NOV 5	7.1	2170	1300	72	33	2.8	0.35	0.21	7.3		0.5	36	0.5	15
NOV 6	6.4	1280	750	61	47	2.5	0.98	0.59	7.4		0.5	28	0.5	12
NOV 7						3.0								
NOV 8	4.5			70		3.0			8.2					
NOV 9	6.0	1360	908	75	55	3.7	0.81	0.55	7.6					
NOV 10	3.2	1470	1010	67	45	3.0	0.53	0.36	7.7	23	0.5	2	0.5	6
NOV 11	5.2	1540	1020	82	53	3.5	0.86	0.52	7.6	24	0.5		0.5	
NOV 12	5.4	3820		96	25	3.9	0.36		7.9	24				
NOV 13	5.5	1020	650	91	89	3.5	0.85	0.53	8.0	23				
NOV 16	5.7	1690	700	82	48	3.2	1.19	0.48	8.4					
NOV 17	6.6	3000	1230	84	28	3.6	0.23	0.09	8.0	43				
NOV 18	6.0	3560	2200	102	28	3.4	0.62	0.38	7.6	39				
NOV 19	2.8	2020	1230	109	53	3.4	1.49	0.94	7.4					
NOV 20	6.2	2460		108	43	3.0	2.05		7.7					

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	BOD MG/L RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	FILT 1 TAP 12	FILT 1 EFF	FILT 2 EFF
FEB 2	56	150	60	18	12			
FEB 3	37	190	50	14	11			
FEB 4	41	85	50	13	10			
FEB 5	57	110	57	14	11			
FEB 6	23	116	31	9	6			
FEB 9	63	131	52	12	21			
FEB 10	39			13	11			
FEB 11	20	110	26	6	7			
FEB 12	46	103	51	13	8			
FEB 13	41	112	44	11	11			
FEB 15								
FEB 16	58			15	11			
FEB 17	84			17	16			
FEB 18								
FEB 19								
FEB 20	58	140	62	15	12			
FEB 23								
FEB 24								
FEB 25								
FEB 26								
FEB 27								
MAR 2								
MAR 3								
MAR 4								
MAR 5								
MAR 6								
MAR 9								
MAR 10								
MAR 11								
MAR 12								
MAR 13								
MAR 16								
MAR 17								
MAR 18								
MAR 19								
MAR 20								
MAR 23								
MAR 24								
MAR 25								
MAR 26								
MAR 27								
MAR 30								

DATE 1970	COD MG/L RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	FILT 1 TAP 12	FILT 1 EFF	FILT 2 EFF
FEB 2	157	360	189	62	55			
FEB 3	189	403	210	68	60			
FEB 4	112	319	127	38	42			
FEB 5	327	272	120	38	35			
FEB 6	101	390	212	57	38			
FEB 9	171	696	191	56	75			
FEB 10	168			67	102			
FEB 11	90	414	102	32	59			
FEB 12	108	319	127	42	42			
FEB 13	161	441	148	43	45			
FEB 15								
FEB 16	190			60	64			
FEB 17	167			58	53			
FEB 18	149			56	49			
FEB 19	148	273	171	24	51			
FEB 20	169	372	157	59	51			
FEB 23	185	740	353	65	67			
FEB 24	131	782	308	51	51			
FEB 25	271	378	260	62	56			
FEB 26	210	347	259	80	68			
FEB 27	202	152	202	63	50			
MAR 2	432	1375	272	67	52			
MAR 3			405	84	38			
MAR 4			291	144	101			
MAR 5			237	70	62			
MAR 6			226	90	66			
MAR 9	284	195	321	65	78			
MAR 10			274	63	80			
MAR 11			219	58	62			
MAR 12			241	87	37			
MAR 13			221	75	71			
MAR 16			315	105	73			
MAR 17								
MAR 18			199	106	91			
MAR 19			286	59	40			
MAR 20			192	37	18			
MAR 23			203	44	48			
MAR 24								
MAR 25			184	97	33			
MAR 26								
MAR 27								
MAR 30	200	354	166	45	37			

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	BOD MG/L RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	FILT 1 TAP 12	FILT 1 EFF	FILT 2 EFF
MAR 31								
APR 1								
APR 2								
APR 3								
APR 6								
APR 7								
APR 8								
APR 9								
APR 10								
APR 13								
APR 14								
APR 15								
APR 16								
APR 17								
APR 20	126	112	109	29	25			
APR 21	66	123	84	21	31			
APR 22	66	104	69	30	32			
APR 23								
APR 24	78	81	50	16	40			
APR 27								
APR 28	139	196	143	27	29			
APR 29	149	168	146	28	35			
APR 30								
MAY 1								
MAY 4	103	66	80	16	14			
MAY 5								
MAY 6	97	65	96	24	16			
MAY 7								
MAY 8	63	46	47	32	21			
MAY 11			76	36	25			
MAY 12			100	35	32			
MAY 13			115	33	31			
MAY 14			113	38	27			
MAY 15			83	35	38			
MAY 18			52	19	26			
MAY 19			70	14	24			
MAY 20			63	27	38			
MAY 21			63	22	32			
MAY 22								
MAY 25			83	23	19			
MAY 26			78	13	2			
MAY 27			66	15	15			

DATE 1970	COD MG/L RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	FILT 1 TAP 12	FILT 1 EFF	FILT 2 EFF
MAR 31								
APR 1	160	332	181	79	41			
APR 2	98	204	102	75	36			
APR 3								
APR 6	141	175	143	50	175			
APR 7		184	121	42	68			
APR 8								
APR 9			198	75	79			
APR 10	172	238	152		62			
APR 13								
APR 14								
APR 15		143	147	36	14			
APR 16			160	88	52			
APR 17			174	47	37			
APR 20			290	97	66			
APR 21			227	88	82			
APR 22	203	232	205	41	63			
APR 23	165	248		86	75			
APR 24	165	269		80	92			
APR 27			207	80	42			
APR 28	305	290	221	99	83			
APR 29	205	255	202	87	68			
APR 30	203	135	207	109	64			
MAY 1			244	39	78			
MAY 4	244	158	225	67	27			
MAY 5	399	479	288	57	30			
MAY 6	195	172	226	54	43			
MAY 7								
MAY 8	212	127	204	88	30			
MAY 11			261	119	108			
MAY 12	202		199	95	53			
MAY 13								
MAY 14	268	107	279	97	49			
MAY 15	228	170	206	104	68			
MAY 18	157	165	161	63	47			
MAY 19	136	250	207	19	39			
MAY 20	135		133	59	67			
MAY 21	201	86	166	78	55			
MAY 22		107	185	58	42			
MAY 25	209		274	87	56			
MAY 26	234	113	280	65	28			
MAY 27	283	92	281	64	27			

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	BOD MG/L RAW INF	BOD MG/L FALULAH INF	BOD MG/L COMB INF	BOD MG/L 1ST STAGE EFF	BOD MG/L 2ND STAGE EFF	BOD MG/L FILT 1 TAP 12	BOD MG/L FILT 1 EFF	BOD MG/L FILT 2 EFF	COD MG/L RAW INF	COD MG/L FALULAH INF	COD MG/L COMB INF	COD MG/L 1ST STAGE EFF	COD MG/L 2ND STAGE EFF	COD MG/L FILT 1 TAP 12	COD MG/L FILT 1 EFF	COD MG/L FILT 2 EFF
MAY 28			67	12	20				344	104	332	54	27			
MAY 29									236	122	275	54	27			
JUN 1			98	22	28				361	118	373	86	70			
JUN 2									255	134	214	90	118			
JUN 3									282	109	266	78	94			
JUN 4									219	137	160	62	62			
JUN 5									218	152	198	54	46			
JUN 8			72	25	36				338	93	294	109	71			
JUN 9			53	25	43				204	121	183	82	62			
JUN 10			80	29	18				236	119	227	109	58			
JUN 11			42	18	28				204	130	241	85	54			
JUN 12			56	15	22				247	144	293	71	42			
JUN 15			99	26	37				354	122	339	117	52			
JUN 16			43	20	32				227	176	229	54	66			
JUN 17			76	22	16				303	142	215	80	42			
JUN 18			50	25	16				344	142	398	110	71			
JUN 19			60	42	17				230	113	214	97	62			
JUN 20																
JUN 21																
JUN 22			126	26	29				307	133	500	89	58			
JUN 23			82	24	8				218	230	248	96	52			
JUN 24			100						279	192	275	95	55			
JUN 25			100	20	20				261	146	282	126	44			
JUN 26			87								307	98	59			
JUN 29			67	16	19						213	82	71			
JUN 30			129								446	188	129			
JUL 1			126								131	95	122			
JUL 2											355	122	54			
JUL 3			80	16	18						592	104	70			
JUL 6			83	21	21					75	23	71	98			
JUL 7			70	23	24					66	39	80	65			
JUL 8			90	16	34					54	27	74	51			
JUL 9			76	14	34					585	4	86	51			
JUL 10			133	26	26					57	25	88	43			
JUL 13			152	25	12						318	88	58			
JUL 14			114	31	11						297	108	85			
JUL 15			138	34	13						302	79	75			
JUL 16			113	28	16						262	103	71			
JUL 17			103	19	9						221	71	55			
JUL 20			190	33	35						303	87	55			
JUL 21			129	18	19						256	94	59			
JUL 22			97	20	6						291	106	66			

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	BOD MG/L RAW INF	BOD MG/L FALULAH INF	BOD MG/L COMB INF	BOD MG/L 1ST STAGE EFF	BOD MG/L 2ND STAGE EFF	BOD MG/L FILT 1 TAP 12	BOD MG/L FILT 1 EFF	BOD MG/L FILT 2 EFF	COD MG/L RAW INF	COD MG/L FALULAH INF	COD MG/L COMB INF	COD MG/L 1ST STAGE EFF	COD MG/L 2ND STAGE EFF	COD MG/L FILT 1 TAP 12	COD MG/L FILT 1 EFF	COD MG/L FILT 2 EFF
JUL 23			97	8	12						297	117	50			
JUL 24			124	17	24						273	85	42			
JUL 27			96	14	16						327	104	46			
JUL 28			106	21	27						233	77	46			
JUL 29			111	34	22						247	58	30			
JUL 30			93	24	12		2				239	92	38	14		
JUL 31											201	75	41			
AUG 3			129	24	16	5	2				372	75	45	30	15	
AUG 4			105	27	19						307	110	41	60	41	
AUG 5			143	46	20	2	1				279	128	60	30	26	
AUG 6																
AUG 7			121	49	24	16	11				273	95	66	44	22	
AUG 10			144	29	32	6	4				381	110	73	36	44	
AUG 11			120	27	19	3	2				295	88	51	36	44	
AUG 12			195	34	24	7	6				363	101	65	21	29	
AUG 13			108	32	43	37	7				302	145	109	83	40	
AUG 14			91	21	41	46	27				293	122	85	100	57	
AUG 15																
AUG 16																
AUG 17						5	3							32	36	
AUG 18			87	10	5	13	6				307	142	69	51	25	
AUG 19			112	14	12	26	12				261	94	61	50	36	
AUG 20			150	9	12	20	13	17			362	89	71	64	39	
AUG 21			84	16	32	19	8	18			225	76	79		43	57
AUG 24			142			7	8	20			417	117	45		34	36
AUG 25			104	29	40	17	35	32								
AUG-26			146			16	27	26			363	105	76		55	65
AUG 27			127			9	16	12			334	119	78		44	49
AUG 28			136			7	11	6			396	68	52		37	29
AUG 31			178								368	103	67			
SEP 1			167			26	16	17			328	113	63		46	17
SEP 2			166			27	19	24			345	99	63		39	55
SEP 3			155			25	15	23			357	119	71		55	55
SEP 4			113			16	15	12			355	63	39	39	39	15
SEP 7			159	27	50						386	94	86			
SEP 8			183	21	33	4	2				461	82	62	39	27	
SEP 9			167	37	43	23	8				477	117	50	35	35	
SEP 10			109	27	44	33	17				360	105	50	66	54	
SEP 11			114	11	29						314	78	66			
SEP 14			204			11	10				465	112	54	23	23	23
SEP 15											293	73	51	57	42	
SEP 16			143			4	3	5			30	81	57		26	30

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	BOD MG/L RAW INF	BOD MG/L FALULAH INF	BOD MG/L COMB INF	BOD MG/L 1ST STAGE EFF	BOD MG/L 2ND STAGE EFF	BOD MG/L FILT 1 TAP 12	BOD MG/L FILT 1 EFF	BOD MG/L FILT 2 EFF	COD MG/L RAW INF	COD MG/L FALULAH INF	COD MG/L COMB INF	COD MG/L 1ST STAGE EFF	COD MG/L 2ND STAGE EFF	COD MG/L FILT 1 TAP 12	COD MG/L FILT 1 EFF	COD MG/L FILT 2 EFF
SEP 17											38	99	68		30	38
SEP 18			124			23	10	11			37	33	83		45	37
SEP 21			164			12	9	9			440	83	53		37	34
SEP 22			234			21	20	13			604	147	68		60	45
SEP 23			140			67	78	16			316	98	75		143	
SEP 24			140			120	1	9			318	81	37		177	
SEP 25			117			85	1	6			334	59	29		171	
SEP 28			264			72	3	12			263	183	51		124	
SEP 29			157			125	30	20			309	155	73		162	
SEP 30			184			179	1	7			358	124	73		146	
OCT 1			267			26	25	26			464	138	72		87	
OCT 2			153			85	59	21			228	118	39		47	
OCT 5			222	50	12	88	12	11			447	127	67		110	
OCT 6			670	16	5	11	30	19			336	145	78		101	
OCT 7			178	14	11		24	11			360	109	62			
OCT 8																
OCT 9			156	25	3	57	1	11			336	94	43	74	90	46
OCT 10																
OCT 11																
OCT 12			174								543	121	58			
OCT 13			153			27	1	15			339	74	58		70	
OCT 14			150			18	30	115			295	69	50		81	
OCT 15			146			25	14	14			308	66	42		50	
OCT 16			134								374	73	42		204	
OCT 17																
OCT 18																
OCT 19			241	24	2	12	1	2			508	88	54	250	239	57
OCT 20			200	28	1	176	1	1			488	107	68		321	
OCT 21			187	50	2	85	21	1			402	101	82		177	
OCT 22			174	29	3	96	1	1			428	92	61		165	
OCT 23			64	16	3	11	2	2			177	67	56		192	
OCT 24																
OCT 25																
OCT 26			207				2	93			349	86	86		131	
OCT 27			165								351	97	52			
OCT 28			162			69	21	0			329	97	52		209	
OCT 29			171								349	86	37		124	
OCT 30			171								383	94	45			
OCT 31																
NOV 1																
NOV 2			216	30	5						488	108	54		132	
NOV 3			135	33	1						360	151	66			310

