CASE HISTORY OF FINE PORE DIFFUSER RETROFIT AT RIDGEWOOD, NEW JERSEY

by

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DISCLAIMER

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

As part of these activities, an EPA cooperative agreement was awarded to the American Society of Civil Engineers (ASCE) in 1985 to evaluate the existing data base on fine pore diffused aeration systems in both clean and process waters, conduct field studies at a number of municipal wastewater treatment facilities employing fine pore aeration, and prepare a comprehensive design manual on the subject. This manual, entitled "Design Manual - Fine Pore Aeration Systems," was completed in September 1989 and is available through EPA's Center for Environmental Research Information, Cincinnati, Ohio 45268 (EPA Report No. EPA/625-1-89/023). The field studies, carried out as contracts under the ASCE cooperative agreement, were designed to produce reliable information on the performance and operational requirements of fine pore devices under process conditions. These studies resulted in 16 separate contractor reports and provided critical input to the design manual. This report summarizes the results of one of the 16 field studies.

E. Timothy Oppelt, Director
Risk Reduction Engineering Laboratory

PREFACE

In 1985, the U.S. Environmental Protection Agency funded Cooperative Research Agreement CR812167 with the American Society of Civil Engineers to evaluate the existing data base on fine pore diffused aeration systems in both clean and process waters, conduct field studies at a number of municipal wastewater treatment facilities employing fine pore diffused aeration, and prepare a comprehensive design manual on the subject. This manual, entitled "Design Manual - Fine Pore Aeration Systems," was published in September 1989 (EPA Report No. EPA/725/1-89/023) and is available from the EPA Center for Environmental Research Information, Cincinnati, OH 45268.

As part of this project, contracts were awarded under the cooperative research agreement to conduct 16 field studies to provide technical input to the Design Manual. Each of these field studies resulted in a contractor report. In addition to quality assurance/quality control (QA/QC) data that may be included in these reports, comprehensive QA/QC information is contained in the Design Manual. A listing of these reports is presented below. All of the reports are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161 (Telephone: 703-487-4650).

1. "Fine Pore Diffuser System Evaluation for the Green Bay Metropolitan Sewerage District" (EPA/600/R-94/093) by J.J. Marx

2. "Oxygen Transfer Efficiency Surveys at the Jones Island Treatment Plants, 1985-1988" (EPA/600/R-94/094) by R. Warriner

3. "Fine Pore Diffuser Fouling: The Los Angeles Studies" (EPA/600/R-94/095) by M.K. Stenstrom and G. Masutani

4. "Oxygen Transfer Studies at the Madison Metropolitan Sewerage District Facilities" (EPA/600/R-94/096) by W.C. Boyle, A. Craven, W. Danley, and M. Rieth

5. "Long Term Performance Characteristics of Fine Pore Ceramic Diffusers at Monroe, Wisconsin" (EPA/600/R-94/097) by D.T. Redmon, L. Ewing, H. Melcer, and G.V. Ellefson

6. "Case History of Fine Pore Diffuser Retrofit at Ridgewood, New Jersey" (EPA/600/R-94/098) by J.A. Mueller and P.D. Saurer

7. "Oxygen Transfer Efficiency Surveys at the South Shore Wastewater Treatment Plant, 1985-1987" (EPA/600/R-94/099) by R. Warriner

8. "Fine Pore Diffuser Case History for Frankenmuth, Michigan" (EPA/600/R-94/100) by T.A. Allbaugh and S.J. Kang

9. "Off-gas Analysis Results and Fine Pore Retrofit Information for Glastonbury, Connecticut" (EPA/600/R-94/101) by R.G. Gilbert and R.C. Sullivan

10. "Off-Gas Analysis Results and Fine Pore Retrofit Case History for Hartford, Connecticut" (EPA/600/R-94/105) by R.G. Gilbert and R.C. Sullivan

11. "The Measurement and Control of Fouling in Fine Pore Diffuser Systems" (EPA/600/R-94/102) by E.L. Barnhart and M. Collins

12. "Fouling of Fine Pore Diffused Aerators: An Interplant Comparison" (EPA/600/R-94/103) by C.R. Baillod and K. Hopkins

13. "Case History Report on Milwaukee Ceramic Plate Aeration Facilities" (EPA/600/R-94/106) by L.A. Ernest

14. "Survey and Evaluation of Porous Polyethylene Media Fine Bubble Tube and Disk Aerators" (EPA/600/R-94/104) by D.H. Houck

15. "Investigations into Biofouling Phenomena in Fine Pore Aeration Devices" (EPA/600/R-94/107) by W. Jansen, J.W. Costerton, and H. Melcer

16. "Characterization of Clean and Fouled Perforated Membrane Diffusers" (EPA/600/R-94/108) by Ewing Engineering Co.

ABSTRACT

In April 1983, the Ridgewood, New Jersey Wastewater Treatment Plant underwent a retrofit from a coarse bubble to a fine pore aeration system. Also, process modification from contact stabilization to tapered aeration occurred. This report presents a case history of plant and aeration performance of each system form 1981 through 1986. Extensive aeration studies were conducted on the fine pore aeration system in 1985 and 1986 to highlight the changing oxygen transfer efficiency with time and evaluate cleaning frequency requirements to maintain the efficiency at a viable level. An economic evaluation including bid prices, maintenance costs, and payoff period based on power savings is included.

This report was submitted in partial fulfillment of Cooperative Agreement No. CR812167 by the American Society of Civil Engineers under subcontract to Manhattan College under the partial sponsorship of the U.S. Environmental Protection Agency. The work reported herein was conducted over the period of 1985-1986.

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ACKNOWLEDGEMENTS

The authors of this paper would like to acknowledge the support of John Lagrosa and the entire staff at the Ridgewood Wastewater Treatment Plant. The work of numerous Manhattan College students is acknowledged, especially: Peter Gerbasi for conducting the initial work on the project and refining measurement techniques in foam; Laurie Davanzo for computer programming, Dennis Scannell, Elizabeth da Rocha Lima, Laura Gavin and Peter Elliott for testing and analysis support; and the various project engineers on the student field laboratories. Finally, thanks to Eileen Lutomski for her patience in preparing the report.

I. INTRODUCTION

The Ridgewood Water Pollution Control Facility is a 3 MGD activated sludge plant located in northwest Bergen County, New Jersey. The plant, treating 100% municipal wastewater, has undergone both process modification and diffuser retrofit. Completed in April 1983, the modification and retrofit changed the plant from a contact stabilization process using coarse bubble spargers to a conventional activated sludge process using fine pore domes. The purpose of the plant retrofit was to reduce energy consumption and minimize power costs. The capital costs of the project are being paid off on a monthly basis using the actual energy cost savings realized from reduced blower power consumption.

Prior to and immediately following the plant upgrade, field aeration studies were conducted by Manhattan College to provide a significant data base on oxygen transfer efficiency of the coarse bubble system and newly installed fine pore system. Both clean and dirty water data were obtained using nonsteady state testing techniques for the majority of the studies. Within a year of installation, a significant deterioration in fine pore diffuser performance occurred resulting in lower energy cost savings than originally projected. No diffuser maintenance or dome cleaning was practiced during this period. After 1½ years of operation, the domes were hosed clean and additional diffusers added.

This present study was begun in June 1985, a little over two years after initial dome installation. The objectives of the study were to (1) provide an in-depth case history of a municipal treatment plant retrofit from coarse bubble to fine pore diffusers, and (2) evaluate the impact of dome cleaning on diffuser performance. To accomplish these objectives, additional field studies were conducted for the next 1½ years during which diffusers were periodically cleaned with either water hosing or acid brushing. Three measurement techniques were used to evaluate oxygen transfer efficiency; steady state, nonsteady state, and offgas.

This report presents the results of the present data collection and combines them with the historical data base to obtain an in-depth case history of the retrofit. The impact of plant operation and cleaning frequency is evaluated. Comparisons of the three measurement techniques are provided along with problems encountered and corrections required when measuring transfer efficiencies in tanks with high levels of "Nocardia" foam. Results of a 24 hour study to provide estimates of the diurnal fluctuations in diffuser performance are included. Finally, an economic evaluation including bid prices, maintenance costs, and actual power costs savings is conducted. Changes in sludge production and disposal costs are also included.

II. PLANT DESCRIPTION

A. Original Activated Sludge Plant

The original activated sludge plant was constructed in 1959 with a design capacity of 5 MGD but an actual operational flow of 3 MGD. The wastewater is substantially 100% municipal sewage with insignificant industrial inputs. The effluent from the plant discharges to the Ho-Ho-Kus Brook approximately three-quarters of a mile above its juncture with the Saddle River which discharges to the Passaic River thence to Upper New York Bay.

The plant flow diagram is given in Figure 1 with unit sizes given in Table 1. Influent flow to the primary treatment portion of the plant is by gravity with the screens, grit chambers, and primary clarifiers constructed below grade. Only primary clarifier #1 is used for the raw wastewater flow with the #2 clarifier used for sludge supernatant settling. The primary clarifier #1 effluent discharges to a wet well from which it is lifted by four centrifugal pumps to the inlet channel of the aeration tanks. Return sludge is combined with the primary effluent in the influent channel. The mixed liquor flowed to aeration tank #1, used as the contact tank in the original contact stabilization process. From the contact tank, flow was discharged to both secondary clarifiers which are center feed and peripheral effluent draw-off. Four contact chambers are used for chlorination prior to discharge to the Ho-Ho-Kus Brook.

Return sludge was drawn off the center hopper in each secondary clarifier and returned to aeration tank #2 for stabilization prior to combining with the primary effluent. Sludge is wasted from the secondary portion of the system to the primary clarifier. The combined primary-secondary sludge is pumped to the primary digester, which is mixed and heated, and thence to the secondary digester for supernatant separation. Sludge is then hauled by truck offsite for incineration at another plant. Vacuum filtration was originally used for sludge dewatering prior to disposal on a sod farm or onsite land application. It was abandoned in August 1982 due to high chemical and energy costs. Land application was also no longer viable due to more stringent regulations.

Figure 1. Ridgewood Plant Layout and Flow Diagram for the Coarse Bubble Aeration System

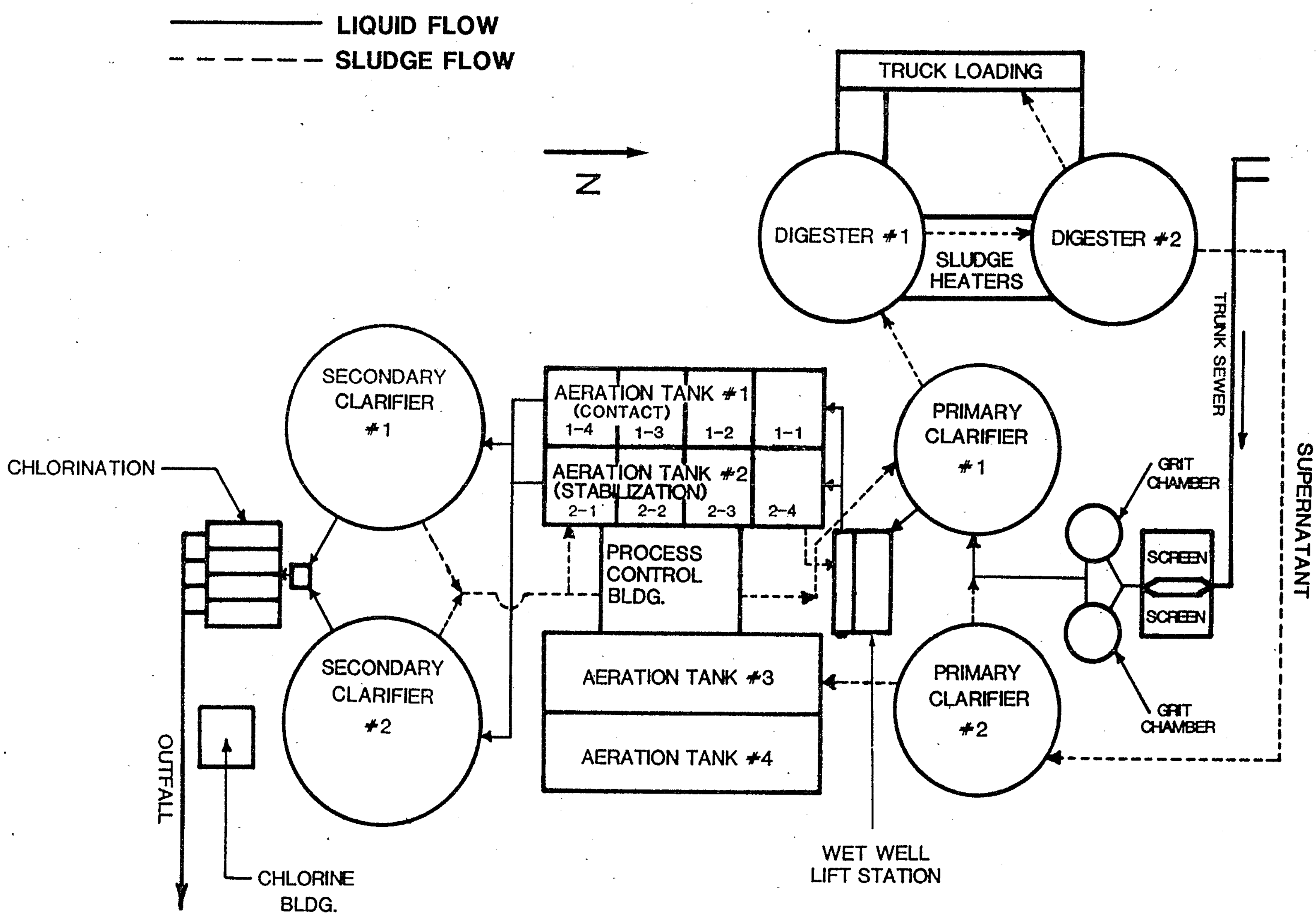


TABLE 1

Ridgewood Tank Sizes

Unit	Number	Dimensions, ft: Length	Dimensions, ft: Width or Diameter	Dimensions, ft: Approximate Depth	Tank Volume, Gallons
Grit Chamber	2	-	~17.7	6.5	12,000
Primary Clarifier	2	-	60	9.6	204,000
Aeration Tanks					
Tanks 1 & 2	2	113	24	14.8	300,000
Tanks 3 & 4	2	116	24	14.8*	308,000
Secondary Clarifier	2	-	75	10.6	350,000
Chlorine Contact	4	42.5	11	6.5	23,000
Anaerobic Digesters	2	-	60	24.7	522,000

* Average value at 10:00 a.m. on 1/12/87 for tanks 3 and 4 at a raw flow of 4 MGD with both secondary clarifiers operational.

Sludge supernatant was settled in primary clarifier #2 and aerated in aeration tank #3 until the oxygen demand was satisfied and nitrification occurred as determined by a marked decrease in alkalinity. After the supernatant oxygen demand was satisfied, the contents of tank #3 were pumped into the primary effluent flow causing insignificant impact on the secondary system. An unknown quantity of sludge was also discharged from primary clarifier #2 to on-site lagoons which have been abandoned since August 1982 and subsequently filled in.

An additional sludge recycle stream to the aeration tank influent is solids settling in the chlorine contact chamber. Once per month the supernatant from the contact chambers is drained and the septic sludge layer on the bottom of the tanks is pumped back to the aeration tank influent. Aeration tank #4 was not utilized in the original plant due to the lower raw wastewater flow than designed.

In the original plant the aeration system consisted of coarse bubble Walker sparjers. Two manifolds were located adjacent to the side wall of each aeration compartment providing spiral roll wide band aeration. The number of diffusers is given in Table 2. Water level varies since the two tanks are hydraulically connected with no free overfall existing in the aeration tank. At high flows tank depth is greater than at low flows, thus a range of tank depths is given with a typical depth taken as 14.8 ft. providing a tank volume of 300,000 gallons. Air lift pumps using approximately 15% (300 scfm) of the total plant gas flow were located in compartment 2-4 and used to return the aeration influent.

As indicated in Table 2, two blowers were continually used to supply the air requirements for the total plant. Temperature, pressure and gas flow measurements were available on the blower discharge. For tanks #1 and #2 both flow tube and orifice plate data was available as shown in Mueller et al., 1982. During summer months, blower capacity was often unable to maintain measurable D.O. in the aeration tanks resulting in periodic odors.

B. Basis for Plant Upgrade

Plant retrofit from coarse bubble to fine pore diffusers was undertaken to reduce energy costs of the blowers. Specific design

TABLE 2

Original Coarse Bubble Aeration System

in Ridgewood Tanks 1 and 2

	AERATION TANKS	
	Tank #1 Contact	Tank #2 Stabilization
Type Diffuser	Walker Sparjers	Walker Sparjers
# Compartments	4	4
Surface Area/Compartment, ft^2	678	678
# Sparjers/Compartment	40	28
# Sparjers/Tank	160	112
Diffuser Density, ft^2/Diffuser	17.0	24.2
Height of Diffusers off Tank Bottom, ft	2	2
Tank Water Depth	∿14.5-15.5 ft	∿14.5-15.5

BLOWERS	
Name	Spencer Turbine - Turbo-Compressor Model 362
Type	Centrifugal
Nominal Rating	75 hp
Total Number	5
Number in use at any one time	2
Typical Efficiency	43%

criteria used for the retrofit is not available. However, field studies were undertaken by Manhattan College (Mueller, et al., 1982) to characterize the coarse bubble system. Based on these results a projection of fine pore system advantages was made. The average transfer efficiency for the coarse bubble diffusers in batch and flowing systems in the contact and stabilization tanks was 4.8% at zero D.O. Using an alpha of 0.4 from laboratory data and a cleanwater efficiency of 28% for dome diffusers, an oxygen transfer efficiency of 11.1% at zero D.O. was projected. This would allow one blower to be used instead of two at the same oxygen utilization rate of the coarse bubble system.

Table 3 summarizes the economic advantages anticipated from the upgrade. Based on energy savings, a payoff period of 6.2 years was estimated for the retrofit. During summer months, odors from the aeration tanks would be eliminated due to ability to maintain measurable D.O. at all times with the fine pore system. Based on a COD balance, less secondary sludge production was anticipated due to the ability to supply more oxygen with the fine pore system. This would eliminate oxygen limitation thus providing greater sludge endogenous respiration.

C. Fine Pore Diffuser Retrofit

In the Fall and Winter of 1982, a fine pore diffuser (Gray "Fine Air") system was installed in tanks #3 and #4 at Ridgewood. To minimize total plant gas flow, air lift pumps were abandoned with return sludge pumped from the secondary clarifiers directly to the aeration tank influent channel. The contact stabilization process was also abandoned with mixed liquor flow to both aeration tanks in parallel operated in the conventional plug flow mode as shown in Figure 2.

At the influent and effluent ends of both tanks, wooden baffles were installed to distribute and collect the flow across the total aeration tank width to minimize short circuiting as shown in Figures 3 and 4. Figure 5 indicates the full floor cover system used in the retrofit (Burde, 1983). Four grids were used in each tank with a greater number of domes from inlet to effluent end providing tapered aeration to balance oxygen supply with demand. All domes are 7 inch diameter Carborundum (Aloxite) diffusers which were initially connected to the

TABLE 3

Projected Energy Savings for the Fine Pore Retrofit, Mueller et al., 1982

	Aeration System	
	Coarse Bubble	Fine Pore
SOTE, %	8.6	28.0
T, °C	20	20
α	0.55	0.40
β	0.99	0.99
C_L, mg/ℓ	0	0
OTE_f, %	4.8	11.1
G_s, scfm	2100	1100
# Compressors	2	1
Power Drawn, kwhr/day	3000	1500
Power Cost, $/yr @ 6.5¢/kwhr	71200	35600
Bid Price for Retrofit	-	$218,000
Pay-off period	-	6.1 yrs

Figure 2. Ridgewood Plant Layout and Flow Diagram for the Fine Pore Aeration System

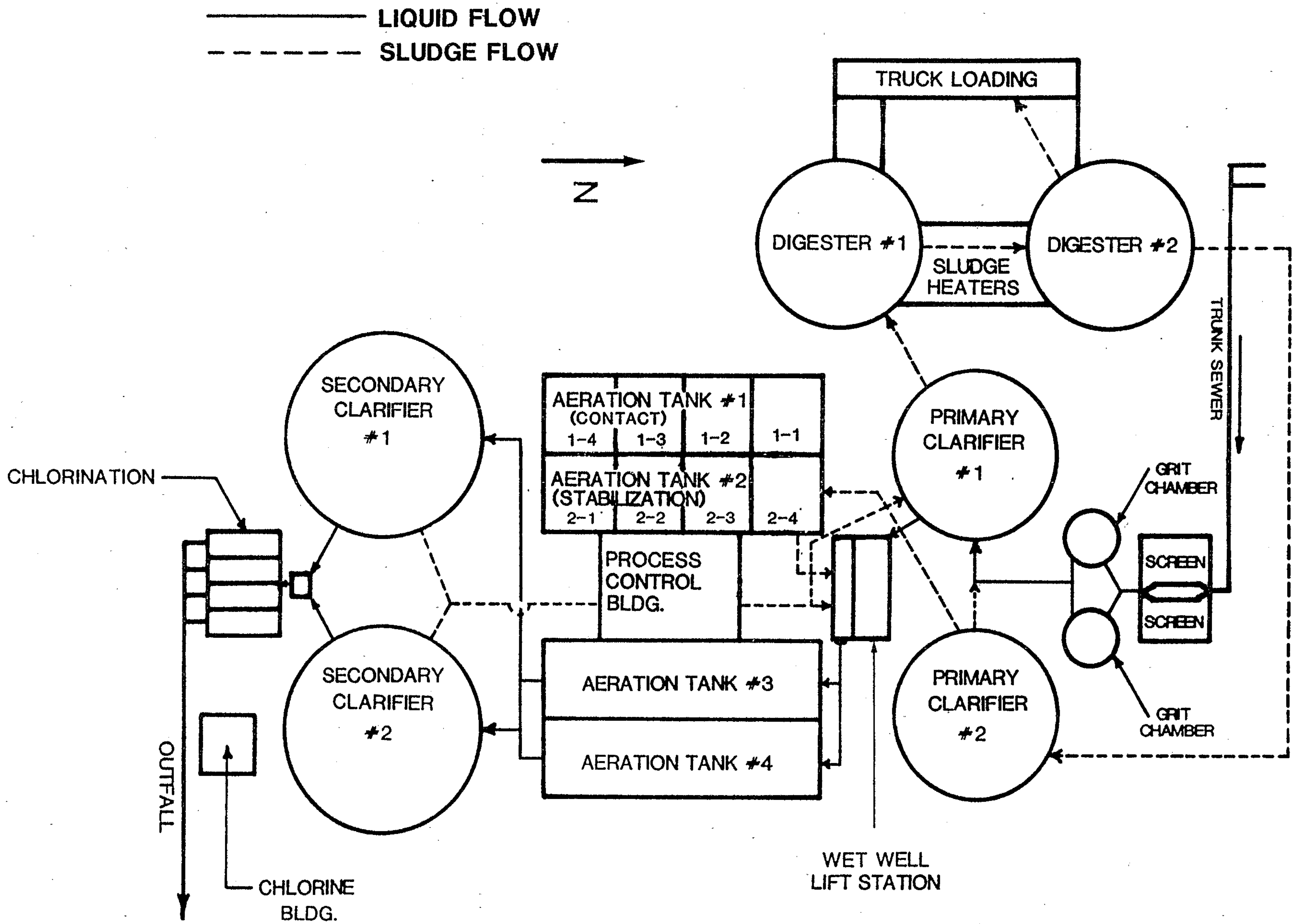


Figure 3. Influent Baffle Design (Fine Pore System)

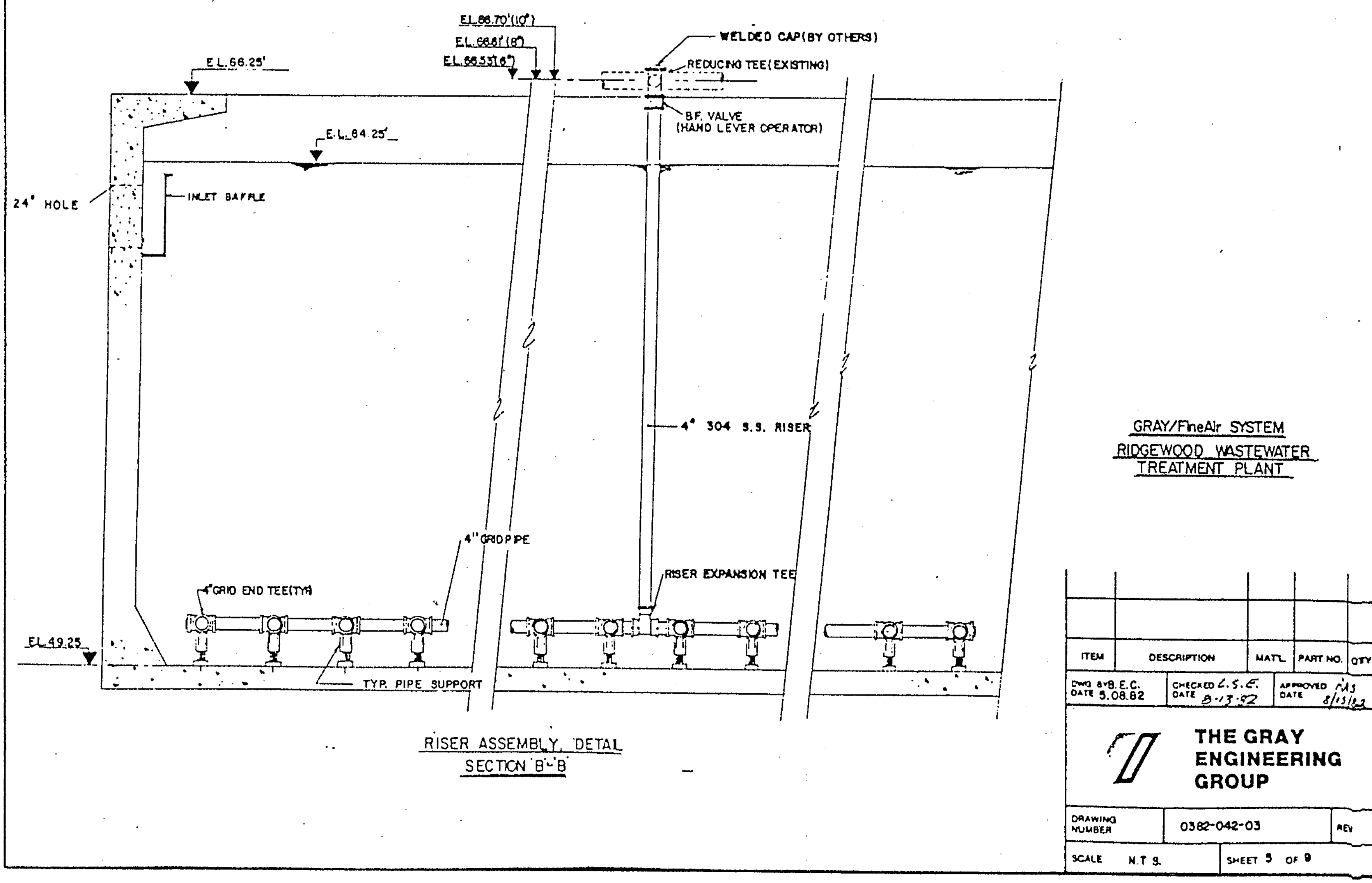


Figure 4. Effluent Baffle Design (Fine Pore System)

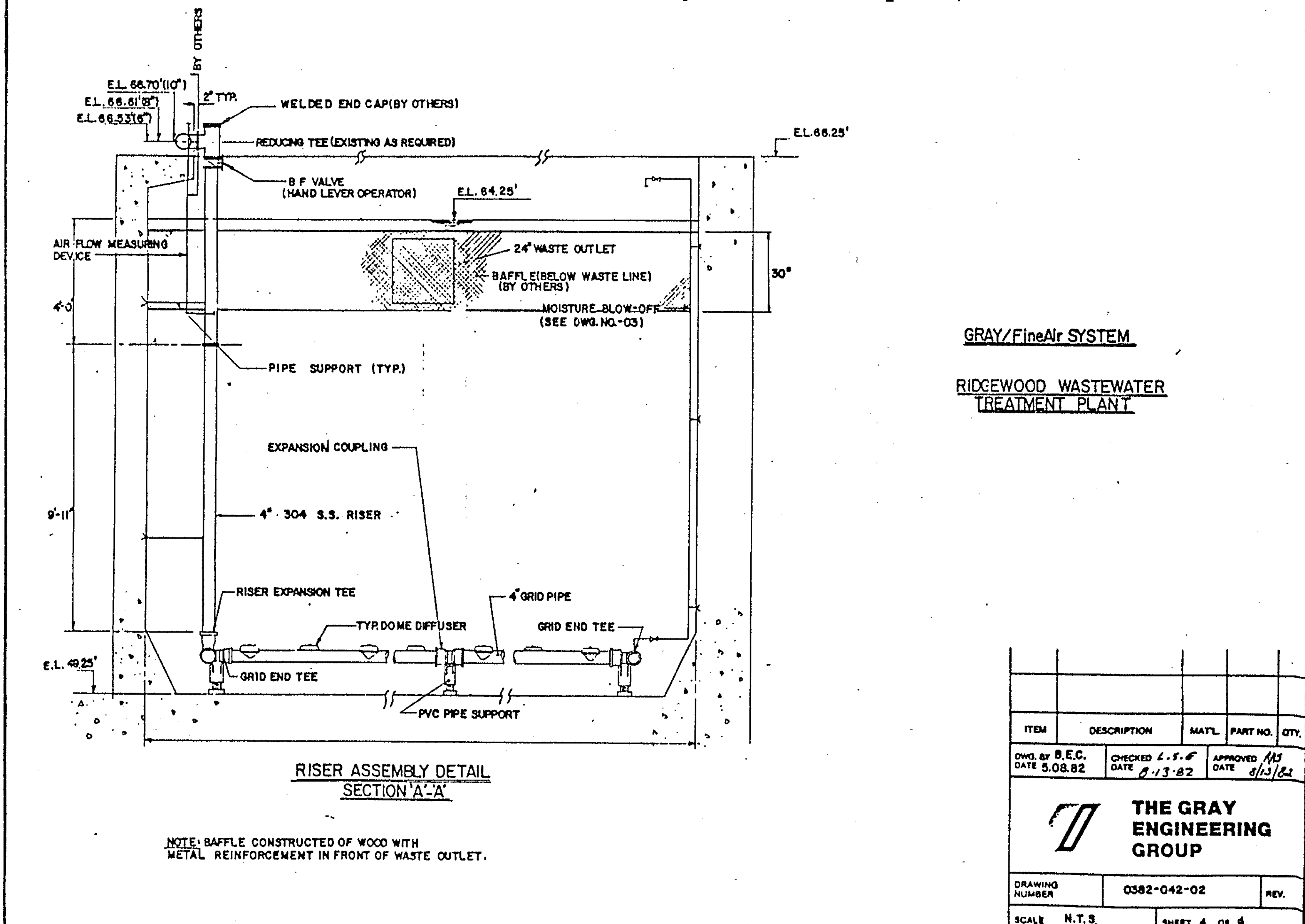
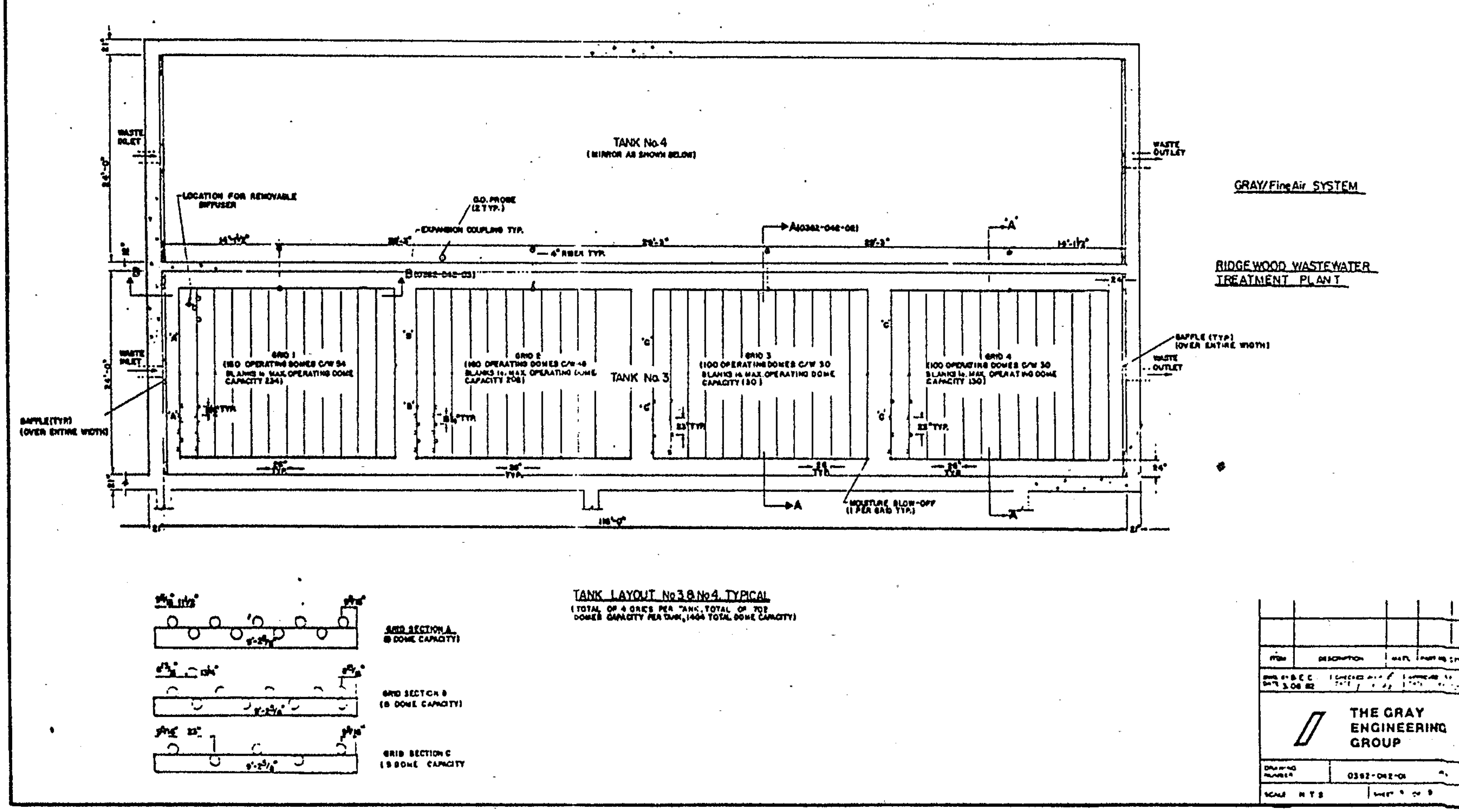


Figure 5. Aeration Grid Design (Fine Pore System)



saddles approximately 10" off the bottom using plastic (acetal) bolts. After 1-1/2 years of operation all bolts were replaced with brass due to bolt failures and diffuser density increased at the inlet of the plant to reduce gas flow per dome as summarized in Table 4.

On 12 April 1983, the fine pore system was started and continues in operation to the present. The waste sludge handling system differed somewhat from the coarse bubble operation since the sludge lagoons were no longer available for excess sludge removal. Initially overflow from primary clarifier #2 containing digester supernatant was discharged directly to the influent without prior aeration. In mid 1985 aeration compartment #2-4, still containing the original sparjers, was placed in operation to reduce digester supernatant load. A separate small blower was used to aerate this tank.

Often during summer months, sludge accumulation in the plant was significant due to abandonment of the sludge lagoons with aeration tanks #1 and #2 periodically used for waste sludge storage. Digester sludge supernatant quality during this time was generally poor with a significant quantity of digested solids probably recycling through the aeration system. A significant amount of "Nocardia" growth appeared in the late Spring or early Summer months and remained until the Winter. This resulted in a thick surface foam layer periodically overflowing from the tanks. The poor quality digester supernatant return was felt to contribute markedly to "Nocardia" growth.

TABLE 4

Fine Pore Aeration Retrofit in Ridgewood Aeration Tanks 3 and 4

	Each Tank	Grid A	Grid B	Grid C	Grid D
Type Diffuser	7" Gray/Fine Air Domes				
Surface Area, ft^2	2784	696	696	696	696
Number of Grids	4				
Tank Water Depth, ft	14.5-15.5				
Height of Diffusers off Tank Bottom, inches	10				
Initial Operation 4/83-9/84					
# Diffusers	540	180	160	100	100
Dome Density, ft^2/dome	5.15	3.87	4.35	6.96	6.96
Final Operation 9/84-present					
# Diffusers	650	234	208	104	104
Dome Density, ft^2/dome	4.28	2.97	3.35	6.69	6.69

III. FIELD STUDY DESCRIPTION

Since October, 1981, eight field aeration studies have been conducted at the Ridgewood WWTP. Extensive testing was conducted in Study 8 with 67 aeration tests performed over a 1½ year period. Previous studies were not as extensive, but provide a reasonable data base to highlight the changing oxygen transfer efficiency of the fine pore system with time. A summary of the studies can be found in Table 5.

The oxygen transfer efficiency was measured using three different techniques; 1) offgas, 2) nonsteady state, and 3) steady state. Initial studies utilized the nonsteady state technique for clean and wastewater tests, while the final study used offgas, nonsteady and steady state techniques. The offgas method is considered the most accurate, simply because it is a direct measure of oxygen transfer. The OTE20 calculated for each technique is at standard temperature using zero dissolved oxygen concentrations and $\beta(0.99)$ corrected clean water oxygen saturation values.

The offgas testing procedure utilized at Ridgewood from August 1985 to September 1986 was based on the protocol given in both 1) Manual of Methods for FBDA Field Studies, Appendix A, and 2) the Operations Manual supplied by Ewing Engineering. The Mark V Aerator-Rator offgas analyzer, manufactured by Ewing Engineers, was used in the field studies. Prior to a test, hoods were positioned at the center of each grid as shown in Figure 6. Typically, a test would begin in the morning with calibration of all DO probes in a bucket of clean water which had been saturated and DO measured in duplicate by Winkler technique. A leak test would then be conducted as indicated on pg 41, FBDA. A small nitrogen cylinder was purchased for this purpose. A significant leak was obtained only once when the dessicant was replaced and fittings not properly tightened. Prior to and after testing each day, the local weather bureau would then be called for barometric pressure, air temperature, and relative humidity. Testing of the hood connection was conducted prior to startup in August by forcing a rubber stopper into the underside of the hood opening in the wood. A leak was found requiring additional sealant around the flange. Similar testing was conducted when the hoods were removed in December with no leaks being found.