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	BOD MG/L RAW INF	BOD MG/L FALULAH INF	BOD MG/L COMB INF	BOD MG/L 1ST STAGE EFF	BOD MG/L 2ND STAGE EFF	BOD MG/L FILT 1 TAP 12	BOD MG/L FILT 1 EFF	BOD MG/L FILT 2 EFF
NOV 4			166	29	1			
NOV 5			138	25	1			
NOV 6			114	39				
NOV 7								
NOV 8								
NOV 9								
NOV 10								
NOV 11								
NOV 12								
NOV 13								
NOV 16								
NOV 17								
NOV 18								
NOV 19								
NOV 20								

DATE 1970	COD MG/L RAW INF	COD MG/L FALULAH INF	COD MG/L COMB INF	COD MG/L 1ST STAGE EFF	COD MG/L 2ND STAGE EFF	COD MG/L FILT 1 TAP 12	COD MG/L FILT 1 EFF	COD MG/L FILT 2 EFF
NOV 4			383	117	39		411	
NOV 5			430	101	39		477	602
NOV 6			312	150	53		451	
NOV 7								
NOV 8								
NOV 9			620	187	68			
NOV 10			417	190	106		76	
NOV 11			275		68		61	76
NOV 12			318	136	75			
NOV 13			400	218	68			
NOV 16			383		59			
NOV 17			400	304	67			
NOV 18			415	415	74			
NOV 19								
NOV 20								

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	SUSPENDED SOLIDS MG/L RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	FILT 1 TAP 12	FILT 1 EFF	FILT 2 EFF	VOLATILE SUSPENDED SOLIDS MG/L RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF
FEB 2	246	200	256	65	63				90	123	114	28	24
FEB 3	164	274	166	59	44				67	178	88	39	36
FEB 4	32	186	36	14	17				32	149			15
FEB 5	24	146	28	13	5				47	109	37	27	28
FEB 6	53	238	97	26	27				47	141	61	14	14
FEB 9	64	590	99	32	62				50	402	77	14	31
FEB 10	220			30	32				84			28	34
FEB 11	44	198	69	1	18				24	156	45	11	12
FEB 12	24	189	75	15					20	124	61	3	
FEB 13	65	273	100	16	30				57	202	84	15	29
FEB 15													
FEB 16	37			18	5				36			18	5
FEB 17	54			19	21				48			14	14
FEB 18	58			17	17				55			17	16
FEB 19	90	128	101	39					59	96	69	34	
FEB 20	51	167	8	9	3				62	117	47	29	25
FEB 23	118	651	168	20	26				113	571	116	25	19
FEB 24	71	348	198	34	18				53	184	114	19	10
FEB 25	82	360	123	42	35				76	212	98	37	29
FEB 26	93	228	138	28	37				76	160	93	15	29
FEB 27	92	158	110		18				71	85	69		2
MAR 2	72	622	126	14	21				63	524	111	14	21
MAR 3													
MAR 4													
MAR 5													
MAR 6			115	42	29						102	40	22
MAR 9	67	67	61	3	20				76	41	61	20	31
MAR 10													
MAR 11													
MAR 12													
MAR 13													
MAR 16													
MAR 17													
MAR 18													
MAR 19													
MAR 20													
MAR 23													
MAR 24													
MAR 25													
MAR 26													
MAR 27													
MAR 30													

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	SUSPENDED SOLIDS MG/L RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	FILT 1 TAP 12	FILT 1 EFF	FILT 2 EFF	VOLATILE SUSPENDED SOLIDS MG/L RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF
MAR 31													
APR 1													
APR 2				57	46							36	23
APR 3													
APR 6	47	62	63	14	151				41	31	39		111
APR 7	60	81	80	37	53				59	49	68	21	38
APR 8	48	56	52	29	15				27	12	30		1
APR 9													
APR 10	59	146	64		41				57		53		26
APR 13													
APR 14	50		88	15	1						65		
APR 15													
APR 16	70		80	88	40				70		73	68	36
APR 17	75	182	84	15	27				66	61	64	6	16
APR 20													
APR 21	70	339	113	19					56	221	71	10	16
APR 22	42	172	116	59	23					86	95	42	16
APR 23	72	76	117	46	52				58	32	87	27	25
APR 24	113	61	115	11	73				56	18	57	4	31
APR 27	99	50	110	27	16				93	24	84	20	10
APR 28	64	109	165	32	22				60	36		32	15
APR 29	100	133	108	50	45				90	44	76	38	29
APR 30	84	143	83	47	26				68	42	77	45	18
MAY 1	134	105	139	12	14				111	38	113	12	7
MAY 4	121	54	133	35	23				103	31	85	29	23
MAY 5	150	248	177	18	19				92	183	110	6	5
MAY 6	124	99	133	15	20				124	72	113		
MAY 7	72	57	114	17	7				54	31	79	15	2
MAY 8	62	119	70	11	0				54	0	57	8	0
MAY 11	81	37	119	42	27					26	85	42	27
MAY 12	87	52	108	43	32				69	21	78	30	18
MAY 13	126	79	134	65	36				89	30	88	30	21
MAY 14	80	64	96	43	23				55	8	59	12	0
MAY 15	93	84	98	46	32				83	57	85	42	32
MAY 18	70	42	112	21	16				25	30	63	21	14
MAY 19	37	65	102	20	20				26	36	56	19	16
MAY 20	32	29	63	23	29								
MAY 21	60	36	54	32	29								
MAY 22	82	54	83	37	41				70	34	72	26	31
MAY 25	84		113	28	22				83		104		21
MAY 26	70	30	89						70	12	72		
MAY 27	67	41	62	4	1				67	41	33	1	0

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	SUSPENDED SOLIDS MG/L RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	FILT 1 TAP 12	FILT 1 EFF	FILT 2 EFF	VOLATILE SUSPENDED SOLIDS MG/L RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF
MAY 28	68	37		10	24				58	9		6	2
MAY 29	93	61	114	25	23				72	26		12	11
JUN 1	150	71	157	30	37				117	35	123	21	19
JUN 2	105	94	118	46	87				84	45	91	31	50
JUN 3	165	43	160	41	57				107	23	103	25	35
JUN 4	81	65	106	21	28				61	24	72	18	22
JUN 5	92	91	92	19	32				73	39	66	8	24
JUN 8	136	66	118	47	40				113	44	99	37	33
JUN 9	93	45	112	47	31				73	15	78	29	17
JUN 10	114	36	88	37	19				97	17	76	26	13
JUN 11	100	107	96	51	32				78	37	76	23	16
JUN 12	119	127	106		31				84	35	82		11
JUN 15	160	42	155	51	22				133	22	128	41	20
JUN 16	90	54	94	23	32				85	31		22	21
JUN 17	97	82	40	40	23				97	41		38	17
JUN 18	170	48	124	15	42				124	27	94	13	29
JUN 19	68	28	109	33	15				64	15	77	25	15
JUN 20													
JUN 21													
JUN 22	101	55	140	19	9				82	20	21	7	2
JUN 23	52	54	34	7	12				51	15	23	7	9
JUN 24	49	30	64	27	17				19	0	18		
JUN 25	110	51	120	32	20				111	31			13
JUN 26			75	17	9						68	7	5
JUN 29			132	69	44						120	55	36
JUN 30			110	55	36						94	42	36
JUL 1			88	37	25						75	27	19
JUL 2			73	25	15						65	17	13
JUL 3			45	17	12						45	16	10
JUL 6			104	37	25						86	22	13
JUL 7			82	36	25						73	32	19
JUL 8			125	36	34						102	23	21
JUL 9			124	61	60						85	39	40
JUL 10													
JUL 13			103	24	9						103		
JUL 14			87	25	35						87		
JUL 15			97	43	36						91	35	35
JUL 16			95	28	26						86		23
JUL 17			78	21	26						72	19	24
JUL 20			181	42	28						163	40	25
JUL 21			119	34	26						102	34	19
JUL 22			114	30	20						106	28	18

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	SUSPENDED SOLIDS MG/L								VOLATILE SUSPENDED SOLIDS MG/L				
	RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	FILT 1 TAP 12	FILT 1 EFF	FILT 2 EFF	RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF
JUL 23			100	4	17						83	4	12
JUL 24			105	27	14						88	17	6
JUL 27			105	29	13		9				80	18	6
JUL 28			98	21	12						77	15	10
JUL 29			71	10	3		10				64	10	3
JUL 30			111	35	6	11	3				90	34	6
JUL 31			85	40	12	3	1				62	24	3
AUG 3			135	27	7	0	0				110	19	4
AUG 4			136	57	23						98	41	13
AUG 5			60	50	17	0	0				44	24	
AUG 6													
AUG 7			107	34	27	13	5				90	31	17
AUG 10			183	36	16	0	0				142	30	15
AUG 11			139	25	15	0	0				124	21	8
AUG 12			138	19	17	6	0				112	18	13
AUG 13			87	24	28	6	0				70	24	16
AUG 14			139	50	42	63	15				123	39	33
AUG 15													
AUG 16													
AUG 17						5	4						
AUG 18			140	47	35	15	5				97	29	19
AUG 19			90	21	18	10	0				78	19	12
AUG 20			174	34	40	24	6	10			125	12	16
AUG 21			92	35	44	18	8	46			59	15	38
AUG 24		5	167	45	17	5	3	11			100	30	15
AUG 25													
AUG 26		10	126	27	21	10	0	8			83	11	1
AUG 27		28	104	46	34	28	16	20			84	33	25
AUG 28		35	173	58	41	35	25	22			129	31	8
AUG 31			138	51	28						86	36	29
SEP 1			137	45	35	32	17	2			113	12	15
SEP 2			83	63	45	38	11	19			70	54	41
SEP 3			142	55	29	17	1	13			111	47	
SEP 4			234	27	22	20	5	3			184	12	6
SEP 7			149	42	59						146	42	50
SEP 8			213	37	34	2	2				154	35	31
SEP 9			170	46	18	10	0				133	37	8
SEP 10			211	37	32	41	0				159	28	24
SEP 11			123	30	25						107	23	25
SEP 14			101	71	41	13	12				89	60	29
SEP 15			56	22	32	14	0					17	23

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	SUSPENDED SOLIDS MG/L								VOLATILE SUSPENDED SOLIDS MG/L				
	RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	FILT 1 TAP 12	FILT 1 EFF	FILT 2 EFF	RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF
SEP 16			69	26	27	2	0	1			49	9	8
SEP 17			96	37	27	2	2	0			72	13	16
SEP 18			80	30	44	8	1	3			60	25	22
SEP 21			254	48	42	22	17	17			220	23	19
SEP 22			162	35	22	4	2	2			136	32	19
SEP 23			114	29	24	19	6	2			96	17	10
SEP 24			104	24	32	2	11	2			100	21	22
SEP 25			124	50	15	1	0	0			96		7
SEP 28			180	64	46	6	43	1			170	52	22
SEP 29			182	61	60	100	53	13			164	47	54
SEP 30			140	46	78	84	46	7			138	43	68
OCT 1			138	95	38	15	17	10			120	49	29
OCT 2			128	64	78	60	21	16			114	42	75
OCT 5			126	31	129	2	93	6			108	24	
OCT 6													
OCT 7			188	58	48	11	2	1			114	47	47
OCT 8													
OCT 9			140	51	39	16	132	11			136	34	31
OCT 10													
OCT 11													
OCT 12			264	49	30						198	36	19
OCT 13			138	18	29	3	4	19			118	13	18
OCT 14			118	21	15	6	0	2			118	18	15
OCT 15			116	25	20	9	11	0			108	21	18
OCT 16			154	22	17	3	0	0			116	21	17
OCT 17													
OCT 18													
OCT 19			158	27	79	5	10	47			154	27	77
OCT 20			132	9	29	17	23	3			114	9	21
OCT 21			132	75	30	0	0				116		20
OCT 22			190	23	40	8	11	0			182	23	32
OCT 23			108	94	21	2	0	0			98	48	21
OCT 24													
OCT 25													
OCT 26			144		24	0	0	0			121		23
OCT 27			86	25	24						86	22	21
OCT 28			112	30	38	13	1	4			106	30	36
OCT 29			136	16	38	7	3	5			118	16	33
OCT 30			102	19	29						96	18	12
OCT 31													
NOV 1													
NOV 2			218	210	46	7	6	1			164		36

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	SUSPENDED SOLIDS MG/L RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	FILT 1 TAP 12	FILT 1 EFF	FILT 2 EFF	VOLATILE SUSPENDED SOLIDS MG/L RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF
NOV 3			144	192	50	22		9			142	115	40
NOV 4			144	50	46	30	21	19			126	46	
NOV 5						5	0	0					
NOV 6			120	32	62	14	9	2			88	31	39
NOV 7													
NOV 8													
NOV 9													
NOV 10													
NOV 11													
NOV 12													
NOV 13													
NOV 16													
NOV 17													
NOV 18													
NOV 19													
NOV 20													

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	PH RAW INF	PH FALULAH INF	PH COMB INF	PH 1ST STAGE EFF	PH 2ND STAGE EFF	TOTAL SOLIDS MG/L COMB INF	TOTAL SOLIDS MG/L 1ST STAGE EFF	TOTAL SOLIDS MG/L 2ND STAGE EFF	TOTAL VOLATILE SOLIDS MG/L COMB INF	TOTAL VOLATILE SOLIDS MG/L 1ST STAGE EFF	TOTAL VOLATILE SOLIDS MG/L 2ND STAGE EFF
FEB 2	6.6	4.3	7.0	6.9	7.1	575	344	334	179	93	80
FEB 3	6.0	4.2	5.4	5.6	5.6	410	292	281	152	84	78
FEB 4	6.4	4.4	5.9	6.1	6.2	365	277	260	116	68	51
FEB 5	6.3	4.1	5.5	5.8	5.9	359	304	287	158	96	106
FEB 6	5.8	4.1	5.6	5.8	6.0	563	421	339	140	47	53
FEB 9	6.9	4.2	6.7	7.1	7.1	433	318	363	179	58	79
FEB 10	6.7		6.7	6.7	6.8	456	265	305	178	69	86
FEB 11	6.2	4.2	5.3	5.9	6.0	310	262	293	186	148	118
FEB 12	6.1	4.5	5.4	5.7	5.8	327	265	282	38	1	13
FEB 13	6.7	4.6	5.8	6.2	6.3	425	303	313	160	59	77
FEB 15											
FEB 16	6.1		6.1	6.3	6.5	355	267	264	113	31	31
FEB 17	6.3		6.3	7.0	7.2	394	314	314	109	37	44
FEB 18	6.6			6.7	6.9	370	283	298	118	40	50
FEB 19	6.6	4.7	6.5	7.9	8.0	482	361	374	101	20	59
FEB 20	6.3	4.4	5.7	6.1	6.1	331	307	347	38	53	105
FEB 23	6.9	4.9	5.8	5.8	6.1	397	153	257	153	30	20
FEB 24	7.7	5.3	6.3	6.8	7.0	488	324	309	194	54	41
FEB 25	6.7	5.7	6.4	7.8	6.6	408	303	316	163	76	65
FEB 26	6.9	5.3	6.0	6.1	6.2	435	301	305	206	87	83
FEB 27	6.7	6.7	6.8	6.6	6.9	381	321	252	136	49	55
MAR 2	6.4	4.8	5.8	6.1	6.2	679	546	563	295	62	67
MAR 3						645	468	485	247	76	58
MAR 4											
MAR 5						702	511	372	237	130	147
MAR 6											
MAR 9											
MAR 10											
MAR 11											
MAR 12											
MAR 13											
MAR 16											
MAR 17											
MAR 18											
MAR 19											
MAR 20											
MAR 23											
MAR 24											
MAR 25											
MAR 26											
MAR 27											
MAR 30											

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE	PH					TOTAL SOLIDS MG/L			TOTAL VOLATILE SOLIDS MG/L		
1970	RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	COMB INF	1ST STAGE EFF	2ND STAGE EFF
MAR 31											
APR 1											
APR 2											
APR 3											
APR 6	6.2	4.3	5.9	7.0	7.0	444	364	484	150	71	176
APR 7	6.8	4.4	5.7	6.3	7.3						
APR 8	6.6	4.5	6.1	6.6	7.7	397	328	383	94	29	33
APR 9	6.2	4.4	6.0	6.6	8.4						
APR 10	6.4	5.8	6.4		10.0						
APR 13											
APR 14	6.7	4.3	6.9		6.5						
APR 15											
APR 16	6.7	4.4	6.2	6.4	6.7	398	371	400	143	140	102
APR 17											
APR 20						450	314	354	194	85	98
APR 21	6.7	4.3	6.5	6.5	7.6						
APR 22	6.3	4.4	6.3	6.5	7.7	450	338	420	156	70	59
APR 23	6.7	4.3	6.4	7.0	8.3						
APR 24						339	272	489	88	60	97
APR 27	7.0	4.3	6.9	7.3	8.2						
APR 28	6.7	4.2	6.5	7.1	8.1	364	303	437	145	82	90
APR 29	6.4	4.5	6.3	6.7	7.4						
APR 30	6.7	4.6	6.4	6.8	7.9	397	329	427	153	88	121
MAY 1	8.0	4.6	7.6	7.4	7.9	437	282	431	188	78	119
MAY 4						462	374	474	221	116	121
MAY 5	7.1	4.5	6.4	8.4	8.2	514	358	481	218	69	160
MAY 6											
MAY 7	6.8	4.3	6.1	6.5	7.2						
MAY 8	6.9	4.3	7.2		7.9	426	269	429	153	81	95
MAY 11	7.3	4.4	7.1	7.2	7.7	414	315	404	122	31	112
MAY 12	7.0	4.6	7.0	7.3	8.1	423	321	461	174	67	135
MAY 13						416	312	437	147	51	97
MAY 14	6.9	4.6	6.9	7.0	7.9	398	328	464	138	53	93
MAY 15	6.9	4.6	6.9	7.2	7.7	412	348	428	144	55	157
MAY 18	6.9	4.4	6.7	7.0	8.0						
MAY 19						364	202	256	86	25	25
MAY 20	6.8	4.4	6.4	6.6	7.7	352	300	350	150	131	118
MAY 21	7.2	4.7	6.7	7.0	7.7	387	299	379	124	65	80
MAY 22						361	319	410	125	110	97
MAY 25	7.2		7.2	8.2	8.0	441	389	417	177	72	89
MAY 26	7.1	4.5	6.3	7.3	7.5	353	245	338	120	14	73
MAY 27						398	309	452	251	136	133

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	PH					TOTAL SOLIDS MG/L			TOTAL VOLATILE SOLIDS MG/L		
	RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	COMB INF	1ST STAGE EFF	2ND STAGE EFF
MAY 28	7.1	4.5	6.7	7.2	7.7	373	288	373	137	37	95
MAY 29						402	304	362	118	34	68
JUN 1						454	300	504	201	68	136
JUN 2	7.0	4.4	6.9	7.2	7.9	351	287	426	122	84	123
JUN 3	6.7	4.2	6.6	7.0	7.7	393	265	375	139	31	60
JUN 4	7.0	4.6	6.9	7.5	7.7	382	236	368	131	35	117
JUN 5	7.4	4.6	7.4	7.8	7.7	377	276	367	103		33
JUN 8						471	337	448	188	128	125
JUN 9						352	291	339	114	44	55
JUN 10	6.9	4.3	7.0	7.3	7.9	357	304	373	151	83	59
JUN 11						366	313	391	143	68	81
JUN 12	7.0	4.7	7.0	7.3	7.8	324	284	354	99	55	66
JUN 15	7.1	4.5	7.1	7.5	7.8	488	354	425	218	99	91
JUN 16	7.0	4.4	6.9	7.0	7.6	345	257	336	90	10	28
JUN 17						352		331	148		52
JUN 18	6.8	4.6	6.6	7.1	7.7	386	277	331	152	60	56
JUN 19							329	340		78	100
JUN 20											
JUN 21											
JUN 22	7.0	4.4	7.0	7.5	8.3	443	311	442	183	78	102
JUN 23	6.9	4.2	6.5	7.0	8.0	450	350	402			
JUN 24	7.0	4.4	6.8	7.3	8.2		364	428		117	123
JUN 25	7.0	4.5	6.6	6.9	7.7	510	322	400	225	44	136
JUN 26			7.2	7.5	7.8	334	231	292	151	45	59
JUN 29						374	218	411	205	137	92
JUN 30			7.2	7.8	8.4	537	404	518	232	214	119
JUL 1						339	297	374	123	86	104
JUL 2						294	272	389	142	40	81
JUL 3			7.6	7.7	8.2	403	293	457	207	84	157
JUL 6			7.2	7.5	7.8	426	288	367	190	87	98
JUL 7			7.3	7.8	8.1	361	326	385	132	146	88
JUL 8						383	267	418	167	65	110
JUL 9						386	321	480	181	94	155
JUL 10			7.0	7.2	7.8						
JUL 13						411	260	334	175	52	77
JUL 14			7.3	7.7	8.5	426	367	564	159	80	158
JUL 15			7.1	7.3	7.9	399	350	492	238	161	163
JUL 16			7.4	7.7	8.0	358	259	436	151	71	135
JUL 17			7.1	7.4	8.0	342	221	451	158	67	168
JUL 20			7.2	7.3	7.9	376	264	458	142	42	82
JUL 21			7.0	7.2	8.0	350	253	446	173	54	131
JUL 22			7.1	7.5	8.1	404	304	437	170	91	90

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	PH RAW INF	PH FALULAH INF	PH COMB INF	PH 1ST STAGE EFF	PH 2ND STAGE EFF	TOTAL SOLIDS MG/L COMB INF	TOTAL SOLIDS MG/L 1ST STAGE EFF	TOTAL SOLIDS MG/L 2ND STAGE EFF	TOTAL VOLATILE SOLIDS MG/L COMB INF	TOTAL VOLATILE SOLIDS MG/L 1ST STAGE EFF	TOTAL VOLATILE SOLIDS MG/L 2ND STAGE EFF
JUL 23						378	213	431	163	35	60
JUL 24			7.0	7.4	8.1	341	239	423	134	50	99
JUL 27			7.1	7.6	7.7	389	238	335	171	59	88
JUL 28			6.9	7.5	8.8	306	222	452	96	41	109
JUL 29			7.0	7.3	8.0	252	191	359	100	36	77
JUL 30			7.0	7.3	7.9	345	213	351	167	71	100
JUL 31			7.0	7.3	7.8	302	239	370	128	55	132
AUG 3			6.9	7.2	7.8	400	246	368	184	62	91
AUG 4			7.0	7.2	7.8	363	361	404	158	83	110
AUG 5			7.2	7.3	7.8	349	247	376	215	87	106
AUG 6											
AUG 7			7.0	7.2	7.9	350	226	370	159	84	92
AUG 10			6.9	7.2	7.7	416	265	383	200	76	111
AUG 11			7.1	7.3	8.1	349	251	417	136	66	100
AUG 12						398	287	468	205	122	153
AUG 13			6.9	6.9	8.0	283	252	428	127	76	114
AUG 14			7.0	7.2	7.8	379	301	450	187	134	149
AUG 15											
AUG 16											
AUG 17											
AUG 18			7.0	7.2	7.7	380	317	444	153	107	127
AUG 19			6.8	7.2	7.7	319	261	457	139	97	120
AUG 20			6.9	7.1	8.0	437	282	514	185	43	143
AUG 21			7.0	7.5	8.8	329	285	458	146	157	222
AUG 24			7.3	7.6	8.0						
AUG 25											
AUG 26			5.6	7.2	7.8	394	300	409	167	104	142
AUG 27			6.9	7.2	7.8	376	277	451	157	72	142
AUG 28			7.4	7.9	8.1	512	306	423	249	101	126
AUG 31			7.1	7.5	7.9	437	266	439	248	71	152
SEP 1			6.9	7.6	7.7	456	427	532	256	213	234
SEP 2			7.0	7.4	7.8	454	315	541	272	125	255
SEP 3			6.9	7.5	7.9	420	282	480	247	129	183
SEP 4						395	229	450	256	55	203
SEP 7			7.1	7.4	7.2	315	300	267	116	103	66
SEP 8						548	428	551	309	180	227
SEP 9			7.0	7.4	7.8	363	316	578	158	146	193
SEP 10			7.1	7.4	7.7	457	278	443	246	91	194
SEP 11			7.2	7.8	7.9	358	231	438	185	41	133
SEP 14			7.1	7.7	8.0	500	393	524	298	195	258
SEP 15			7.1	7.5	7.9	200	311	399	147	74	123
SEP 16						437	230	399	225	63	109

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	PH: RAW INF	PH: FALULAH INF	PH: COMB INF	PH: 1ST STAGE EFF	PH: 2ND STAGE EFF	TOTAL SOLIDS MG/L: COMB INF	TOTAL SOLIDS MG/L: 1ST STAGE EFF	TOTAL SOLIDS MG/L: 2ND STAGE EFF	TOTAL VOLATILE SOLIDS MG/L: COMB INF	TOTAL VOLATILE SOLIDS MG/L: 1ST STAGE EFF	TOTAL VOLATILE SOLIDS MG/L: 2ND STAGE EFF
SEP 17						352	291	393	162	100	82
SEP 18			7.0	7.4	7.5	367	252	382	178	83	82
SEP 21			6.9	7.3	7.6	514	289	460	265	87	152
SEP 22			7.1	7.3	7.9	440	308	514	229	117	158
SEP 23			7.0	7.2	8.0	389	341	625	203	131	194
SEP 24			6.8	7.3	7.4	387	350	456	196	159	142
SEP 25			7.0	7.6	7.7	387	400	468	158	190	162
SEP 28			7.0	7.5	7.3	520	357	529	297	165	216
SEP 29						489	371	363			
SEP 30			7.0	7.6	7.7	391	324	415	203	165	160
OCT 1			6.9	7.4	7.7	570	341	316	343	140	18
OCT 2			7.0	8.0	7.6	436	444	461	222	227	180
OCT 5			6.9	7.1	7.7	443	380	510	116	158	127
OCT 6			7.0	7.4	7.6						
OCT 7				8.1	8.5	525	366	615	239	151	215
OCT 8											
OCT 9			6.5	7.8	8.0	616	420	674	297	195	250
OCT 10											
OCT 11											
OCT 12			7.1	7.6	8.1	591		671	312		285
OCT 13			6.9	7.6	7.7	424	398	616	234	258	223
OCT 14			6.9	7.8	8.0	358	448	584	185	224	226
OCT 15			6.8	7.8	7.9	369	491	670	192	166	300
OCT 16			6.9	7.9	8.2	385	364	620	192	180	300
OCT 17											
OCT 18											
OCT 19			6.9	7.7	7.1	474	510	595	264	264	332
OCT 20			7.0	8.0	7.1	438	514	593	235	247	281
OCT 21			7.0	8.4	7.5	412	624	622	195	248	341
OCT 22			6.8	8.1	7.5	418	582	627	239	257	273
OCT 23			6.5	8.9	7.5	241	559	607	95	262	294
OCT 24											
OCT 25											
OCT 26			7.0	7.9	7.2						
OCT 27			7.0	8.5	7.7	353	784	695	147	325	247
OCT 28			7.0	8.9	7.7	372	884	835	201	393	401
OCT 29			7.0	8.7	7.8						
OCT 30			7.0	8.5	7.9	466	651	669	276	228	271
OCT 31											
NOV 1											
NOV 2			7.1	9.0	7.9	509	893	675	249	333	232
NOV 3						407	899	874	219	378	337