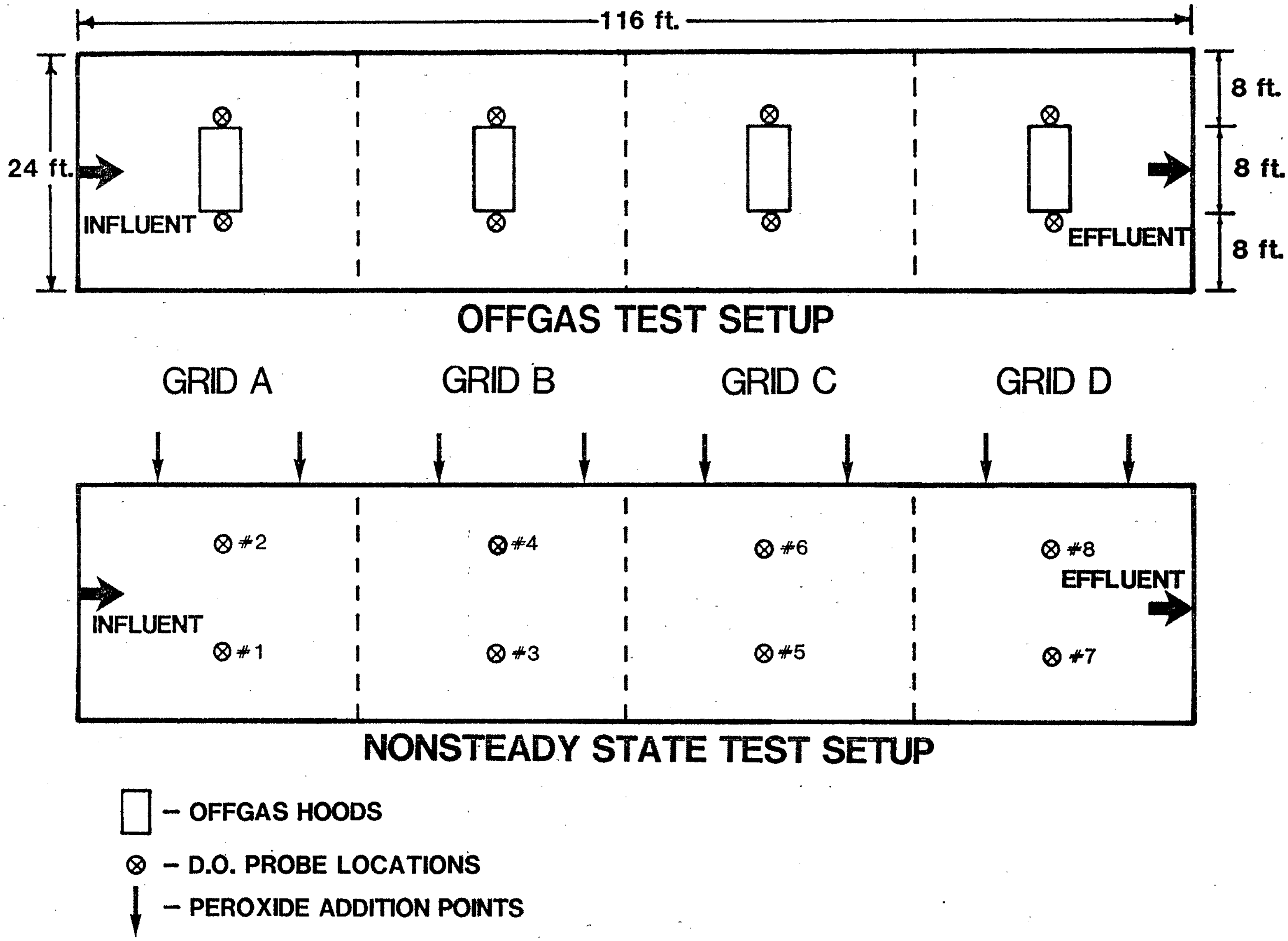
TABLE 5

Description of Aeration Studies

Study (Ref. No.)	Date	No. of Tests	Aeration System	Measurement Technique	Aeration Tank Tested
1. Ridgewood Aeration Systems Analysis Phase I (Ref. 8)	10/1-11/21 1981	5 Batch wastewater 2 Flowing wastewater 3 Clean water	Coarse bubble	NSS, SS	1 & 2
2. Nonsteady State Field Testing of Surface and Diffused Aeration Equipment (Ref. 9)	7/9-7/21 1982	18 Flowing wastewater	Coarse bubble	NSS, SS	1
3. Ridgewood Aeration System Analysis (Ref. 10)	3/25-3/31 1983	4 Clean water 4 Batch wastewater	Fine Pore	NSS, SS	3
4. Graduate Thesis - Susan Hildreth (Ref. 6)	6/28 1983	4 Flowing wastewater	Fine Pore	NSS, SS	3
5. Nonsteady State Testing of Ridgewood Aeration (Ref. 4)	3/14 1984	4 Flowing wastewater	Fine Pore	NSS, SS	3 & 4
6. Nonsteady State Testing of Ridgewood Tanks 3 & 4 (Ref. 11)	7/10-7/11 1984	4 Flowing wastewater	Fine Pore	NSS, SS	3 & 4
7. Field Lab Aeration Study (Ref. 1)	3/5 1985	2 Flowing wastewater	Fine Pore	NSS, SS	3
8. ASCE Evaluation of High Efficiency Diffused Aeration System (Ref. 12 & present report)	6/13/85-9/03/86	1 Batch wastewater 66 Flowing wastewater	Fine Pore	OG, NSS, SS	3 & 4

OG - Offgas
NSS - Nonsteady State
SS - Steady State

Figure 6. Offgas and Nonsteady State Test Setups



After the leak testing and calibration, the 50 ft. length of vacuum hose was connected to the first hood. Offgas readings were taken alternately using reference then offgas measurements, typically 3 to 5 readings were taken at each station. The average OTE20 value from each station was weighted according to gas flow or dome distribution and then summed to obtain a tank average value. If foam was not present, gas flow would be increased to attain an equilibrium condition. This was judged to be reached when hood pressure was about 0.6-0.8 inches of water and the hood was stable in the water with no noticeable gas escaping from the sides of the hood. Two samples of offgas would typically be taken for Orsat analysis for carbon dioxide. DO was measured at each hood location generally using two probes, one on each side of the hood. Upon completion of a test at a station, the vacuum hose would be connected to the next hood location and the test repeated. Typically a test would require one hour to complete after measurement began. In the case of severe foaming, when accurate gas flow measurement could not be attained, a complete test could be conducted in less than one hour since equilibrium gas flow conditions were not attempted.

Nonsteady state data was collected using D.O. probes located at mid-depth in four equal volume grids in the aeration tanks. Two probes were used in each grid to obtain replicate data. Nonsteady state testing was normally conducted for a time period of $4/K_La$ as recommended by ASCE for clean water tests. At each location, the K_La_f values were obtained using the ASCE three parameter estimation model and the average value used to represent the total tank. Gas flow measurements were obtained using pressure drop readings across a flow tube with header temperature and pressure measurements to correct to standard conditions. The nonsteady state equations required to obtain the oxygen transfer rate are developed in "Nonsteady State Field Testing of Surface and Diffused Aeration Equipment," (Mueller, 1983).

Steady state testing, the simplest technique, was conducted to evaluate its adequacy compared to offgas and nonsteady state techniques. The measured oxygen uptake rates were used to indicate constant test conditions and to serve as a basis for data correlation. The steady state equations required to obtain the oxygen transfer rate are given in Mueller, 1983.

IV. CLEAN WATER PERFORMANCE

A. Coarse Bubble System

In order to evaluate standard oxygen transfer efficiency (SOTE) and the oxygen saturation value ($C^*_{\infty 20}$) clean water studies were conducted on both the coarse bubble sparger and fine pore dome systems. The SOTE values are used to determine alpha, the ratio of the OTE20 under process conditions to that in clean water. The saturation value is used to provide the driving force required to correct the measured OTE values under process DO conditions to the maximum OTE20 under zero DO conditions.

The clean water study on the sparger system was conducted in November, 1981. Three individual tests were conducted and resulted in a $\beta C^*_{\infty 20}$ of 9.54 mg/l with beta equal to 0.99 (Mueller, 1982). Figure 7 illustrates the relationship between gas flow and SOTE. At gas flows of 6 and 12 scfm/diffuser, SOTE is a constant at 8.6%.

B. Fine Pore System

In March 1983, four clean water studies were conducted on the newly installed fine pore system. These tests resulted in an $\beta C^*_{\infty 20}$ equal to 10.26 mg/l with beta equal to 0.99 as previously (Mueller, 1983). Figure 8 presents the effect of gas flow on SOTE for the fine pore system under the original and the modified dome density. Unlike the sparger system, increased gas flows significantly decrease SOTE. Aeration tanks 3 and 4 were modified by increasing the average dome density from 5.15 ft^2/dome to 4.28 ft^2/dome in late fall of 1984. The dome configuration for each density is shown in Figure 9. No clean water studies were conducted after the modification, therefore, the following model was employed to evaluate the effect of increased dome density (Huibregtse, 1986).

$$SOTE = \frac{5.138 S^{0.7454} D^{0.0893}}{Q^{0.1088}} \quad (1)$$

S = submergence, ft
D = density, diff/ft^2
Q = air flow per diffuser, scfm

Figure 7.

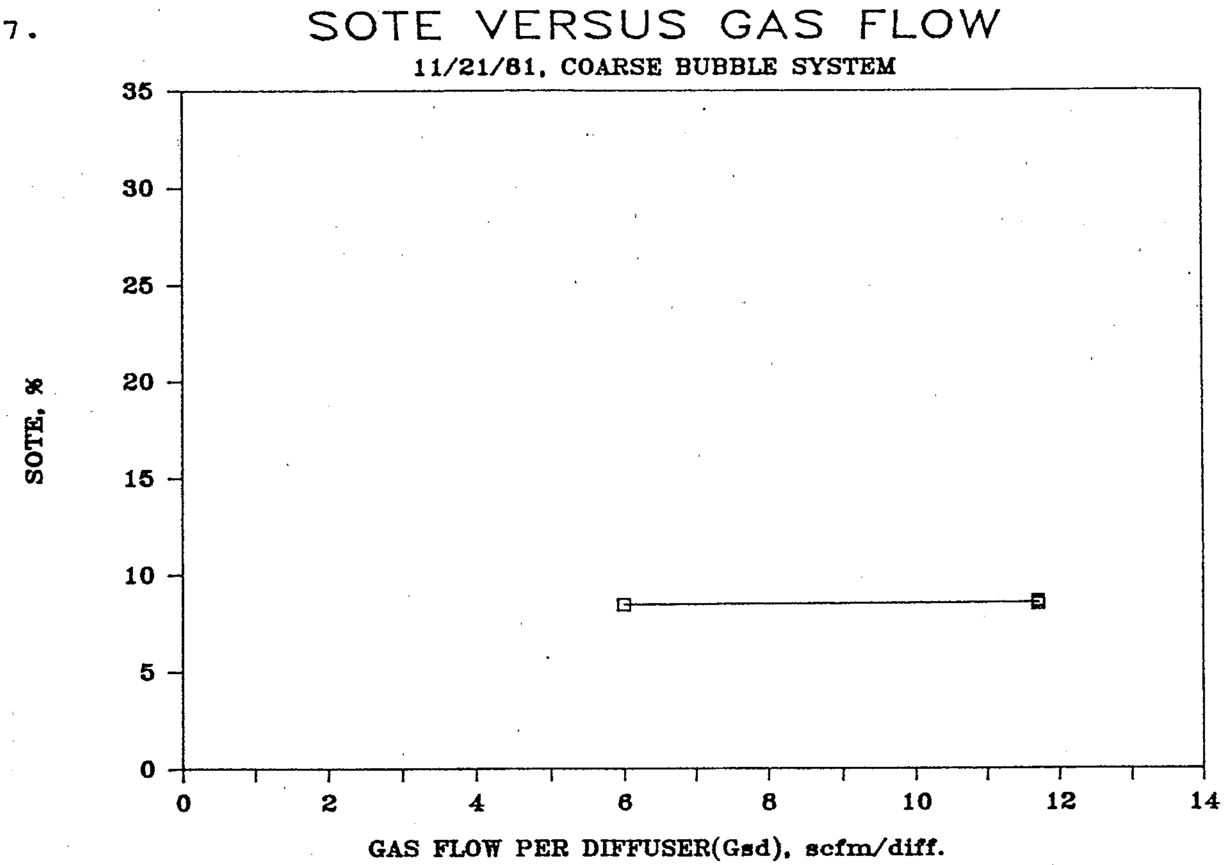


Figure 8.

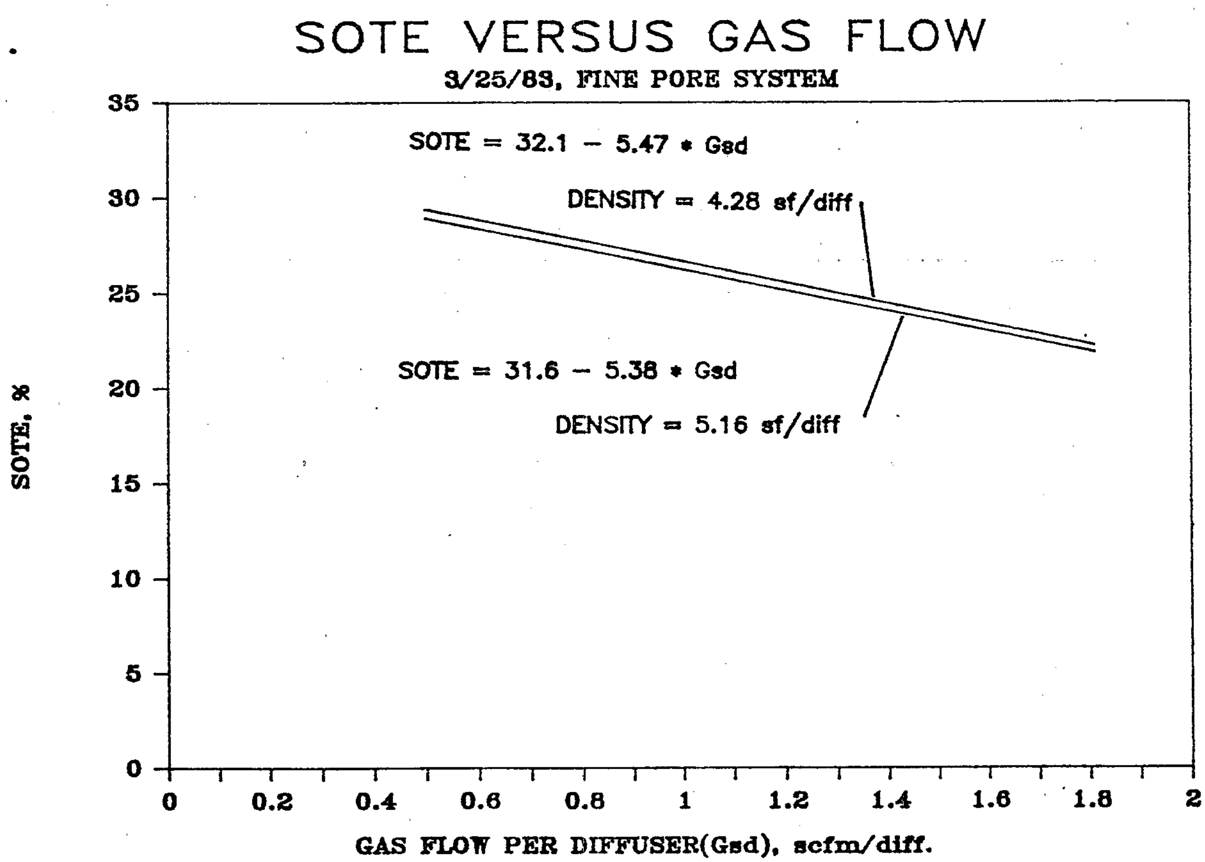
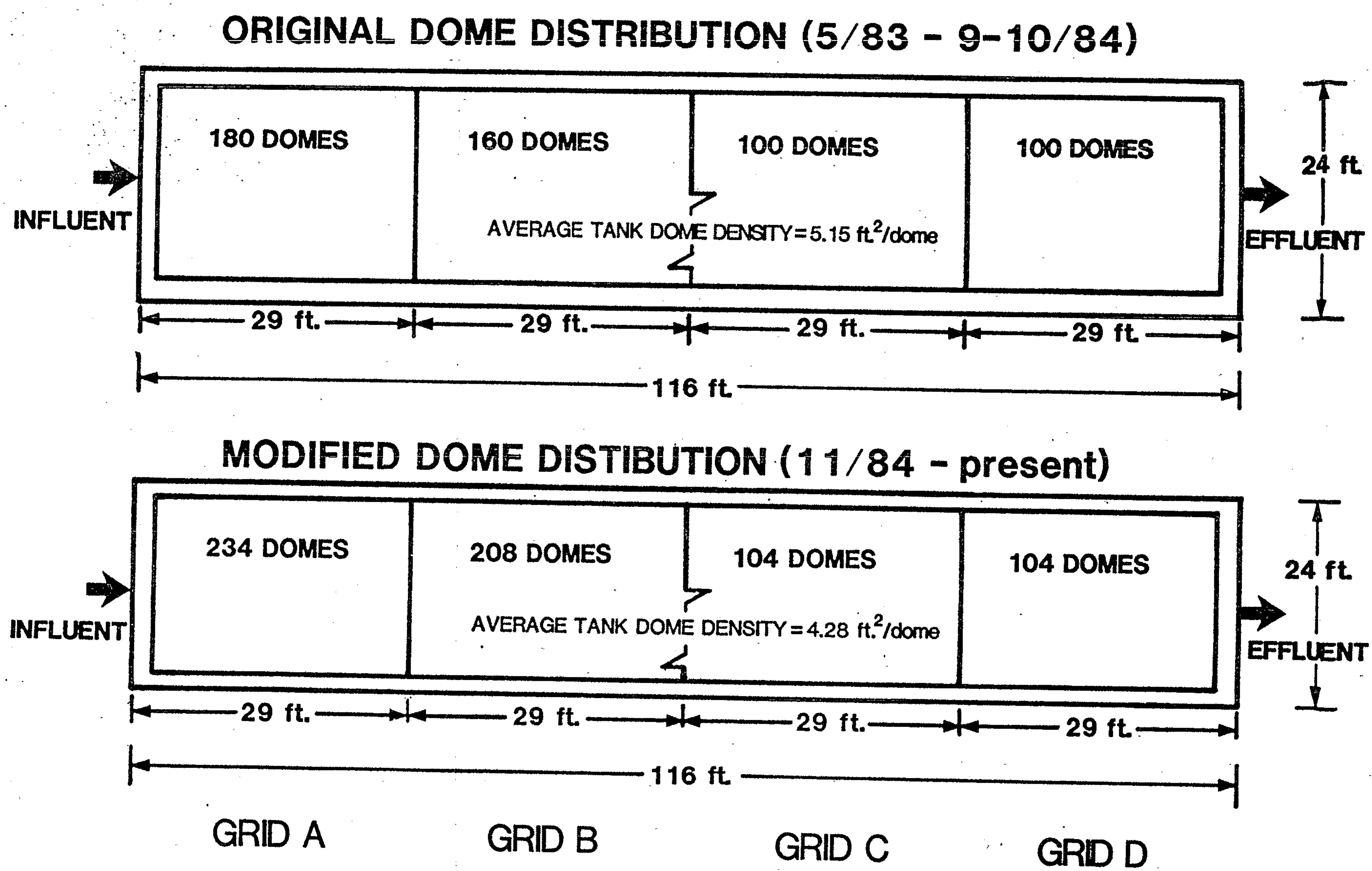


Figure 9 Original and Modified Fine Pore Dome Distribution



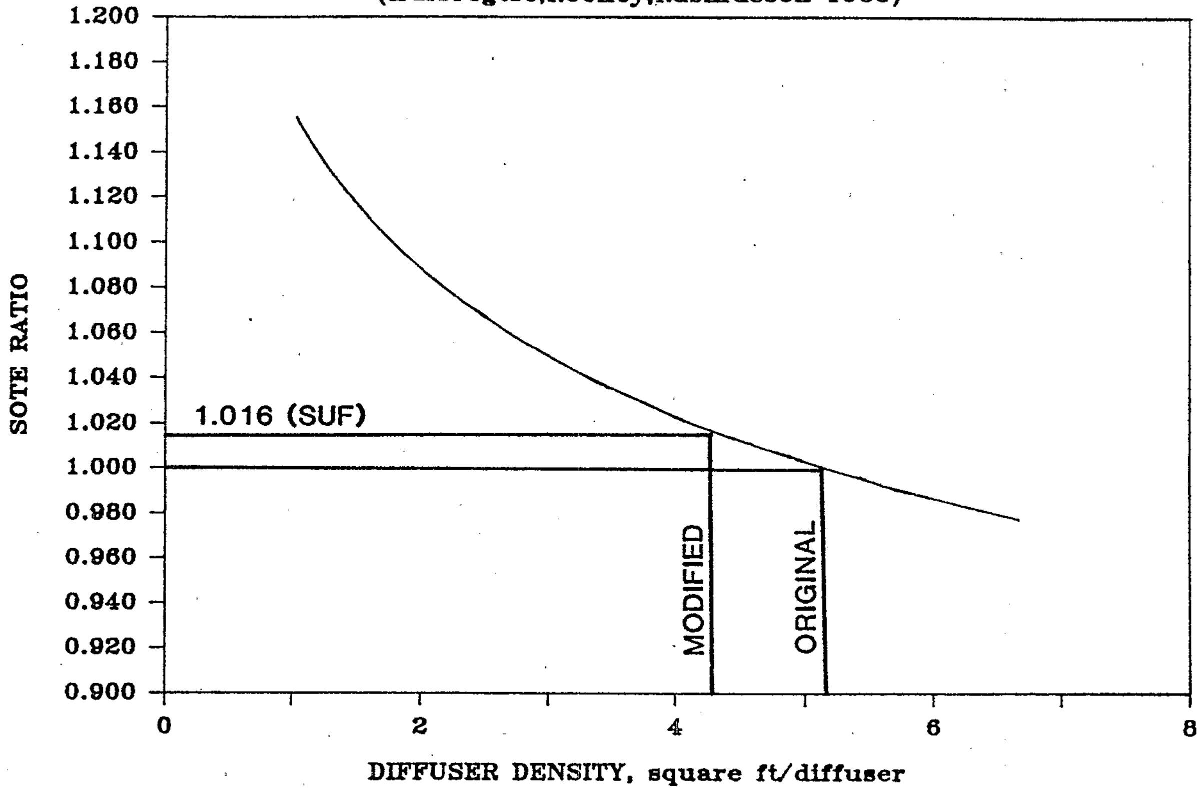
By maintaining submergence and air flow as constants in the model the effect of different dome densities on SOTE can be evaluated. Figure 10 illustrates this effect, as dome density increases the SOTE also increases. SOTE increased by 1.6% at constant submergence and airflow rates resulting in a scaleup factor of 1.016. The equation used to calculate SOTE as a function of gas flow for Ridgewood is:

$$SOTE = 31.6 - 5.38(G_{SD}) \quad \text{(original)}$$

$$SOTE = 32.1 - 5.47(G_{SD}) \quad \text{(modified)}$$

Figure 10. EFFECT OF DIFFUSER DENSITY ON SOTE

(Huibregtse,Rooney,Rasmussen 1983)



V. CASE HISTORY SUMMARY (Oct. 1981-Sept. 1986)

Table 6 summarizes the 8 field studies conducted at the Ridgewood WWTP. Two studies were conducted on the coarse bubble system while the remaining 6 studies were performed on the fine pore aeration system. Figures 11 and 12 illustrate the variability in OTE20 and alpha values measured from October 1981 through September 1986. The coarse bubble OTE20 results are values measured in each bay, while the fine pore values represent average tank values. Batch test conditions and low and high gas flows are shown by different symbols. Estimated yearly averages are indicated for the two systems under both low and high gas flows. These values are summarized in Table 7.

The nonsteady state technique was employed to evaluate the coarse bubble system. Testing was initiated on October 21, 1981 with 5 batch wastewater, 2 flowing wastewater, and 3 clean water tests conducted. In July of 1982, 18 nonsteady state flowing wastewater tests were conducted. For each of the flowing wastewater tests the primary clarifier effluent and return sludge flows were reduced using a temporary sluice gate. This provided reduced load conditions and positive dissolved oxygen concentrations for testing. The OTE20 results on the coarse bubble system were from 3.6 to 6.4% under wastewater conditions, while the clean SOTE was 8.6%. The coarse bubble system had an estimated yearly OTE20 average of 4.8% and an alpha of 0.55.

Testing of the fine pore aeration system began in March of 1983, using the nonsteady state technique for both clean and wastewater. The results of the clean water transfer efficiencies were from 21.3 to 30.2%, while the batch wastewater values ranged from 15.9 to 20.3% all on tank 3 at high and low gas flows respectively. The batch test results are conducted with highly treated effluent and mixed liquor in the endogenous phase, not representative of plant operation under actual wastewater conditions. A total of 14 tests were performed from June 1983 to March 1985 (studies 4 through 7), again, using the nonsteady state technique. The OTE20's measured during this period showed a significant decline in the beginning of 1984. The first aeration test of tank 4 in March 1984 resulted in an OTE20 of only 5.7% and in July of the same year it decreased to 4.8%. The transfer efficiency

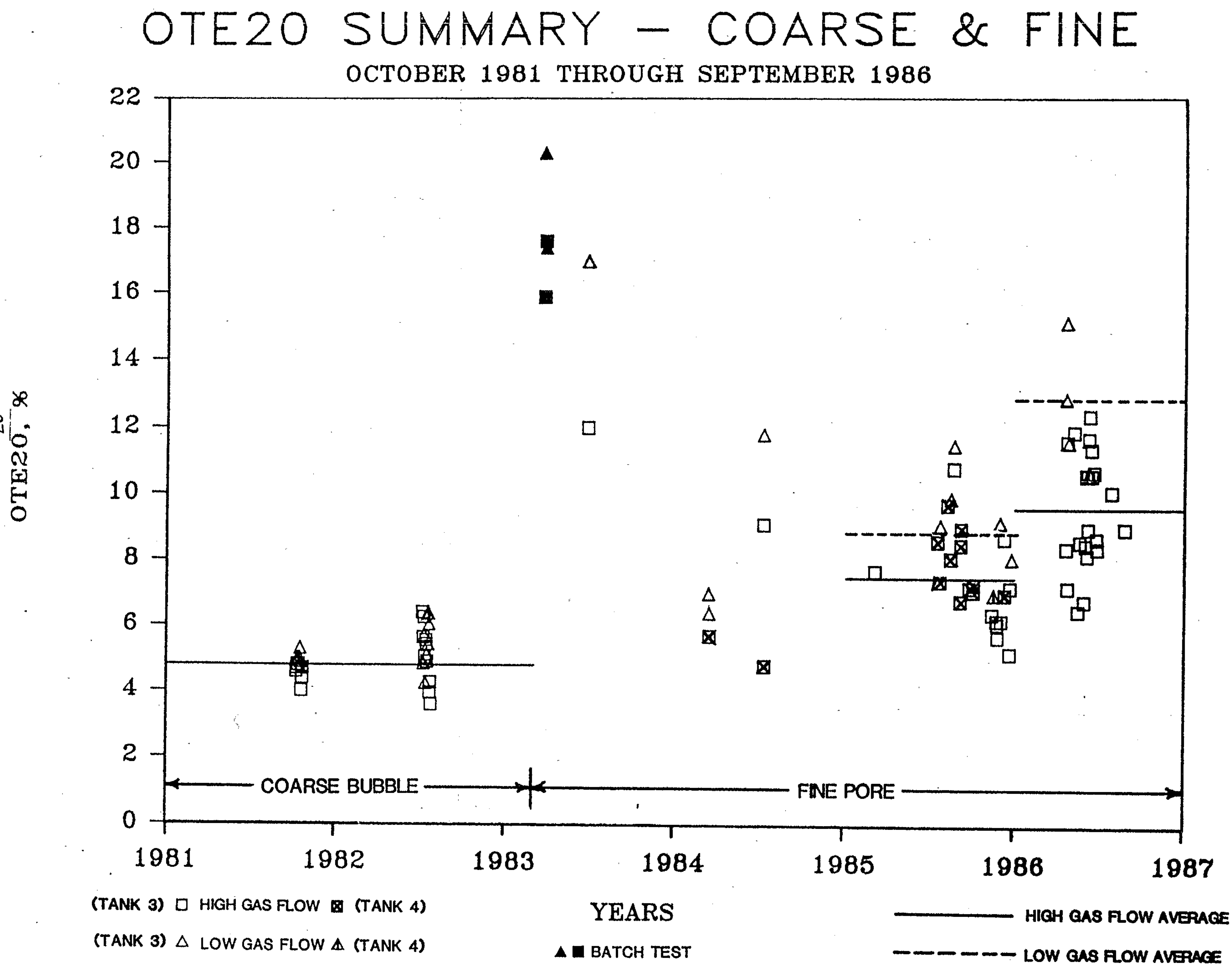
TABLE 6

Summary of Aeration Results

Study	Dates of Study	Type of System	Range of OTE Results			
			SOTE, %		OTE20, %	
			High G_s	Low G_s	High G_s	Low G_s
1	10/1-11/21 1981	Coarse	8.5-8.7*	8.5*	4.2-5.0	4.9-5.3
2	7/9-7/21 1982	Coarse			3.6-6.4	4.3-6.4
3	3/25-3/31 1983	Fine	21.3-22.5*	27.6-30.2*	15.9-17.6*	17.4-20.3*
4	6/28 1983	Fine			12.0	17.0
5	3/14 1984	Fine			5.7	6.4-7.0
6	7/10-7/11 1984	Fine			4.8-9.1	11.8
7	3/05 1985	Fine			7.7	
8	6/13/85- 9/03/86	Fine			5.2-11.9	7.0-15.2

*Batch Tests

Figure 11.



OTE20 SUMMARY — COARSE & FINE
OCTOBER 1981 THROUGH SEPTEMBER 1986
OTE20, %
22
20
18
16
14
12
10
8
6
4
2
0
1981
1982
1983
1984
1985
1986
1987
YEARS
COARSE BUBBLE
FINE PORE
(TANK 3) □ HIGH GAS FLOW ⊠ (TANK 4)
(TANK 3) △ LOW GAS FLOW ▲ (TANK 4)
▲ ■ BATCH TEST
HIGH GAS FLOW AVERAGE
LOW GAS FLOW AVERAGE

Figure 12.

ALPHA SUMMARY — COARSE & FINE

OCTOBER 1981 THROUGH SEPTEMBER 1986

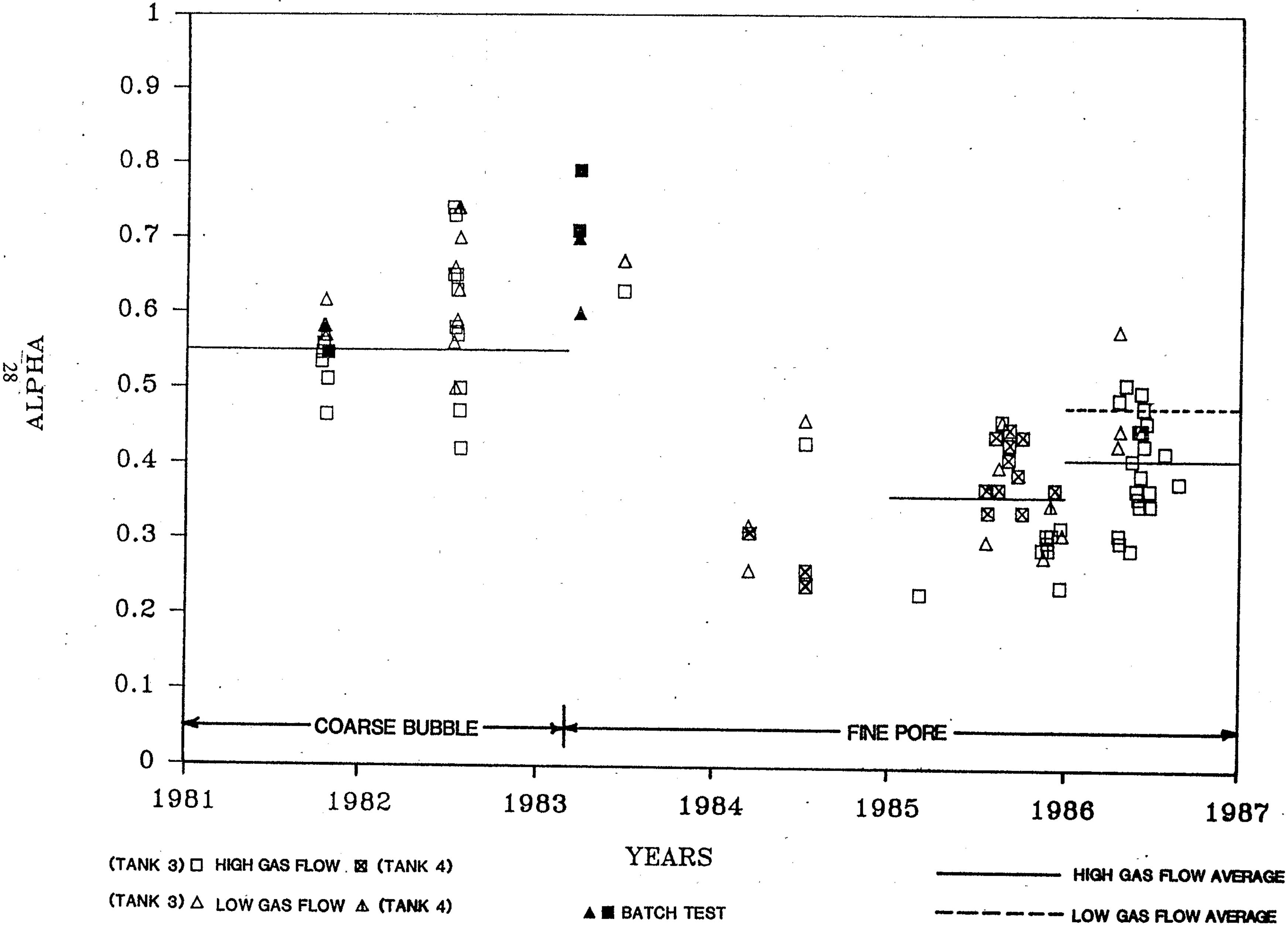


TABLE 7

Estimated Yearly Average OTE20 and Alpha Values For Both Aeration Systems

System	Time Period	Number of Tests	Gas Flow	OTE20, %	Alpha
Coarse	1981-3/83	25	High & Low	4.8	0.55
Fine	1985-1986	21	High	7.5	0.36
		7	Low	8.9	0.36
Fine	1986-1987	20	High	9.6	0.41
		4	Low	12.6	0.48

of tank 3 went from 17% to 6.4% (Study 5) and 11.8% (Study 6) all under low gas flows. The reason for the difference in transfer efficiency between the tanks may be due to the fact that tank 3 was hosed clean before it went into service for the clean water testing. Tank 4 did not receive any cleaning and had significant algae growth on the domes. The reason for the overall decline in transfer efficiency was discovered in the Fall of 1984 when aeration tanks 3 & 4 were drained and hosed. Approximately 15 and 40 domes were missing from tanks 3 and 4 respectively with many of the plastic bolts loose. All the plastic bolts were replaced by brass bolts and the dome density was increased. Thus, the low OTE20's measured before the cleaning (Studies 5 & 6) are a result of the poor condition of the aeration grids and coarsing due to missing domes. The one test of Study 7 in March 1985 at high gas flow yielded an OTE20 of 7.7%.

From June 1985 to September 1986, 66 flowing wastewater tests and 1 batch wastewater test were conducted (Study 8). The offgas and nonsteady state technique was employed during the final stage of the case study, with steady state analysis also performed. The measured OTE20's showed a large degree of variability during the study with results ranging from 5.2 to 15.2%. In 1985 the fine pore system had an OTE20 average of 7.5% and an alpha of 0.36 under high gas flows. Under low gas flows, the average values were 8.9% and 0.36. Average alpha values did not change due to the fact that low and high gas flow testing was conducted at approximately the same time of the day. Thus the wastewater effect on OTE20 remained constant. For 1986 the estimated OTE20 average was 9.6% with an average alpha of 0.41 under high gas flows. Under low gas flows conducted in the morning hours during low load, the average values were 12.6% and 0.48. Since no significant correlation existed between alpha and gas flow per dome as discussed later, the lower alpha value at high gas flow is due to the greater wastewater load in the afternoon compared to morning hours. Nocardia foam was a problem during these studies and tended to affect the OTE results. This effect is further defined in the "Problems encountered and solutions" section of this report.

VI. ASCE STUDY (JUNE 1985-SEPT. 1986)

A. Summary

Table 8 presents a summary of the individual tests conducted in 1985 and 1986 for Study 8. As mentioned, Nocardia foam present on the aeration tank was a major obstacle in performing the aeration tests and in some cases terminated a test. Often, Nocardia foam interfered with gas flow measurements and for a few tests provided unrealistically high OTE due to the oxygen uptake of the foam. A 24 hour study (tests 51-60) was conducted in June 1986 and a detailed analysis of the data can be found in a separate section.

Table 9 gives the process conditions for each test in Study 8. Weekly or monthly average BOD_5 and MLVSS values were used if the laboratory staff at Ridgewood did not perform the particular analysis on the test day. Tables 10 and 11 present the nonsteady state and off-gas aeration results for each aeration tank. Two gas flows are given, one measured using a differential manometer in the blower building and the other measured using the offgas analyzer. When good testing conditions are present (no foam) the two values agree within 10% or better. All aeration calculations using gas flow are performed with the manometer measured values. Figures 13 and 14 illustrate the effect of one aeration tank in service on the performance of the system. Low and high gas flow tests are indicated by the different symbols. The high gas flow average OTE20 and alpha for one tank in service is approximately 7.1% and 0.36, respectively. Two aeration tanks in operation yielded a high gas flow average OTE20 of 8.9% and 9.9% with alpha values of 0.39 to 0.42. The average OTE20 for low gas flows with two aeration tanks in service was 9.5 with an alpha value of 0.39. Thus, having one aeration tank in service with a detention time less than 2 hours results in reduced performance of the aeration equipment. These results are summarized in Table 12.

Table 13 and Figure 15 indicate that as gas flow to the aeration tank increases OTE20 decreases with an r^2 value of 42%. Gas flow per dome varied from 0.4 to 2.8 scfm/dome. Using the hypothesis testing procedure for the correlation coefficient (Blank, p. 521), it was

TABLE 8
Summary of Aeration Tests, 1985 & 1986

Test	Date 1985	Tank	Test Type	Comments
1	6/13	3	NSS	O_2 limited, septic conditions
2	6/18	3	NSS,SS	Heavy foaming Tank 3
3	6/20	3	NSS,SS	Heavy foaming Tank 3
4	6/25	4	NSS,SS	Light foam Tank 4
5	6/25	3	NSS,SS	Light foam Tank 3
6	7/11	4	NSS,SS	Tank 4 cleaned and refilled
7	7/18	4	NSS,SS	Light foam due to chlorination
8	7/18	3	NSS,SS	Tank 3 cleaned and refilled
9	7/25	4	NSS	Light foam due to chlorination
10	7/25	3	NSS	Light foam due to chlorination
11	8/7	3	OG	Batch Test-limited gas flow
12	8/9	4	OG,SS	Medium foam Tank 4 - insufficient gas flow measurement. OTE20 corrected for Nocardia foam uptake.
13	8/13	4	OG	Only 1 grid tested due to foam pulled into analyzer
14	8/15	4	OG,SS	Medium foam Tank 4 - gas flows could not be determined. OTE20 corrected for Nocardia foam uptake.
15	8/15	4	NSS,SS	Medium foam - Tank 4
16	9/3	4	OG	Heavy foam Tank 4 - gas flows could not be measured OTE for grid C estimated. OTE20 corrected for Nocardia foam uptake.
17	9/11	4	OG	Heavy foam Tank 4 - OTE20 corrected for Nocardia foam uptake.

(continued....)

TABLE 8 (cont'd)

Test	Date 1985,86	Tank	Test Type	Comments
18	9/11	4	OG	Heavy foam Tank 4 - gas flows >1500 scfm could not be measured. OTE20 corrected for Nocardia foam uptake
19	10/21/85	4	OG	Heavy foam tank 4-gas flow could not be determined.
20	10/24	4	OG	Heavy foam tank 4-gas flows could not be determined.
21	10/30	3	OG,SS	Medium foam-gas flows could not be determined. Tank 3 acid cleaned and refilled.
22	11/1	3	OG,SS	No foam-gas flow accurately measured
23	11/1	3	OG,SS	No foam-gas flow accurately measured
24	11/8	3	OG,SS	No foam-low gas flow test. Accurate measurement not obtained.
25	11/8	3	OG,SS	No foam-high gas flow test. Accurate measurement not obtained.
26	11/15		OG,SS	No foam-gas flow accurately measured
27	11/15	3	OG,SS	No foam-high gas flow. Gas flow accurately measured.
28	11/22	3	SS	No foam-OG tests 28-31 invalid due to leak in analyzer. SS results used in analysis.
29	12/11	3	OG,SS	No foam-gas flow not determined accurately. Tank 4 acid cleaned and refilled.
30	12/11	4	OG,SS	No foam-accurate gas flow measurement obtained.
31	12/18	3	OG,SS	No foam-low gas flow. Gas flow not determined accurately.

(continued...)

TABLE 8 (cont'd)

Test	Date 1986	Tank #	Test Type	Comments
32	4/21/86	3	OG,SS	Domes cleaned beginning of April by hosing. Low gas flow and dilute waste water due to heavy rain. One final clarifier out of service. (1 compressor on.)
33	4/21	3	NSS,SS	2 compressors on
34	4/22	3	OG,SS	1 compressor on
35	4/22	3	OG, NSS, SS	2 compressors on
36	4/23	3	OG	Linearity slightly off, moisture may have gotten into micro fuel cell. Final clarifier back in service. (1 compressor on.)
37	5/6	3	OG	Hoods caulked. (2 compressors on.)
38	5/15	3	OG,SS	Tank 4 down. All flow through Tank 3 (2 compressors on.)
39	5/22	3	OG,SS	Tank 4 down. Two compressors left on overnight. Nearly septic conditions and foam starting to develop. (2 compressors on.)
40	5/29	3	OG,SS	Tank 4 down. Primary clarifier overflowing and digestor supernatant overloading aeration tank. Nearly septic conditions, foam developing, and high uptake. (2 compressors on.)
41	6/2	3	OG,SS	Tank 4 put back in operation in morning. Lower uptakes and foam disappearing. (2 compressors on.)
42	6/4	3	OG,SS	Reaction time for micro fuel cell slowing down. Primary clarifier not overflowing and digestor supernatant not overloading aeration tank. (2 compressors on.)

(continued...)

TABLE 8 (cont'd)

Test	Date 1986	Tank #3	Test Type	Comments
43	6/4	3	OG,SS	Second compressor must be turned on between 8:00-9:00 AM.
44	6/5	3	OG,SS	2 compressors on
45	6/5	3	OG,SS	2 compressors on
46	6/10	3	OG,SS	2 compressors on
47	6/10	3	OG,SS	2 compressors on
48	6/12	3	OG	1 compressor shut off 8:00 P.M. last night due to humidity. Usually shut off at 3:00 A.M. Possibly septic conditions through the night. Test started at 8:00 A.M.
49	6/12	3	OG	Second compressor turned on at 9:00 A.M. with testing immediately following.
50	6/12	3	OG	Two compressors on, OTE dropping with increasing influent load. Test started at 10:00 A.M.
51-60	6/16-6/17	3	OG	Total of 10 runs throughout a 24-hour period.
61	6/30	3	OG	Nocardia foam covering entire tank (3"-6" thick). High uptake in foam. 2 compressors on. OTE20 corrected for Nocardia foam uptake
62	6/30	3	OG	2 compressors on. OTE20 corrected for Nocardia foam uptake.
63	7/08	3	OG	Foam covering entire tank (2'-3' thick). Poor testing conditions. 2 compressors on. Results not presented in report.

(continued...)

TABLE 8 (cont'd)

Test	Date 1986	Tank #	Test Type	Comments
64	7/31	3	OG	Foam covering entire tank (1/2 to 1' thick). Chlorine surface spray being employed to kill foam. Spray concentration is about 0.3 mg/ℓ of chlorine. 2 compressors on. Results not presented in report.
65	8/06	3	OG	No foam covering tank. Surface spray appears to be wiping out the foam. 2 compressors on.
66	8/21	3	OG	Tank 3 acid cleaned on 8/20. Back in operation that night with significant foam levels developing immediately. 2 compressors on. Results not presented in report.
67	9/03	3	OG	Foam level very low. 2 compressors on.

OG - offgas
NSS - nonsteady state
SS - steady state

TABLE 9

Process Conditions For All Tests, 1985 and 1986

		During Testing Period			Daily Average Values		
Test	Tanks in operation	Average Flow $Q_i + Q_R$ (MGD)	Average Detention Time, t_o (hrs)	Temperature C°	Primary Effluent BOD_5 (mg/1)	MLVSS mg/1	F/M[1] $\frac{\text{lbs } BOD_5\text{/day}}{\text{lbs. MLVSS}}$
1	1	–	–	–	–	–	–
2	2	3.7	3.9	21	115	2160	0.11
3	2	4.0	3.6	22	133[2]	3380	0.11
4	2	4.0	3.6	23	159	2060	0.15
5	2	4.1	3.5	22.5	159	2060	0.15
6	2	3.8	3.8	22	97	3450[2]	0.07
7	2	3.6	4.0	23	141[2]	2320	0.12
8	2	3.6	4.0	23	141[2]	2320	0.12
9	2	3.9	3.7	22	97	2120	0.09
10	2	3.5	4.1	22	97	2120	0.09
(11)	1	–	–	23	–	–	–
12	1	3.9	1.8	23	135[2]	1750	0.21
13	1	4.2	1.7	24	154	2650	0.25
14	1	3.8	1.9	24	191	1970	0.26
15	1	3.9	1.8	24	191	1970	0.24
16	1	4.0	1.8	23	114[2]	2710[2]	0.11
17	1	4.2	1.7	21	137[2]	1380	0.26
18	1	3.8	1.9	21	137[2]	1380	0.26
19	1	4.2	1.7	18	166	1960	0.22
20	1	3.8	1.9	18	124	3350	0.06

(continued....)

TABLE 9 (continued)

Test	Tanks in operation	During Testing Period: Average Flow $Q_i + Q_R$ (MGD)	Average Detention Time, t_o (hrs)	Temperature C°	Daily Average Values: Primary Effluent BOD_5 (mg/1)	MLVSS mg/1	F/M^1 lbs BOD_5/day / lbs. MLVSS
21	1	5.1	1.4	18	144	2140	0.17
22	1	4.0	1.8	18	162	1870^2	0.22
23	1	3.8	1.9	18	162	1870^2	0.22
24	1	5.1	1.4	17	150	1860^2	0.20
25	1	4.2	1.7	17.5	150	1860^2	0.21
26	1	4.0	1.6	17	74	1520	0.12
27	1	3.9	1.8	17	74	1520	0.12
28	1	4.4	1.4	17	117	1460	0.23
29	2	4.8	3.0	15	102	2330	0.10
30	2	4.0	3.6	15	102	2330	0.09
31	2	4.4	3.3	14	195	1860	0.23
32	2	5.6	2.6	15	118	1070	0.41
33	2	4.8	3.0	15	118	1070	0.41
34	2	5.6	2.6	15	118	880	0.48
35	2	3.8	3.8	15	118	880	0.48
36	2	4.8	3.0	15	118	1070^2	0.43
37	2	4.6	3.1	17.5	88	1750	0.12
38	1	4.4	1.6	18	126	810	0.48
39	1	4.8	1.5	20	138	1970	0.25
40	1	5.1	1.4	20	175	1500	0.44
41	2	4.6	3.1	20	123	1600	0.18

(continued....)

TABLE 9 (continued)

Test	Tanks in operation	During Testing Period: Average Flow $Q_i + Q_R$ (MGD)	Average Detention Time, t_o (hrs)	Temperature C°	Daily Average Values: Primary Effluent BOD_5 (mg/1)	MLVSS mg/1	F/M[1] lbs BOD_5/day / lbs. MLVSS
42	2	5.0	2.9	20	123	990	0.29
43	2	3.9	3.7	20.0	123	990	0.29
44	2	4.6	3.1	20.5	138	1400[2]	0.23
45	2	4.4	3.3	20.5	138	1400[2]	0.23
46	2	5.0	2.9	20.6	150	1210	0.30
47	2	4.6	3.1	20.6	150	1210	0.30
48	2	5.6	2.6	20.6	235	1970	0.29
49	2	6.7	2.1	20.6	235	1970	0.29
50	2	5.6	2.6	20.6	235	1970	0.29
61	2	4.9	2.9	21.5	153[2]	1900	0.22
62	2	4.5	3.2	21.5	153[2]	1900	0.19
63	2	4.8	3.0	23.8	153[2]	1970	0.18
64	2	4.4	3.3	24.5	153[2]	1970	0.17
65	2	5.5	2.6	24.5	153[2]	1420	0.25
66	2	5.2	2.8	25.0	116	1380	0.19
67	2	4.9	2.9	22.3	153[2]	1660	0.20

( ) Batch test - Off-Gas Training

1 F/M based on aeration tank and clarifier volumes

2 Weekly or monthly averages

TABLE 10

Nonsteady State and Offgas Aeration Results for Ridgewood Tank #3, 1985 & 1986

Test	Date 1985,86	Blowers in Operation	Manometer Measured Gas Flow G_m, scfm	Offgas Measured Gas Flow G_s, scfm	OTR20 lb O_2/hr	Dh_p	AE20 (e=60%) lb O_2/hp·hr	OTE20 %	Alpha
2	6/18/85	2	1070	-	94.5	34.0	1.7	8.6	0.37
3	6/20	1	890	-	68.0	27.6	1.5	7.4	0.30
5	6/25	1	860	-	80.6	27.0	1.8	9.1	0.37
8	7/18	1	900	-	88.8	26.2	2.0	9.9	0.40
10	7/25	1	870	-	103.5	26.6	2.3	11.5	0.46
21	10/30	2	1440	680	92.5	50.4	1.1	6.2	0.31
22	11/01	2	1450	1420	90.2	50.6	1.1	6.1	0.30
23	11/01	2	1450	1480	84.3	50.8	1.0	5.7	0.29
24	11/08	1	707	1160	67.8	22.0	1.9	9.2	0.35
25	11/08	2	1430	1590	92.4	49.0	1.1	6.2	0.31
26	11/15	2	1040	1130	92.8	33.0	1.7	8.7	0.37
27	11/15	2	1560	1650	109.6	54.4	1.2	7.0	0.37
29	12/11	2	1190	1350	65.0	38.8	1.0	5.2	0.24
31	12/18	1	720	920	61.0	19.2	1.9	8.1	0.31
32	4/21/86	1	290	280	38.0	9.3	2.5	12.9	0.43
33	4/21	2	620	-	53.7	18.6	1.7	8.4	0.31
34	4/22	1	292	-	108.8	22.5	2.9	15.2	0.58
35	4/22	2	771	-	118.0	31.0	2.3	11.6	0.49
36	4/23	1	760	680	91.7	25.6	2.2	11.6	0.45

(continued....)

TABLE 10 (cont'd)

Test	Date 1986	Blowers in Operation	Manometer Measured Gas Flow G_m, scfm	Offgas Measured Gas Flow G_s, scfm	OTR20 lb O_2/hr	Dh_p	AE20 (e=60%) lb O_2/hp·hr	OTE20 %	Alpha
37	5/06	2	1070	1400	131.8	31.4	2.5	11.9	0.51
38	5/18	2	1210	1380	81.4	37.7	1.3	6.5	0.29
39	5/22	2	1350	1610	120.6	46.0	1.6	8.6	0.41
40	5/29	2	1620	1570	113.0	55.1	1.3	6.8	0.37
41	6/02	2	990	1130	87.1	31.3	1.7	8.5	0.36
42	6/04	2	1040	1160	113.7	33.1	2.0	10.6	0.45
43	6/04	2	1050	1090	87.6	32.1	1.7	8.2	0.35
44	6/05	2	1050	1210	115.6	32.7	2.1	10.6	0.45
45	6/05	2	1060	1220	98.6	32.5	1.8	9.0	0.39
46	6/10	2	1030	1070	123.2	32.6	2.3	11.7	0.50
47	6/10	2	1000	1040	109.3	30.7	2.2	10.7	0.45
48	6/12	1	550	-	70.2	15.6	2.7	12.4	0.45
49	6/12	2	1000	980	118.9	28.7	2.5	11.4	0.48
50	6/12	2	890	1010	98.9	25.6	2.3	10.6	0.43
61*	6/30	2	970	1080	85.0	29.3	1.7	8.7	0.37
62	6/30	2	960	1120	80.8	28.9	1.7	8.4	0.35
65	8/06	2	890	1050	89.8	29.3	1.8	10.0	0.42
67	9/03	2	1000	1090	89.6	30.1	1.8	9.0	0.38

* Test 51-60 (24 Hour Study)

TABLE 11

Nonsteady State and Offgas Aeration Results for Ridgewood Tank #4, 1985 & 1986

Test	Date 1985	Blowers in Operation	Manometer Measured Gas Flow G_m, scfm	Offgas Measured Gas Flow G_s, scfm	OTR20 lb O_2/hr	Dh_p	AE20 (e=60%) lb O_2/hp·hr	OTE20 %	Alpha
4	6/25	2	1260	–	96.5	40.2	1.4	7.4	0.34
6	7/11	2	1190	–	119.4	36.1	2.0	9.7	0.44
7	7/18	2	1230	–	103.7	37.4	1.7	8.1	0.37
9	7/25	2	1030	–	115.5	32.1	2.2	10.8	0.46
12	8/09	2	1860	1480	130.7	57.5	1.4	6.8	0.41
14	8/15	2	1460	1620	123.8	48.2	1.7	8.5	0.43
15	8/15	2	1460	–	135.3	48.2	1.7	9.0	0.45
16	9/03	2	1600	–	115.2	51.9	1.3	7.2	0.39
17	9/11	2	1290	1350	92.2	36.9	1.5	7.1	0.34
18	9/11	2	1860	1360	135.4	62.1	1.3	7.3	0.44
19	10/21	2	1200	1040	76.4	38.1	1.2	6.4	0.29
20	10/24	1	840	–	61.0	25.3	1.4	7.0	0.28
30	12/11	2	1190	1280	88.7	38.1	1.4	7.2	0.32

Figure 13.

EFFECT OF ONE TANK IN SERVICE ON OTE20

JUNE 1985 through SEPTEMBER 1986

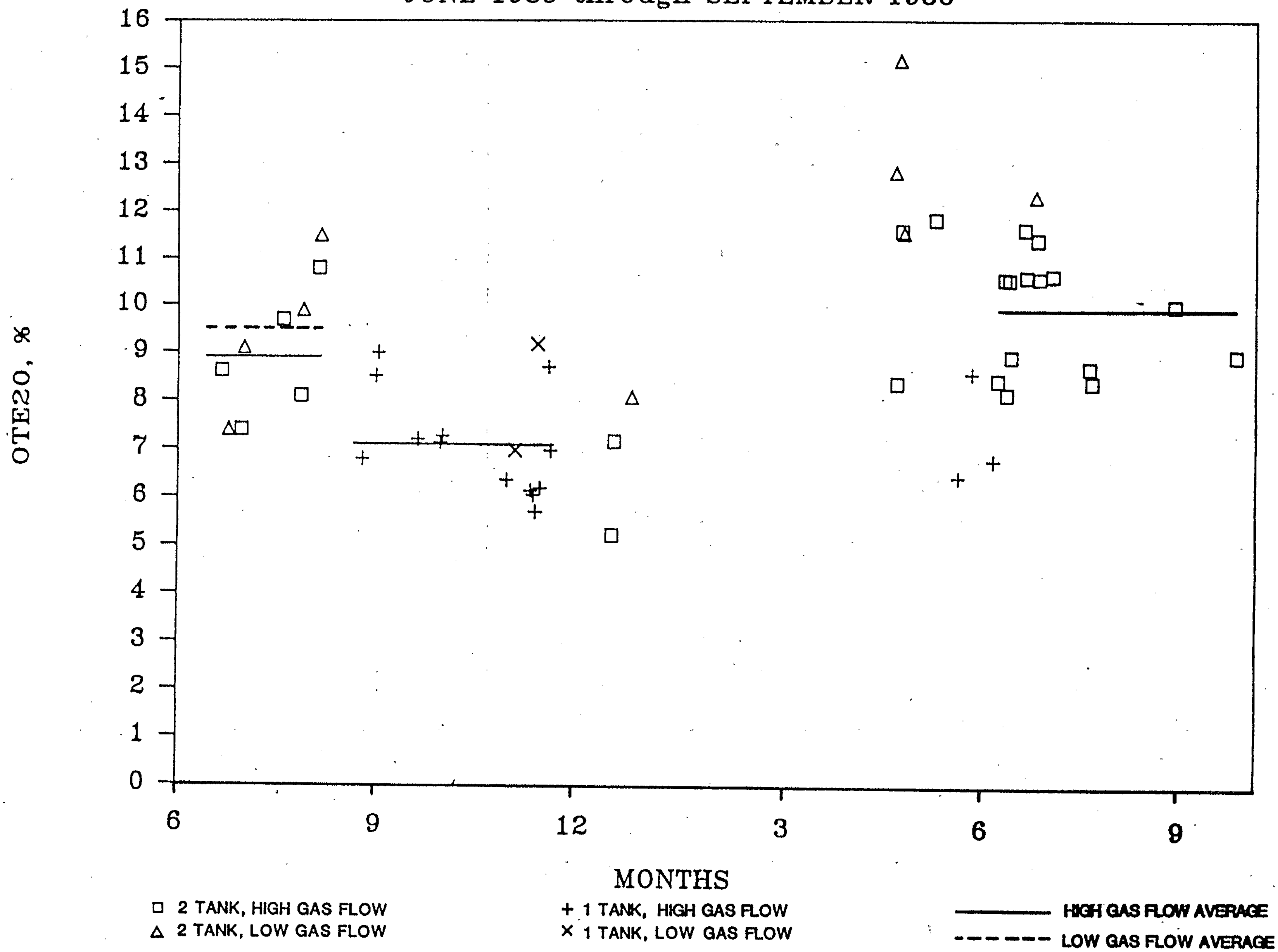


Figure 14.

EFFECT OF ONE TANK IN SERVICE ON ALPHA

JUNE 1985 through SEPTEMBER 1986

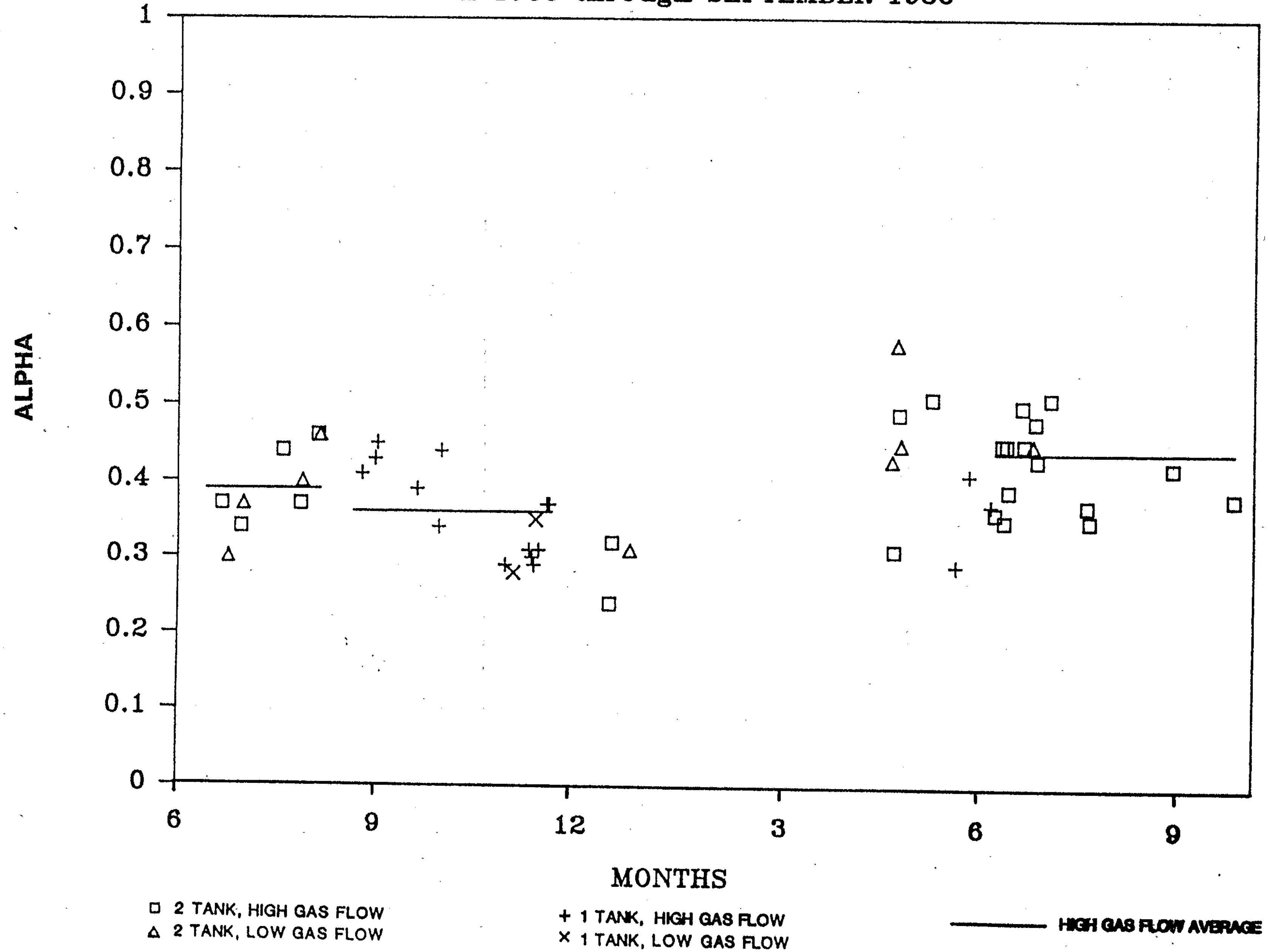


TABLE 12

Effect of One Aeration Tank in Service on OTE20 and Alpha

		One Aeration Tank in Service		Two Aeration Tanks in Service	
Tests	Year	OTE20	Alpha	OTE20	Alpha
1-10	1985			8.9%	0.39
				9.5%*	0.39*
11-27	1985	7.1%	0.36		
38-40	1986	7.3%	0.36		
41-67	1986			9.9%	0.42

* Low gas flow averages

TABLE 13

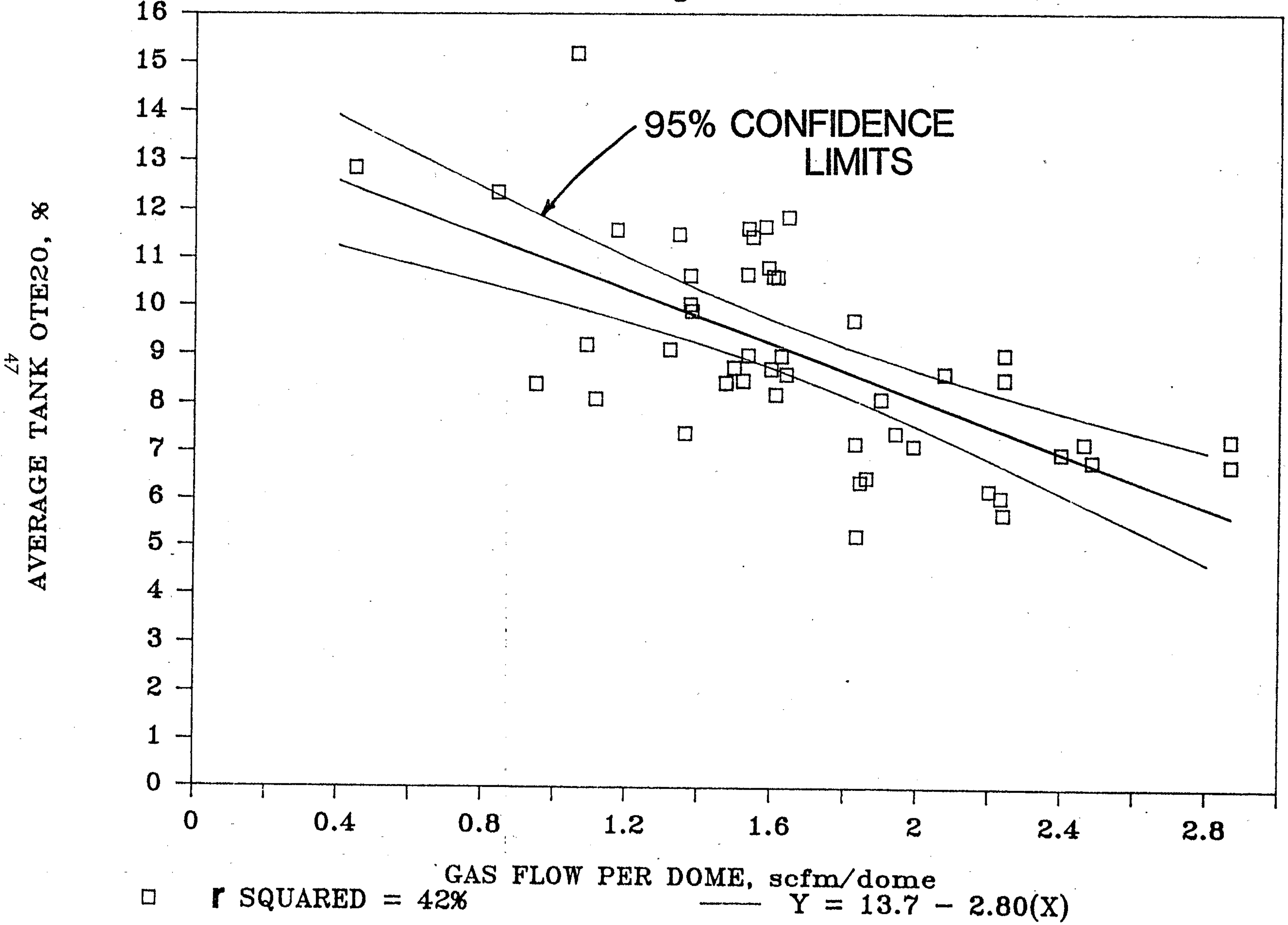
Parameter Correlation, 1985 & 1986

Type of Data	y Variable	x Variable	No. of Data Points	Intercept	Slope	r^2(%)	Significant Correlation
Tank Averages	OTE20	Gas flow per dome	48	13.7	-2.80	42	yes
Tank Averages	Alpha	Gas flow per dome	48	0.44	-0.026	3	no
Grid Values	OTE20	Unit oxygen uptake rate	64	12.2	-0.119	13	yes
Tank Averages	OTE20	Unit oxygen uptake rate	41	10.3	-0.0846	9	no

Figure 15.

EFFECT OF GAS FLOW ON OTE20

JUNE 1985 through SEPTEMBER 1986



determined that r^2 was large enough to be statistically significant. Table 13 also shows the effect of unit O_2 uptake on average tank OTE20. Higher unit uptake rates cause the OTE20 to decrease. This effect is further defined with grid unit uptake values impacting grid OTE20. The higher unit uptakes in grid A result in lower OTE20's, while grids C & D have the lowest unit uptakes and the highest OTE20's. A significant correlation exists for the grid values, but not for the tank averages. This is due to tank average values removing the variability within the tank. Therefore, the impact of unit O_2 uptake on OTE20 is more significant with respect to location in the tank than with average values over a period of time.

Tables 14 and 15 present the steady state test conditions and results. Typically, the steady state OTE20 values differed from the offgas OTE20's by ± 20% with higher differences not uncommon. The steady state technique relies on an accurate measurement of the oxygen uptake rate in the tank. Often, the aeration tanks at Ridgewood were oxygen limited with the steady state OTE20 on the average greater by approximately 11-12% than the offgas or nonsteady state values.

TABLE 14

Steady State Test Conditions, 1985 & 1986

Test	Average Flow (Q_i+Q_R) MGD	Detention Time, to hrs	Field Oxygen Saturation Value, $C^*_{\infty f}$ mg/ℓ	Average Tank Dissolved Oxygen, C_r mg/ℓ	Average Tank Oxygen Uptake, R mg/ℓ/hr	Average Unit Tank Oxygen Uptake Rate, mg/gVSS/hr
2	3.7	3.9	9.96	3.9	23.3	10.8
3	4.0	3.6	9.88	1.0	30.8	14.2
4	4.0	3.6	9.68	2.4	39.9	18.4
5	4.1	3.5	9.77	1.2	33.4	15.4
6	3.8	3.8	9.87	2.4	44.9	20.8
7	3.6	4.0	9.78	2.7	40.5	18.7
8	3.6	4.0	9.74	1.6	46.2	21.4
12	3.9	1.8	9.72	0.7	61.8	28.6
14	3.8	1.9	9.49	0.7	66.2	30.6
15	3.9	1.8	9.49	0.6	63.3	29.3
21	5.1	1.4	10.79	3.4	23.1	10.7
22	4.0	1.8	10.73	0.9	36.4	16.8
23	3.8	1.9	10.73	0.4	38.0	17.6
24	5.1	1.4	10.95	0.5	23.9	11.0
25	4.2	1.7	10.86	0.8	29.7	13.7
26	4.4	1.6	11.06	2.9	24.3	11.2
27	3.9	1.8	11.05	3.1	28.3	13.1
28	5.1	1.4	11.07	3.2	24.3	16.6
29	4.8	3.0	11.45	3.3	17.1	7.9
30	4.0	3.6	11.45	3.5	33.8	15.6
31	4.4	3.3	11.66	2.1	20.3	9.4
32	5.6	2.6	11.26	1.4	12.7	5.9
33	4.8	3.0	11.26	2.8	18.3	8.5
34	5.6	2.6	11.31	1.3	13.4	6.2
35	3.8	3.8	11.30	5.4	13.1	6.1
38	4.4	1.6	10.83	1.2	26.5	12.3
39	4.8	1.5	10.28	1.5	35.8	16.6
40	5.1	1.4	10.27	0.1	71.9	33.2

TABLE 14 (cont'd)

Test	Average Flow (Q_i+Q_R) MGD	Detention Time, to hrs	Field Oxygen Saturation Value, $C^*_{\infty f}$ mg/ℓ	Average Tank Dissolved Oxygen, C_r mg/ℓ	Average Tank Oxygen Uptake, R mg/ℓ/hr	Average Unit Tank Oxygen Uptake Rate, mg/gVSS/hr
41	4.6	3.2	10.23	1.6	30.2	14.0
42	5.0	2.9	10.37	3.7	25.1	11.6
43	3.9	3.7	10.33	2.3	28.6	13.2
44	4.6	3.1	10.20	2.9	34.4	15.9
45	4.4	3.3	10.19	1.8	39.3	18.2
46	5.0	2.9	10.24	3.2	32.0	14.8
47	4.6	3.1	10.23	2.4	35.8	16.6
48	5.6	2.6	10.09	0.5	29.7	13.7
49	6.7	2.1	10.13	0.6	36.6	16.9
50	5.6	2.6	10.13	0.9	31.1	14.4
61	4.9	2.9	9.94	0.6	64.7	29.9
62	4.5	3.2	9.95	0.4	58.9	27.2
65	5.5	2.6	9.48	2.7	27.1	12.5

TABLE 15

Steady State Results, 1985 & 1986

Test	Oxygen Transfer Coeff. K_La_f, 1/hr	Standard Oxygen Transfer Coeff. K_La_{f20}, 1/hr	SS[1] OTE20, %	NSS[1] OTE20, %	OG[1] OTE20, %	Steady State Difference from Offgas or NSS OTE20[2] % Diff.
2	4.0	3.9	9.1	8.6		+ 5.8
3	3.5	3.3	9.3	7.4		+25.7
4	5.6	5.2	10.2	7.4		+37.9
5	4.0	3.7	10.7	9.1		+17.6
6	6.1	5.8	12.1	9.7		+24.7
7	5.8	5.4	10.8	8.1		+33.3
8	5.7	5.3	15.2	9.9		+53.5
12	6.9	6.4	8.5		6.8	+25.0
14	7.6	6.9	11.7		8.5	+37.6
15	7.1	6.5	11.0			
21	3.4	3.6	6.2		6.2	0.0
22	3.8	3.9	6.7		6.1	+10.2
23	3.7	3.9	6.6		5.7	+14.9
24	2.3	2.5	8.7		9.2	-5.6
25	3.0	3.2	5.5		6.2	-12.2
26	3.2	3.4	8.1		8.7	-6.6
27	3.8	4.0	6.4		7.0	-8.3
28	3.4	3.7	8.5			
29	2.2	2.5	5.2		5.2	-0.7
30	4.4	4.9	10.2		7.2	+42.4
31	2.2	2.5	8.6		8.1	+6.1
32	1.3	1.5	12.7		12.9	-1.03
33	2.3	2.6	10.3	8.4		+22.6
34	1.4	1.6	12.8		15.2	-15.8
35	2.5	2.8	8.9	7.2	11.6	+19.1, -23.3
38	2.8	2.9	6.0		6.5	-7.2
39	4.2	4.2	7.7		8.6	-10.6

(continued...)

TABLE 15 (cont'd)

Test	Oxygen Transfer Coeff. K_La_f, 1/hr	Standard Oxygen Transfer Coeff. K_La_{f20}, 1/hr	SS[1] OTE20, %	NSS[1] OTE20, %	OG[1] OTE20, %	Steady State Difference from Offgas or NSS OTE20[2] % Diff.
40	7.1	7.1	10.8		6.8	+58.4
41	3.5	3.5	8.8		8.5	+ 4.1
42	3.9	3.9	9.3		10.6	−12.3
43	3.6	3.6	8.6		8.2	+ 4.6
44	4.8	4.7	11.2		10.6	+ 5.3
45	4.8	4.7	11.0		9.0	+22.7
46	4.7	4.7	11.2		11.7	− 4.1
47	4.7	4.6	11.4		10.7	+ 7.0
48	3.1	3.1	13.9		12.4	+12.4
49	3.9	3.8	9.4		11.4	−18.1
50	3.4	3.4	9.3		10.6	−12.9
61	7.0	6.7	17.0		8.7	+95.4
62	6.2	6.0	15.4		8.4	+83.3
65	4.1	3.7	10.3		10.0	+ 2.4

[1] SS = Steady State, NSS = Nonsteady State, OG = Offgas

[2] $\% \text{ Diff.} = \dfrac{\text{SS OTE20} - \text{OG or NSS OTE20}}{\text{OG or NSS OTE20}}$

B. ASCE 24 Hour Study (June 16-17, 1986)

1. Description of Study

On June 16-17, 1986 a 24 hour study was performed at the Ridgewood Wastewater Treatment Plant. The purpose of this study was to examine the variability in OTE20 during a day and attempt to correlate OTE20 with changing process conditions. The study consisted of both offgas and steady state analyses conducted on Aeration Tank #3 throughout the day. The aeration tank was analyzed at the center point of each grid for a total of 4 stations. The first test, Test 51, started at 8:50 a.m. on June 16th and the last test, Test 60, ended at 8:00 a.m. on June 17th for a total of 10 tests. Eight of the tests were performed with 2 compressors on, while the remaining two tests had only 1 compressor on. The one compressor runs were performed at 3:30 and 6:30 a.m. on June 17th. A summary of the study can be found in Table 16.

During each offgas test, a wastewater sample was taken at each station to measure the oxygen uptake rate. Also, dissolved oxygen concentrations were measured at each station. The oxygen uptake rate and dissolved oxygen concentration were both measured using YSI Model 57 probes with the oxygen uptake rate being recorded on a Cole Parmer recorder.

The primary clarifier effluent was sampled hourly using an ISCO sequential automatic sampler to determine changing influent conditions. The samples were kept on ice until soluble TOC and total suspended solids analyses were conducted the following day. To assist in monitoring the changing influent conditions, the dissolved oxygen concentration was continuously recorded in Grid A (influent) throughout the study.