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	PH RAW INF	PH FALULAH INF	PH COMB INF	PH 1ST STAGE EFF	PH 2ND STAGE EFF	TOTAL SOLIDS MG/L COMB INF	TOTAL SOLIDS MG/L 1ST STAGE EFF	TOTAL SOLIDS MG/L 2ND STAGE EFF	TOTAL VOLATILE SOLIDS MG/L COMB INF	TOTAL VOLATILE SOLIDS MG/L 1ST STAGE EFF	TOTAL VOLATILE SOLIDS MG/L 2ND STAGE EFF
NOV 4			7.0	8.6	8.3	264	708	790	80	323	307
NOV 5			7.0	8.8	7.9						
NOV 6			7.2	8.8	7.8	365	631	816	158	178	317
NOV 7											
NOV 8											
NOV 9											
NOV 10											
NOV 11											
NOV 12											
NOV 13											
NOV 16											
NOV 17											
NOV 18											
NOV 19											
NOV 20											

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	TURBIDITY JTU'S RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	FILT 1 TAP 12	FILT 1 EFF	FILT 2 EFF	CHLORIDES MG/L COMB INF	1ST STAGE EFF	2ND STAGE EFF	HEXANES MG/L COMB INF	1ST STAGE EFF	2ND STAGE EFF
FEB 2	80	280	125	28	32					71	61			
FEB 3	86	600	160	43	25					85	89			
FEB 4	33	330	44	26	29					87	79			
FEB 5	24	300	43	25	30					102	99			
FEB 6	24	380	67	27	26					154	114			
FEB 9	35	1000	47	16	52					108	109			
FEB 10	28		26	11	20				96	104	109			
FEB 11	21	175	31	12	22				68	65	79			
FEB 12	18	200	48	16	20				91	90	85			
FEB 13	23	470	86	22	27				89	92	87			
FEB 15														
FEB 16	13		13	7	16				95	90	87			
FEB 17	23		23	6	14				111	105	97			
FEB 18	33			7	12				108	111	112			
FEB 19	62	150	66	9	11				126	133	111			
FEB 20	21	470	70	17	11				79	85	123			
FEB 23	35	1000	225	22	21				81	88	104			
FEB 24	35	1000	275	40	19				72	73	85			
FEB 25	45	700	85	80	50				76	73	71			
FEB 26	45	220	43	42	35				67	74	77			
FEB 27	55	150	80	17	26				73	104	72			
MAR 2	55	1000	140	10	25				154	246	248			
MAR 3									146		200			
MAR 4									84	96	169			
MAR 5									265	210	127			
MAR 6														
MAR 9									73	76	89			
MAR 10														
MAR 11														
MAR 12														
MAR 13														
MAR 16														
MAR 17														
MAR 18														
MAR 19														
MAR 20														
MAR 23														
MAR 24														
MAR 25														
MAR 26														
MAR 27									97	95	91			
MAR 30									174	183	132			

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	TURBIDITY JTU'S RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	FILT 1 TAP 12	FILT 1 EFF	FILT 2 EFF	CHLORIDES MG/L COMB INF	1ST STAGE EFF	2ND STAGE EFF	HEXANES MG/L COMB INF	1ST STAGE EFF	2ND STAGE EFF
MAR 31									132	148	160			
APR 1									126	129	137			
APR 2									110	126	127			
APR 3									113	139	123			
APR 6	29	120	44	16	95				117	145	138			
APR 7	31	130	46	23	38				114	118	127			
APR 8	41	130	65	37	30				111	107	113			
APR 9	28	160	53	33	61									
APR 10	23	460	65		40				115		113			
APR 13									90	93	115			
APR 14	17	32	58		12				90	93	93			
APR 15														
APR 16	23	180	40	55	23									
APR 17									89	97	89			
APR 20									78	86	95			
APR 21	36	220	74	37	38				72	83	87			
APR 22	34	320	67	53	42				77	78	87			
APR 23	33	320	67	40	42				74	79	83			
APR 24									67	86	80			
APR 27	47	130	65	17	15				72	75	82			
APR 28	36	790	97	33	24				73	76	79			
APR 29	43	770	85	45	58				75	77	78			
APR 30	43	420	77	60	31				74	79	80	180		
MAY 1	77	450		12	23				76	82	75			
MAY 4									72	82	91			
MAY 5	58	280	100	8	13				69	73	80			
MAY 6									66	66	70			
MAY 7	42	120	65	14	17				68	68	67			
MAY 8	45	70	65		11									
MAY 11	48	70	65	35	24				73	68	72			
MAY 12	63	180	78	32	35				71	66	72			
MAY 13									74	64	67			
MAY 14	35	125	44	34	28				66	64	54			
MAY 15	53	130	44	36	28									
MAY 18	35	120	45	18	13				36	40	49			
MAY 19														
MAY 20	30	55	69	34	28							22	5	
MAY 21	38	45	37	29	25				63	67	56	5	1	
MAY 22												20	5	
MAY 25	32		100	21	15							19		
MAY 26	32	58	36	11	2				78	74	83			
MAY 27												19	2	1

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	TURBIDITY JTU'S RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	FILT 1 TAP 12	FILT 1 EFF	FILT 2 EFF	CHLORIDES MG/L COMB INF	1ST STAGE EFF	2ND STAGE EFF	HEXANES MG/L COMB INF	1ST STAGE EFF	2ND STAGE EFF
MAY 28	33	62	47	9	2									
MAY 29									65	63	64			
JUN 1									66	73	77	38		
JUN 2	36	88	46	24	42									
JUN 3	46	78	56	19	29									
JUN 4	40		43	13	16							29	6	
JUN 5	35	93	45	15	20							31	8	
JUN 8														
JUN 9												29	18	
JUN 10	46	110	73	22	17				69	66	65	26	11	
JUN 11														
JUN 12	40	350	65	29	15				48	60	63	30	15	9
JUN 15	80	77	73	23	17									
JUN 16	47	200	86	39	17									
JUN 17									64	60	59	23		5
JUN 18	53	135	67	29	11							33	20	
JUN 19									54	45	65			
JUN 20														
JUN 21														
JUN 22	57	190	72	31	15				67	71	77			
JUN 23	31	200	52	38	13							31	13	8
JUN 24	51	270	100	48	22				64	63	60			
JUN 25	50	200	72	36	25									
JUN 26			45	27	18				59	56	65			
JUN 29									61	66	65			
JUN 30			44	25	15									
JUL 1									62	60	61			
JUL 2														
JUL 3			55	16	16									
JUL 6			42	16	16									
JUL 7			35	12	17							32	12	9
JUL 8									64	63	64			
JUL 9												29	5	5
JUL 10			43	9	14									
JUL 13									62	61	62			
JUL 14			42	18	18							51	13	10
JUL 15			43	13	18									
JUL 16			48	14	16							35	4	1
JUL 17			35	9	13									
JUL 20			43	16	12				66	54	53			
JUL 21			44	17	13				54	50	56			
JUL 22			49	17	13									

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	TURBIDITY JTU'S RAW INF	TURBIDITY JTU'S FALULAH INF	TURBIDITY JTU'S COMB INF	TURBIDITY JTU'S 1ST STAGE EFF	TURBIDITY JTU'S 2ND STAGE EFF	TURBIDITY JTU'S FILT 1 TAP 12	TURBIDITY JTU'S FILT 1 EFF	TURBIDITY JTU'S FILT 2 EFF	CHLORIDES MG/L COMB INF	CHLORIDES MG/L 1ST STAGE EFF	CHLORIDES MG/L 2ND STAGE EFF	HEXANES MG/L COMB INF	HEXANES MG/L 1ST STAGE EFF	HEXANES MG/L 2ND STAGE EFF
JUL 23												18	7	7
JUL 24			57	20	11									
JUL 27			52	18	10									
JUL 28			38	13	9							39	6	4
JUL 29			38	12	7		3							
JUL 30			43	20	6	10	3							
JUL 31			38	16	5	2	1							
AUG 3			44	12	5	2	1							
AUG 4			62	22	7									
AUG 5			48	21	9	2	1		49	47	48			
AUG 6														
AUG 7			51	22	12	8	4							
AUG 10			60	15	11	1	1							
AUG 11			52	11	8	2	2							
AUG 12														
AUG 13			51	21	16	9	2							
AUG 14			55	19	17	22	4							
AUG 15														
AUG 16														
AUG 17						2	2							
AUG 18			100	27	13	7	3							
AUG 19			43	17	12	8	2							
AUG 20			54	19	16	12	5	6						
AUG 21			35	21	22	12	6	9						
AUG 24			71	23	10	3	3	8						
AUG 25														
AUG 26			70	20	14	12	8	12						
AUG 27			44	22	15	10	8	7						
AUG 28			76	24	11	11	3	6						
AUG 31			58	20	18									
SEP 1			52	23	17	12	7	10						
SEP 2			47	24	18	12	8	13						
SEP 3			53	23	18	15	7	12						
SEP 4			50	16	14	14	6	5						
SEP 7			62	21	28									
SEP 8						3	3							
SEP 9			87	22	16	6	3							
SEP 10			145	22	16	22	2							
SEP 11			45	15	13									
SEP 14				33	15	4	3							
SEP 15				17	16	9	2							
SEP 16						1	1	1						

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	TURBIDITY JTU'S RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	FILT 1 TAP 12	FILT 1 EFF	FILT 2 EFF	CHLORIDES MG/L COMB INF	1ST STAGE EFF	2ND STAGE EFF	HEXANES MG/L COMB INF	1ST STAGE EFF	2ND STAGE EFF
SEP 17						3	2	2						
SEP 18				12	17	4	2	2						
SEP 21			70	14	12	4	2	2						
SEP 22			83	18	11	2	1	2						
SEP 23			53	16	9	9	3	2		43	45			
SEP 24			59	13	34									
SEP 25			63	32	37					48	50			
SEP 28			82	35	73	6	73	6						
SEP 29			50	34	58	27	57	10						
SEP 30			64	21	65	29	22	3						
OCT 1			65	27	17	10	10	7						
OCT 2			112	33	72	4	4	4						
OCT 5			75	19	97	9	125	8						
OCT 6			69	56	63	6	6	6						
OCT 7				6	6		4	2						
OCT 8														
OCT 9			90	36	44	4	20	3						
OCT 10														
OCT 11														
OCT 12			125	25	17									
OCT 13			100	18	22	4	16	3						
OCT 14			45	18	13	4	3	2						
OCT 15			84	18	11	2	3	2						
OCT 16			75	20	15	3	2	1						
OCT 17														
OCT 18														
OCT 19			76	25	100	4	43	63						
OCT 20			84	21	20	3	4	3						
OCT 21			58	23	22	3	4							
OCT 22			90	14	20	3	2	2						
OCT 23			59	16	15	1	2	2						
OCT 24														
OCT 25														
OCT 26			57	15	16	9	1	0				50	6	3
OCT 27			48	14	12									
OCT 28			39	14	10	1	1	1						
OCT 29			71	15	15	1	1	1						
OCT 30			61	9	24									
OCT 31														
NOV 1														
NOV 2			95	18	18	2	3	3						
NOV 3														

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	TURBIDITY JTU'S RAW INF	TURBIDITY JTU'S FALULAH INF	TURBIDITY JTU'S COMB INF	TURBIDITY JTU'S 1ST STAGE EFF	TURBIDITY JTU'S 2ND STAGE EFF	TURBIDITY JTU'S FILT 1 TAP 12	TURBIDITY JTU'S FILT 1 EFF	TURBIDITY JTU'S FILT 2 EFF	CHLORIDES MG/L COMB INF	CHLORIDES MG/L 1ST STAGE EFF	CHLORIDES MG/L 2ND STAGE EFF	HEXANES MG/L COMB INF	HEXANES MG/L 1ST STAGE EFF	HEXANES MG/L 2ND STAGE EFF
NOV 4			100	15	28	3	3	7						
NOV 5			45	16	17	1	2	2						
NOV 6			48	28	49	2	2	3						
NOV 7														
NOV 8														
NOV 9														
NOV 10														
NOV 11														
NOV 12														
NOV 13														
NOV 16														
NOV 17														
NOV 18														
NOV 19														
NOV 20														