2. Plant Conditions

a) Plant Characteristics

Table 17 presents the plant characteristics for the 24 hour study and for the month of June. The daily average influent flow during the 24 hour study, 2.8 mgd, was 9.7% lower than the monthly average of 3.1 mgd. Figure 16 illustrates the influent flow variability

TABLE 16

Description of 24 Hour Study

Test	Date (June 1986)	Military Time, Hours	# Blowers Used	Comment
51	16	0850-1040	2	Second blower turned on at 8:20 a.m.
52	16	1200-1330	2	
53	16	1500-1630	2	
54	16	1800-1910	2	
55	16	2050-2140	2	
56	16-17	2350-0030	2	
57	17	0200-0300	2	
58	17	0310-0410	1	One blower turned off at 3:00 a.m.
59	17	0610-0700	1	
60	17	0710-0800	2	Second blower turned on at 7:00 a.m.

Locations sampled = 4

Type of Tests = Offgas and Steady State

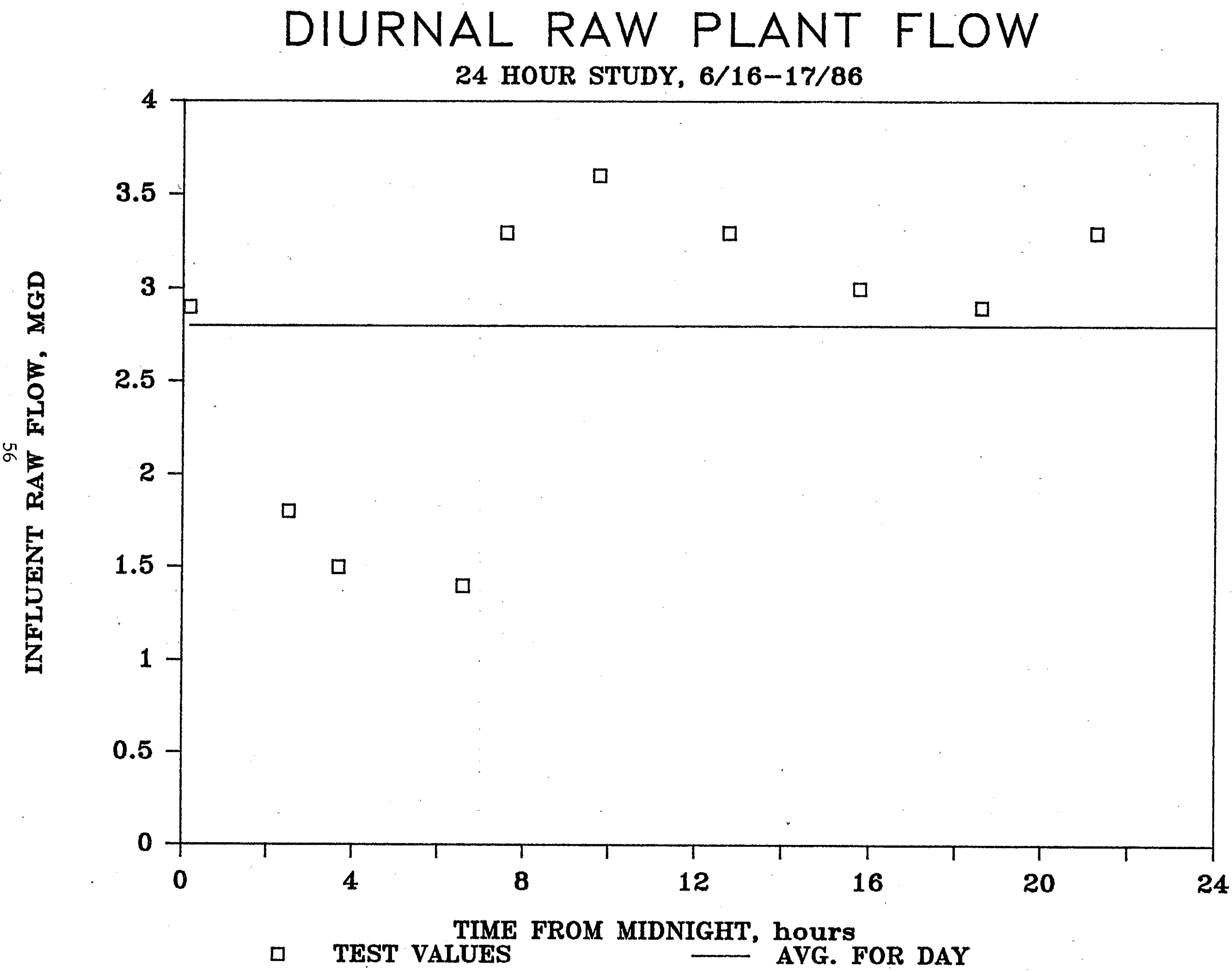
TABLE 17

Plant Characteristics During June 1986

Average Values

	Month of June	During 24 Hour Study, 16-17 June	% Difference from Monthly Value
Flow; (MGD)			
RAW	3.1	2.8	-9.7
RAS	1.3	1.3	0
WAS	0.108	0.124	+14.8
BOD_5; (mg/ℓ)			
Plant Influent	229	198	-13.5
Primary Clarifier Effluent	198	174	-12.1
Plant Effluent	19	18	-5.3
% Removal	91.7	90.9	-0.9
Suspended Solids; (mg/ℓ)			
Plant Influent	195	223	+14.4
Primary Clarifier Effluent	182	155	-14.8
Plant Effluent	9	6	-33.3
% Removal	95.4	97.3	+2.0
MLVSS (mg/ℓ)	1654	1972	+19.2
Waste Sludge Concentration, mg/ℓ VSS	7710		
NH_4^+-N; (mg/ℓ)			
Primary Clarifier Effluent	63.1	64.8	+0.3
Plant Effluent	27.7	49.3	+43.8
NO_3^--N; (mg/ℓ) - Plant Effluent	12.1	7.4	-38.8
F/M (lb BOD_5/lb MLVSS-day)	0.29	0.19	-34.5
Sludge Age, days	2.4	2.6	+8.3

Figure 16.


DIURNAL RAW PLANT FLOW
24 HOUR STUDY, 6/16–17/86
INFLUENT RAW FLOW, MGD
4
3.5
3
2.5
2
1.5
1
0.5
0
0
4
8
12
16
20
24
TIME FROM MIDNIGHT, hours
TEST VALUES
AVG. FOR DAY

during the study with peak flow occurring at 10:00 a.m. and low flow conditions at 6:00 a.m. The BOD_5 and suspended solids removals for both the aeration study and the month of June were excellent - from 90 to 97%. Partial nitrification was occurring. The food to mass ratio (F/M) was significantly lower during the aeration study, 0.19 lb BOD_5/lb MLVSS, due to the combination of reduced influent BOD_5 and increased MLSS concentration. Overall plant characteristics for the 24 hour study were considered typical and provided a good opportunity to evaluate the performance of the aeration system.

b) Influent Load Variability

The diurnal total suspended solid (TSS) and soluble TOC loads to the aeration tank are presented in Table 18. The daily average TSS load is 6625 lb/day, while the soluble TOC load is 557 lb/day. Figures 17 through 20 illustrate the primary clarifier effluent TSS and BOD_5 concentrations and loads. At 9:00 a.m. the TSS concentration was 1025 mg/ℓ while the load is 30,000 lb/day. This is due to secondary sludge wasted during the night to the primary clarifier being flushed out as the plant influent flow increased from 1.4 to 3.3 mgd between 6:00 and 8:00 a.m., resulting in peak solid loadings to the aeration tank. The WAS for the previous night was 133,000 gal/day, 19% higher than the monthly average. Soluble TOC load starts increasing at 6:00 a.m. and remains above average from noon to midnight, with peak conditions occurring between 8:00 and 10:00 p.m.

3. Results

a) Offgas

1. Diurnal OTE20 and Alpha Variability

Table 19 gives the aeration results for each test conducted in the 24 hour study. Table 20 presents the average OTE20 and alpha values for the day using a total mass method. This method sums the mass of oxygen transferred over a day and divides it by the sum of mass of oxygen supplied over a day;

$$OTE = \frac{\Sigma \text{ Mass } O_2 \text{ Transferred}}{\Sigma \text{ Mass } O_2 \text{ Supplied}}$$

TABLE 18

Diurnal Load to Aeration Tank (24 hour study)

Date 1986	Time from Midnight hours		Primary Clarifier Effluent Concentration, mg/l TSS	Soluble TOC	Plant Raw Flow, MGD	Primary Clarifier Effluent Load, lb/day TSS	Soluble TOC
6/16		Midnight	213	24.0	2.9	5152	580
6/17	0100	1.0	136	20.9	2.5	2836	436
6/17	0200	2.0	113	17.7	2.0	1885	295
6/17	0300	3.0	72	16.5	1.7	1021	234
6/17	0400	4.0	94	14.4	1.5	1176	180
6/17	0500	5.0	61	14.7	1.5	738	178
6/17	0600	6.0	73	12.8	1.4	852	149
6/17	0700	7.0	228	16.8	2.2	4183	308
6/17	0800	8.0	218	17.2	3.4	6182	488
6/16	0900	9.0	1025	23.2	3.5	29920	677
6/16	1000	10.0	285	19.0	3.6	8557	570
6/16	1100	11.0	255	17.9	3.5	7443	523
6/16	1200	Noon	420	22.6	3.4	11910	641
6/16	1300	13.0	430	21.5	3.3	11834	592
6/16	1400	14.0	283	26.0	3.2	7553	694
6/16	1500	15.0	310	32.2	3.1	8015	832
6/16	1600	16.0	183	30.3	3.0	4579	758
6/16	1700	17.0	215	34.9	2.9	5200	844
6/16	1800	18.0	193	22.9	2.9	4668	554
6/16	1900	19.0	201	29.4	3.0	5029	736
6/16	2000	20.0	318	33.8	3.1	8222	874
6/16	2100	21.0	270	35.5	3.3	7431	977
6/16	2200	22.0	320	34.3	3.2	8540	915
6/16	2300	23.0	235	31.2	3.1	6076	807
		Average	260	23.7	2.8	6625	557

Figure 17. DIURNAL TSS CONCENTRATION

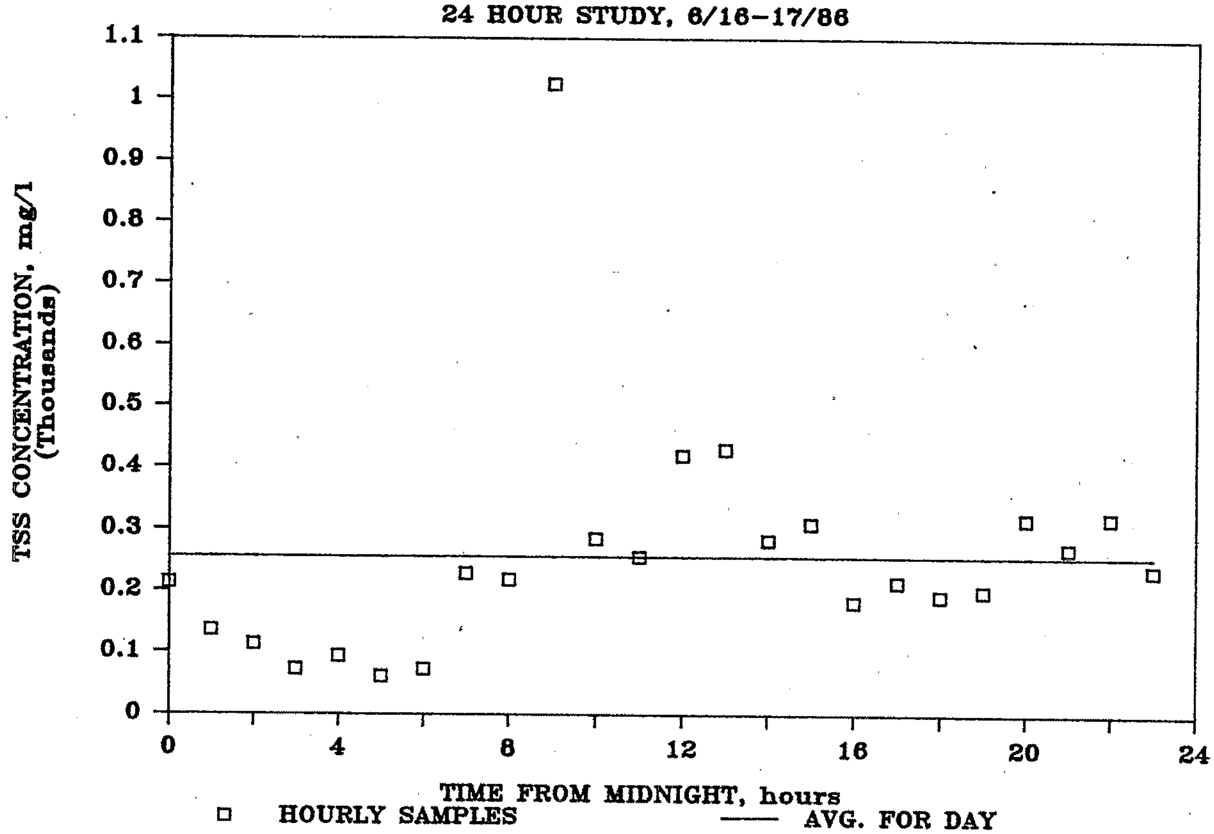


Figure 18. DIURNAL SOLUBLE TOC CONCENTRATION

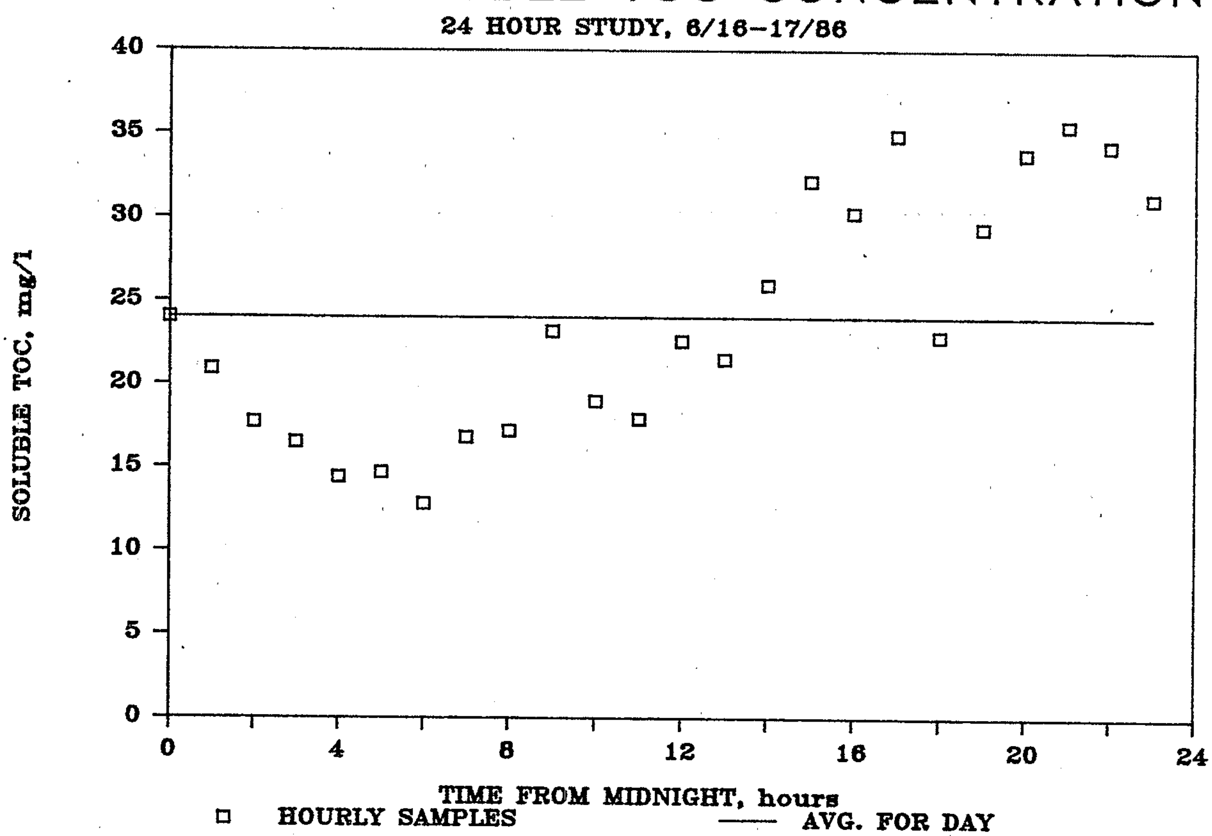


Figure 19. DIURNAL TSS LOAD

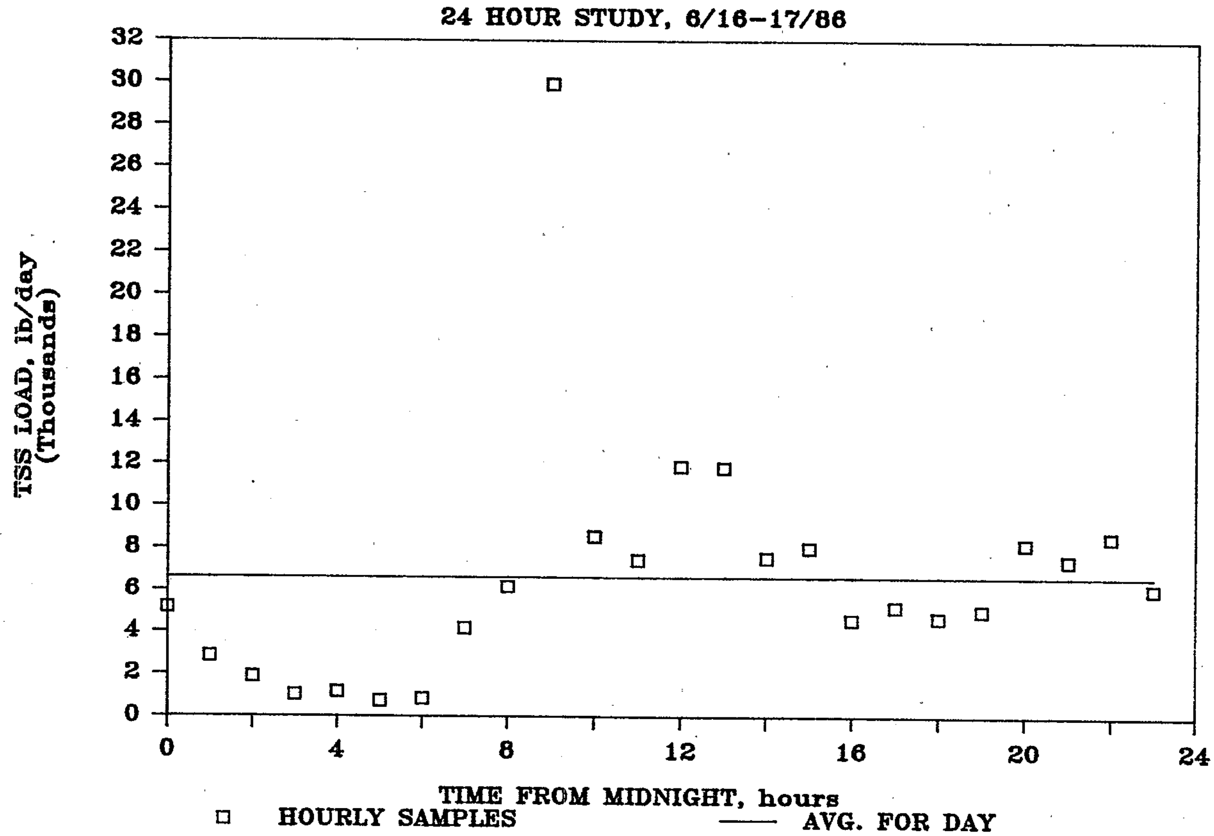


Figure 20. DIURNAL SOLUBLE TOC LOAD

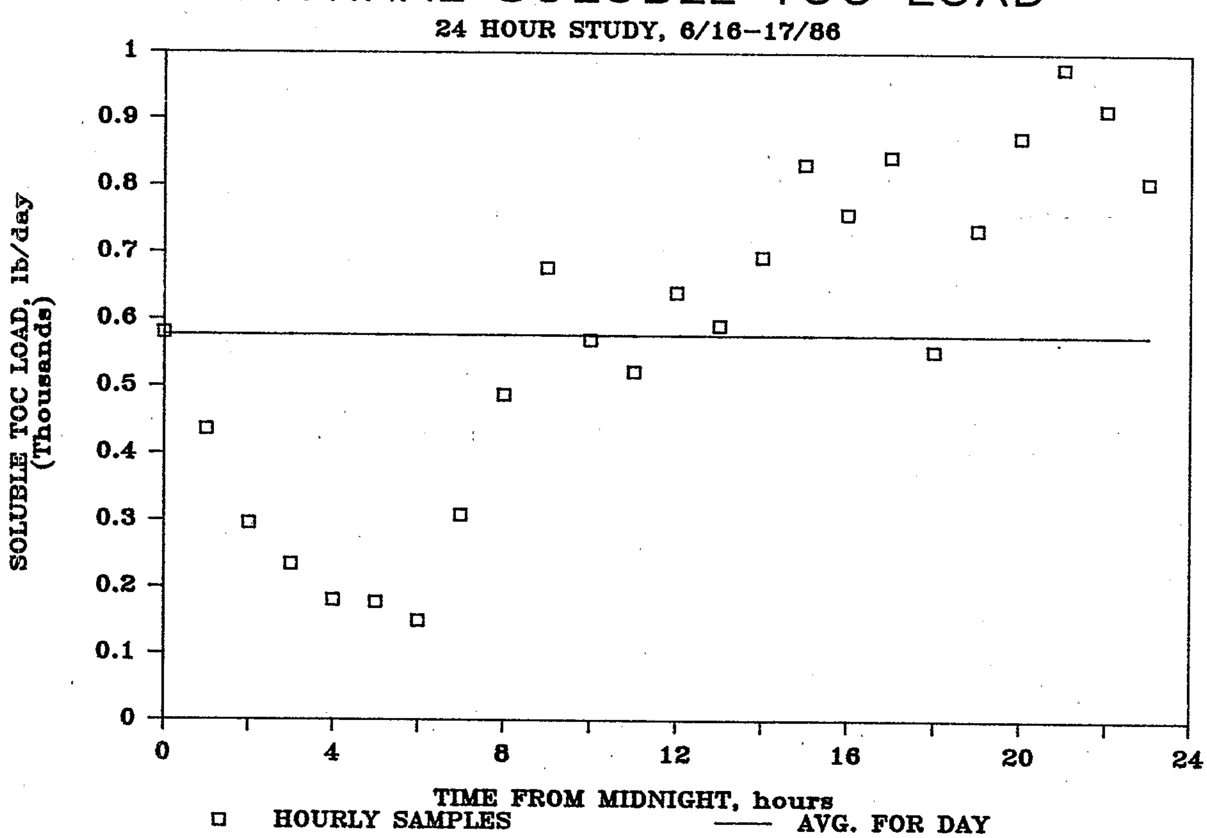


TABLE 19

Offgas Aeration Results for 24 Hour Study

Test	Date June 1986	Blowers in Operation	Dhp	AE20 (e=60%) lb O_2/hp·hr	OTR20 lb O_2/hr	OTE20 %	Alpha
51	16	2	33.4	2.4	134.4	11.7	0.51
52	16	2	36.0	2.0	120.1	9.7	0.44
53	16	2	35.1	2.1	122.7	10.0	0.45
54	16	2	35.3	2.2	129.4	10.4	0.47
55	16	2	35.3	2.0	116.9	9.5	0.43
56	16–17	2	35.8	2.1	122.4	9.9	0.45
57	17	2	42.0	2.0	142.2	11.0	0.51
58	17	1	16.7	2.8	78.4	12.0	0.45
59	17	1	15.6	2.9	74.3	13.1	0.47
60	17	2	35.6	2.6	159.9	13.1	0.59

TABLE 20

Daily Average OTE20 and Alpha (Total Mass Method, 24 Hour Study)

Test	Date June 1986	Avg. Testing Time Range hours	*Time Represented hours	Manometer Measured Gas Flow, G_m scfm	Rate Oxygen Supplied** lb O_2/hr	OTE20 %	Rate Oxygen Transferred lb O_2/hr	Mass Oxygen Supplied lb O_2	Mass Oxygen Transferred lb O_2
51	16	0850-1040	2.59	1105	1149	11.7	134.4	2976	349
52	16	1200-1330	3.00	1203	1251	9.7	120.1	3753	363
53	16	1500-1630	2.92	1187	1234	10.0	122.7	3599	360
54	16	1800-1910	2.75	1194	1242	10.4	129.4	3415	356
55	16	2050-2140	2.80	1194	1242	9.5	116.9	3471	330
56	16-17	2350-0030	2.63	1197	1245	9.9	122.4	3268	324
57	17	0200-0300	1.75	1249	1299	11.0	142.2	2273	250
58	17	0310-0410	2.04	626	651	12.0	78.4	1328	160
59	17	0610-0700	1.96	547	569	13.1	74.3	1112	145
60	17	0710-0800	1.59	1178	1225	13.1	159.9	1942	253
							Total =	27137	2891

Total Mass Supplied = 27137 lb O_2

Total Mass Transferred = 2891 lb O_2

Avg. Rate Supplied = 27137/24 = 1131 lb O_2/hr

Avg. Gas Flow = 1131/1.04 = 1088 scfm

Avg. βSOTE = 23.0% (From Figure 8 using β = 0.99)

Avg. OTE20 = 2891/27137 x 100 = 10.7%

Avg. Alpha = 10.65/23.0 = 0.46

* Total hours that individual tests represent in a day

** $$\frac{\text{lb } O_2}{\text{hr}} = 0.075 \left[\frac{.209 \text{ moles } O_2}{\text{mole air}}\right]\left[\frac{32 \text{ g/mole } O_2}{29 \text{ g/mole air}}\right]\left[\frac{60 \text{ min}}{\text{hr}}\right] G_m = 1.04\ G_m$$

resulting in an OTE20 of 10.7%. The average gas flow was 1088 scfm resulting in a βSOTE of 23.0%. Thus the average alpha for the day was 0.46. Time weighted averages resulted in an OTE20 of 10.8% and an alpha of 0.47, approximately the same as the previous mass weighted values.

Figures 21 and 22 illustrate the variability in OTE20 and alpha throughout the day with the high values measured at 7:00-8:00 a.m. while the low values occurred around noon. This tends to correlate with the soluble TOC load data illustrated in Figure 20. As the soluble TOC load starts increasing around 6:00 a.m., the OTE20 starts decreasing around 8:00 a.m. Thus, there is a lag time of approximately 2 hours before the increasing load fully impacts the aeration tank. This is explained by aeration tank detention times of approximately 3 hours. The soluble TOC load remains above average from noontime on, while the OTE20 is below average for the remainder of the day. The drop in alpha at 3:30 and 6:30 a.m. is explained by oxygen limitation caused by reduced gas flows with only one compressor on.

2. Longitudinal OTE20 and Alpha Variability

Table 21 presents the OTE20 and alpha values for each grid and Figures 23 and 24 illustrate longitudinal effect on OTE20 and alpha, respectively. OTE20 increases from 9.4% at the influent end to 12.5% at the effluent end. Alpha reacts the same, increasing from 0.39 to 0.54. This is explained by reduced substrate concentrations near the effluent end of the aeration tank.

3. Gas Flow and Dissolved Oxygen Variability

Table 22 and Figures 25 and 26 present the diurnal gas flow and grid dissolved oxygen concentrations for the 24 hour study. Only one blower was in operation between 3:00 and 7:00 a.m. with gas flows of approximately 500-700 scfm. Figures 27 and 28 illustrate the tapered air effect on station average gas flow and dissolved oxygen concentrations. Grid A receives almost twice the gas flow of grids C and D. The highest average dissolved oxygen occurs in grid B, 2.3 mg/ℓ, with the tapered air decreasing it to 1.9 and 1.5 mg/ℓ in grids C and D, respectively.

Figure 21.

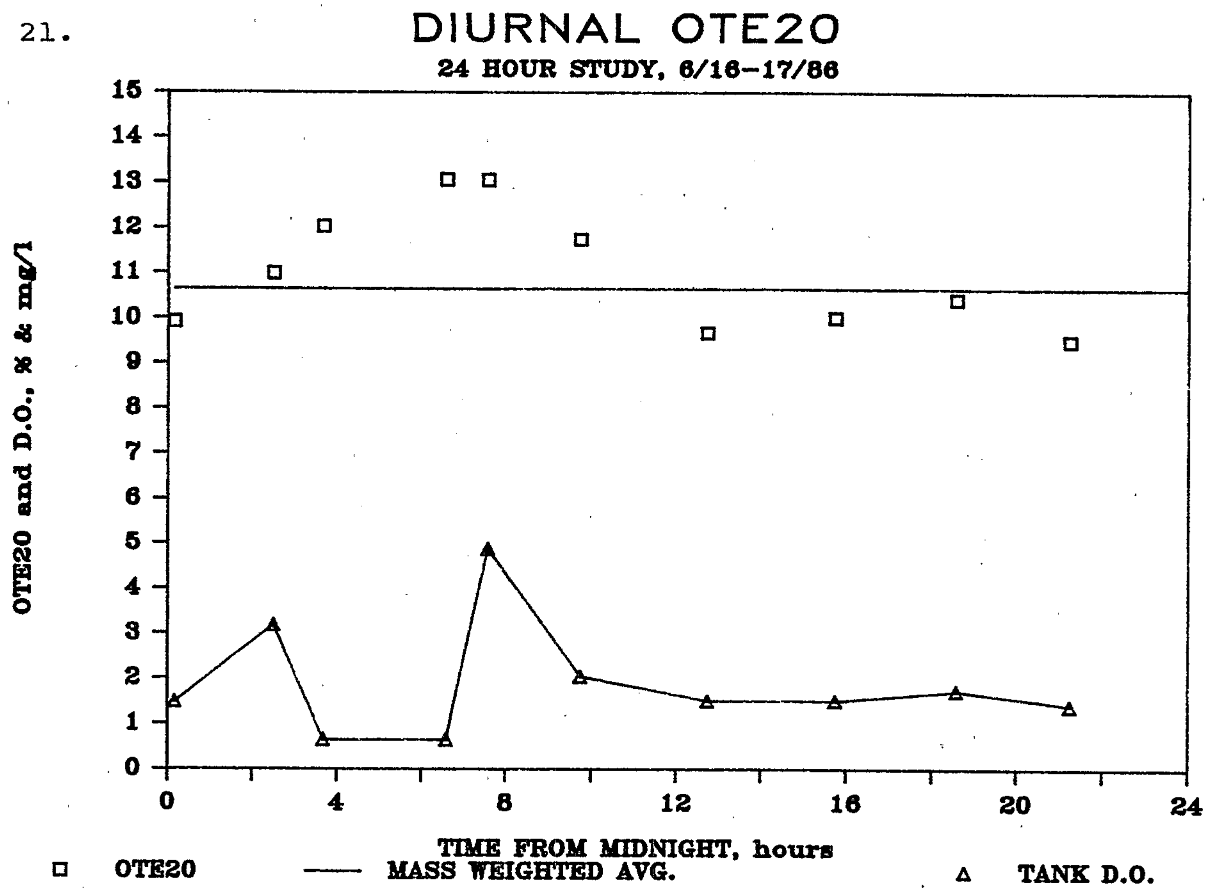


Figure 22.

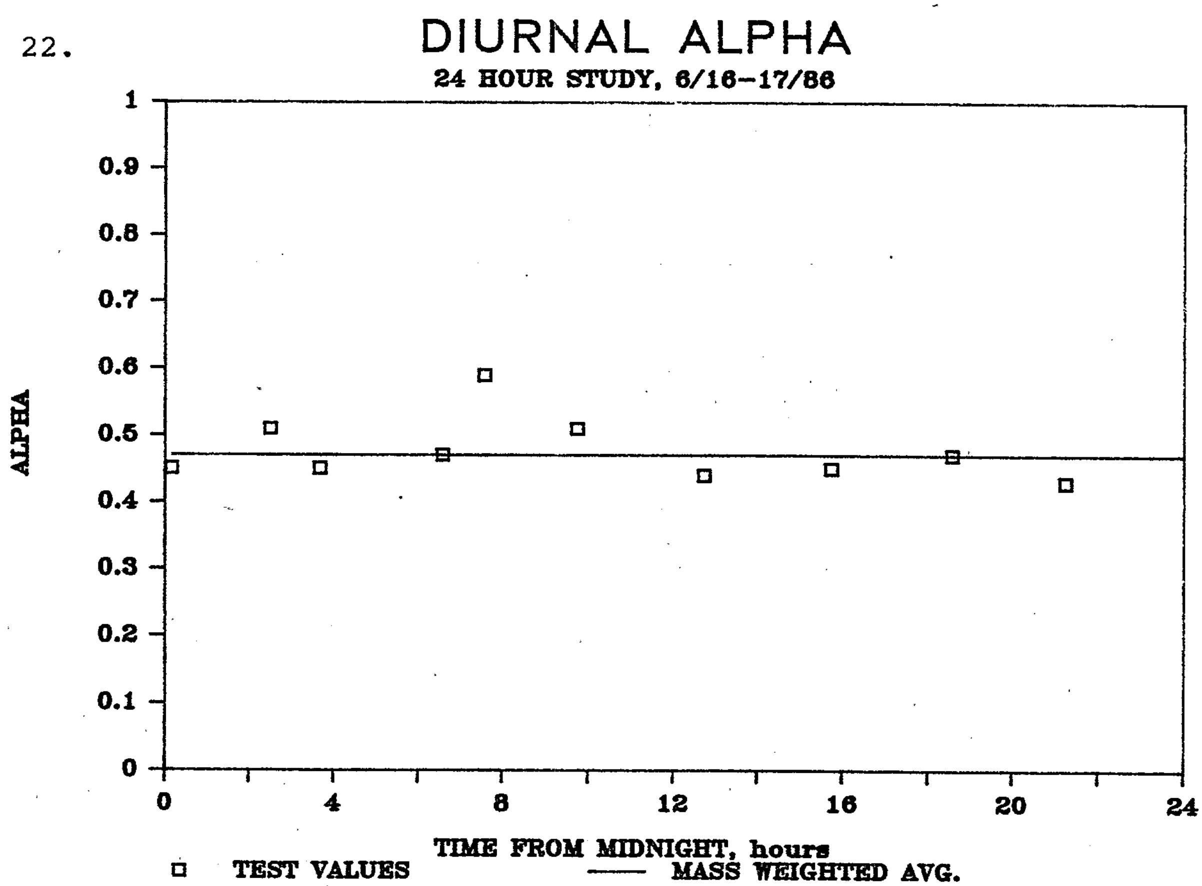


TABLE 21

Grid OTE20 and Alpha for 24 Hour Study

	OTE20 %			
	Grid			
Test	A	B	C	D
51	11.1	11.2	12.6	13.0
52	7.7	9.6	11.4	12.1
53	8.2	9.8	12.2	11.8
54	8.9	10.2	12.8	12.0
55	7.7	9.1	12.0	11.2
56	8.2	9.7	12.2	11.5
57	10.1	10.1	13.4	12.2
58	11.3	11.3	13.7	13.5
59	12.3	13.0	13.4	14.4
60	11.1	12.1	15.9	14.8
Time Weighted Avg.=	9.4	10.4	12.7	12.5
Std. Deviation =	1.6	1.2	1.2	1.2

	ALPHA			
	Grid			
Test	A	B	C	D
51	0.47	0.47	0.56	0.58
52	0.33	0.41	0.52	0.55
53	0.34	0.42	0.53	0.51
54	0.38	0.43	0.54	0.51
55	0.32	0.39	0.52	0.49
56	0.34	0.41	0.54	0.51
57	0.43	0.44	0.60	0.54
58	0.43	0.43	0.52	0.51
59	0.45	0.48	0.52	0.55
60	0.47	0.51	0.77	0.71
Time Weighted Avg. =	0.39	0.43	0.55	0.54
Std. Deviation =	0.06	0.04	0.07	0.06

Figure 23. AVG. GRID OTE20 VS. DISTANCE

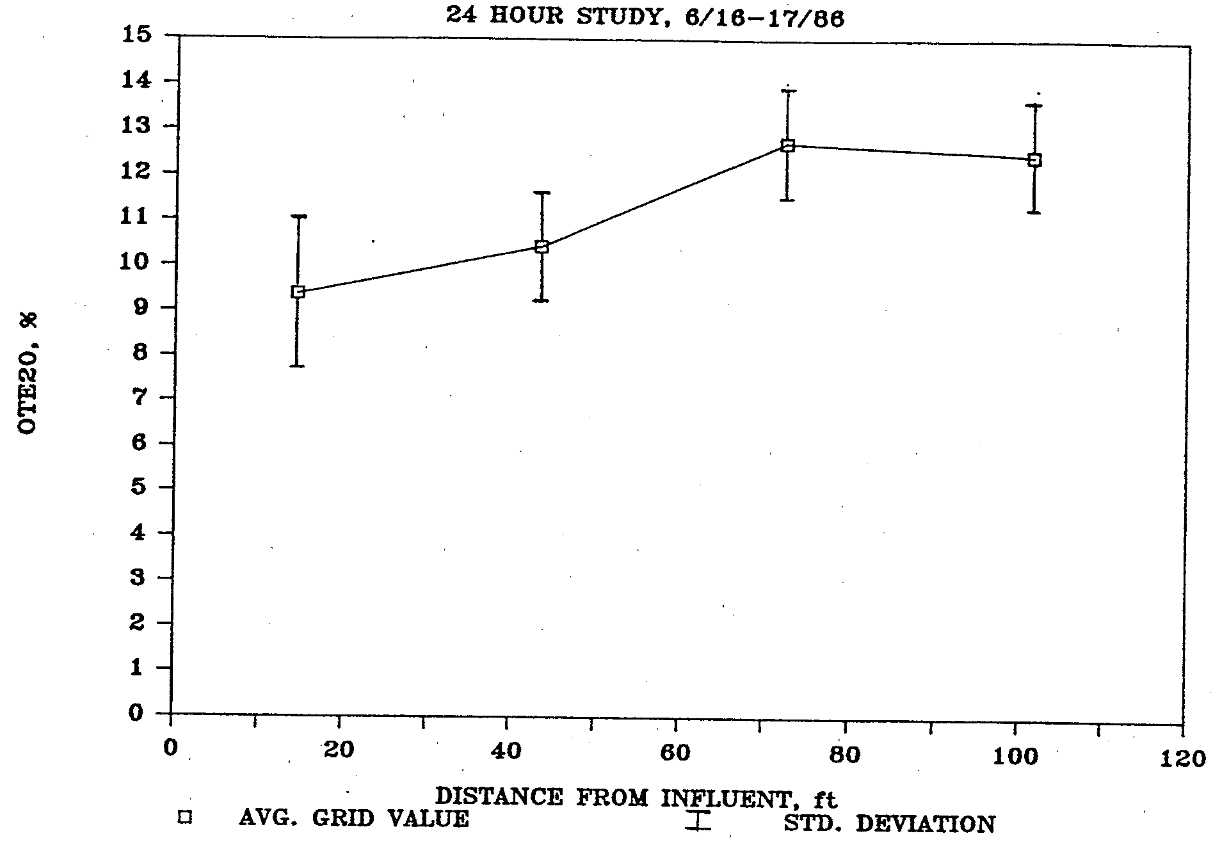


Figure 24. AVG. GRID ALPHA VS. DISTANCE

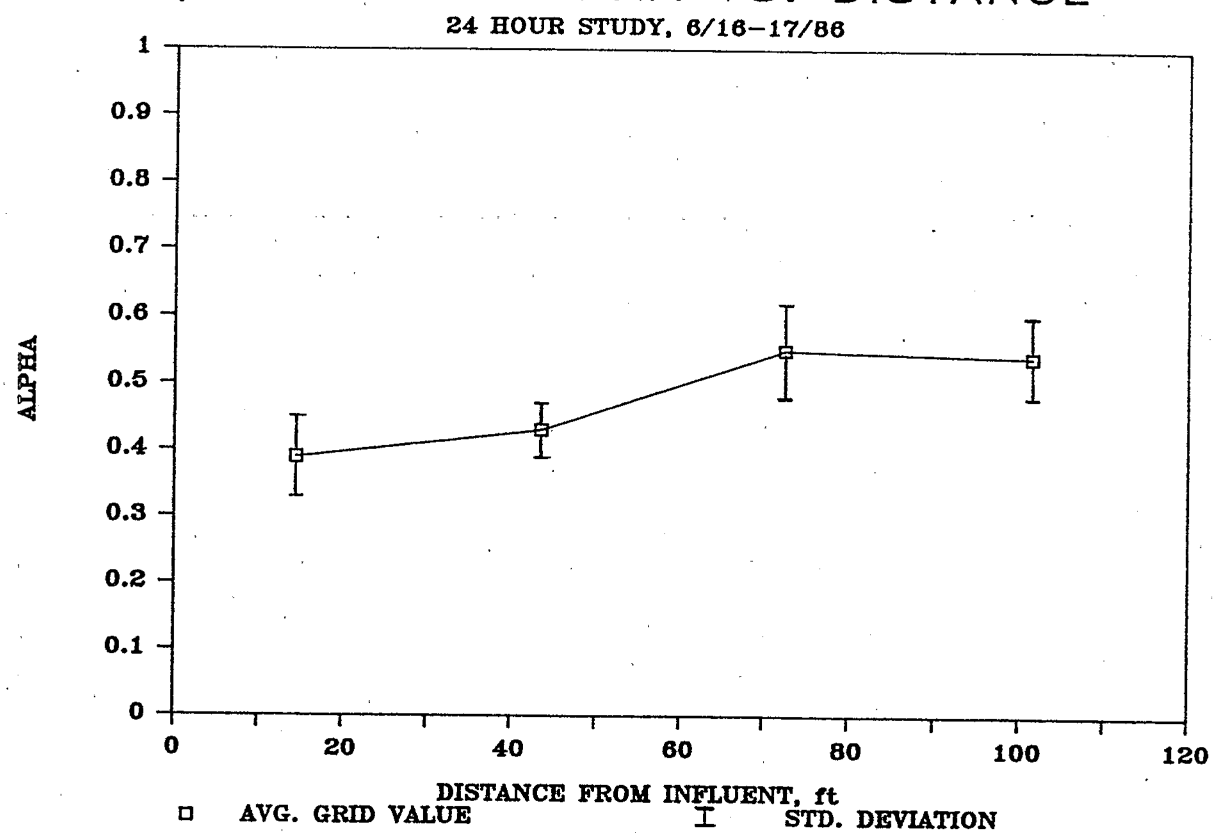


TABLE 22

Grid Gas Flow and Dissolved Oxygen Values for 24 Hour Study

	Offgas Measured Gas Flow, scfm				
	Grid				
Test	A	B	C	D	Total Tank
51	372	312	182	182	1048
52	390	331	192	192	1105
53	346	326	171	171	1014
54	367	327	162	162	1018
55	341	331	173	173	1018
56	351	331	179	179	1040
57	373	355	184	184	1096
58	244	224	111	111	690
59	206	192	116	116	630
60	364	315	215	215	1109
Time Weighted Avg.=	339	308	169	169	985
Std. Deviation =	57	50	31	31	163

	Dissolved Oxygen, mg/ℓ				
	Grid				
Test	A	B	C	D	Avg. Tank
51	1.6	2.4	2.2	2.0	2.1
52	1.3	2.1	1.4	1.2	1.5
53	1.4	2.2	1.3	1.1	1.5
54	1.8	2.3	1.5	1.3	1.7
55	1.2	1.8	1.6	1.0	1.4
56	1.2	2.0	1.6	1.1	1.5
57	3.0	3.6	3.6	2.5	3.2
58	1.2	0.8	0.4	0.2	0.7
59	1.0	1.2	0.2	0.2	0.7
60	4.6	5.0	5.4	4.5	4.9
Time Weighted Avg.=	1.8	2.3	1.9	1.5	1.9
Std. Deviation =	1.1	1.1	1.5	1.2	1.2

Figure 25.

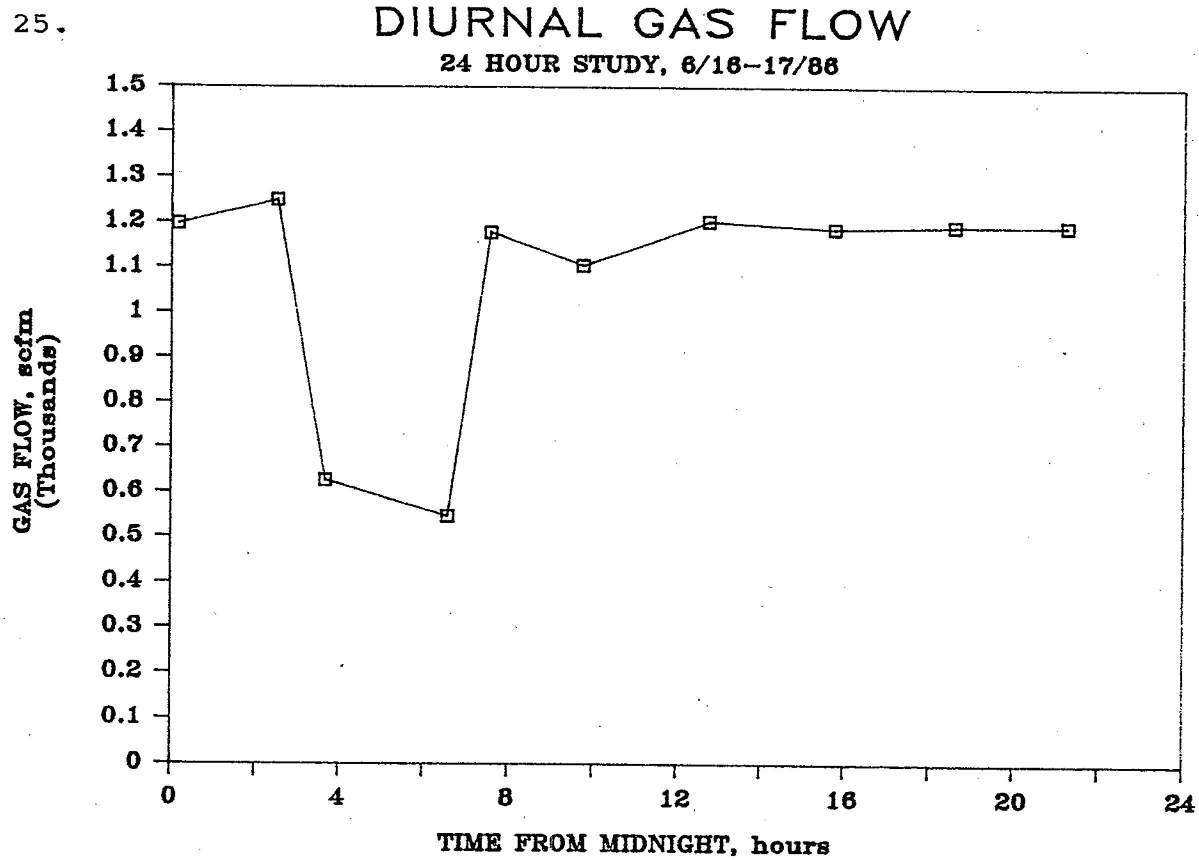


Figure 26.

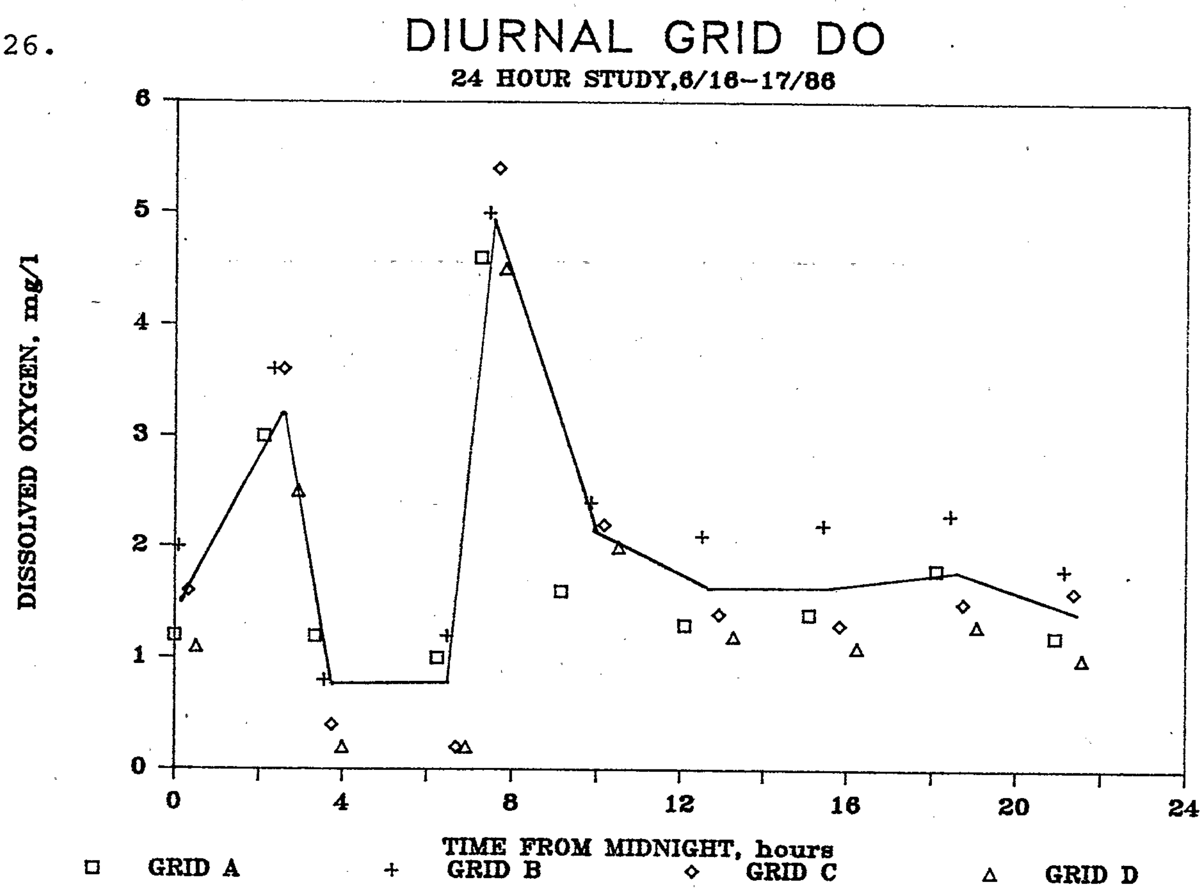


Figure 27. GRID GAS FLOW VS. DISTANCE

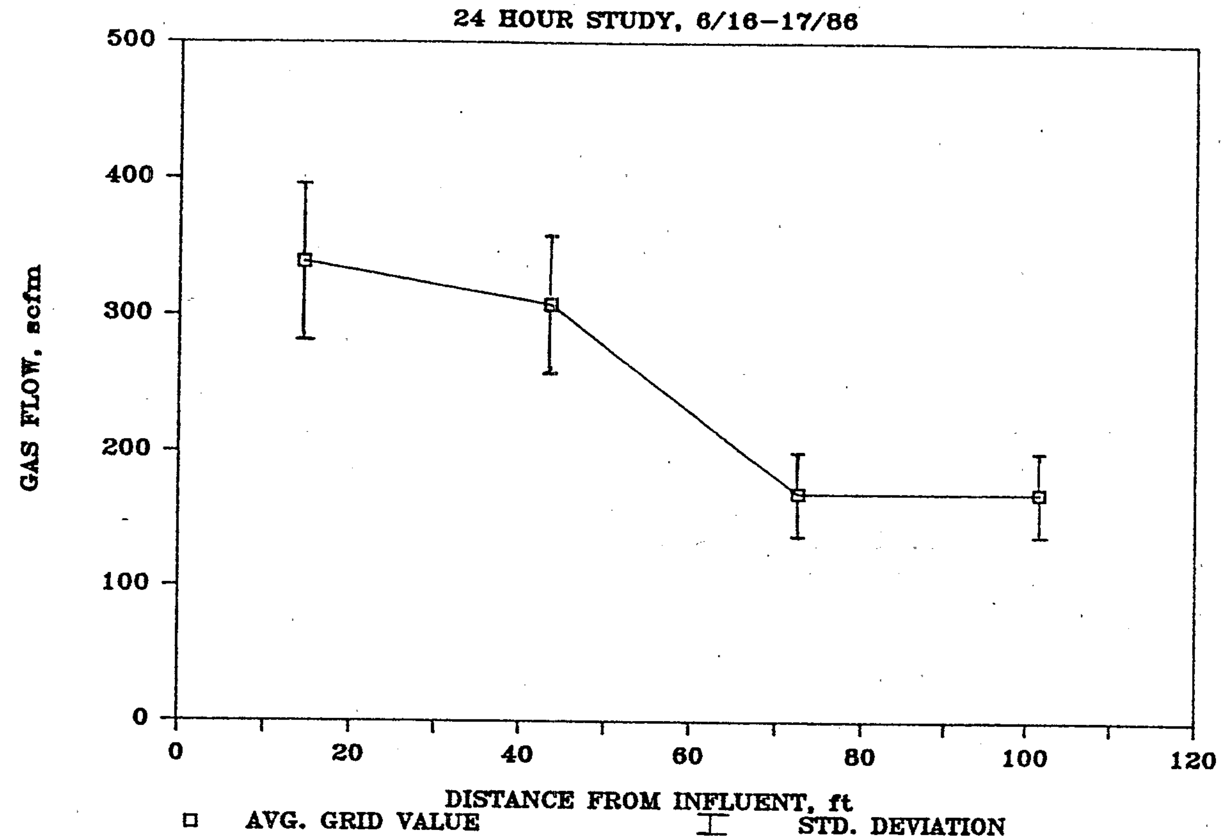
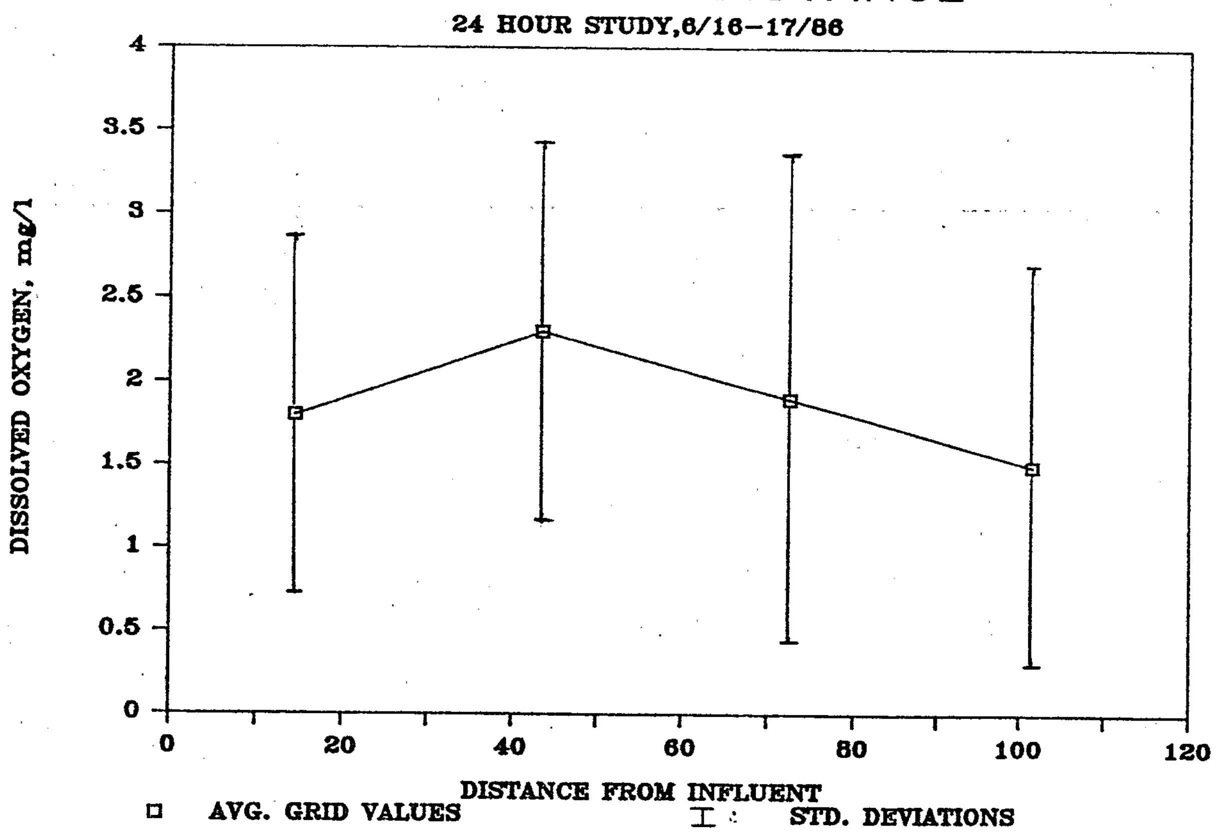


Figure 28. GRID DO VS. DISTANCE



Near septic conditions exist in Grids C and D at 3:30 and 6:30 a.m. with one compressor on. When the second compressor is turned on at 7:00 a.m. the dissolved oxygen concentration approaches 5 mg/ℓ resulting in a marked increase in alpha from 0.52-0.55 to 0.71-0.77 in Grids C and D as shown in Table 21.

Figure 29 shows dissolved oxygen concentrations monitored continuously in grid A with specific point values representing the average concentration used for grid A in the offgas analysis. Figure 30 illustrates the changing dissolved oxygen concentrations from 7:00 to 8:00 a.m. with an average concentration of 4.6 mg/ℓ used in the offgas analysis in Test 60. Table 23 presents the OTE20 corrections for changing dissolved oxygen concentrations. Instead of using an average D.O., the D.O. at the specific sampling time is used in the calculation. The original OTE20 for grid A was 11.6% while the corrected value is 11.1%. The tank OTE20 was corrected from 13.2 to 13.1%. Although not significant in this case for overall tank values, this adjustment should be utilized when DO changes occur during an offgas test.

4. Comparison of Offgas to Manometer Measured Gas Flow

Figure 31 presents the offgas and manometer measured gas flow with respect to each test. The values agree reasonably well with an average percent difference from the manometer measured gas flow of approximately 10%.

b) Steady State

1. OTE20 Comparison

The test conditions and results from the steady state analysis can be found in Tables 24 and 25, respectively. The steady state OTE20's are used for comparative purposes against the more accurate offgas OTE20's. Two steady state OTE20's are calculated, one using manometer measured gas flow and the other using offgas measured gas flow. The OTE20's calculated with manometer measured gas flows ranged from 8.0 to 12.1%. The OTE20's calculated using offgas measured gas flows ranged from 9.2 to 13.1%. The % difference between steady state OTE20, using manometer measured gas flow, and offgas OTE20 was

Figure 29. GRID A DIURNAL DISSOLVED OXYGEN

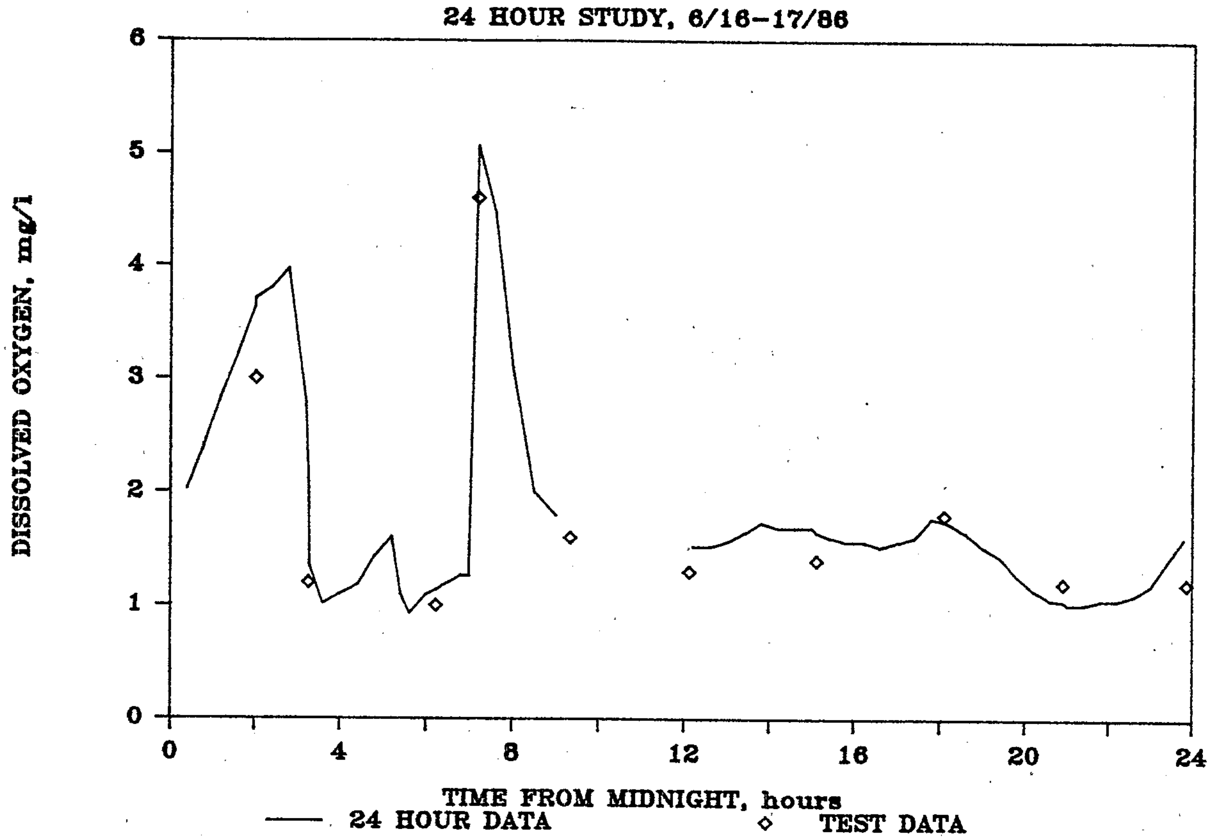


Figure 30. TEST #60 DO VARIABILITY

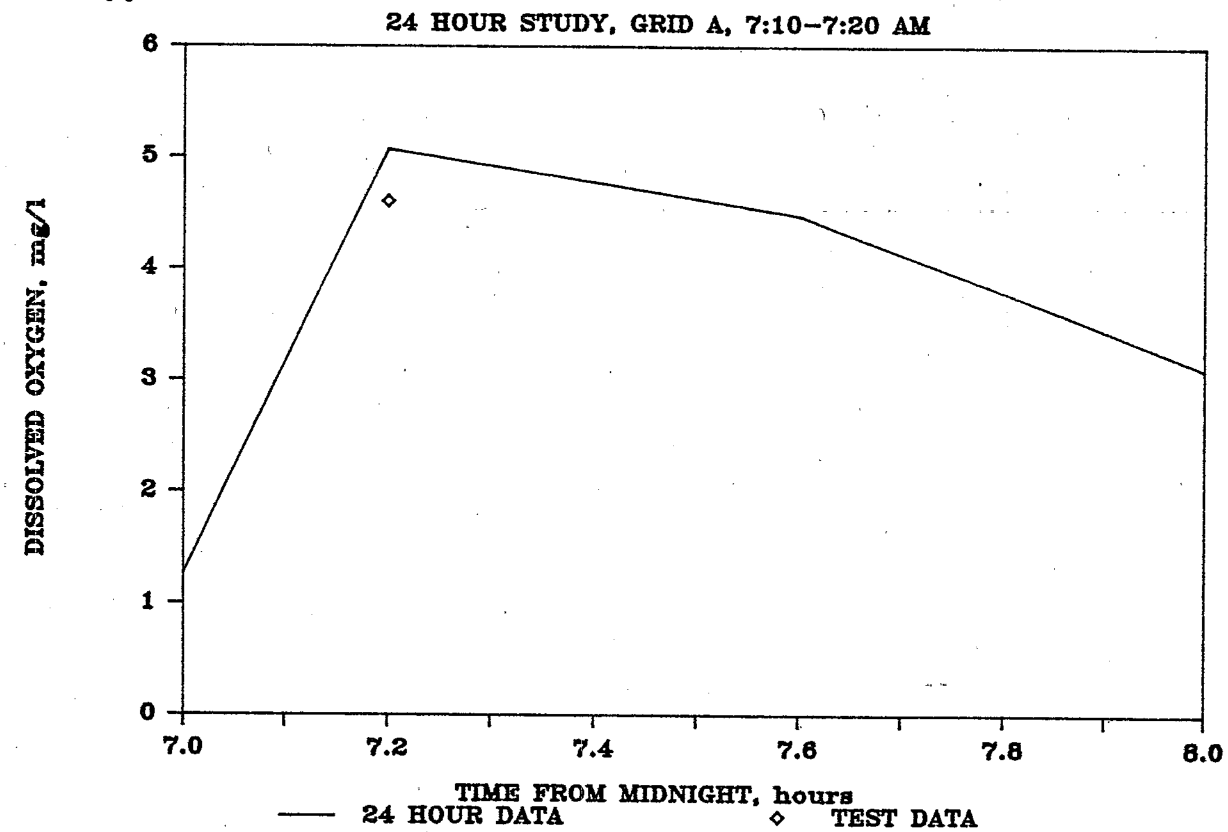


TABLE 23

OTE20 Corrections for DO Variation During Test 60

Grid Corrections

Test	Grid	Sample #	Sampling Time from Midnight (hrs)	Assumed Average DO (mg/ℓ)	Recorder DO (mg/ℓ)	Field OTE (%)	Original OTE20 (%)	*Adjusted OTE20 (%)
60	A	1	7.16		3.83	6.4	11.9	10.4
		2	7.20	4.6	4.6	6.3	11.7	11.7
		3	7.23		4.55	6.3	11.7	11.6
		4	7.28		4.46	6.2	11.5	11.2
		5	7.33		4.37	5.9	11.0	10.6
						Avg. =	11.6	11.1

Tank Corrections

			Original		Adjusted	
Test	Grid	Gas Flow Weight Factor	Grid OTE20 (%)	Weighted OTE20 (%)	Grid OTE20 (%)	Weighted OTE20 (%)
60	A	0.329	11.6	3.8	11.1	3.7
	B	0.284	12.1	3.4	12.1	3.4
	C	0.194	15.9	3.1	15.9	3.1
	D	0.194	14.8	2.9	14.8	2.9
			Tank Value =	13.2		13.1

$$^{*}\ OTE20 = OTE_f\ (1.024)^{20-T} \left(\frac{\beta C^{*}_{\infty 20}}{\beta C^{*}_{\infty f} - DO}\right) \qquad \beta C^{*}_{\infty 20} = 10.26 \qquad \beta C^{*}_{\beta f} = 9.96$$

Figure 31.

GAS FLOW COMPARISON

24 HOUR STUDY, 6/16–17/86

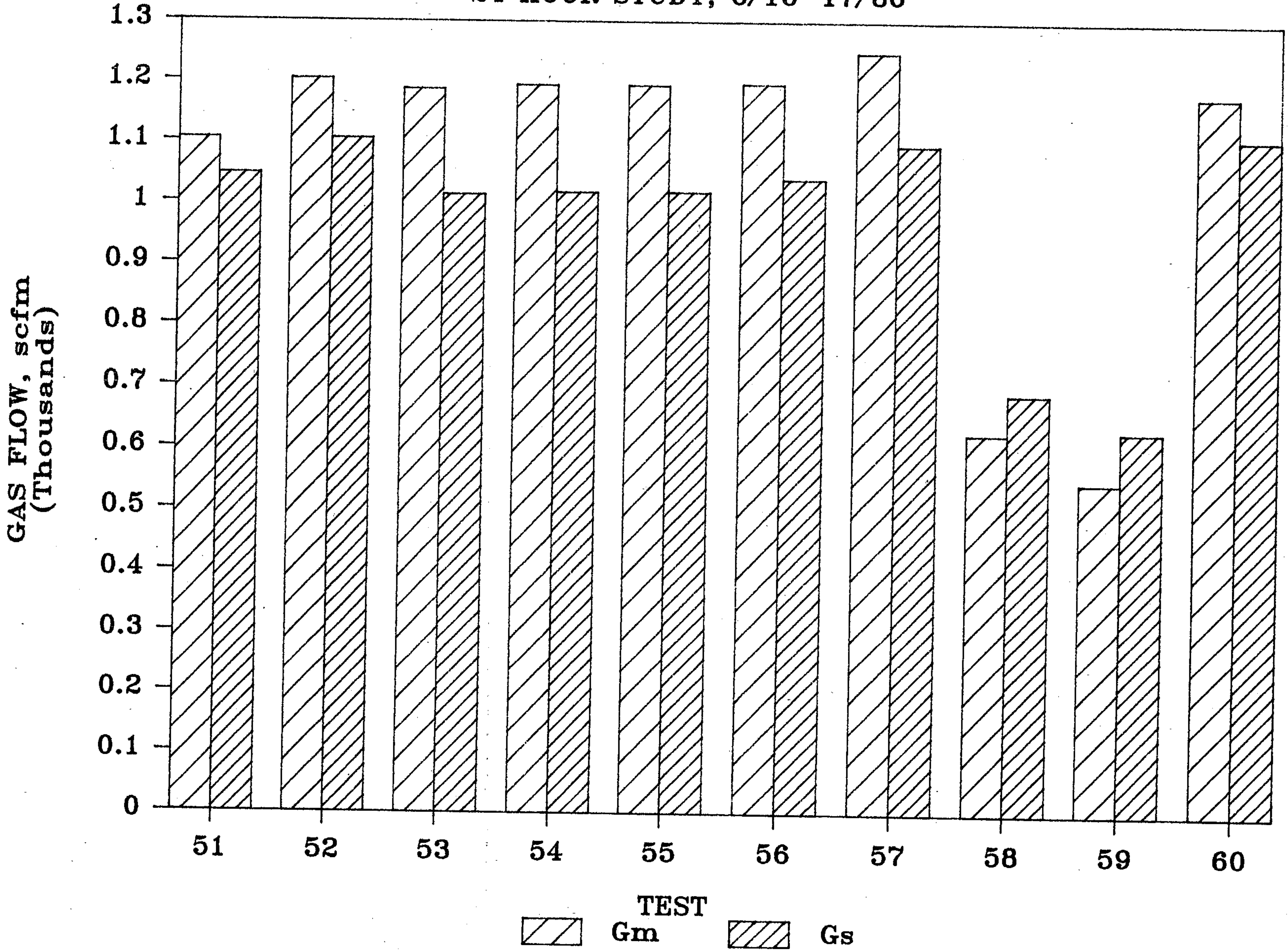


TABLE 24

Steady State Test Conditions, 24 Hour Study

Test	Average Flow To Aeration Tank (Q_i+Q_R) (mgd)	Average Detention Time t_o, (hr)	Field Oxygen Saturat. Value $C^*_{\infty f}$ mg/ℓ	Average Tank Uptake R, mg/ℓ/hr	Average Tank Dissolved Oxygen Cr, mg/ℓ
51	4.9	3.0	10.09	39.3	2.1
52	4.6	3.2	10.07	45.8	1.5
53	4.3	3.3	9.98	47.4	1.5
54	4.2	3.4	9.96	46.3	1.7
55	4.6	3.1	9.93	35.9	1.4
56	4.2	3.4	9.90	33.5	1.5
57	3.1	4.7	9.89	30.9	3.2
58	2.8	5.2	9.89	29.3	0.7
59	2.7	5.3	9.96	24.5	0.7
60	4.6	3.1	9.96	27.5	4.9

Wastewater Temp. = 21.0 - 21.5°C

Volume Aeration Tank = 0.3 MG

Influent Dissolved Oxygen, C_i = 0.1 mg/ℓ

Standard Oxygen Saturation Value $\beta C^*_{\infty 20}$ = 10.26 mg/ℓ

Note: Both C^*_f and C^*_{20} include beta effect of 0.99

TABLE 25

Steady State Results, 24 Hours Study

Test	Field Oxygen Trans. Coeff. K_La_f, 1/hr	Oxygen Trans. Coeff. at 20°C K_La_{f20}, 1/hr	OTR20, lb O_2/hr	Gas Flow G_m[1], scfm	Gas Flow G_s[2], scfm	Steady State (1) OTE20 Using G_m, (%)	Steady State (2) OTE20 Using G_s, (%)	Offgas (3) OTE20, (%)	Comparison with Offgas OTE20[3] % DIFF. (3)&(1)	Comparison with Offgas OTE20[3] % DIFF. (3)&(2)
51	4.97	4.85	124.6	1105	1047	10.8	11.4	11.7	-7.7	-2.5
52	5.40	5.27	135.3	1203	1105	10.8	11.8	9.7	+11.8	+21.7
53	5.64	5.47	140.4	1187	1014	11.4	13.3	10.0	+13.6	+33.0
54	5.68	5.51	141.4	1194	1018	11.4	13.4	10.4	+9.3	+28.2
55	4.26	4.12	105.7	1194	1019	8.5	10.0	9.5	-10.4	+5.0
56	4.02	3.88	99.7	1197	1041	8.0	9.2	9.9	-19.3	-7.2
57	4.70	4.53	116.4	1249	1096	9.0	10.2	11.0	-18.5	-7.1
58	3.18	3.07	78.8	626	690	12.1	11.0	12.0	+0.7	-8.7
59	2.64	2.56	65.8	547	630	11.6	10.0	13.1	-11.5	-23.1
60	5.71	5.53	142.1	1178	1109	11.6	12.3	13.1	-11.1	-5.6

1 G_m = Manometer measured gas flow using plant flow tube

2 G_s = Offgas measured gas flow

3 $\% \text{ Diff} = \frac{\text{SS OTE20} - \text{OG OTE20}}{\text{OG OTE20}} \times 100$

from −19.3% to +13.6%. Figure 32 illustrates this comparison with respect to time. The steady state OTE20's were significantly lower than the offgas values from 6:00 a.m. to 10:00 a.m. This is a result of food limited conditions. The food in a sample taken during the above tests is completely oxidized as the sample is oxygenated. Thus the measured oxygen uptake in the food limited sample is lower than the actual oxygen uptake in the aeration tank resulting in lower OTE20's. From about 4:00 p.m. to midnight some oxygen limitation apparently existed in the aeration tank providing higher measured uptake rates than in situ and higher steady state OTE's.

2. Oxygen Uptake Rates

Figures 33 and 34 illustrate the oxygen uptake rates with respect to time of day. The average tank oxygen uptake rates are low at 6:00 a.m. (24.5 mg/ℓ/hr) and high at 4:00 p.m. (47.4 mg/ℓ/hr). Figure 34 shows values for each station throughout the day. Grid A typically had significantly higher oxygen uptake rates than did grid D due to the reduced substrate concentrations in the effluent end of the aeration tank. During the high load periods in the afternoon, oxygen uptake rate in grid A is as high as 54 mg/ℓ/hr. An increase in the oxygen uptake rate is observed around 7:00 a.m. This correlates well with OTE20, as Figure 21 shows OTE20 starting to decrease shortly after. However, at 9:00 p.m. the oxygen uptake rate drops below the average while the OTE20 also decreases. This could be attributed to an increase in flow from 2.9 to 3.3 MGD causing the oxygen uptake rate and MLSS concentration to decrease, with the unit oxygen uptake remaining relatively constant. Unfortunately, only daily average MLSS concentrations are available.

4. Parameter Correlations

The regression analyses output can be found in Table 26. Both the best fit equation relating the parameters and its coefficient of determination (r^2) are presented. The coefficient of determination represents the portion of the sum of squares of deviations of the Y values

Figure 32.