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	AMMONIA (NH3) MG/L RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	TOTAL KJEDAHL NITROGEN (TKN) MG/L RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	NITRATE (NO3-) MG/L COMB INF	1ST STAGE EFF	2ND STAGE EFF	FILT 1 EFF	FILT 2 EFF
FEB 2	4.8	1.3	5.7	5.9	7.9	12.0	3.9	12.2	11.1	9.4		0.20	0.14		
FEB 3	1.7	0.8	1.6	1.6	4.0	6.5	3.2	6.5	4.4	7.3		0.29	0.18		
FEB 4	1.2	1.6	1.1	1.5	1.8	6.2	3.2	5.4	3.0	3.4		0.25	0.24		
FEB 5	2.1	1.2	2.1	4.0	3.9	9.5	4.2	9.0	4.2	4.0		0.21	0.51		
FEB 6	3.3	1.4	2.1	4.3	5.0	9.6	3.5		6.5	6.9		0.17	0.25		
FEB 9	4.1		3.8	6.2	6.5	14.7		14.2	8.5	10.6		0.17	0.24		
FEB 10				7.3	7.9	9.7			10.3	10.7	0.17	0.32	0.33		
FEB 11	1.4		1.4	2.5	4.4	5.1		5.0	4.1	6.5	0.31	0.26	0.33		
FEB 12	1.8	0.9	1.9	3.0	3.7	9.2	5.2	8.3	6.0	6.3	0.26	0.23	0.29		
FEB 13	3.4	1.5	2.4	4.4	10.2	10.6	4.8	8.8	7.0	7.4	0.32	0.39	0.37		
FEB 15															
FEB 16	3.0			6.4	7.0	119.5			9.4	10.2	0.33	0.31	0.37		
FEB 17	3.9			7.1	7.8	12.8			9.6	10.1	0.39	0.28	0.27		
FEB 18	3.8			7.4	14.9	12.6			10.2	10.2	0.25	0.20	0.56		
FEB 19	3.7	1.4	3.4	8.1	8.3	14.3		13.3	11.1	12.3	0.74	0.53	0.56		
FEB 20	5.8	1.3	4.5	8.2	8.2						0.41	0.37	0.37		
FEB 23	7.1		5.2	6.7	8.2	16.8		14.6	10.1	11.9		0.63	0.49		
FEB 24	5.7	1.5	4.0	4.8	6.7	14.3	3.0	12.9	8.1	8.6		0.36	0.38		
FEB 25	5.5	1.4	4.2	6.0	6.0	16.0	3.6	14.5	11.5	10.4	0.43	0.21	0.26		
FEB 26	8.0	1.4	4.0	6.9	7.0	16.7	3.6	14.6	10.9	10.7	0.27	0.08	0.20		
FEB 27	6.9	2.0	4.9	9.9	7.9	17.3	4.4	13.5	14.2	11.7	0.15	0.34	0.19		
MAR 2	6.5	1.1	5.9	10.5	10.9	16.2	1.9	15.3	12.6	14.2		0.49	0.29		
MAR 3								16.0	12.0		0.47		0.37		
MAR 4				9.1				16.2		12.0	0.42	0.30	0.28		
MAR 5				7.8				13.9	19.6	10.4	0.30	0.35	0.27		
MAR 6				9.7				15.7	13.8		0.46				
MAR 9			10.4		10.8							0.49	0.50		
MAR 10			5.8	9.3	10.0										
MAR 11			5.5	10.5	10.3										
MAR 12			7.2	11.4	11.0										
MAR 13			10.0	10.7	14.4										
MAR 16															
MAR 17			9.2	15.8	11.1										
MAR 18			6.6	7.4	8.7										
MAR 19			6.4	7.3	8.4							0.72	0.80		
MAR 20			5.5	7.5	6.5										
MAR 23			2.9	4.1	6.7										
MAR 24															
MAR 25															
MAR 26			2.1									1.50			
MAR 27			4.3	6.2	5.2						0.26	0.45	0.17		
MAR 30			5.0	5.5	5.9			12.3	7.0	7.3		0.30	0.40		

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	AMMONIA (NH3) MG/L RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	TOTAL KJEDAHL NITROGEN (TKN) MG/L RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	NITRATE (NO3-) MG/L COMB INF	1ST STAGE EFF	2ND STAGE EFF	FILT 1 EFF	FILT 2 EFF
MAR 31			5.9	6.0	6.3						0.37	0.25	0.37		
APR 1			3.0	5.0	6.7			9.5	8.8	7.9	0.15	0.18	0.14		
APR 2			2.5	5.2	6.6			7.3	7.7	8.3	0.42	0.18	0.18		
APR 3			0.9	3.5	5.5						0.28	0.25	0.19		
APR 6			2.5	4.7	5.3	10.3		9.2	6.6	11.9		0.26	0.32		
APR 7			2.1	4.3	3.7	9.9		8.7	6.5	7.1	0.36	0.16	0.84		
APR 8			2.7	5.0	2.9	11.9		11.3	7.7	5.8	0.31	0.48	2.70		
APR 9			2.1	5.6	6.4			9.8	7.1	8.3					
APR 10			5.1		4.0						0.40		0.77		
APR 13			3.0	4.0	5.5							0.00	0.90		
APR 14			3.4	4.8	3.8						0.31	0.65	0.75		
APR 15			4.6	5.8	4.6							0.21	0.63		
APR 16			4.7	5.8	4.6										
APR 17			7.5	7.8	5.3						0.20	0.21	0.80		
APR 20			6.9	8.8	7.1							0.17	0.84		
APR 21			2.8	5.5	5.5						0.28	0.18	1.15		
APR 22			4.9	6.8	4.4			11.6	10.6	7.5	0.31		0.46		
APR 23			6.4	7.0	3.4	15.6		11.7	10.4	6.5	0.07	0.20	1.07		
APR 24			6.1	9.5	2.5	12.3		12.5	13.3	6.4	0.17	0.16	2.95		
APR 27			7.0	8.6	0.4							0.09	1.61		
APR 28			7.5	8.6	0.4	15.6		14.3	11.5	2.8	0.11	0.21	5.00		
APR 29			6.9	8.4	0.7	16.2		14.4	11.4	3.3	0.25	0.20	5.55		
APR 30			5.6	7.9	1.0	16.1	2.1	13.3	12.2	4.3	0.31	0.30	6.05		
MAY 1			9.2	9.9	0.5	18.4	2.1	16.7	13.7	3.1	0.28	0.25	3.52		
MAY 4	7.5	2.0	6.5	8.6	0.0	19.8	3.2	17.9	12.5	2.3		0.50	5.90		
MAY 5	9.2		7.6	6.7	0.3	17.5					0.31	0.39	3.10		
MAY 6	6.3	1.4	4.5	8.5	0.0	16.2	2.0	13.0	12.0	1.3	0.33	0.60	8.10		
MAY 7	7.3	0.8	5.1	6.0	0.6	16.6	2.6		8.6	3.2	0.27	0.29	6.50		
MAY 8	10.9	0.7	7.6	9.6	0.0	20.6	2.5	17.1	13.7	2.8	0.45	1.23	2.30		
MAY 11	6.4	2.5	5.9	8.0	1.4	18.4	4.5	17.1	13.2	4.4	0.50	1.85	7.50		
MAY 12	5.9	3.2	5.6	5.9	0.2	14.1	4.9	10.4	6.7	3.0	0.30	2.37	5.50		
MAY 13	8.2	1.6	6.0	7.5	0.0	20.5	3.5	16.0	12.0	3.0	0.69	1.59	6.50		
MAY 14	8.5	1.0	7.5	8.8	0.6	19.2	2.1	17.0	14.1		0.45	1.04	1.18		
MAY 15	11.7	1.0	11.5	10.0	2.3	20.3	3.0	19.4	15.7	5.8	0.41	0.71	7.40		
MAY 18	3.1		3.4	3.6	0.0	10.7		10.1	7.3	2.7	0.47	0.21	0.69		
MAY 19	4.4	1.9	3.9	3.1	0.0	15.7	3.6	10.9	5.4	2.9	0.65	1.37	4.37		
MAY 20	4.3.	3.9	4.2	5.3	0.5	12.2	5.4	11.3	8.9	3.7	0.53	0.69	2.75		
MAY 21	4.9	1.0	4.0	5.0	0.1	14.8	2.8	12.4	8.9	5.0					
MAY 22	7.5		6.1		0.0										
MAY 25	10.1		11.1	8.4	1.4	19.5		20.6	12.5	4.4	0.70	1.75	4.38		
MAY 26	9.5	2.7	8.2	9.3	0.5	17.9	3.3	15.8	12.2	1.8	0.37	0.31	4.26		
MAY 27	9.7	4.0	7.0	6.0	0.0	18.6	5.1	14.1	10.0	2.2		2.22	2.75		

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE	-----AMMONIA (NH3) MG/L-----					TOTAL KJEDAHL ----NITROGEN (TKN) MG/L-----					-------NITRATE (NO3-) MG/L-------				
1970	RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	RAW INF	FALULAH INF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	COMB INF	1ST STAGE EFF	2ND STAGE EFF	FILT 1 EFF	FILT 2 EFF
MAY 28	9.6	1.6	8.2	6.3	0.0	17.9	3.3	15.3	9.4	1.6					
MAY 29	10.5	1.2	9.7	8.0	3.0	19.2	2.5	17.3	10.0	2.0	0.29	0.82	8.55		
JUN 1	11.6	1.0	10.6	10.4	0.8	23.3	2.1	21.4	15.0	4.5	0.18	0.67	8.05		
JUN 2	10.1	3.1	8.4	7.8	3.4	18.1	4.3	16.1	11.1	9.5	0.30	0.80	4.50		
JUN 3	7.9	1.8	6.4	6.4	0.4	15.9	3.4	14.1	10.1	4.6	0.10	0.17	3.50		
JUN 4	5.3	1.0	5.2	3.8	0.4	14.3	2.5	14.0	6.7	3.3					
JUN 5	9.4	0.7	7.5	7.8	2.5	18.1	2.9	16.2	11.0	3.4		0.56	5.00		
JUN 8	10.1	1.7	9.4	9.7	2.3	22.0	3.1	19.5	13.9	6.0	0.25	0.20	5.30		
JUN 9	9.8	0.9	8.3	7.9	5.7	16.2	2.8	13.8	12.3	9.0					
JUN 10	9.8	0.2	8.9	7.8	1.9	18.2		17.0		5.5	0.24	0.36	2.50		
JUN 11	9.2	0.4	10.3	14.2	3.1	16.8	3.1	15.2		6.4					
JUN 12	10.7	0.3	7.7	11.3	2.3	20.5	3.5	14.6		6.1	0.21	0.33	1.32		
JUN 15	6.4	0.0	6.3	4.7	4.5	25.0	1.6	23.7	15.8	8.5	0.21	0.38	3.00		
JUN 16	6.7	0.0	5.5	4.3	4.3	21.9	3.4	18.8	11.8	10.1	0.16	0.46	1.05		
JUN 17	5.0	0.2	4.4	4.2	4.4	22.0	4.3	17.8	8.2	11.8	0.11	0.33	0.40		
JUN 18	5.0	1.1	4.4	4.6	4.8	20.3		15.0		10.3	0.20	0.30	0.29		
JUN 19	5.5	0.0	3.8	4.2	4.1	18.1	2.0	14.0	11.4	8.6	0.35	0.75	1.22		
JUN 20															
JUN 21															
JUN 22	5.7	0.4	6.8	2.0	0.9	23.3	4.6	22.1	16.1	6.4	0.17	0.57	5.80		
JUN 23	5.0	0.0	4.3	4.7	4.4	20.1	3.2	17.8	14.4	12.3	0.23	0.41	0.88		
JUN 24	5.4	0.0	5.0	4.0	4.6	22.3	1.5	19.1	13.2	12.2	0.15	0.71	0.91		
JUN 25	12.1	0.8	10.0	8.4	5.0	20.6	2.8	18.3		7.4	0.88				
JUN 26			11.1	8.5	2.5			20.5	12.5	6.4	0.88	4.00	6.00		
JUN 29			13.7	16.3	5.4			24.7	24.1	6.0	0.64	1.06	2.90		
JUN 30				8.7	9.3				19.9	13.5	0.30	0.25	2.50		
JUL 1			7.7	8.7	4.6			12.5	11.1	8.3	1.20	1.06	8.60		
JUL 2			9.1	16.5	1.7										
JUL 3			15.2	9.0	0.9			16.1	10.8	2.6	0.10	0.41	7.50		
JUL 6			8.4	7.4	1.1			14.4	10.6	2.9	0.20	0.37	8.17		
JUL 7			7.9	9.0	4.1			12.8	11.0	7.7	0.12	0.53	1.31		
JUL 8			8.0	6.5	3.0			13.4	9.1	6.0	0.11	1.75	5.00		
JUL 9			8.0	7.0	2.2			13.0	10.2	4.3	0.21	0.87	6.80		
JUL 10			8.0	7.0	0.2			13.7	9.6	2.0	0.27	0.48	9.06		
JUL 13			7.9		0.0			11.3		2.1	1.60	3.25	9.30		
JUL 14			7.3		5.8			13.5		10.2	0.29	0.75	7.26		
JUL 15			11.7		4.9			22.1		9.6	0.22	1.01	5.30		
JUL 16			12.8		1.6			18.8		5.8		0.73	7.40		
JUL 17			11.9		0.4			15.6		3.9	0.14	0.53	11.30		
JUL 20			15.3	14.7	0.3			27.7	21.1	5.7	0.23	1.31	10.85		
JUL 21			12.8	12.7	0.0			22.2	18.0	3.4	0.18	0.41	10.25		
JUL 22			13.1	12.7	0.1			21.6	18.5	2.4	0.16	0.28	3.75		