OFFGAS & STEADY STATE OTE COMPARISON

24 HOUR STUDY, 6/16-17/86

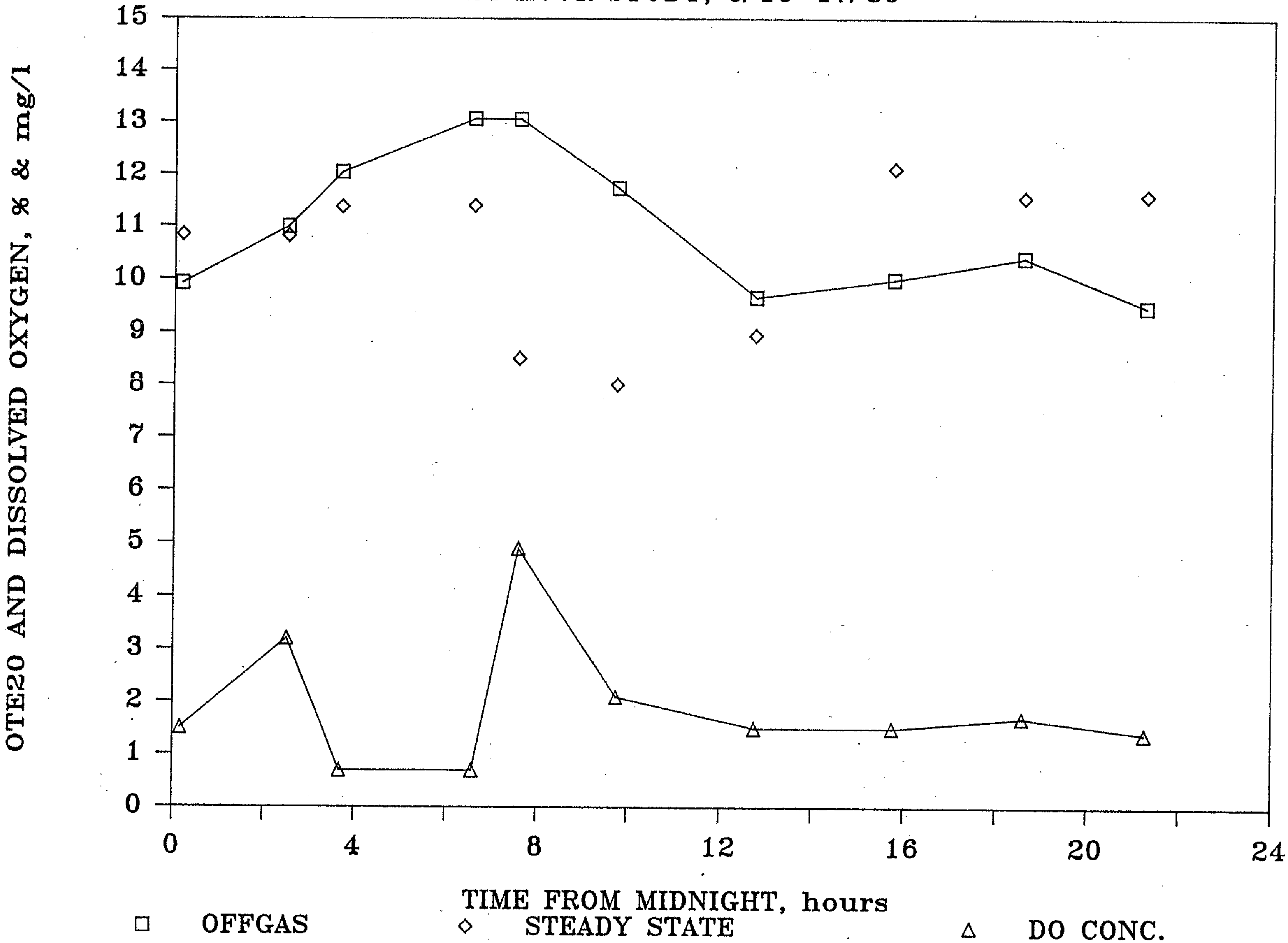


Figure 33.

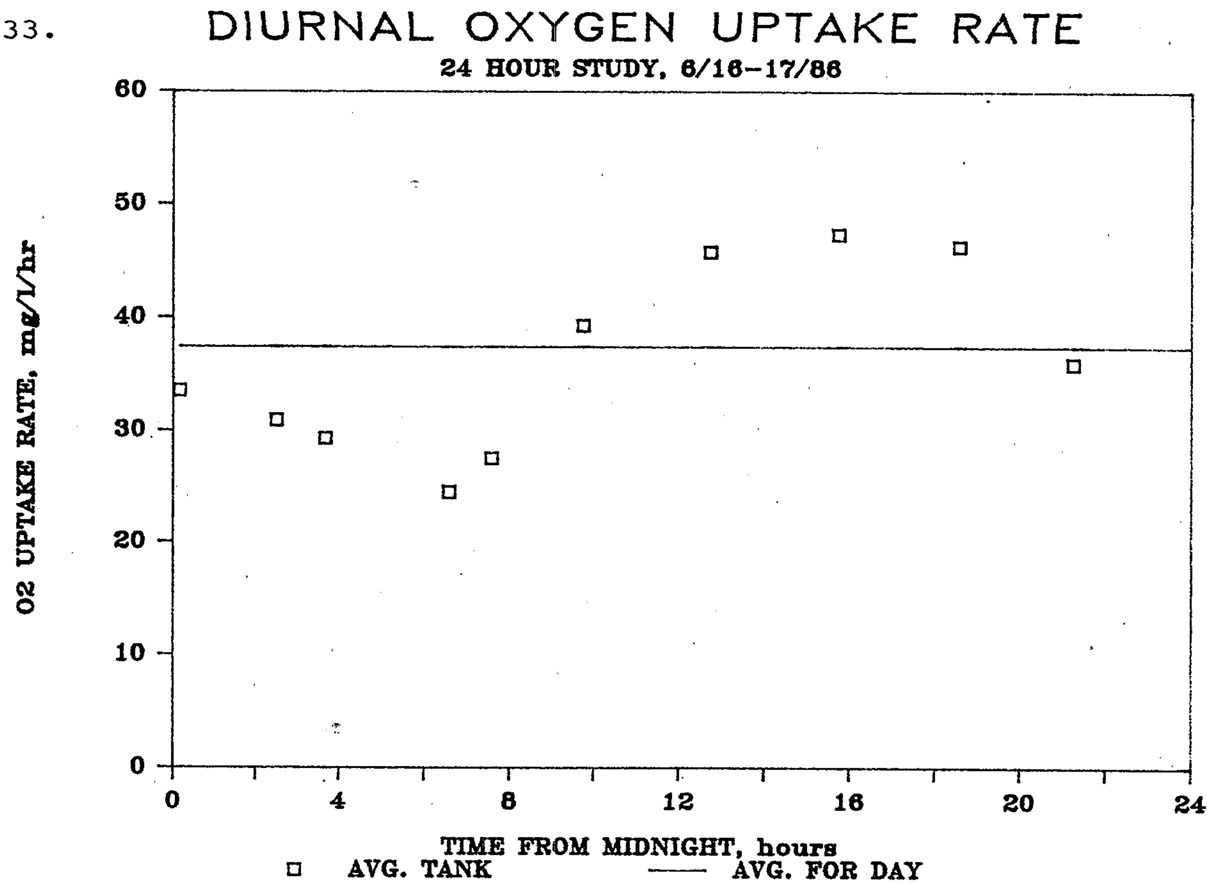


Figure 34.

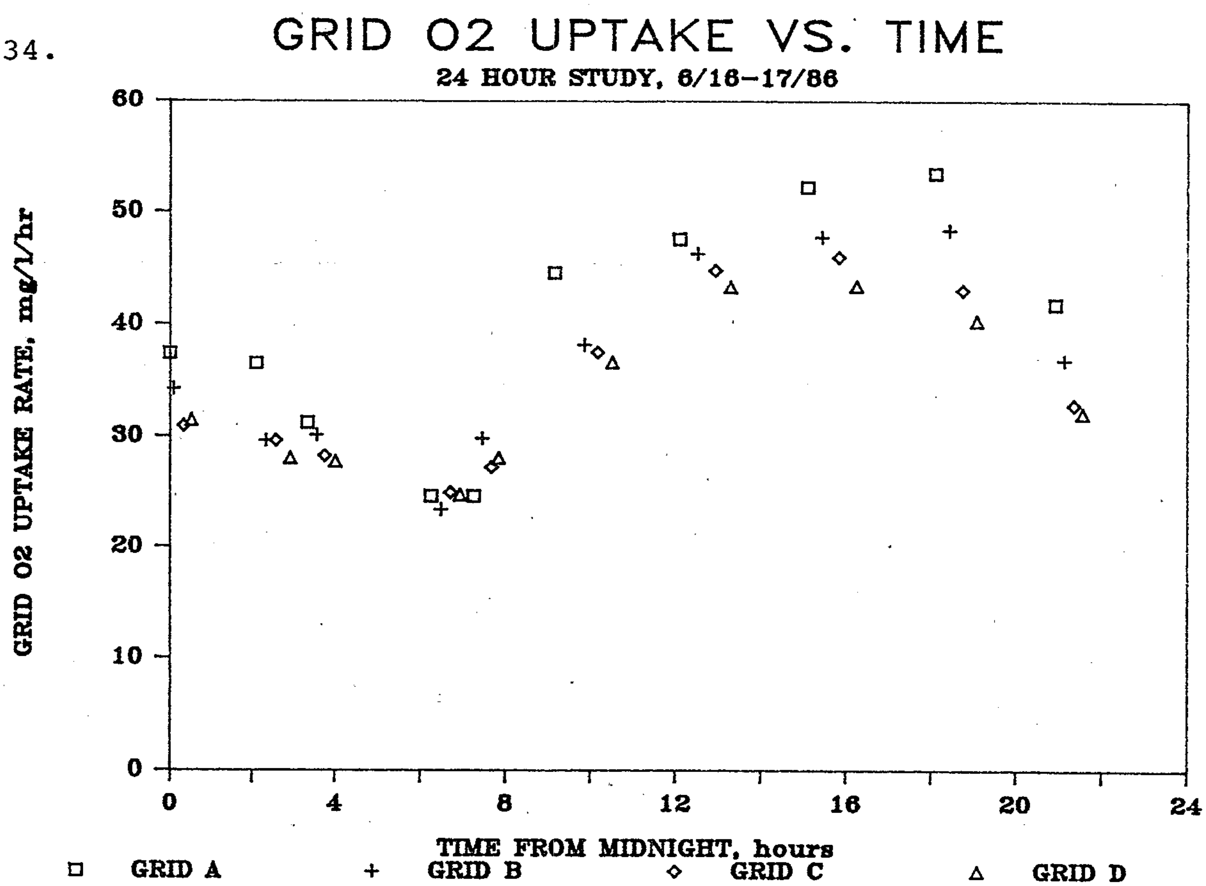


TABLE 26

Parameter Correlations, 24 Hour Study

Type of data	y Variable	x Variable	No. of Data Points	Intercept	Slope	r^2(%)	Significant Correlation
Grid Values	OTE20	O_2 Uptake	32	16.1	-0.130	28	yes
Tank Averages	OTE20	O_2 Uptake	8	14.1	-0.0893	31	no
Grid Averages	OTE20	O_2 Uptake	4	34.1	-0.640	89	no
Grid Values	alpha	O_2 Uptake	32	0.743	-0.00675	28	yes
Tank Averages	alpha	O_2 Uptake	8	0.649	-0.00437	39	no
Grid Averages	alpha	O_2 Uptake	4	1.63	-0.0317	89	no
Tank Averages	alpha	Soluble TOC	10	0.515	-0.00007	14	no
Tank Averages[1]	alpha	Soluble TOC	10	0.527	-0.00009	27	no
Tank Averages[2]	alpha	Soluble TOC	10	0.536	-0.00010	32	no
Tank Averages[3]	alpha	Soluble TOC	10	0.536	-0.00011	32	no
Grid A Values	alpha	Soluble TOC	10	0.485	-0.00016	53	yes

[1] using 1 hour lag time

[2] using 2 hour lag time

[3] using 3 hour lag time

about their mean that can be attributed to a linear relationship between Y and X. Simply stated, r^2 tells what percent of the Y variable is explained by the X variable.

It should be noted that another variable, gas flow, is a factor involved in the correlations. Gas flow is relatively constant during the two blower tests, but is reduced by half for the one blower runs. Therefore, values measured during one blower operation are not included in the correlations.

Figure 35 shows the effect of grid oxygen uptake rates on grid OTE20's. As oxygen uptake rate increases, OTE20 decreases. As with OTE20, Figure 36 shows that alpha decreases as oxygen uptake rate increases. The effect of primary clarifier effluent soluble TOC load on grid A alpha is shown in Figure 37. Using the t statistic in the hypothesis testing procedure evaluated whether or not the correlations were significant (Blank, pg. 521). The regression output for each correlation performed is summarized in Table 26. Again, no significant correlation exists for the tank average or grid average values similar to the results in Table 13.

Figure 35.

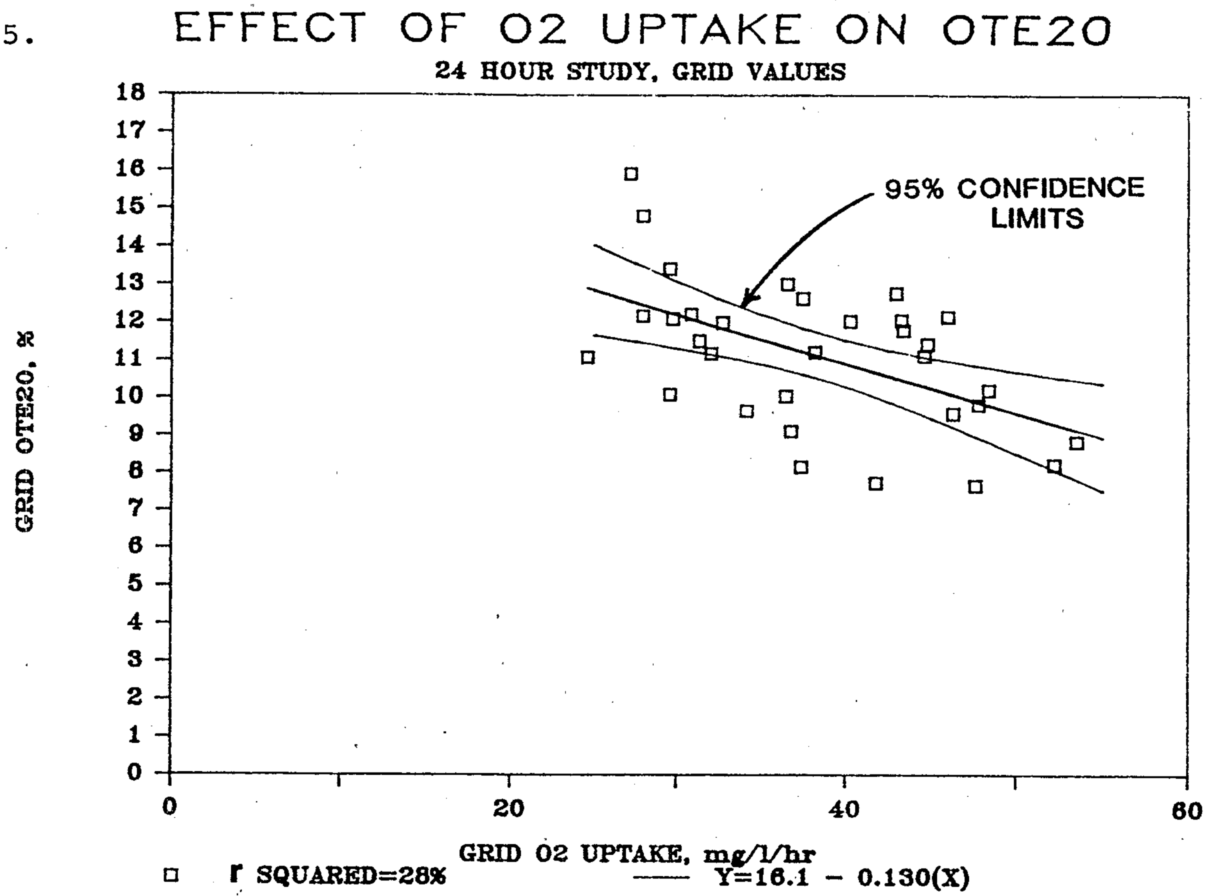


Figure 36.

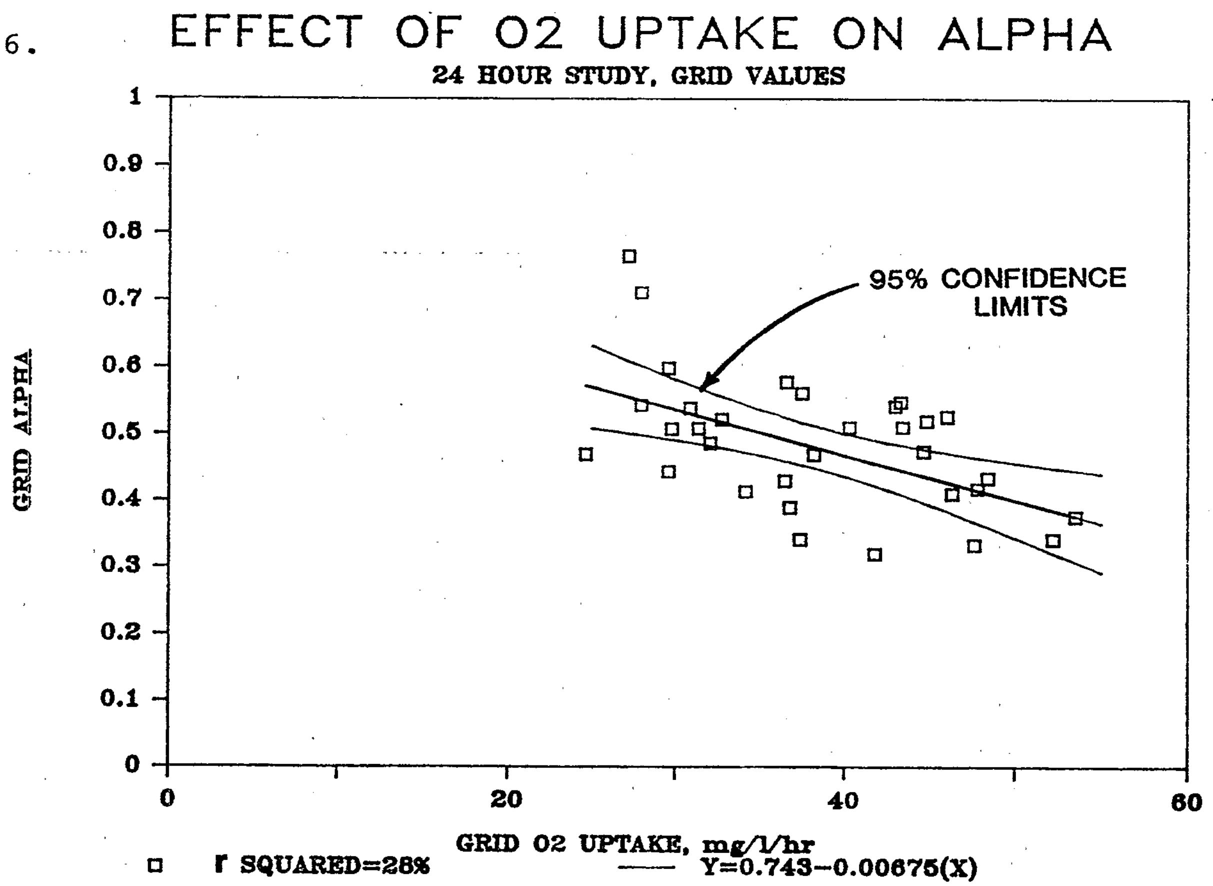
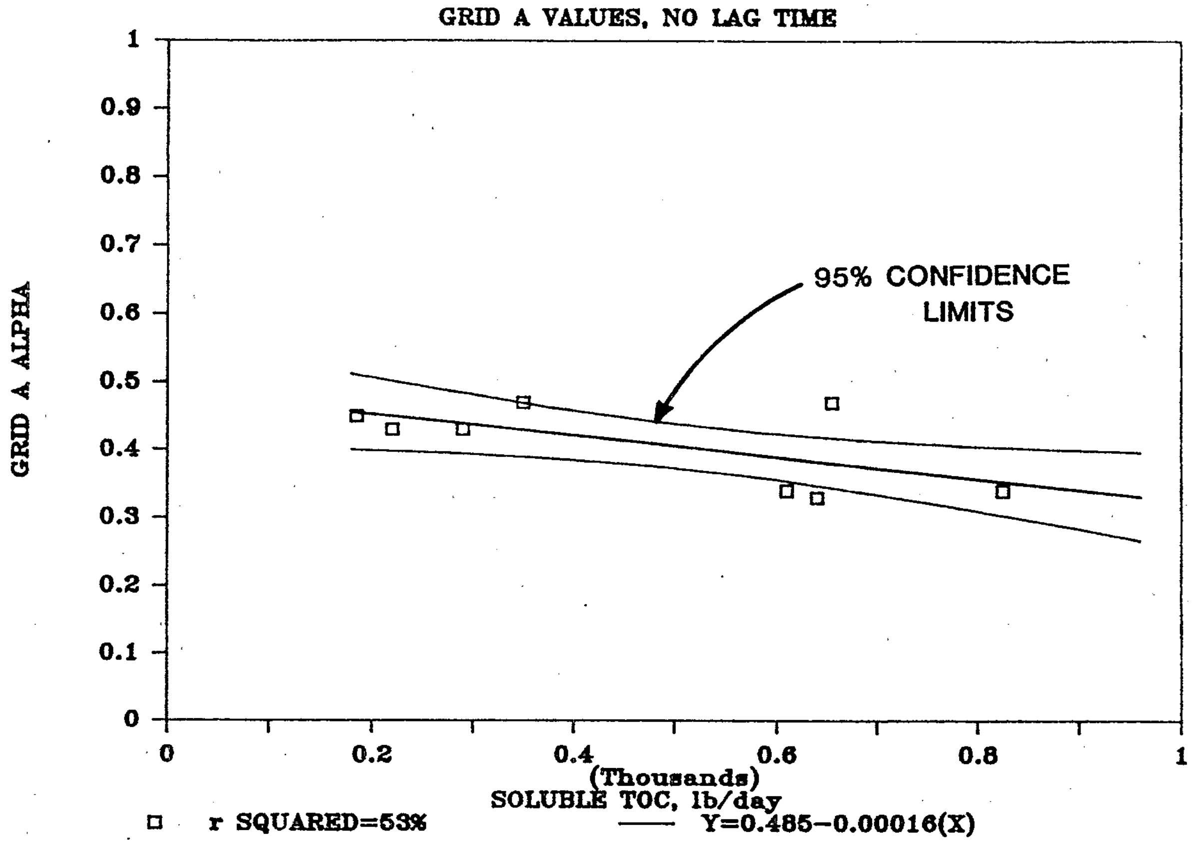


Figure 37. EFFECT OF SOLUBLE TOC LOAD ON ALPHA



C. Effect of Cleaning on Aeration Equipment

Tables 27 and 28 present the cleaning frequencies for aeration tanks 3 and 4 at Ridgewood. Two methods of cleaning were utilized on the dome diffusers, acid brushing and water hosing. To acid clean the domes a ½ carboy of 20% HCl diluted 1:1 was used to brush each dome. The water hose cleaning used a high pressure stream of water from a fire hose sprayed directly onto the domes from the top of the aeration tank. Typically an aeration tank was out of service for less than 15 days during a cleaning. The first cleanings were conducted in September 1984 on aeration tank 4 and October 1984 for aeration tank 3. As mentioned previously, approximately 40 and 15 domes, respectively, were missing from the aeration tanks with a large number of domes loose. The plastic bolts were replaced by brass bolts and the dome density increased by adding 110 new domes. The future cleanings showed the brass bolts to be effective and did not require tightening until 1 year later. In general, slime deposits did build up on the domes on the liquid side, with hosing effectively removing it.

Figures 38 and 39 illustrate the OTE20 and alpha values for 1984 through 1986 with cleaning times indicated. It is difficult to evaluate an immediate cleaning effect on OTE20 because of changing wastewater characteristics and availability of data before and after a cleaning. For example, an immediate increase in OTE20 can be seen after the July 17th and July 28th 1985 cleaning on aeration tank 3. The low gas flow OTE20 measured before the cleanings was 9.1% and increased to 9.9% after the first hose cleaning. After a second cleaning by acid brushing the low gas flow OTE20 increased to 11.5%. However, primary clarifier effluent BOD_5 for the above tests (5,8,10) decreased from 159 mg/ℓ to 141 and 97 mg/ℓ. Thus, it is not clear what immediate impact, if any, cleaning had on OTE20. An overall cleaning effect can be seen from Figures 38 and 39. The OTE20s measured in 1984 gradually increase with the successive cleanings and suggest that a scheduled frequency of cleaning is desirable to maintain the efficiency of the aeration system.

TABLE 27

Cleaning Frequency at Ridgewood for Tank 3

No.	Type of Cleaning and Comments	Date: Out of Service	Date: Date Cleaned	Date: Returned to Service	Interval of operation between cleanings, days
	Plant operation begun using domes			4/12/83	
1.	Initial cleaning, drained & hosed, ∿15 broken plastic bolts, many loose, all bolts replaced with brass, increased dome density.	10/11/84	–	11/29/84	547
2.	Drained & hosed	3/20/85	–	3/26/85	112
3.	Drained & hosed	5/21/85	–	6/4/85	55
4.	Drained & hosed	7/15/85	7/17/85	7/17/85	41
5.	Drained & acid cleaned – ½ carboy of 20% HCl diluted 1:1.	7/25/85	7/28/85	–	8
6.	Acid washed. Same as 5 to wash off algae. Tightened all bolts and cemented all leaks with hot glue gun.	–	10/25/85	10/28/85	0
7.	Drained & hosed	3/20/86	Est. 4/07/86	Est. 4/08/86	161
8.	Drained & acid cleaned	8/19/86	8/20/86	8/20/86	133

* Tank 3 was hose cleaned prior to startup in 4/83 to remove algae buildup.

TABLE 28

Cleaning Frequency at Ridgewood for Tank 4

No.	Type of Cleaning and Comments	Date			Interval of operation between cleanings, days
		Out of Service	Date Cleaned	Returned to Service	
	Plant operation begun using domes			4/12/83	
1.	Initial cleaning, drained & hosed, ~40 broken plastic bolts, many loose, replaced with brass, increased dome density.	9/19/84	-	9/28/84	525
2.	Drained & hosed	3/25/85	-	3/29/85	178
3.	Drained & hosed	5/13/85	-	5/21/85	45
4.	Drained & hosed	6/5/85	-	6/14/85	15
5.	Drained & hosed	7/9/85	7/11/85	7/11/85	25
6.	Drained & acid cleaned with ½ carboy of 20% HCl diluted 1:1. Tightened all bolts and cemented all leaks with hot glue gun.	10/28/85	11/27/85	12/2/85	109
7.	Drained & hosed	2/25/86	3/19/86	3/20/86	85
8.	Drained & hosed	5/15/86	5/28/86	5/30/86	72-73

Figure 38.

CLEANING EFFECT ON OTE20(TANK #3)

1984 through 1986

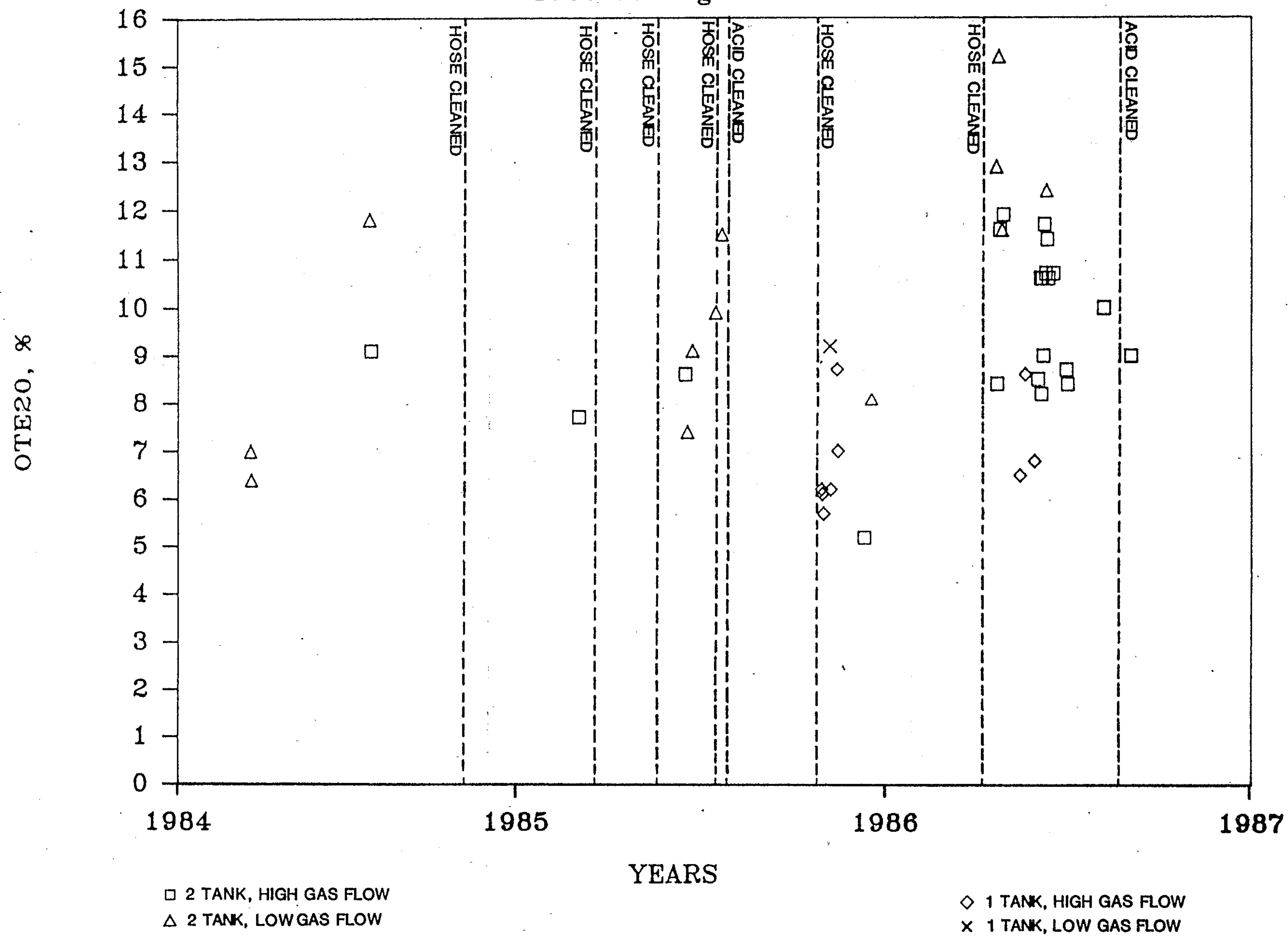
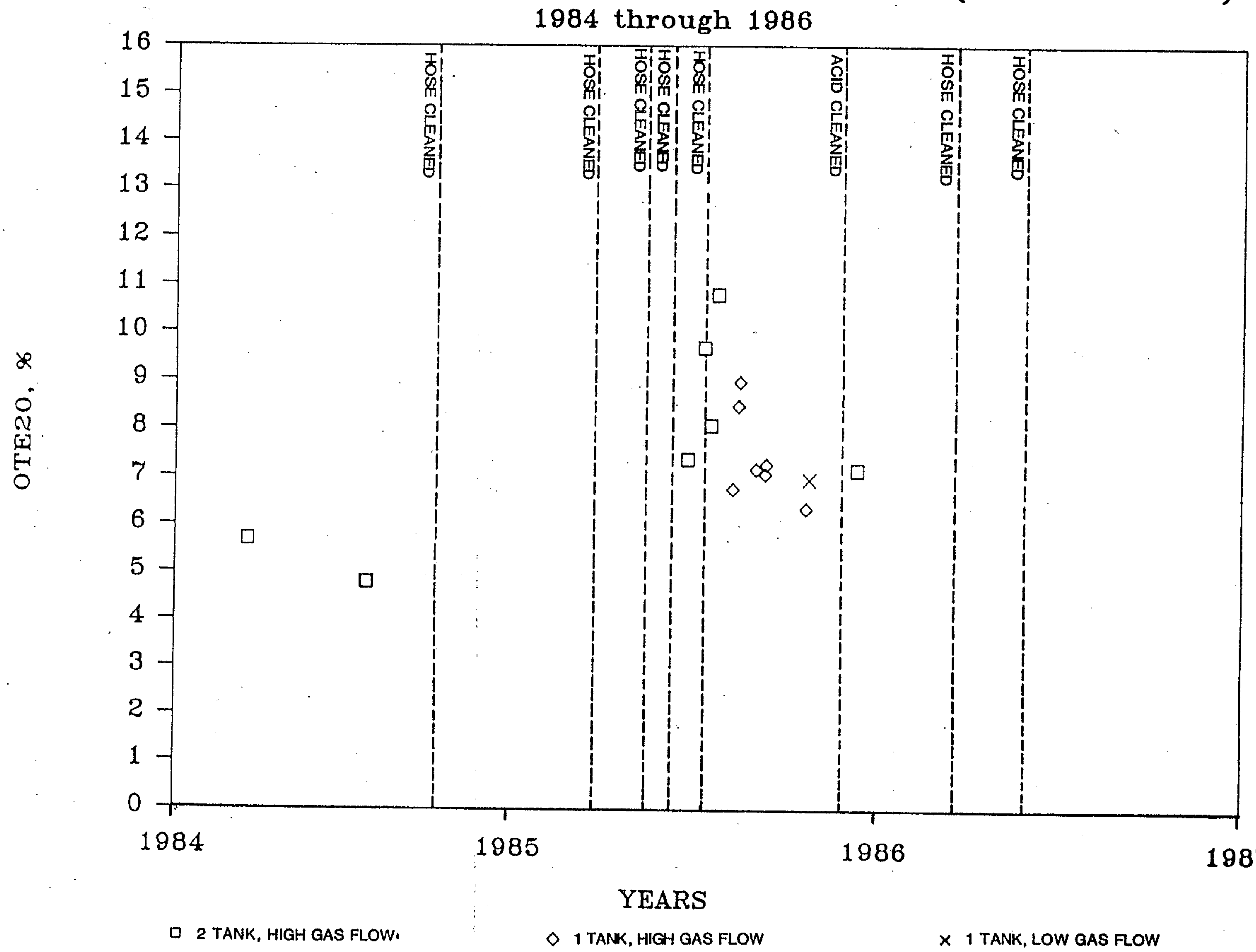


Figure 39.

CLEANING EFFECT ON OTE20(TANK #4)



D. Problems Encountered and Solutions

1. Nocardia Foam

The major problem in collecting OTE data at the Ridgewood WWTP was Nocardia foam present on the surface of aeration tanks 3 and 4. Foam developed in late May of 1985 and was present through the Fall of the same year. It redeveloped at the end of June, 1986 and again was present through late Fall. The offgas technique for measuring OTE is directly affected by the presence of foam. Relatively high offgas flow rates are unattainable without pulling foam into the offgas hoses, thus terminating the test. Also, the high oxygen uptake rate of the foam provided unrealistically high OTE. This was especially true with low offgas flow rates providing longer detention times through the foam under the hoods during offgas testing. The foam also affected the non-steady state technique using hydrogen peroxide due to the extremely high oxygen demand of the foam reducing the incremental change in tank DO from 10 mg/ℓ down to about 3 mg/ℓ.

Three strategies were employed to combat this problem; 1) reduce the foam in the aeration tanks, 2) modify the offgas hoods to allow measurement, and 3) measure the foam oxygen uptake rate and correct the offgas OTE values.

To reduce the foam in the tank, a chlorine surface spray was tried initially. A drum of 15% sodium hypochlorite was diluted 4:1 and sprayed across the tank surface with a garden hose over about 1 hour. After use of three 55 gallon drums supplied by Ridgewood at a cost of about $200 the foam disappeared. However it again reappeared within a week and a second application was made at ASCE costs. It again reappeared indicating the chlorine spray was not a long term solution. Injection of gaseous chlorine at the inlet of the aeration tank also proved fruitless due to the high demand. Finally a foam suction system discharging back to the primary clarifier with chlorination at the clarifier inlet had some measure of success in controlling foam at 1 to 2 ft. levels in the tank. Low sludge ages were also attempted with only 1 aeration tank held in service, however this had no significant impact on the foam. To date it appears that foaming at Ridgewood will continue to be a significant problem through the summer months into the early fall.

Hood modification was then employed in an attempt to measure offgas flow rates in 1 to 3 feet of foam. The 1.5" diameter offgas pipe was extended vertically 18" followed by a 90 degree elbow and another length of pipe to act as a foam break and return. At low tank foam levels, a few inches, this worked satisfactorily. However at high foam levels it did not. A 5 gallon plastic jug was finally modified and used as a foam collector to provide reasonable gas flow measurements. Data collection for OTE measurement was conducted at relatively low gas flows in the presence of foam. Higher gas flows were attempted until the jug was close to full. If the results of the gas flow summation were not within 10% of the tank measured value, the weighted average OTE was calculated based on prior gas flow distributions or on dome distribution.

To evaluate the effect of foam oxygen uptake on OTE measurements using the offgas technique, a mass balance as shown in the Appendix was performed about the aeration system including the offgas hoods. The resulting equation takes into account initial oxygen concentration, foam detention time and foam uptake rate.

$$OTE20_{\ell} = OTE20_{m} - \frac{R_f t_{of}}{C_{go}}$$

where:

$$t_{of} = \frac{V_f}{G_H}$$

$$C_{go} = \frac{16\ PM}{T}$$

OTE_{ℓ} = oxygen transfer efficiency in liquid

OTE_{m} = Measured oxygen transfer efficiency

R_f = Foam oxygen uptake rate (mg/ℓ • min)

t_{of} = Foam detentiobn time (minutes)

V_f = Foam volume (ft^3)

G_H = Hood gas flow (scfm)

P = Oxygen Partial Pressure (mm Hg)

M = 32 gO_2/mole

T = Ambient air temperature (°K)

C_{go} = Ambient gas phase O_2 concentration, mg/ℓ

Table 29 presents the foam oxygen uptake rate measured at the Ridgewood plant. The average tank foam oxygen uptake rate was 340 mg/ℓ/hr while the suspended solids concentration in the foam was about 18,000 mg/ℓ. The average uptakes were relatively constant in the first two grids at 400 to 430 mg/ℓ/hr but showed a significant reduction in the last two grids, down to 300 and 250 mg/ℓ/hr at the effluent. It appears that the uptakes in the foam parallel the uptakes in the aeration tank, which are higher in the first two grids and significantly lower in the latter two. Thus, there must be significant correlation between the activity in the foam and the activity in the tank.