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	AMMONIA (NH3) MG/L RAW INF	AMMONIA FALULAH INF	AMMONIA COMB INF	AMMONIA 1ST STAGE EFF	AMMONIA 2ND STAGE EFF	TOTAL KJEDAHL NITROGEN (TKN) MG/L RAW INF	TKN FALULAH INF	TKN COMB INF	TKN 1ST STAGE EFF	TKN 2ND STAGE EFF	NITRATE (NO3-) MG/L COMB INF	NITRATE 1ST STAGE EFF	NITRATE 2ND STAGE EFF	NITRATE FILT 1 EFF	NITRATE FILT 2 EFF
JUL 23			13.3	13.2	0.0			23.4	19.2	3.2					
JUL 24			15.0	12.7	0.2			21.2	20.2	3.9					
JUL 27			16.4	9.4	0.5			23.3	21.1	4.1					
JUL 28			9.1	12.6	0.0			16.5	17.3	3.4					
JUL 29			10.6	9.3	0.0			18.2	13.6	2.8	0.19	0.48	7.13		
JUL 30			11.1	9.4	0.0			16.5	14.5	3.1	0.25	0.65	7.20		
JUL 31			10.9	11.3	0.0			17.2	16.9	3.0	0.32	0.90	7.00		
AUG 3			14.3	12.0	0.0						0.15	0.43	5.63		
AUG 4			15.1	11.5	0.5						0.16	0.75	4.50		
AUG 5			13.6	11.1	1.2			24.3	17.3	3.3	0.15	0.65	6.75		
AUG 6															
AUG 7			13.8	11.3	0.9			23.0	16.2	4.3	0.18	0.63	4.00		
AUG 10			14.2	13.7	2.6			25.3	18.7	5.9	0.28	0.47	4.75		
AUG 11			14.1	11.9	0.3			22.9	16.0	3.1	0.21	0.47	5.50		
AUG 12			13.3	12.3	0.8			22.4	17.1	4.5	0.25	0.51	6.00		
AUG 13			13.3	11.7	1.6			21.5	17.8	6.0					
AUG 14			13.9	11.1	3.1			23.5	16.0	7.6	0.23	0.47	4.37		
AUG 15															
AUG 16															
AUG 17															
AUG 18			13.5	13.5	0.9			22.5	21.3	4.4	0.24	0.40	6.25		
AUG 19			13.6	13.3	0.6			22.8	18.5	3.7	0.23	0.52	6.50		
AUG 20			14.9	12.2	0.4			23.0	17.9	4.3	0.21	0.59	6.10		
AUG 21			12.2	11.1	0.5			20.2	15.2	4.8	0.29	0.60	5.80		
AUG 24			14.7	12.0	2.1		0.2	27.1	20.3	4.6		0.45	5.00		
AUG 25															
AUG 26			13.5	11.3	4.1		0.2	23.6	17.0	7.8		0.53	2.72		
AUG 27			14.3	11.5	2.0		0.2	23.5	17.5	5.5		0.60	3.40		
AUG 28			18.7	15.4	0.3		0.2	29.5	19.6	2.6		0.43	4.25		
AUG 31			16.4	13.8	0.5			27.7	22.3	3.9	0.19	0.35	10.50		
SEP 1			15.9	13.6	0.2			24.5	18.3	3.5	0.25	0.34	6.12		
SEP 2			16.0	15.4	0.4			25.8	20.7	3.9	0.35	0.37	5.50		
SEP 3			16.7	14.2	0.5			27.4	20.1	4.3	0.31	0.60	3.60		
SEP 4			11.7	10.9	0.2			22.7	15.4	4.0	0.28	0.45	2.80		
SEP 7			17.7	14.8	0.9			32.9	23.1	7.5	0.17	0.39	6.50		
SEP 8			18.3	15.8	0.9			30.1	21.7	4.8	0.15	0.35	7.00		
SEP 9			15.7	15.2	0.2			29.0	20.3	3.6					
SEP 10			15.8	14.4	0.3			27.7	19.8	3.8	0.16	0.42	6.90		
SEP 11			15.5	13.8	0.7			26.3	17.7	4.0	0.18	0.37	5.00		
SEP 14			19.5	18.0	1.6		0.3	27.8	20.7	4.3		0.40	6.50		
SEP 15			12.4	12.3	1.0		0.2	20.8	16.9	4.8		0.42	4.50		
SEP 16			12.3	11.1	0.0		0.2	22.6	17.1	3.8		0.30	2.75		

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

PILOT PLANT STUDY ON TWO-STAGE ACTIVATED SLUDGE SEWAGE TREATMENT

ANALYTIC DATA

DATE 1970	AMMONIA (NH3) MG/L RAW INF	AMMONIA FALULAH INF	AMMONIA COMB INF	AMMONIA 1ST STAGE EFF	AMMONIA 2ND STAGE EFF	TOTAL KJEDAHL NITROGEN (TKN) MG/L RAW INF	TKN FALULAH INF	TKN COMB INF	TKN 1ST STAGE EFF	TKN 2ND STAGE EFF	NITRATE (NO3-) MG/L COMB INF	NITRATE 1ST STAGE EFF	NITRATE 2ND STAGE EFF	NITRATE FILT 1 EFF	NITRATE FILT 2 EFF
SEP 17			15.4	14.9	1.2		0.2	26.9	20.9	2.4		0.31	3.10		
SEP 18			15.4	11.0	3.1		0.2	20.5	12.3	5.9		0.40	3.50		
SEP 21			16.7	14.6	0.7			30.7	18.9	3.8	0.18	0.48	5.83		
SEP 22			14.6	13.8	0.0			25.2	18.4	3.3	0.24	0.40	6.00		
SEP 23			13.9	12.9	0.9				17.3	3.8		0.29	5.00		
SEP 24			16.1	14.3	1.2			25.3	18.3	4.7		0.31	6.40	2.60	
SEP 25			15.7	15.3	0.7			27.4	21.6	2.9		0.29	4.00	8.90	
SEP 28			18.2	16.8	2.5			29.8	23.8	5.5		0.33	6.15	9.30	
SEP 29			15.1	13.2	7.0			24.5	19.0	10.8		0.26	3.00	2.00	
SEP 30			18.7	15.9	5.4			28.2	20.6	8.9		0.32	2.92	2.37	
OCT 1			23.6	17.5	7.0			40.4	23.5	10.7		0.46	3.10	6.30	
OCT 2			16.8	16.5	8.5			27.7	24.8	11.9		0.50	3.50	3.55	
OCT 5			15.5	14.4	4.2			31.3	20.5	9.9		0.26	3.37	3.24	
OCT 6			14.4	13.6	5.3			25.5	21.8	9.9		0.36	4.37	4.50	
OCT 7			16.2	13.2	1.8			26.5	19.1	5.3					
OCT 8															
OCT 9			13.9	13.2	0.4			25.3	19.2	3.4		0.27	8.60	6.87	
OCT 10															
OCT 11															
OCT 12			19.1	17.4	0.0							0.31	8.10		
OCT 13			15.6	13.8	0.3			26.8	17.3	3.1		0.22	7.63	4.63	
OCT 14			14.3	14.4	0.4			24.2	18.2	2.9			7.00	8.90	6.60
OCT 15			14.3	14.4	0.4			25.2	18.7	2.8					
OCT 16			14.7	10.1	0.0			29.1	13.9	3.0			5.75	5.37	5.77
OCT 17															
OCT 18															
OCT 19			18.1	15.6	2.9			31.6	20.3	8.0			4.12	4.25	5.50
OCT 20			17.0	14.4	0.7			30.3	20.2	3.9			5.25	6.50	7.00
OCT 21			16.6	14.2	0.3			27.9	19.7	3.6			4.12	5.50	
OCT 22			14.5	11.2	0.0			26.3	17.3	3.7					
OCT 23			8.5	6.4	0.0			13.1	10.5	2.9			3.50	3.50	2.75
OCT 24															
OCT 25															
OCT 26			16.5	15.7	0.2			29.9	21.2	3.1			7.00	5.87	7.00
OCT 27			15.5	13.7	0.0			26.7	19.4	2.8		0.23	5.80		
OCT 28			16.8	13.5	0.0			27.4	19.1	3.1			5.90	3.80	5.00
OCT 29			17.0	14.0	0.0			27.6	19.1	3.3			7.80	7.00	9.00
OCT 30			17.6	13.3	0.0				18.9	3.0			5.80		
OCT 31															
NOV 1															
NOV 2			18.5	16.5	0.0			33.6	21.9	3.4			12.30	8.00	10.40
NOV 3			16.7	15.7	0.5			27.5	23.1	3.2			14.70		13.60

FITCHBURG, MASSACHUSETTS - RESEARCH AND DEMONSTRATION PROJECT

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ANALYTIC DATA

DATE 1970	AMMONIA (NH3) MG/L RAW INF	AMMONIA FALULAH INF	AMMONIA COMB INF	AMMONIA 1ST STAGE EFF	AMMONIA 2ND STAGE EFF	TOTAL KJEDAHL NITROGEN (TKN) MG/L RAW INF	TKN FALULAH INF	TKN COMB INF	TKN 1ST STAGE EFF	TKN 2ND STAGE EFF	NITRATE (NO3-) MG/L COMB INF	NITRATE 1ST STAGE EFF	NITRATE 2ND STAGE EFF	NITRATE FILT 1 EFF	NITRATE FILT 2 EFF
NOV 4			17.1	13.9	0.0			27.7	19.9	3.3			15.30	4.00	11.40
NOV 5			11.3	10.5	0.0			20.6	16.1	3.0			13.60	1.60	10.40
NOV 6			16.6	11.7	0.4			26.0	20.2	4.2			11.40	1.50	7.60
NOV 7															
NOV 8															
NOV 9			16.9	16.4	1.7			38.3	26.6	5.5			15.60		
NOV 10			15.2	14.6	2.6			26.8	24.0	7.5			11.80	2.90	6.75
NOV 11			10.7	9.3	1.2			20.5	14.8	4.9			11.50	0.90	4.50
NOV 12			14.0	15.0	1.0			29.2	20.3	5.2			12.00		
NOV 13				16.3	0.7								18.50		
NOV 16			15.9	11.8	0.2								7.80		
NOV 17			22.6	27.6	3.2								7.20		
NOV 18			19.2	20.7	1.6								7.30		
NOV 19			13.9	15.5	4.8								11.70		
NOV 20			10.7	6.8	2.2			18.6	13.6	6.7			6.00		

Appendix II
PILOT PLANT DATA FORMS

FITCHBURG PILOT PLANT

DAILY OPERATING DATA LOG

Date ______________

Ref. No. ______________

Time of Day	Flows (gpm)					Sludge Wasted (gallons)		Sludge Depth in Clarifier (feet)		Initial
	Raw	Falulah	Combined	Return Sludge						
				1st Stage	2nd Stage	1st Stage	2nd Stage	1st Stage	2nd Stage	
0100										
0300										
0500										
0700										
0900										
1100										
1300										
1500										
1700										
1900										
2100										
2300										

FITCHBURG PILOT PLANT

DAILY OPERATING DATA LOG

Date ____________

Ref. No. ____________

Time of Day	DISSOLVED OXYGEN (mg/l)		pH			TEMPERATURE, °F				
			Combined Influent	Effluent		Raw Sewage	Falulah Waste	Comb. Influent	Effluent	
	1st Stage	2nd Stage		1st Stage	2nd Stage				1st Stage	2nd Stage
0200										
0600										
1000										
1400										
1800										
2200										

Time of Day	MLSS (mg/l)		M.L. SET. SOLIDS*		SLUDGE VOLUME INDEX		Air Temperature °F	Initial
	1st Stage	2nd Stage	1st Stage	2nd Stage	1st Stage	2nd Stage		
0200								
0600								
1000								
1400								
1800								
2200								

*30-minute settling (ml/l)

Ref. No. ___

FITCHBURG PILOT PLANT

SUMMARY OF DAILY OPERATING DATA

Day and Date							
Rainfall							
Average Air Temp. °F							
Waste Temp °F							
Raw Sewage							
Falulah Waste							
Combined Influent							
1st Stage Effluent							
2nd Stage Effluent							
Combined Influent Flow gpm							
Maximum							
Minimum							
Average							
1st Stage Aeration							
Air Used cfm Average							
DO mg/l - Average							
- Maximum							
- Minimum							
Return Sludge gpm Average							
Waste Sludge gpm Average							
Suspended Solids %							
Volatile Susp. Solids %							
MLSS mg/l							
MLVSS mg/l							
ML Set. Sol. 30 min. ml/l							
Sludge Volume Index							
2nd Stage Aeration							
Air Used cfm Average							
DO mg/l - Average							
- Maximum							
- Minimum							
Return Sludge gpm Average							
Waste Sludge gal							
Suspended Solids %							
Volatile Susp. Solids %							
MLSS mg/l							
MLVSS mg/l							
ML Set. Sol. 30 min. ml/l							
Sludge Volume Index							
pH Value							
Combined Influent							
1st Stage Effluent							
2nd Stage Effluent							

Form 1-CDM-448-3-1-20-70

Ref. No. ___

FITCHBURG PILOT PLANT

ANALYTIC DATA - COMPOSITE SAMPLES

Day and Date							
pH Value							
Raw Sewage							
Falulah Waste							
Combined Influent							
1st Stage Effluent							
2nd Stage Effluent							
Alk/Acid pH 7.0 mh/1 as $CaCO_3$							
Raw Sewage							
Falulah Waste							
Combined Influent							
Turbidity JTU							
Raw Sewage							
Falulah Waste							
Combined Influent							
1st Stage Effluent							
2nd Stage Effluent							
Suspended Solids - mg/1							
Raw Sewage							
Falulah Waste							
Combined Influent							
1st Stage Effluent							
2nd Stage Effluent							
Volatile Suspended Solids - mg/1							
Raw Sewage							
Falulah Waste							
Combined Influent							
1st Stage Effluent							
2nd Stage Effluent							
Residue on Evaporation - mg/1							
Combined Influent - Total							
- Volatile							
1st Stage Effluent - Total							
- Volatile							
2nd Stage Effluent - Total							
- Volatile							
Hexanol Soluble - mg/1							
Combined Influent							
1st Stage Effluent							
2nd Stage Effluent							

FITCHBURG PILOT PLANT

ANALYTIC DATA - COMPOSITE SAMPLES

Day and Date							
BOD - 5 day - 20°C - mg/l							
Raw Sewage							
Falulah Waste							
Combined Influent							
1st Stage Effluent							
2nd Stage Effluent							
COD - mg/l							
Raw Sewage							
Falulah Waste							
Combined Influent							
1st Stage Effluent							
2nd Stage Effluent							
Nitrogen Forms as N - mg/l							
Raw Sewage - TKN							
- NH_3							
Falulah Waste - TKN							
- NH_3							
Combined Influent - TKN							
- NH_3							
1st Stage Effluent - TKN							
- NH_3							
- NO_2							
- NO_3							
2nd Stage Effluent - TKN							
- NH_3							
- NO_2							
- NO_3							
Chlorides - mg/l							
Combined Influent							
1st Stage Effluent							
2nd Stage Effluent							
Phosphate as P - mg/l							
Combined Influent - Total							
- Dissolved							
1st Stage Effluent - Total							
- Dissolved							
2nd Stage Effluent - Total							
- Dissolved							

Form 2-CDM-448-3-1-20-70

Date ________

PILOT FILTER ANALYSES

	Tap No. 4	Tap No. 12	No. 1 Effluent	No. 2 Effluent
Date Flow (gpm) CH_3OH (ml/min)				
Turbidity Suspended Solids COD BOD NO_3				
Date Flow CH_3OH (ml/min)				
Turbidity Suspended Solids COD BOD NO_3				
Date Flow CH_3OH (ml/min)				
Turbidity Suspended Solids COD BOD NO_3				

FITCHBURG PILOT PLANT
SUMMARY
PILOT FILTER NO. ____
OPERATING DATA

Ref. No. ____________

Date ____________

Hour	Head Loss at Tap Number															Turbidity at Tap Number															Flow (gpm)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
0000																															
0100																															
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2100																															
2200																															
2300																															
2400																															

Notes on Backwashing: Flow Rate (gpm) ____________ Percent Expansion ____________ Length of Backwash (Min) ____________

General Comments:

Date: ____________

Tester: __________

CAMP, DRESSER & McKEE

Fitchburg Pilot Plant

Vacuum Filter Tests

SLURRY CHARACTERISTICS				
1. Temperature				
2. pH				
3. % Suspended Solids				
4. Ml $FeCl_3$				
5. Ml CaO				
6. Additive				
TEST CONDITIONS				
1. Filter Media				
2. % Submergence				
3. Drum Speed MPR				
4. Filtration Time (Sec)				
5. Dewatering Time				
6. Vacuum (in) Mercury				
OBSERVED DATA				
1. Vacuum Break (Sec)				
2. Filter Cake				
a. Total wt. wet				
b. Total wt. dry				
c. Total Solids				
d. Thickness (in)				
3. Filtrate				
a. Total vol ml				
b. pH				
c. Suspended Solids				
CALCULATED RESULTS				
1. % Moisture in Cake				
2. Yield lbs/sq ft/hr				
3. Filtrate gal/sq ft/hr				

REMARKS

Appendix III
WET OXIDATION REPORT

REPORT ON

LABORATORY OXIDATIONS

WASTE ACTIVATED PILOT PLANT SLUDGE

FITCHBURG, MASSACHUSETTS

FOR

CAMP, DRESSER & MCKEE

Prepared By: ZIMPRO INC.
Subsidiary of Sterling Drug Inc.

FEBRUARY, 1970

DIVISION OF STERLING DRUG INC.

ZIMPRO®
ROTHSCHILD, WISCONSIN 54474

TELEPHONE (WAUSAU) 715/359-3166

REGIONAL OFFICES: CHICAGO • NEW YORK • ATLANTA • DALLAS • SAN DIEGO

ZIMPRO® INC.
ROTHSCHILD, WISCONSIN 54474
TELEPHONE (WAUSAU) 715/359-3166

February 13, 1970

Mr. Allan E. Rimer
Camp, Dresser & McKee
One Center Plaza
Boston, Massachusetts 02108

Dear Mr. Rimer:

Subject: Fitchburg, Massachusetts
Waste Activated Pilot Plant Sludge
Laboratory Oxidations

In accordance with your discussions with Mr. Frank Groman, we are pleased to submit for your review two copies of our report on the above laboratory work including appropriate discussions on the following:

Method of Processing Samples
Recommended Alternative Systems
Performance Criteria
Summary and Discussion of Results

We are sending under separate cover the oxidized slurries and dried filter cake from the Low and Intermediate laboratory oxidations. We are happy to have the opportunity to perform this work and look forward to your comments.

Mr. Frank Groman will be in contact with you. If you have any questions, please do not hesitate to call on us.

Very truly yours,

ZIMPRO INC.

J. Robert Nicholson
Manager of Sales Development

JRN:ad
enclosures

cc: Mr. Frank Groman, Jr.

METHOD OF PROCESSING SAMPLES

Low and Intermediate oxidations were performed in a laboratory shaking autoclave to determine the effects of each oxidation. One hundred milliliters of the sludge to be processed were placed in a rocking autoclave and charged with the appropriate quantity of air. The system was brought to temperature and held for the specified length of time. The system was cooled and the sample removed for analysis. This yielded a 4.1% and 25.6% COD reduction respectively.

Filtration characteristics of these samples were determined by the method in which the specific filtration resistance is used to estimate the vacuum filtration rate.

BOD values were also determined. Analytical and settling data are given in Table I and II respectively.

RECOMMENDED ALTERNATIVE SYSTEMS

Based on the above results and our experience, two (2) alternative Zimpro systems are presented for consideration. They are:

(1) Low Oxidation - Dewatering

- 1A - with vacuum filtration
- 1B - with centrifugation

(2) Intermediate Oxidation - Dewatering

- 2A - with vacuum filtration
- 2B - with centrifugation

Flow diagrams showing a schematic for the above alternate Zimpro systems will be furnished upon request.

PERFORMANCE CRITERIA

Based on the laboratory results and our considerable experience involving continuous processing of other sludges, which are composed mainly of waste activated sludges from other municipalities, we predict the following performance criteria for the above recommended alternatives:

	Low Oxidation	Intermediate Oxidation
Design Pressure, psi	350	800
Insoluble Volatile Solids Reduction, %	45	85
Vacuum Filtration:		
Suspended Solids Feed, %	6-7.0	20.0
Filter Rate, lbs./ft.^{2}/hour	3.0	15.0
Cake Moisture , %	64-68	50-55
Suspended Solids Capture, %	88-92	99.5
Centrifugation:		
Cake Moisture, %	66-70	60-65
Suspended Solids Capture, %	88-92	88-92

Filtrate and Supernatant Treatment Characteristics:(1)

(Activated Sludge System)		
BOD5, ppm	4000	4000
BOD5 loading, lbs BOD/lbs MLVSS	1.5	1.5
BOD5 Reduction, %	95	95
MLVSS, ppm	3000	3000
Activated Sludge Production: lb/lb BOD5 removed	0.6	0.23

(1) For further information on biotreatment of filtrate and supernatant, see Appendix C.

SUMMARY AND DISCUSSION OF RESULTS

A. Batch vs. Continuous Pilot Plant Runs: Zimpro has collected data from continuous pilot plant runs using a vacuum rotary filter. This pilot plant has been in operation for about 4 years handling all types and combinations of sludges at different oxidation and heat treatment levels (250 8-hour runs using a vacuum rotary filter). Our laboratory autoclave runs cover 15 years and 500 separate runs. Comparison of results from laboratory autoclave and continuous pilot plant runs are as follows:

(1) Higher filtration rates using leaf tests and lower specific filtration resistances are obtained in batch runs than in continuous runs at low oxidation levels.

(2) Any results at high oxidation levels with batch and continuous pilot plant runs and laboratory autoclaves are comparable.

Therefore, the results from the laboratory autoclave runs on Fitchburg sludge as given in Tables I and II must be tempered with this experience and know-how gained by Zimpro.

B. Zimpro Experience - Waste Activated Sludge: Zimpro has collected data from continuous low oxidation pilot plant runs using a vacuum rotary filter in correlation with filter leaf tests and specific filtration resistances (25 8-hour runs on straight waste activated sludge). We have developed considerable data over several years on activated sludges from Denver, Colorado, Kalamazoo, Michigan, and other locations which indicate specific filtration resistances comparable to those for Fitchburg in Table I and separate vacuum filter rates of straight activated in the neighborhood of 2.0 to 4.0 lbs. dry solids per square foot per hour. These data are summarized in Appendix A.

C. Zimpro Experience - Installation: The current operating Zimpro systems total an aggregate of 52 years of operation at thermal conditioning and high oxidation levels. Presently, there are 19 installations under construction. A list of all installations is given in Appendix D.

Zimpro sludge systems have been developed and designed and technical and operational services have been provided entirely by our Research and Development Center in Wisconsin. Our systems are not a result of a license granted by an outside designer.

D. Dewatering of Intermediate Oxidation Sludge: The results of the Intermediate Oxidation run given in Tables I and II also need interpretation due to the low raw COD value. Based on these results and our experience in pilot plant and operating installations, consideration should be given to dewatering and direct disposal of higher oxidation sludge in lieu of low oxidation - dewatering - incineration. We have obtained encouraging results from our 12.4 TPD Unit operating in Rockland County, New York, which are summarized in Appendix B-1.

E. Phosphorus Removal: According to Table I, the total influent phosphorus is 0.09 grams per liter with about 50% and 65% of this phosphorus precipitated into the filter cake as calcium or magnesium for low and intermediate oxidations respectively. These removals are low compared to those normally experienced in pilot plant and operating installations, principally due to a low initial COD value. Normal removals should be:

Low Oxidation 70- 80%
Intermediate Oxidation . . 95-100%

F. Primary Sludge: Raw primary sludge generally contains more crude fiber than straight waste activated sludge. The use of primary (if available) with activated sludge will generally improve vacuum filtration rates as follows:

Primary Content, %	Estimated Filtration Rate lbs./ft.^{2}/hour
0-10	2-3
20-25	4-5
30-50	10-15

LABORATORY OXIDATIONS - FITCHBURG, MASSACHUSETTS

ANALYTICAL DATA

	Waste As Received	LOW OXIDATION			INTERMEDIATE OXIDATION		
Fraction	Primary-Activated	Oxidized Slurry	Filtrate	Filter Cake	Oxidized Slurry	Filtrate	Filter Cake
Sample Number	0-2	305-13-1	305-13-2	305-13-3	305-13-4	305-13-5	305-13-6
COD, g/l	12.2	11.7	4.7	6.5	9.1	5.4	3.2
% COD Reduction	-	4.1	-	-	25.6	-	-
Volatile Acids as Acetic Acid, g/l	0.1	0.3	0.3	-	3.4	0.9	-
Total Solids, g/l	9.6	9.8	3.5	6.3	7.2	2.9	4.4
Ash, g/l	2.0	2.0	0.4	1.8	2.0	0.5	1.4
Volatile Solids, g/l	7.6	7.8	3.1	4.5	5.2	2.4	3.0
pH	6.1	4.7	4.8	-	4.2	4.2	-
Chlorides, g/l	0.07	-	-	-	-	-	-
Total Phosphorus, g/l	0.09	0.10	0.05	0.05	0.11	0.04	0.07
Total Nitrogen, g/l	0.42	0.41	0.35	0.05	-	-	-
Ammonia, g/l	0.05	0.11	0.11	-	0.26	0.25	-
Soluble Hardness as $CaCO_3$, mg/l	165	-	-	-	-	-	-
% Insoluble Volatile Solids Reduction	-	40.1	-	-	60.1	-	-
Volume, ml/l	-	-	980	-	-	970	-
Wet Weight, g/l	-	-	-	14.4	-	-	12.9
Specific Filtration Resistance $sec^2/g \times 10^7$	1080	5	-	-	23	-	-
BOD_5, mg/l	-	-	1860	-	-	3560	-

TABLE I

TABLE II

LABORATORY OXIDATIONS - FITCHBURG, MASSACHUSETTS

SETTLING DATA

		Waste as Received	Low Oxidation	Intermediate Oxidation
Sample Number		0.2	305-13-1	305-13-4
% COD Reduction		-	4.1	25.6
Settling Time	¼ Hour	990 ml/l T	680 ml/l T	390 ml/l T
	½ Hour	970 ml/l T	550 ml/l C	370 ml/l T
	1 Hour	750 ml/l T	550 ml/l C	370 ml/l T
	2 Hours	750 ml/l T	550 ml/l C	370 ml/l T
	4 Hours	750 ml/l T	470 ml/l C	370 ml/l C
	8 Hours	700 ml/l C	450 ml/l C	370 ml/l C
	24 Hours	500 ml/l C	440 ml/l C	370 ml/l C

Appendix IV
CENTRIFUGE REPORT

BIRD MACHINE COMPANY, SO. WALPOLE, MASS. 02071
PHONE: 617 668-0400 / TELEX: 92 4428 / CABLE: BIRDMACHIN SOWALPOLEMASS

BIRD

August 10, 1970

Camp, Dresser & McKee
Consulting Engineers
One Center Plaza
Boston, Massachusetts

Attention: Mr. A. Rymer

Reference: Fitchburg, Mass.
Pilot Plant Sludge Sample

Gentlemen:

Enclosed please find a copy of our Laboratory Report #7044 outlining the test work that was done on the above mentioned sludge, and indicating that completely erratic results were received which could be attributed to the small quantity of sample sludge that was available to us. The 50 gallon sample did not permit stable operation and I believe on the next tests we perform that a larger quantity of sample material plus fewer runs made would provide much more conclusive results.

Please advise us with information on the approximate date when your next sample would be available in order that we may schedule our lab time accordingly. Scheduling of our lab facilities is becoming more and more difficult and I would again draw your attention to the fact that a 6" test machine would perhaps be of more value to you at the pilot plant. We have a $300./day fee for the Walpole Lab Facilities which may have to be imposed after the next series of tests, but I will endeavor to keep this service on a no-charge basis for as long as possible.