TABLE 29

Nocardia Foam Oxygen Uptake Rate

Test	Date	Level (ft)	Grid A	Grid B	Grid C	Grid D	O_2 Uptake Rate of Collapsed Foam, (mg/ℓ-hr)
Lima's Thesis	1985	2	347	380	387	262	344
51 and 52	6/30/86	0.25-0.5		438			
	7/14/86	2	390	380	180	120	268
57	9/03/86	0.25	551	408	334	367	415
		Average	430	400	300	250	340

Note: Foam uptake measured in collapsed state

$$\frac{\text{volume collapsed}}{\text{volume foam}} = \frac{1}{4}$$

Nocardia foam was present in 14 of the 52 offgas tests performed. Table 30 shows the measured OTE20's and the foam corrected OTE20's evaluated in these tests. The foam correction for OTE is considered a best estimate. Its accuracy is limited by lack of foam uptake data on actual test dates and lack of actual offgas hood foam volumes. The OTE measured in each grid was corrected by using the average foam uptake and gas flow measured in that grid. The degree of correction is a function of the gas flow rates through the offgas hood. Relatively high gas flow rates, causing short detention times in the foam, resulted in small correction factors. Conversely, relatively low gas flow rates, causing long detention times in the foam, resulted in large correction factors. This is observed in test 66 where the OTE20 measured is 11.8% while the foam corrected value is 4.7% with foam detention times greater than 10 minutes. However, due to the magnitude of the correction, the validity of the test is in question. Foam oxygen uptake rates were not measured on the test day and simultaneous steady state data is not available. This was also the case in tests 63 and 64. Therefore, the results from these tests are not presented in the case history study. The steady state OTE20 calculated in test 21 indicates the uncorrected offgas OTE20 to be a better estimate than the foam corrected value. Therefore, the uncorrected value is presented in the Case History study.

2. Four Lunger and In Situ Dome DWP Taps

A second problem area has been with the 4 lunger. Initially difficulty was encountered due to the wet gas supply provided by Ridgewood from the grid blowoff piping. Plant personnel subsequently changed the supply line by tapping the header piping instead of using the blowoff from the manifolds which solved the moisture problem. Difficulties also occurred with maintaining the single dome at 1.5" head loss. During the study it was generally set higher to insure gas flow did not reduce to zero. During winter months operation was poor, with periodic clogging and freezing of the lines occurring. Similar problems existed for the dome pressure taps with clogging and freezing of the lines. Moisture buildup continuously was a problem and often terminated the DWP measurements. Due to lack of available plant personnel and equipment problems, proper 4 lunger and in situ DWP monitoring could not be conducted.

TABLE 30

Foam Corrected Oxygen Transfer Efficiencies

Test	Date	Grid	Ambient Gas Phase Conc. C_{go} mg/ℓ	Hood Offgas Flow, G_H scfm	Hood Detention Time, t_{of} min.	Grid OTE20, %		Avg. Tank OTE20,	
						Uncorr.	Foam Corr.	Uncorr.	Foam Corr.
12	8/09/85	A	277	20.11	0.80	5.5	5.0	7.4	6.8
		B	277	9.97	1.60	7.7	6.8		
		C	277	12.40	1.29	9.2	8.7		
		D	277	10.26	1.56	9.3	8.7		
14	8/14/85	A	273	19.99	0.80	5.5	5.0	9.2	8.5
		B	273	15.44	1.04	11.4	10.8		
		C	273	8.10	1.97	11.1	10.2		
		D	273	5.95	2.69	11.2	10.1		
16	9/02/85	A	277	12.76	1.25	6.2	5.4	8.4	7.2
		B	277	8.54	1.87	8.9	7.8		
		C	277	4.02	3.98	10.3	8.5		
		D	277	4.02	3.98	10.3	8.8		
17	9/11/85	A	279	15.50	1.03	6.7	6.1	7.9	7.1
		B	279	11.34	1.41	7.6	6.8		
		C	279	8.62	1.86	9.7	8.9		
		D	279	7.47	2.14	8.5	7.7		
18	9/11/85	A	279	16.14	0.99	6.4	5.8	8.0	7.3
		B	279	10.91	1.47	8.5	7.7		
		C	279	10.01	1.60	9.4	8.7		
		D	279	7.57	2.11	9.3	8.5		
19	10/21/85	A	286	10.28	1.56	5.7	4.7	7.4	6.4
		B	286	9.13	1.75	7.9	6.9		
		C	286	7.51	2.13	7.9	7.0		
		D	286	6.12	2.61	9.4	8.5		

(continued....)

TABLE 30 (cont'd)

Test	Date	Grid	Ambient Gas Phase Conc. C_{go} mg/ℓ	Hood Offgas Flow, G_H scfm	Hood Detention Time, t_{of} min.	Grid OTE20, % Uncorr.	Grid OTE20, % Foam Corr.	Avg. Tank OTE20, Uncorr.	Avg. Tank OTE20, Foam Corr.
20[1]	10/24/85	A	282	2.62	6.11	5.9	2.0	7.0	2.9
		B	282	2.16	7.41	7.2	2.9		
		C	282	1.62	9.89	8.1	3.7		
		D	282	1.62	9.89	8.1	4.4		
21[1]	10/30/85	A	283	5.52	2.90	4.9	3.1	6.2	3.7
		B	283	4.60	3.48	6.2	4.2		
		C	283	1.84	8.72	7.0	3.2		
		D	283	1.84	8.70	8.0	4.8		
61	6/30/86	A	276	13.94	1.15	7.5	6.8	9.6	8.7
		B	276	11.85	1.35	10.6	9.8		
		C	276	7.32	2.19	11.3	10.3		
		D	276	7.33	2.18	10.4	9.6		
62	6/30/86	A	276	14.00	1.14	7.5	6.8	9.2	8.4
		B	276	14.00	1.14	10.0	9.3		
		C	276	7.32	2.18	10.8	9.8		
		D	276	7.34	2.18	9.9	9.1		
63[2]	7/08/86	A	276	1.81	8.86	10.6	4.8	12.8	6.5
		B	276	1.81	8.86	14.4	9.2		
		C	276	0.84	18.96	12.8	4.2		
		D	276	0.84	18.96	14.7	7.6		
64[2]	7/31/86	A	274	8.28	1.93	9.6	8.3	11.3	7.7
		B	274	3.33	4.80	12.5	9.6		
		C	274	0.96	16.73	12.0	4.3		
		D	274	0.96	16.73	12.3	5.9		

(continued....)

TABLE 30 (cont'd)

Test	Date	Grid	Ambient Gas Phase Conc. Cg_o mg/ℓ	Hood Offgas Flow, G_H scfm	Hood Detention Time, R_f min.	Grid OTE20, % Uncorr.	Grid OTE20, % Foam Corr.	Avg. Tank OTE20, Uncorr.	Avg. Tank OTE20, Foam Corr.
66 [2]	8/21/86	A	276	1.40	11.44	10.9	3.5	11.8	4.7
		B	276	1.40	11.44	11.8	5.1		
		C	276	0.96	16.64	12.9	5.4		
		D	276	0.96	16.64	12.5	6.2		
67	9/03/86	A	279	9.96	1.61	8.2	7.1	10.0	9.0
		B	279	9.13	1.75	9.9	8.8		
		C	279	7.03	2.28	11.5	10.4		
		D	279	7.04	2.27	12.4	11.6		

NOTE: Average tank OTE values based on dome distribution weighting and average foam O_2 uptake rates used as follows:

Grid	Foam O_2 Uptake Rate, R_f, mg/ℓ-min	OTE Weighting Factor
A	1.8	0.360
B	1.6	0.320
C	1.3	0.160
D	1.0	0.160

Hood Foam Volume assumed to be 16 ft^3.

[1] The steady state OTE20's indicate the uncorrected value to be a better estimate

[2] Tests not presented in analysis

VII. PLANT PERFORMANCE - COARSE BUBBLE AND FINE PORE SYSTEMS

A. Operating Conditions and Controls

In reviewing the operating conditions and controls of the coarse bubble and fine pore aeration systems not only diffuser type but method of aeration was changed. The coarse bubble system operated under a contact-stabilization method, while the fine pore system utilizes a conventional tapered air method. Within these two systems operating parameters and plant performance vary considerably.

The contact-stabilization (coarse) system operated at a lower food to mass(F/M) and higher solids retention time(SRT) than the tapered air (fine) system as shown in Table 31.

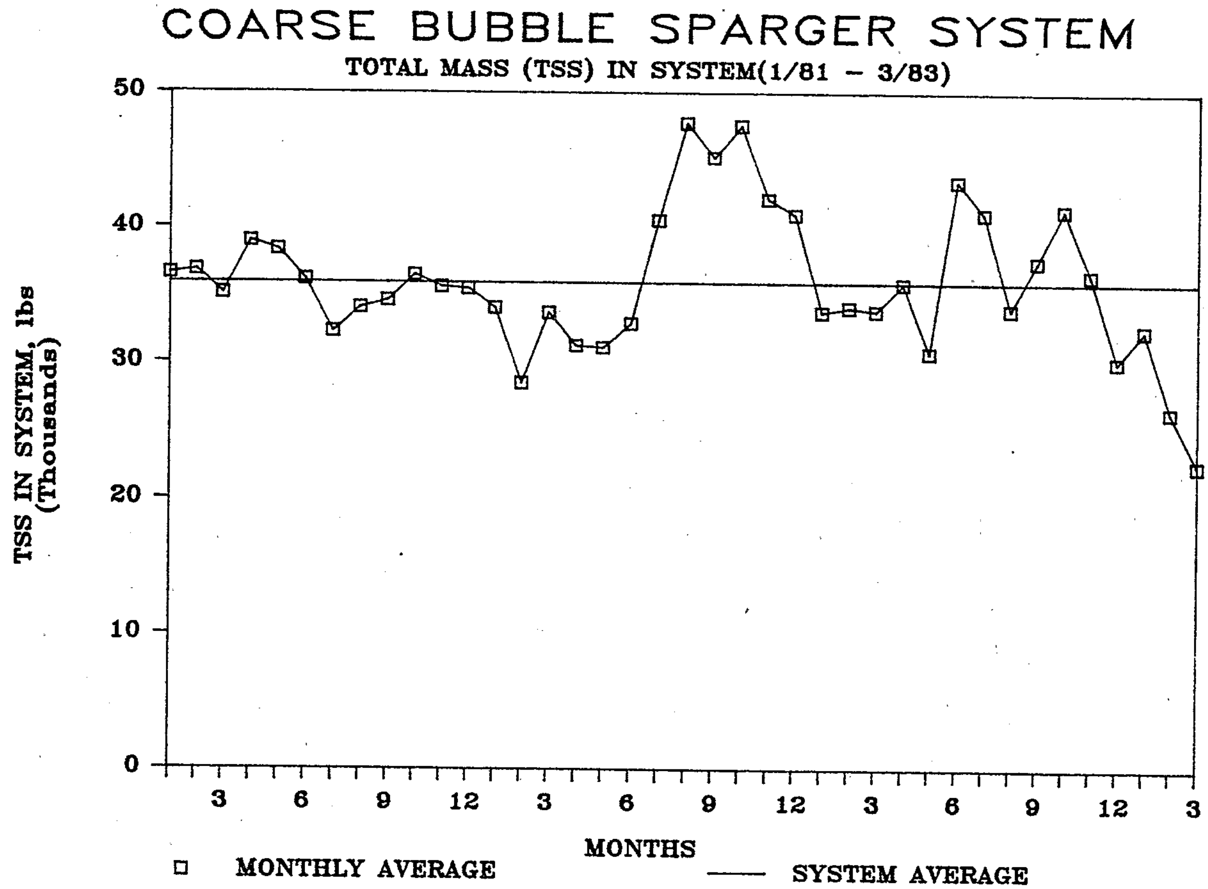
TABLE 31

Average Operating Conditions for Both Aeration Systems at Ridgewood

System	Dates	Average TSS in System lbs.	Average F/M lb BOD_5/d-lb MLVSS	Average SRT days
Coarse	1/80-03/83	35,900	0.13	17.7
Fine	4/83-12/86	21,500	0.25	7.2

The F/M is based on the pounds of BOD_5 per day in the primary clarifier effluent divided by the pounds of MLVSS in the aeration tanks and secondary clarifiers. The SRT is based on the pounds of MLVSS in the aeration tanks and secondary clarifiers divided by the pounds per day leaving the system as waste activated sludge and effluent solids. Figures 40 through 42 illustrate the variability and average values of sludge mass, F/M and SRT for each aeration system. The mass in the system was fairly constant during the operation of the coarse bubble system. For approximately the first year after the startup of the fine pore system plant solids were almost twice the average. This correlates with low F/M and high SRT values for the same time period. Also, the air supplied to the fine pore system during this period was well above average as shown later in this report.

Figure 40. Total Mass (TSS) in System - Coarse and Fine



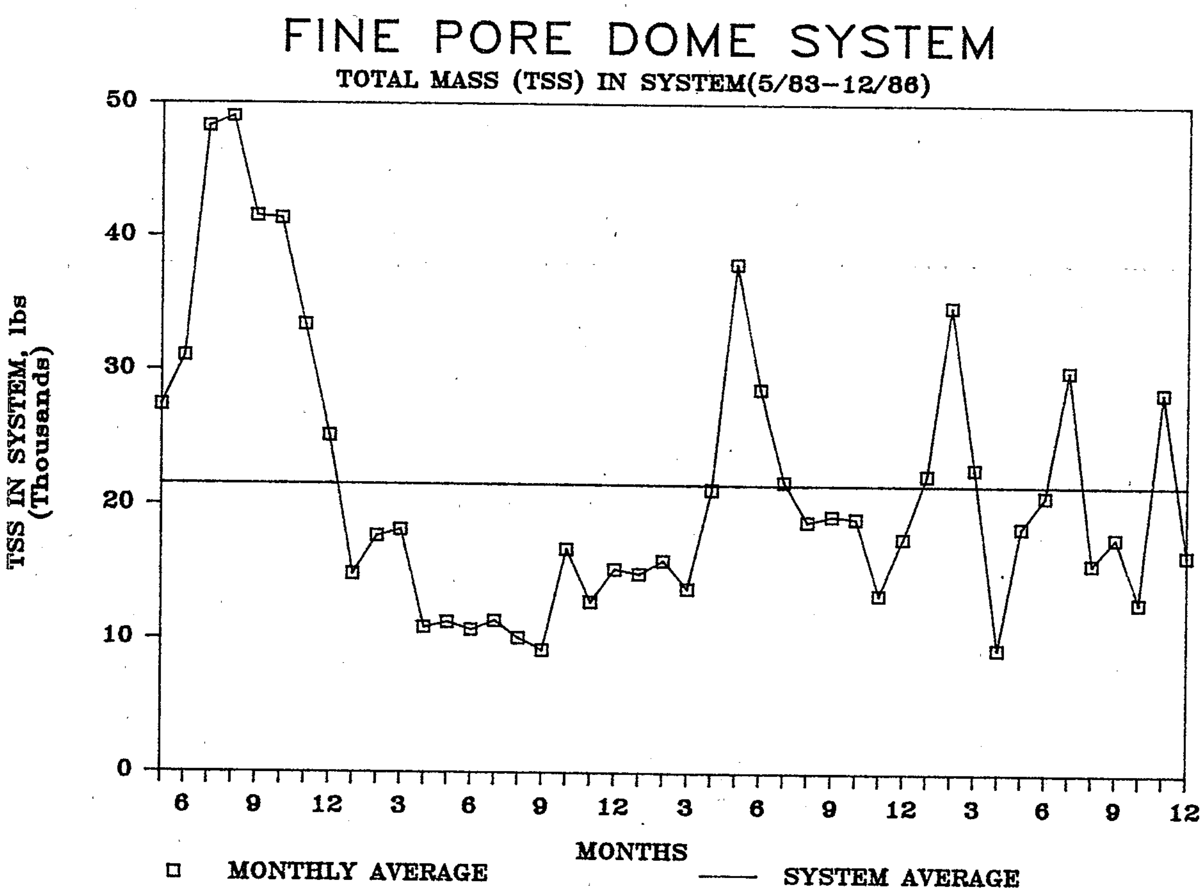
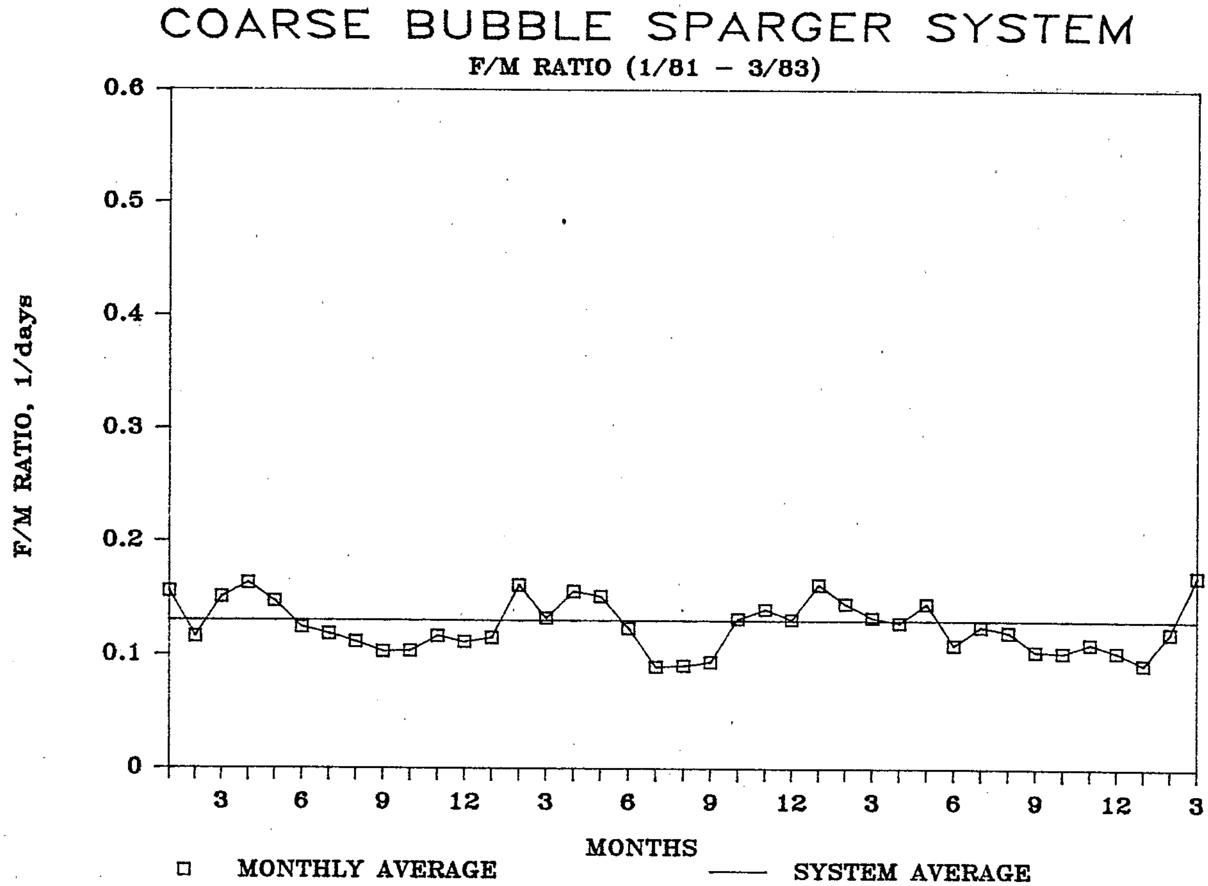


Figure 41. F/M Ratio - Coarse and Fine



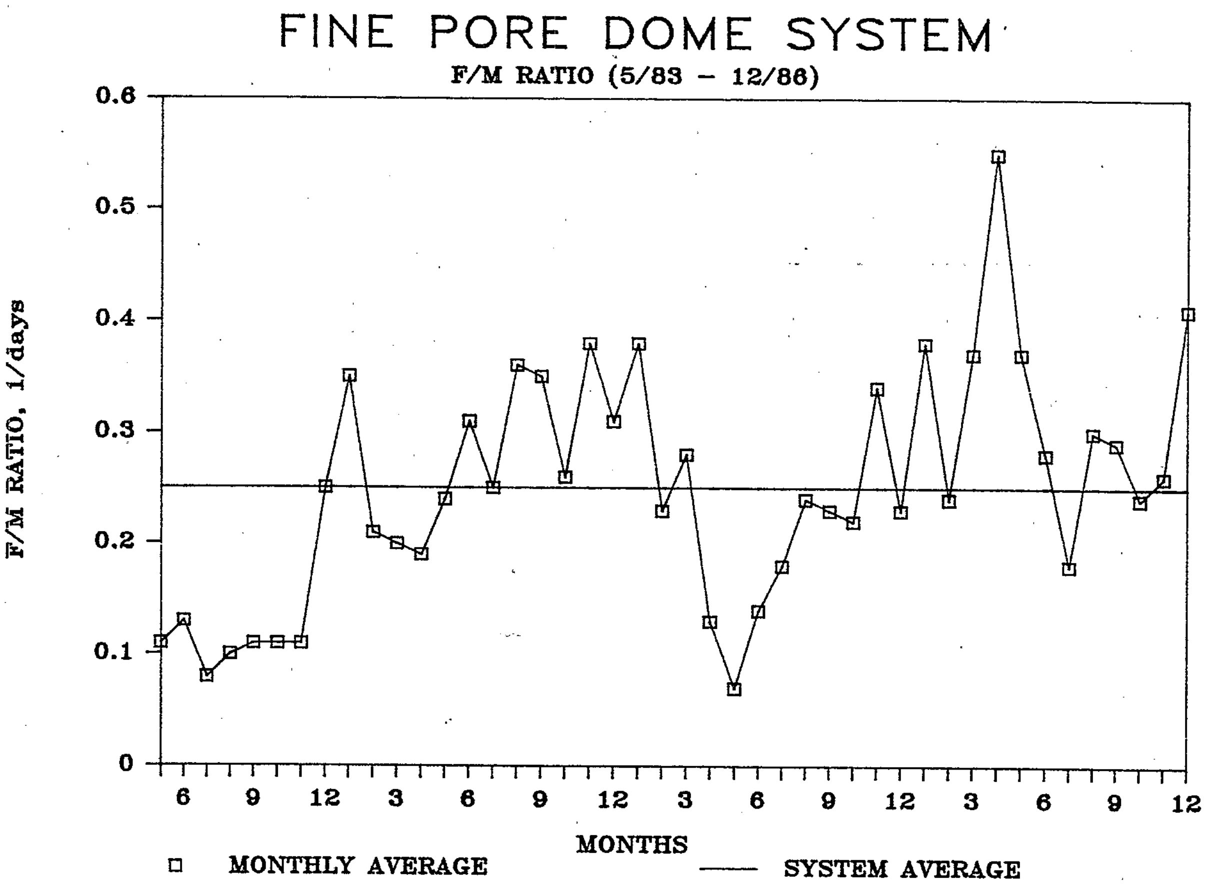
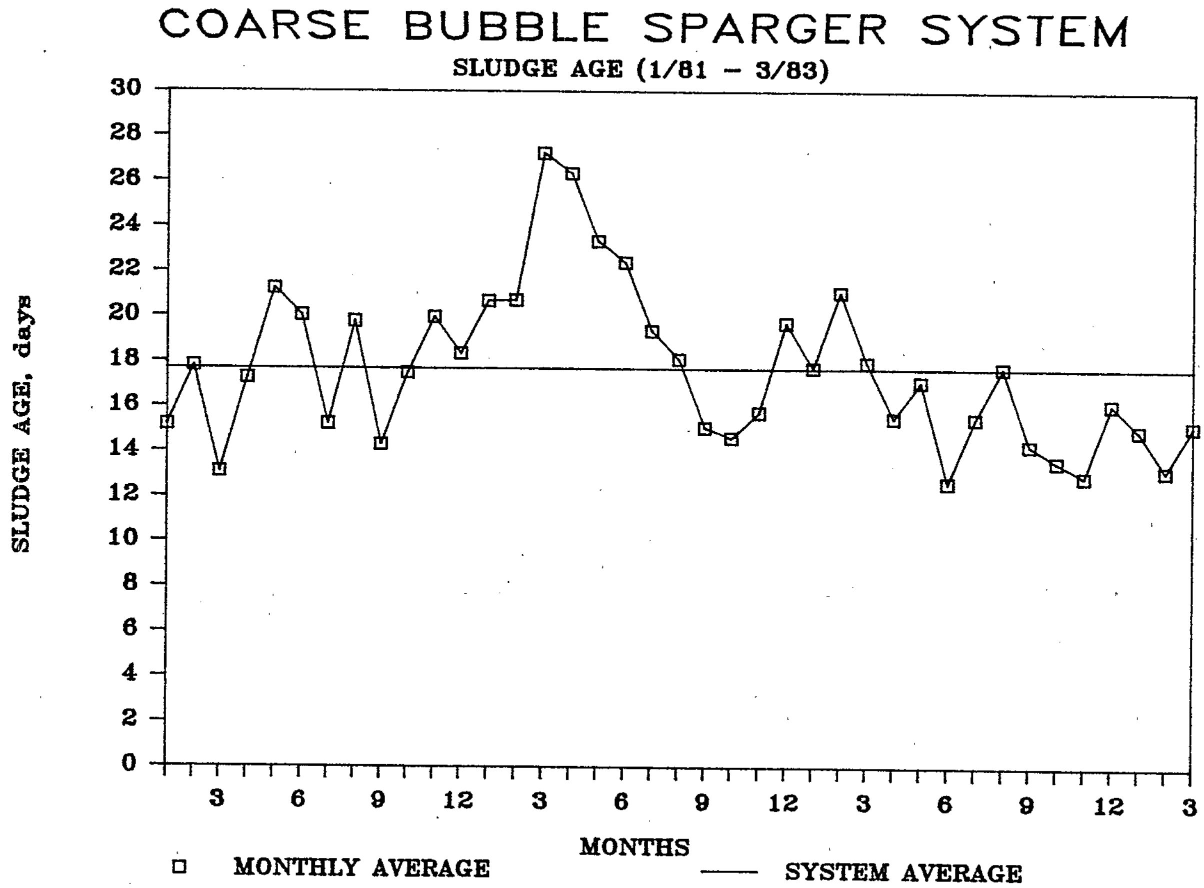
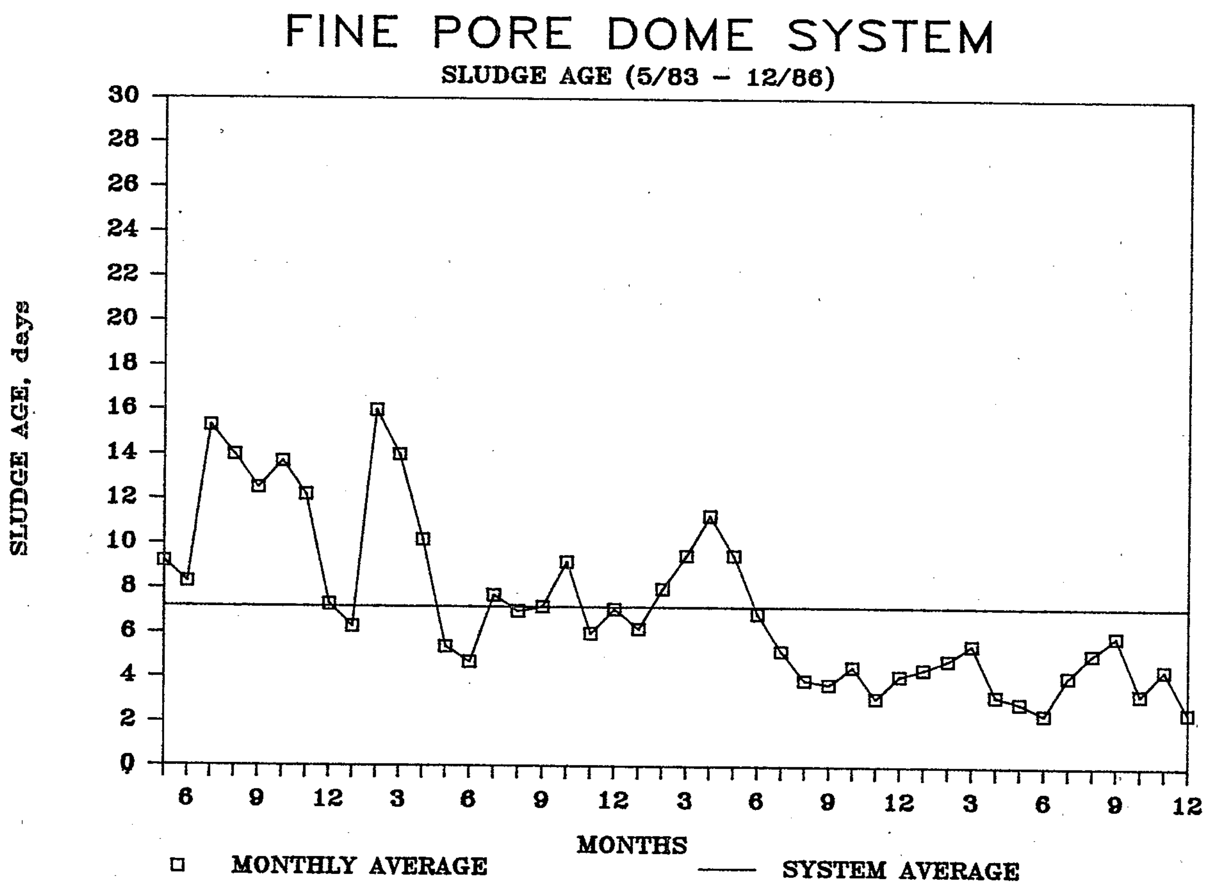


Figure 42. Sludge Age - Coarse and Fine





The coarse bubble system required continuous 2 blower operation and all valves to the tank wide open. The increased efficiency of the fine pore system provided flexibility with respect to air supply. Dissolved oxygen concentrations are monitored in grid B in both aeration tanks. During low load periods, one blower is utilized. Regulating the amount of air supplied during aeration is a function of the amount of dissolved oxygen present in the tanks. When the dissolved oxygen concentration drops to 0.6 mg/ℓ, a second blower is turned on. Butterfly valves can adjust the gas flow to each grid, but typically are wide open during operation.

B. Treatment Performance

1. Influent and Effluent Characteristics

Table 32 lists the average monthly influent and effluent values for the coarse bubble and fine pore aeration system. The coarse bubble results represent the period from January 1980 to March 1983, while fine pore values cover the period of May 1983 to December 1986. Average influent concentrations have decreased since the fine pore aeration startup in April, 1983, due to an increase in average flow, from 2.9 to 3.3 MGD as shown in Figure 43. Periodic high monthly flows are due to infiltration and inflow during wet weather with high groundwater tables.

Figures 44 through 46 show the monthly influent and effluent concentrations for both aeration systems. Significant variability occurred especially for the fine bubble system due in part to the significant flow variability. High effluent BOD_5 and suspended solids losses occurred from the fine pore system in the winter of 1983-84. The solids recycle load from the chlorination tank sludge were roughly five times greater than normal during this period due to the high effluent solids from the secondary clarifier. A marked decrease in the total mass of solids in the aeration tank and clarifier also occurred during this time as solids were rapidly wasted from the system to reduce O_2 demand.

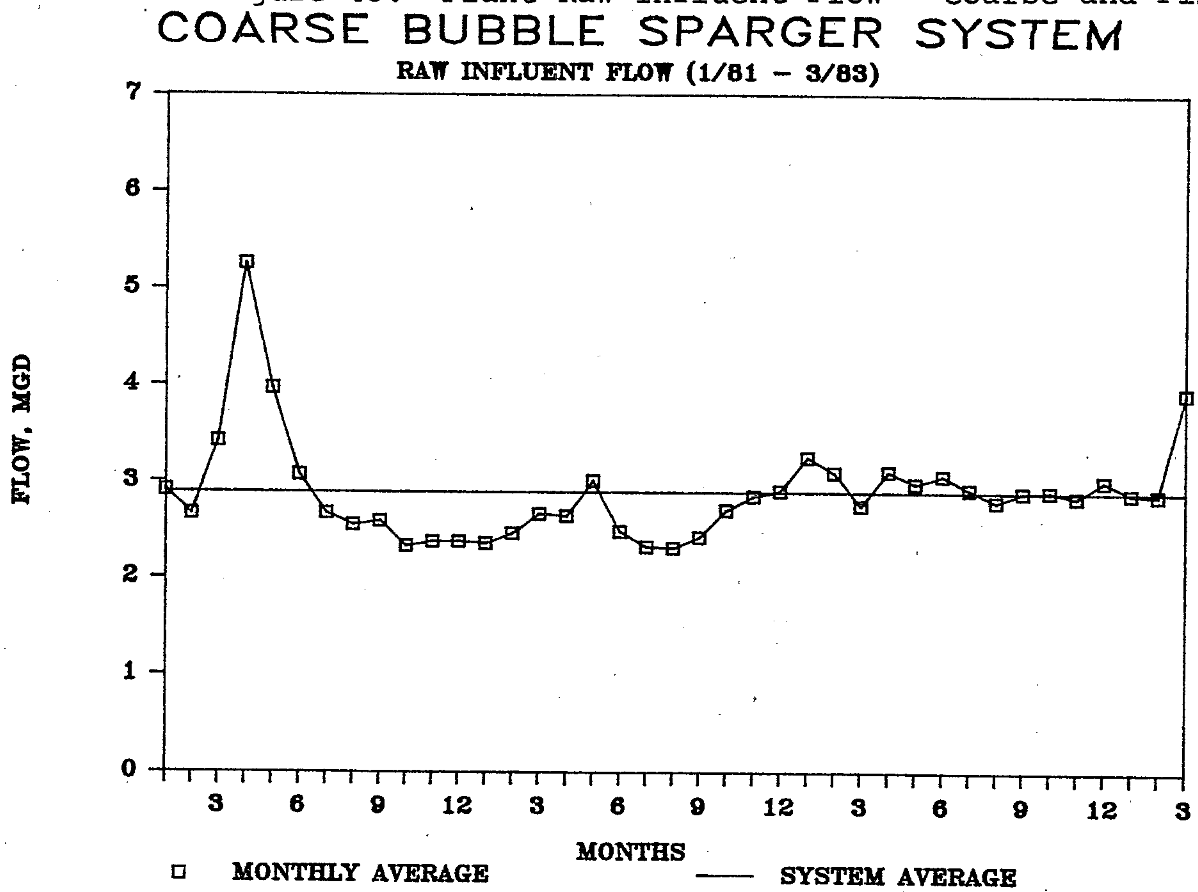
Figure 46 indicates a marked increase in nitrification during the summer months for the fine pore system due to the higher D.O. levels

TABLE 32

Plant Performance Results for Fine and Coarse Bubble Aeration Systems

Parameter	Units	Average Values and Standard Deviations ( ) for Each System					
		Coarse (1/80-3/83)			Fine (4/83-12/86)		
		Influent	Effluent	% Removal	Influent	Effluent	% Removal
Raw Flow	MGD	2.89 (0.55)			3.27 (0.74)		
TSS	mg/ℓ	148 (25)	6.1 (1.8)	96 (2)	152 (48)	13 8	91 (8)
	lb/d	3530 (661)	147 (53)		4150 (1010)	355 (267)	
BOD_5	mg/ℓ	207 (23)	13.1 (1.3)	94 (1)	195 (43)	15 (5)	92 (4)
	lb/d	4940 (738)	316 (69)		5320 (962)	410 (129)	
NH_4^+-N	mg/ℓ		28.7 (3.5)		37 (10.2)	28 (13)	25 (27)
	lb/d		692 (84)		1009 (279)	764 (376)	
NO_3^--N	mg/ℓ					6.8 (5)	
	lb/d					185 (192)	