Very truly yours,

BIRD MACHINE COMPANY

A S Nisbet

Sales Engineer
Environmental Control Equipment

A.S.Nisbet:dc:7
Enc.

BIRD MACHINE COMPANY

South Walpole, Massachusetts

Laboratory Report No. 7044

CUSTOMER:	Camp, Dresser, McKee Boston, Massachusetts
CROSS REFERENCE:	City of Fitchburg Sewage Treatment Plant, Pilot facilities
MATERIAL:	Waste Activated Sludge
PROBLEM:	Dewater and Clarification
TESTS:	Bird 6" OBS Centrifuge
TEST DATE:	July 9, 1970
WITNESS:	Mr. Don Grogen
REFERENCES:	Discussion with the witness

<u>SAMPLE # 966 (received July 9, 1970)</u>

One barrel containing waste activated sludge was received in the laborator for large scale test work. The sample, as received, contained 0.89% total solids and has a specific gravity of 1.0, also a pH of 7.

<u>PROBLEM</u>

The customer wishes to dewater and clarify this material. The sludge is from a pilot plant at Fitchburg, Mass. and consists of municipal sewage and infiltration. Presently the thickened sludge going into drying beds and the effluent into sand filters. Greater removal of nitrates, nitrites and phosphates is desired so sand and activated charcoal or column filter is contemplated. Daily, about 6.5 million gallons of straight sewage at 3 to 4 thousand parts per million suspended solids are received at the existing facility, which is being heavily overtaxed.

<u>TESTS</u>

A total of 15 test runs were conducted using the 6" continuous Centrifuge on this activated sludge. Variables investigated doing these tests consisted of various feed rates, pool depth, dilution water, and both type and amount of chemical flocculation. The material was tested with 22 flocculants to determine the most efficient. The following is a list of flocculants tested:

Bird Machine Company
Laboratory Report No. 7044
Camp, Dresser, McKee

Tylac Tychem	8030
" "	8011
" "	8020
" "	8013
" "	8023
Dow Purifloc	A-21
" "	A-23
" "	A-22
" "	501
" "	N-12
Dow Seperan	AP-273
" "	S-2610
Nalco	670
"	673
Calgon	ST-270
"	ST-269
"	WCL-565
"	PCL-7127
Hercules Reten	220
" "	205
" "	210
Cyanamid Superflox	84

The best test was with Dow Purifloc A-23 at 0.1% solids. For details of the test runs, please refer to the dats sheets attached to this report.

DISCUSSION

Dewatering and clarification tests indicate that material similar to that tested would be a good application for Bird Centirfugal. Recoveries range form 63 - 93% at feed rates varying form 0.5 - 2.1 gallons per minute. There was some benifit from the use of flocculants through the quality of the cake declined: Dilution water does not appear to aid the results.

RNelson/jlk

Bird Machine Company
Solid Bowl Centrifugal
Laboratory Report No. 7044

Customer: Camp, Dresser, McKee
Material: Sludge
Date: 7-9-70

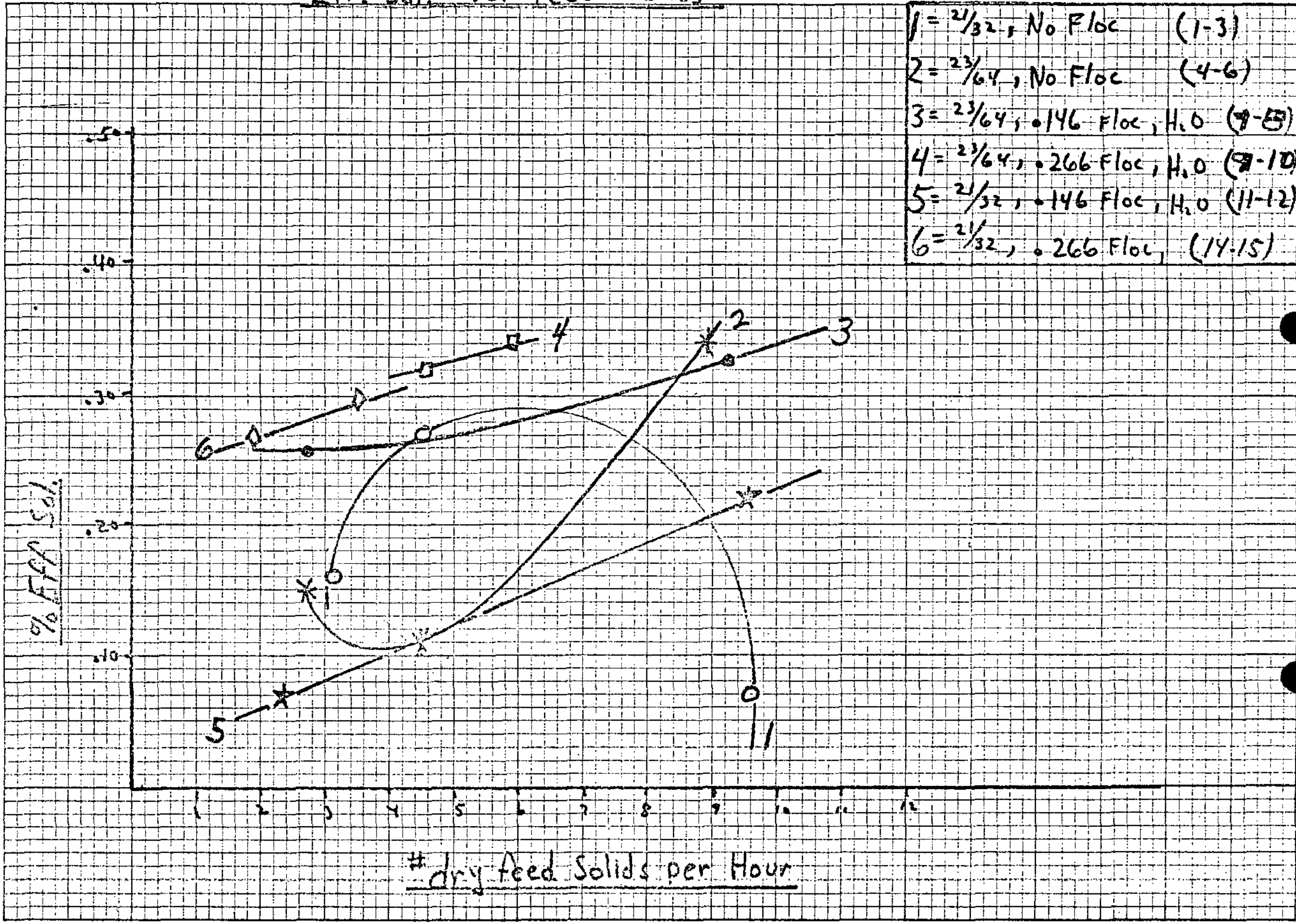
RUN NO.		1	2	3	4	5	6	7
Feed:	% Solids	.897 ----------------------------------→						
	Sp. Gr.	1.01 ----------------------------------→						
	Temp.	ROOM						
	GPM	.98	.7	2.12	.59	.94	1.97	2.04
Cake:	% Solids	11.7	9.8	5.6	36.1	33.5	21.9	17.7
	PPH Wet	40	30	189	5	7.5	36	40
	PPH Dry	4.7	2.94	10.6	1.8	2.5	7.9	7.1
	#/ft^3 Wet	36.3 --------→		38.4	36.6 ----------------------→			
	ft^3/hr. Wet	1.1	.83	4.9	.14	.20	.98	1.1
Effluent:	% Solids	0.27	0.16	0.07	0.15	0.11	0.34	0.33
	Sp. Gr.	1.0 ----------------------------------→						
AMP	In	8.5	8.5	8.5	9	8	8	8
	Out	9	9	9	9	9	9	9
Volt	In	170	170	170	170	170	170	170
	Out	170	170	170	170	170	170	170
Floc:	% Solids							0.1
	PPH Solids							.146
dosage #/ton								31.6
GPM dilution H_2O								.495
% Recovery		71.6	71.9	93.4	83.6	88.1	63.1	64.4
RPM		5000 ----------------------------------→						
X Gravity		2125 ----------------------------------→						

Bird Machine Company
Solid Bowl Centrifugal
Laboratory Report No. 7044

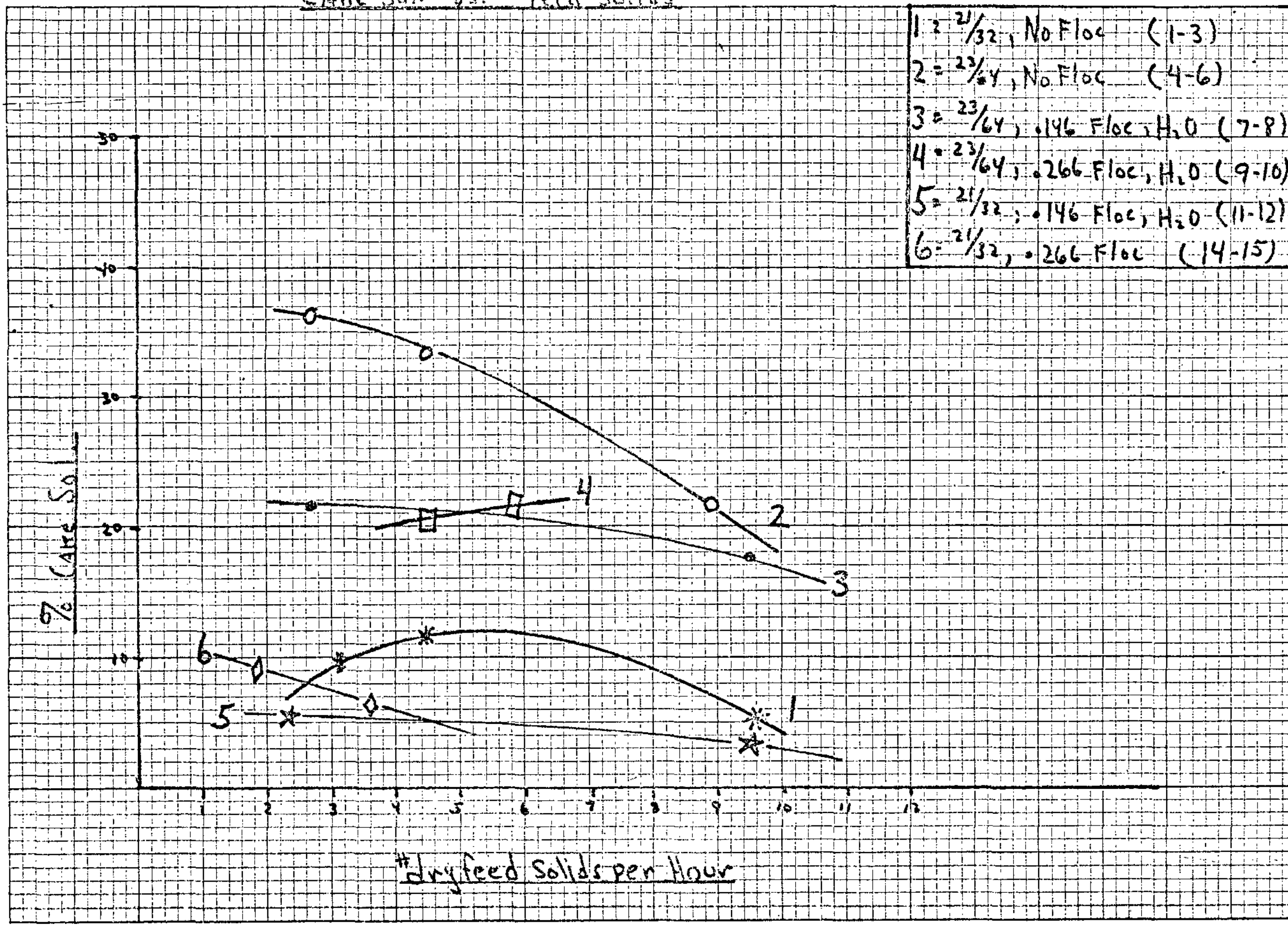
Customer: Camp, Dresser, McKee
Material: Sludge
Date: 7-9-70

RUN NO.		8	9	10	11	12	13	14	15
Feed:	%Solids	.897 ----->							
	Sp. Gr	1.01 ----->							
	Temp.	ROOM ----->							
	GPM	.59	1.31	1.09	2.11	.52	.81	.4	.79
Cake:	% Solids	21.3	21.3	20.5	3.8	5.5	7.9	9.6	6.6
	PPH Wet	7.5	16	15	204	36	39	15	54
	PPH Dry	1.6	3.4	3.7	7.7	1.98	3.08	1.44	3.56
	$\#/ft^3$ Wet	36.6 ----->			36.3	38.2	36.9 ----->		
	ft^3/hr. Wet	.20	.44	.41	5.6	.95	1.06	.41	1.46
Effluent:	% Solids	0.26	0.34	0.32	0.22	0.07	0.07	0.27	0.30
	Sp. Gr.	1.0 ----->							
AMP	In	8	8	8	8	8	8	8	8
	Out	9	9.5	9.5	9	9	9	9	9
Volt	In	170	170	170	170	170	170	170	170
	Out	170	170	170	170	170	170	170	170
Floc:	% Solids	0.1 ----->							
	PPH Solids	.146	.266 ----->		.146 ----->			.266 ----->	
dosage #/ton		109.2	84.1	101	30.5	123.9	79.6	275.4	139.4
GPM dilution H_2O		.495 ----->							
% recovery		71.9	63.1	65.4	80.1	93.4	93.0	71.9	69.7
RPM		5000 ----->							
X Gravity		2125 ----->							

Eff. Sol. vs. feed solids



Cake Sol. vs. feed solids



Recovery vs. feed solids