Figure 43. Plant Raw Influent Flow - Coarse and Fine



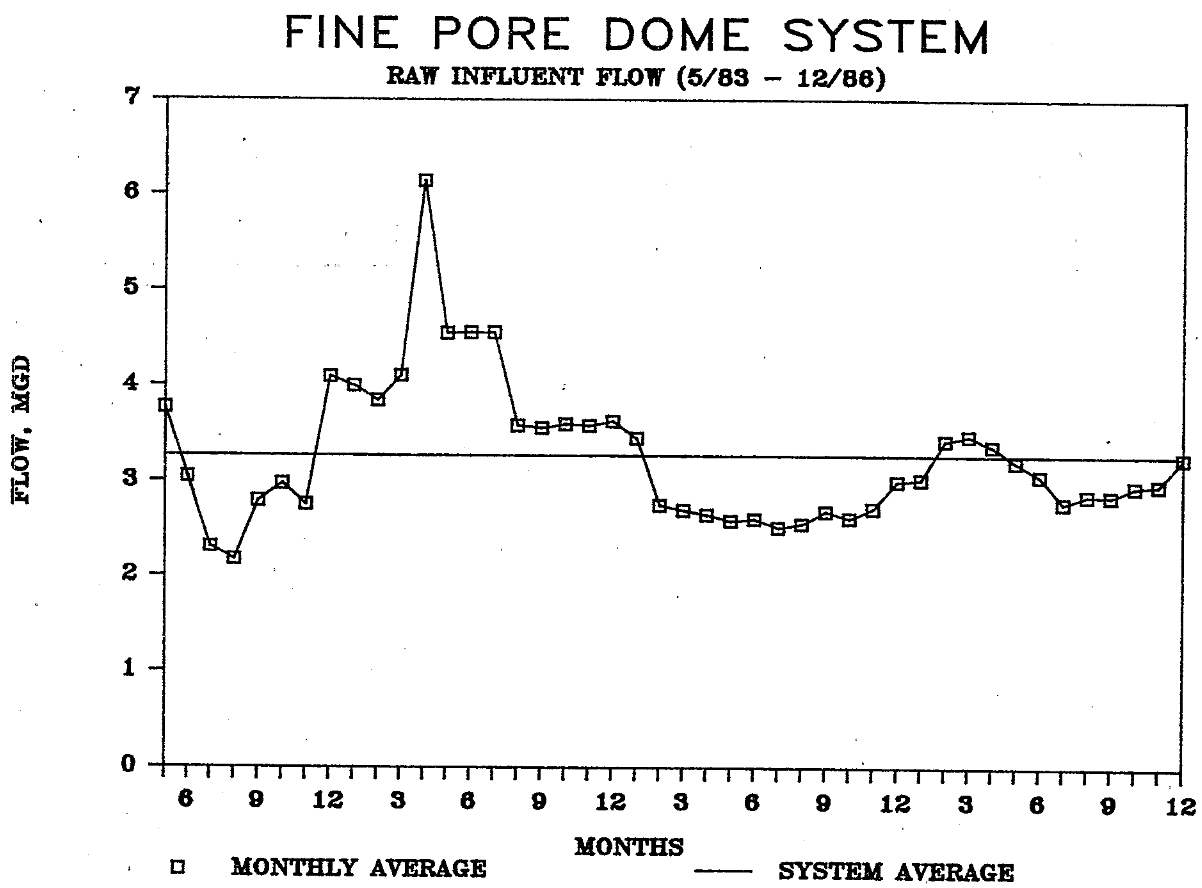
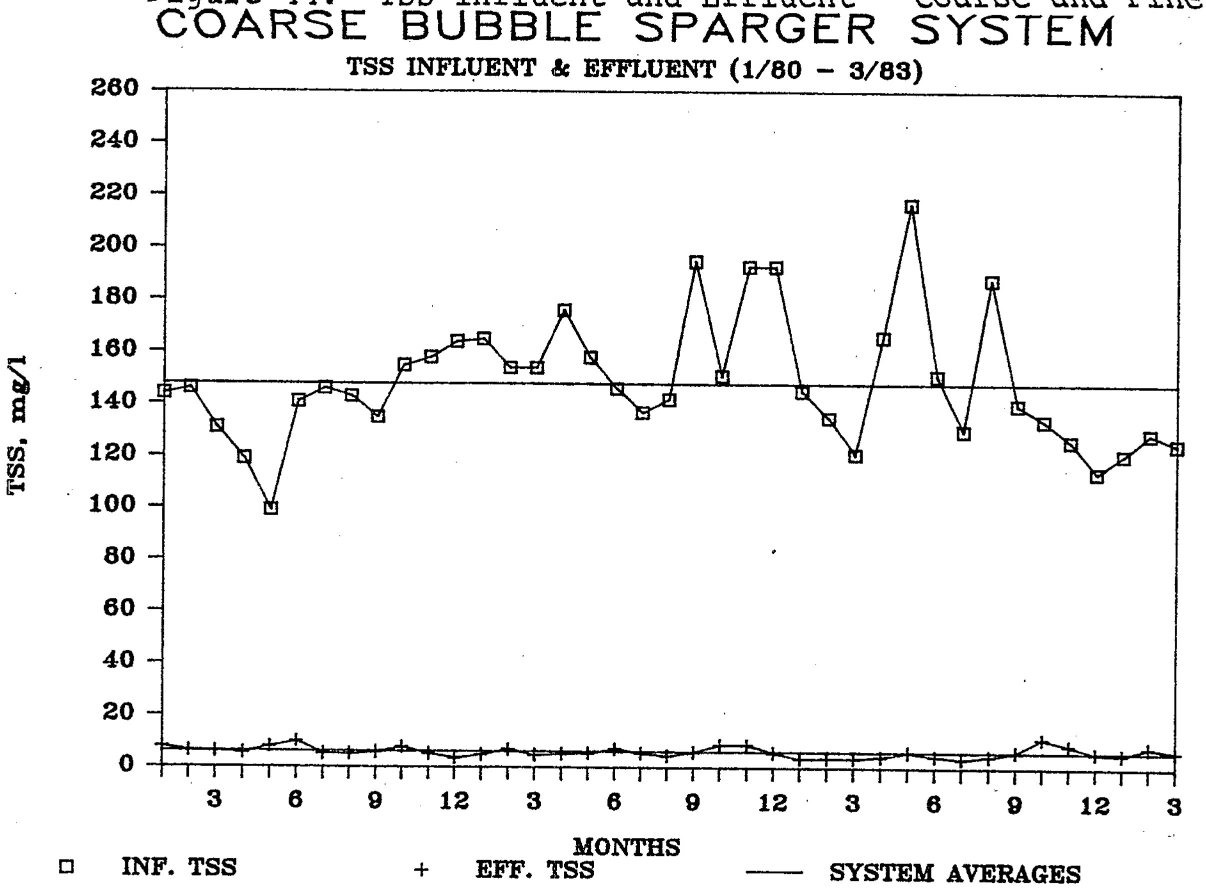


Figure 44. TSS Influent and Effluent - Coarse and Fine



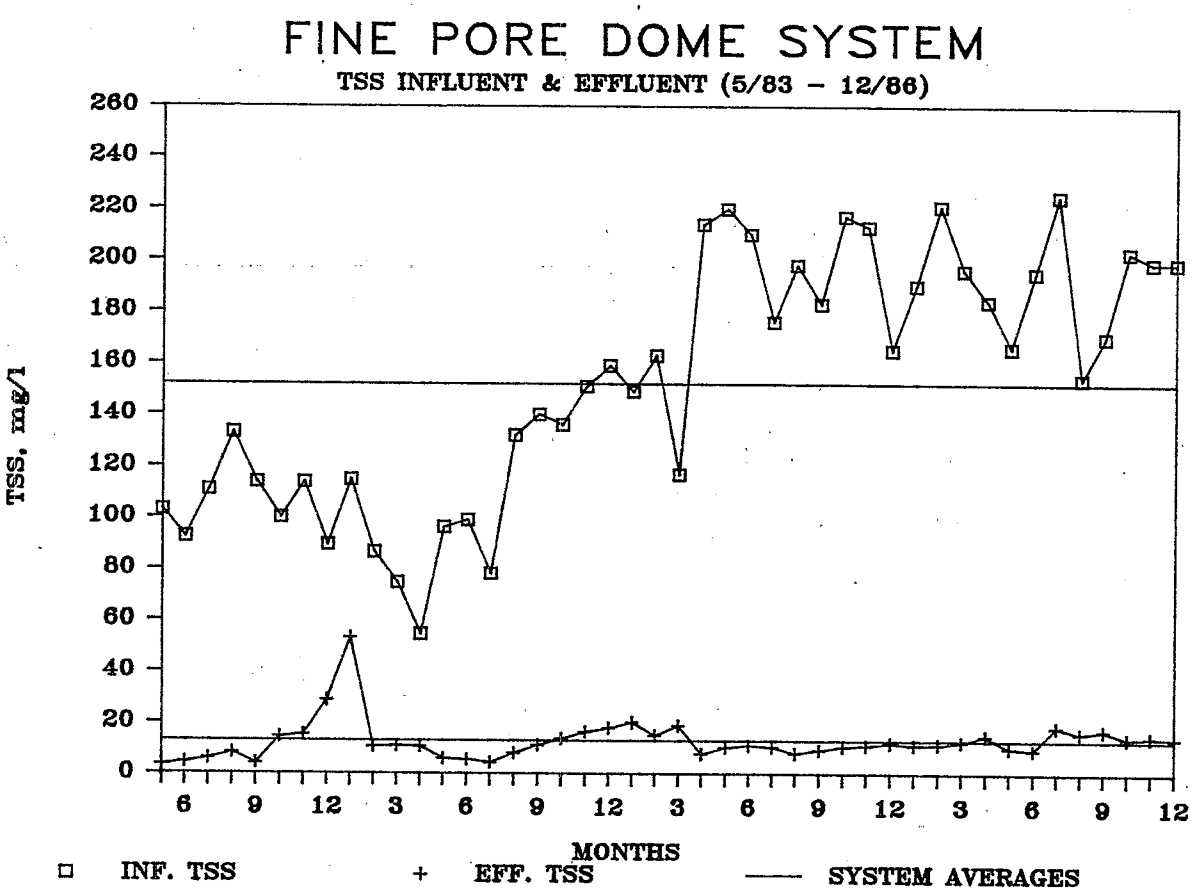
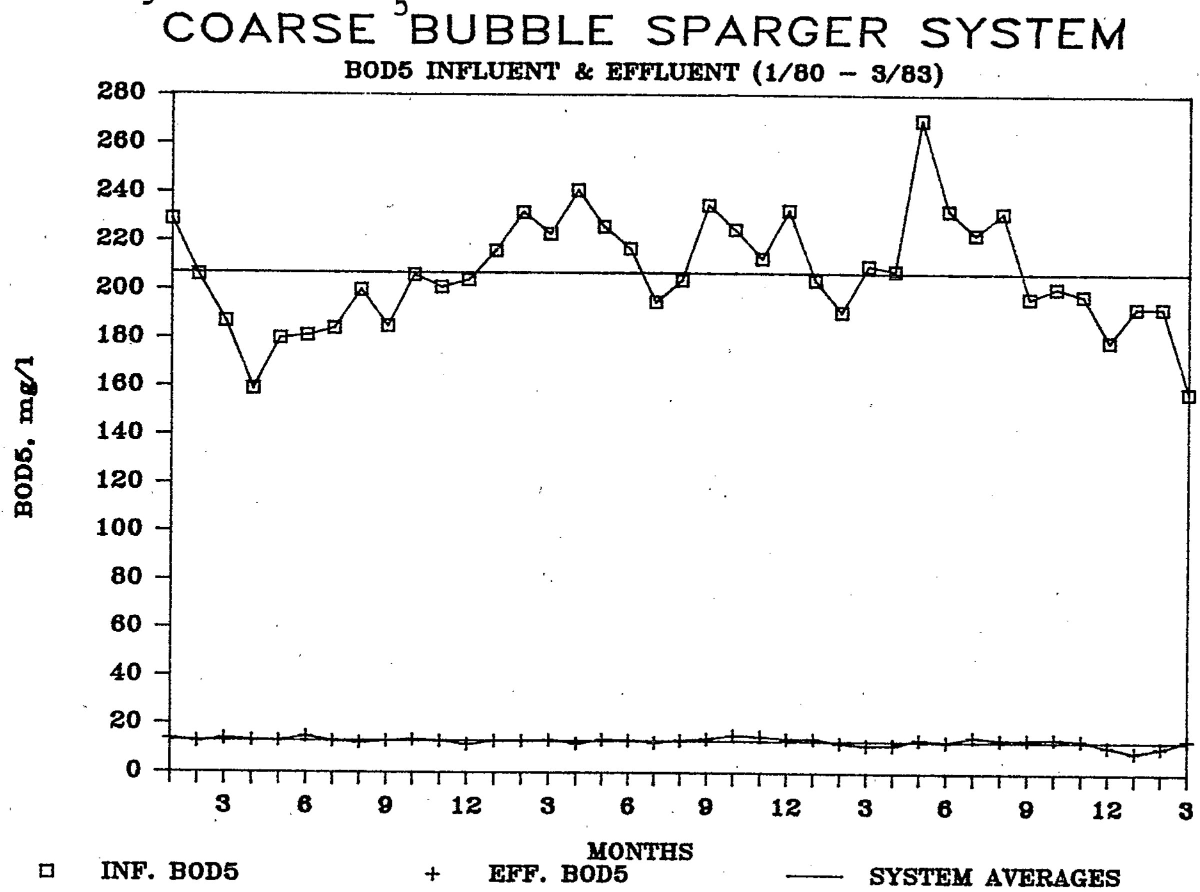


Figure 45. BOD_5 Influent and Effluent - Coarse and Fine



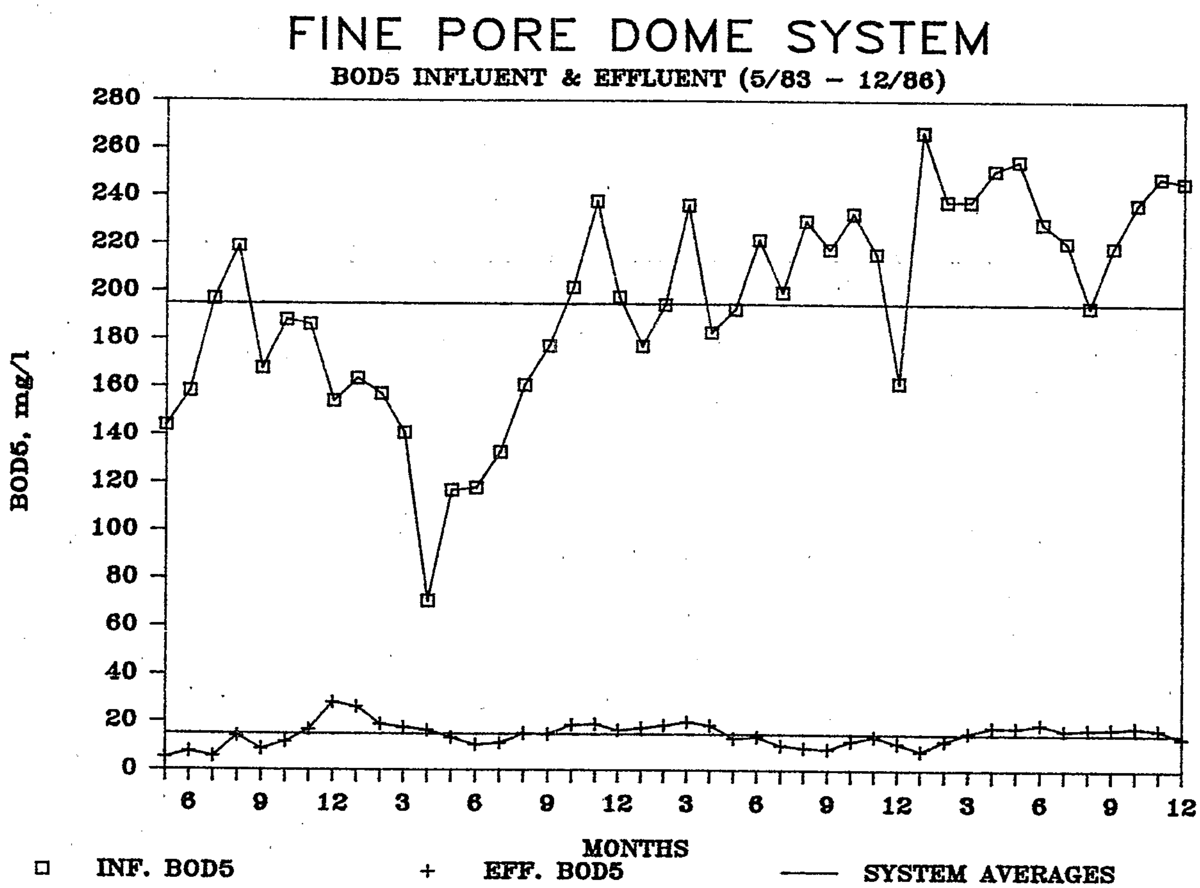
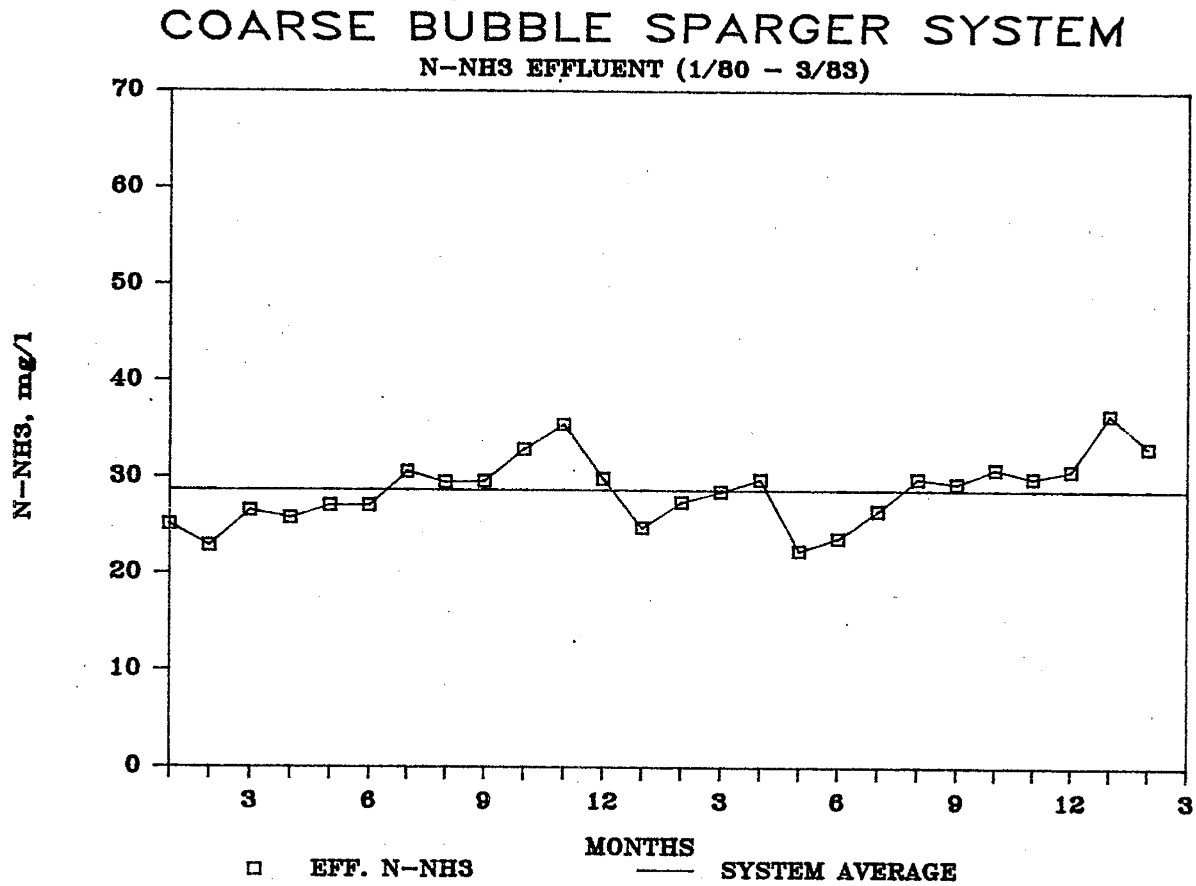
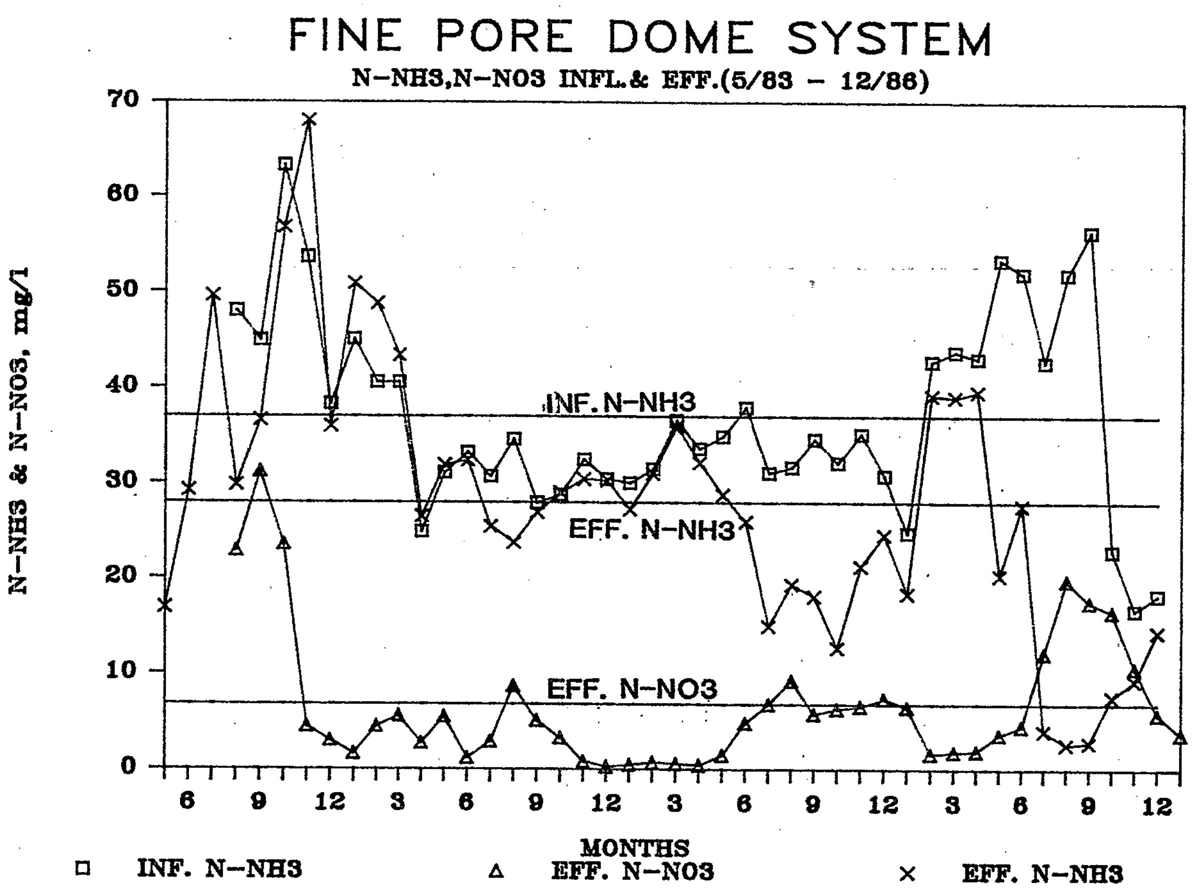


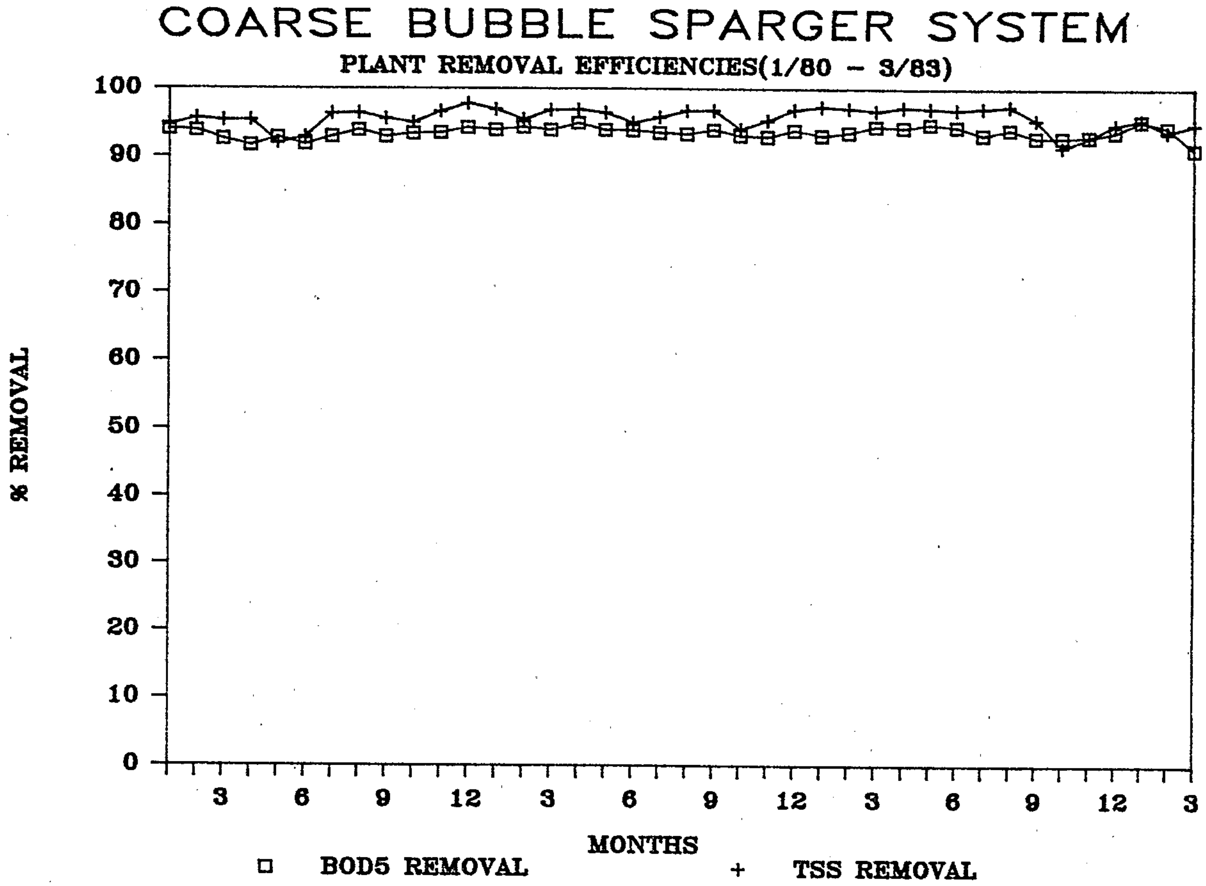
Figure 46. N-NH_3, NO_3 Influent and Effluent - Coarse and Fine

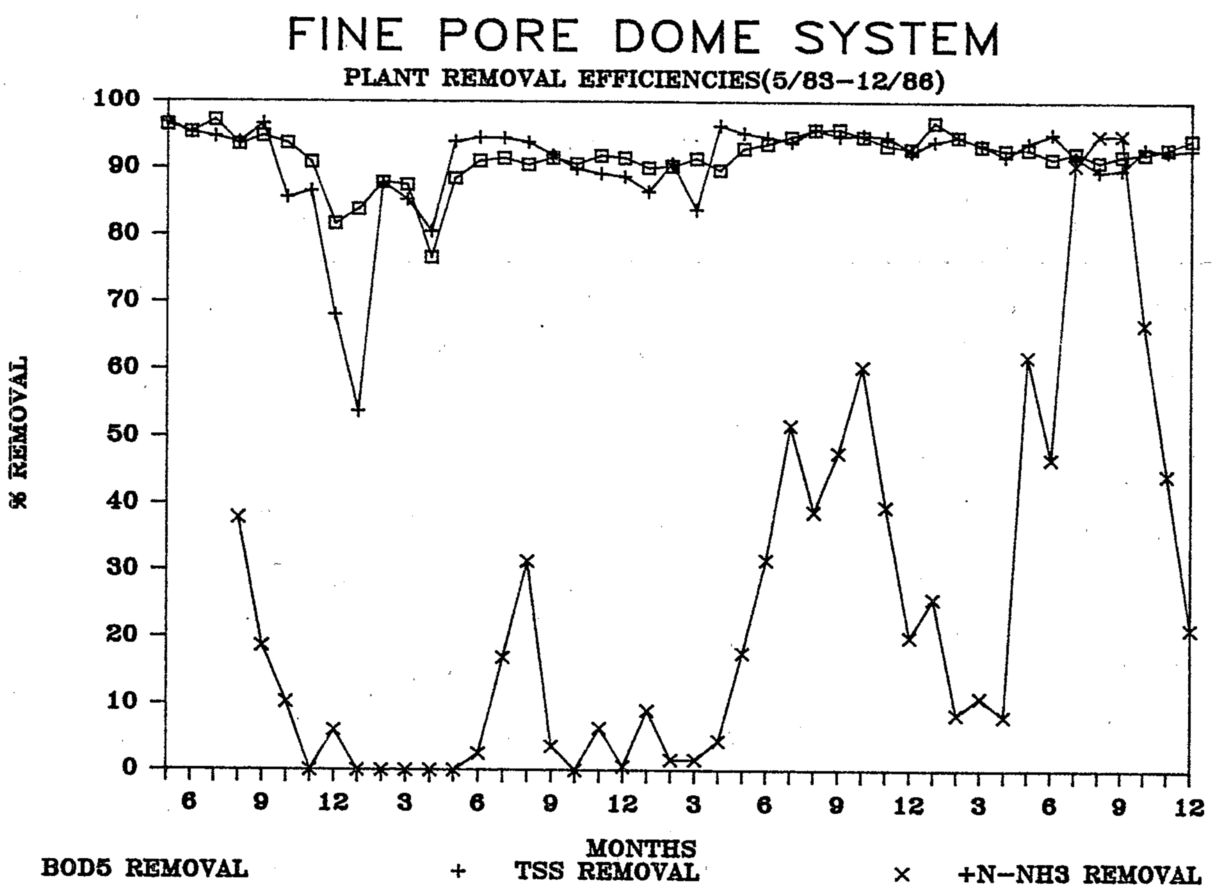




maintained in the aeration tanks. Thus the oxygen demand on the fine pore system was significantly greater than on the coarse bubble system due to the oxidation of the nitrogeneous load. Figure 47 summarizes the % removals obtained by both systems showing the coarse bubble consistently outperformed the fine pore system on BOD_5 and TSS removals while nitrogen removal occurred in the fine pore system, but not in the coarse system. Periodic low suspended solids and BOD removal efficiencies in the fine pore system was due to the inability of Ridgewood's sludge handling system to adequately waste sludge without the availability of the sludge lagoons.

Figure 47. Plant Removal Efficiencies - Coarse and Fine





2. Sludge Production Comparison

The startup of the fine pore diffuser system was expected to reduce aeration costs and sludge production. An 18% reduction in secondary sludge production was predicted (Phase I, 1982). Analysis of actual field data, shown in Table 33, shows an increase in secondary sludge production of 980 lb/day and an average increase of 585 lb/day being hauled offsite. This is due to the high F/M of the fine pore system and sludge discharged to onsite lagoons during the operation of the coarse bubble system thus reducing the amount of sludge hauled offsite. The lagoons were phased out in August of 1982 and data is not available as to the amount of sludge handled by them. On the average 20.5% of the influent TSS was hauled offsite during the operation of the coarse bubble system, while 31.6% of the influent TSS was hauled offsite for the fine pore system (Holmes, 1986).

The thickening characteristics of the contact stabilization sludge from the coarse bubble system were better than those from the conventional fine bubble system as indicated by the greater WAS and primary clarifier under flow (digester influent) concentrations.

3. Recycle Stream Impact on Fine Pore Aeration System

The majority of flow to the aeration tanks is comprised of the primary clarifier effluent and return activated sludge (RAS). However, the recycle streams from the chlorination tank and the anaerobic digestor supernatant significantly contribute to the aeration tank load. Tables 34 and 35 present the recycle stream loads based on average monthly values and during their period of return.

Chlorination is the final process stage at Ridgewood prior to discharging secondary effluent into the Ho-Ho-Kus Brook. The tanks are drained and cleaned of sediment on an average of once each month. The tank is divided into 4 sections, with 2 of 4 sections generally cleaned at one time to allow uninterrupted plant operation during the cleaning process. Field tests (Holmes, 1986) indicate that there is a 15% suspended solids removal rate across the chlorination tank. Based on that removal, and a cleaning rate of once per month, the chlorination tank recycle stream solids concentration averaged approximately 2200 mg/ℓ.

TABLE 33

Sludge Wastage Results for Fine and Coarse Bubble Systems

Parameter	Average TSS Values for each System	
	Coarse (1/80-3/83)	Fine (4/83-12/86)
LOADS, lb/d		
Secondary Waste Solids		
Effluent	147	355
WAS	2000	2770
TOTAL	2147	3125
Digester Influent	4350	4430
Sludge Haulage	725	1310
Lagoon Storage	>0	0
CONCENTRATIONS, mg/ℓ		
WAS	6700	5850
Digester Influent	42000	31800
Sludge Haulage	50200	45100

TABLE 34

Influent and Recycle Loads to Aeration Tank
Based on Average Monthly Values

Stream	Flow (mgd)	TSS (lb/day)	BOD (lb/day)	TOC (lb/day)	TKN (lb/day)	PHOS-T (lb/day)
RAS	1.39	67,800	32,000	23,400	6,700	1,550
Primary Effluent	1.88	4,720	4,630	2,140	1,120	184
Chlorination Tank*	0.003	69	79	117	9	9
Digester Supernatant*	0.009	634	29	22	84	-

*Sampled twice, November 21 and December 4, 1985

TABLE 35

TSS Recycle Stream Impact on Aeration Tank Load

	Units	Chlorination Tank	Settled Digester Supernatant
Average Return Time per day	(hrs)	2	4
% of Return to Aeration Tank	(%)	97.6	100(assumed)
Average Return Cycle		1.1/month	Daily
Average TSS Concentration	(mg/ℓ)	2200	4570
Flow	(MG/hr)	0.05	0.0023
Recycle TSS Load	(lb/hr)	900	90
(1)% of Aeration Influent Load	(%)	27	3
(2)% of Primary Effluent Load	(%)	900	63

(1) Average Aeration Influent Load = 3400 lb/hr

(2) Average Primary Effluent Load = 103 lb/hr

Thus, the recycle stream results in a 27% increase in suspended solids load to the aeration tank during the cleaning process which typically takes 2 hours. The chlorination tank load is approximately 9 times greater than the primary clarifier effluent load and 6 times that of the average daily raw influent load during the recycle period.

Combined primary and secondary sludges for the primary clarifier underflow are pumped to digestor No. 1 which is mixed and heated. Settled sludge is removed from digestor No. 2 and hauled offsite, while supernatant is discharged to primary clarifier No. 2 for further settling. From there, settled sludge is disposed of and supernatant is returned to the system where it is mixed with primary influent or aerated prior to return. Presently, it is aerated in aeration tanks No. 2-4 to satisfy the oxygen demand before discharging into the aeration tank influent stream. The digester supernatant load was based on an assumed average concentration of 9400 mg/ℓ and was derived from field sampling. The settled supernatant load was based on an average concentration of 4570 mg/ℓ. This results in a 3% increase of the load entering the aeration tanks during its period of return. It is a 63% increase over the average raw influent load and a 86% increase over the average primary effluent load. The field sampling was conducted in November and December of 1985 and may not represent typical loadings from the digester recycle. In fact, summer loadings from digester recycle are suspected to be significantly higher for the fine pore system due to the solids wasting difficulties mentioned previously.

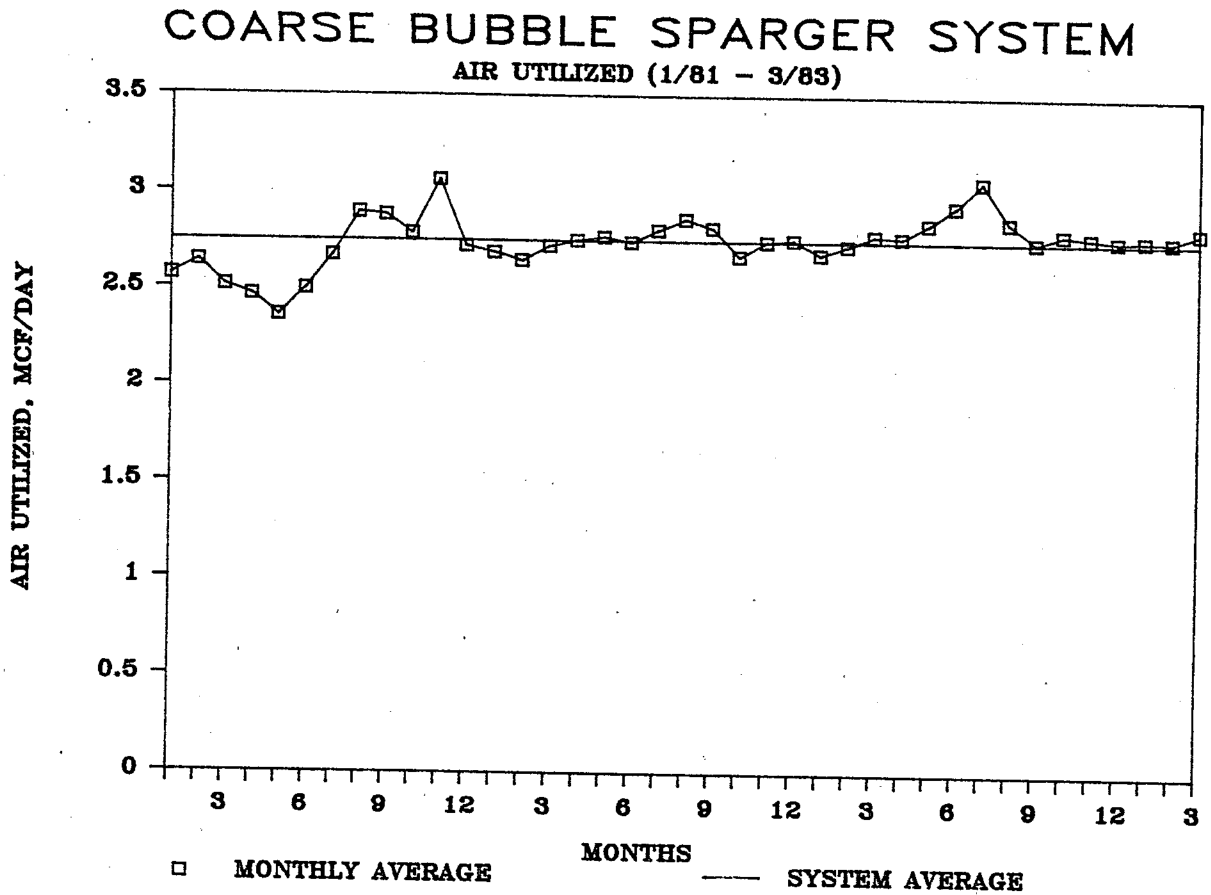
C) Air Utilization Comparison

It was anticipated that the fine pore diffuser retrofit would enable Ridgewood to reduce energy costs by operating one blower rather than two, because of the increased efficiency of the new system. Plant records indicate an average blower usage of 2950 kwh/day for the coarse bubble system. The average blower usage predicted for the fine pore system was 1475 kwh/day; actual records show an average value of approximately 2090 kwh/day. This translates to a 28% reduction of blower usage. This is a substantial savings of blower time, but is below the anticipated 50% reduction. Typical plant operation utilizes two blowers during high flow and load periods, while one blower is used during low load periods.

Figure 48 illustrates the air flow rates for the coarse bubble and fine pore aeration systems. The average air required for the coarse bubble system is 2.75 MCF/day, while 1.63 MCF/day is the average value for the fine pore system. From the startup of the new system to the beginning of 1984, the average air supplied was approximately 2.5 MCF/day with the second blower utilized a large percentage of the time. Plant conditions were poor during this time with high solid levels in the system (Figure 40) and coarsing in the aeration tank due to loose and missing domes. Second blower on time has increased from 24% of the time in 1984 to 65% in 1986. The increased on time for the second blower is a result of a greater oxygen demand of the system due to nitrification. A seasonal nitrification permit will go into effect for Ridgewood starting in April, 1987. Thus, the blower on time in 1986 may be typical in order for Ridgewood to meet the new standard.

Figure 49 shows the amount of air necessary to treat 1 gallon of influent wastewater. Roughly, 1 CF of air was necessary for 1 gallon of influent wastewater during the operation of the coarse bubble system. Due to the fine pore diffuser retrofit approximately 0.5 CF is necessary to treat 1 gallon of influent wastewater. As shown in Figure 50, the coarse bubble system required 610 cubic feet of air per pound BOD_5 removal compared to 370 for the fine pore system.

Figure 48. Air Utilized - Coarse and Fine



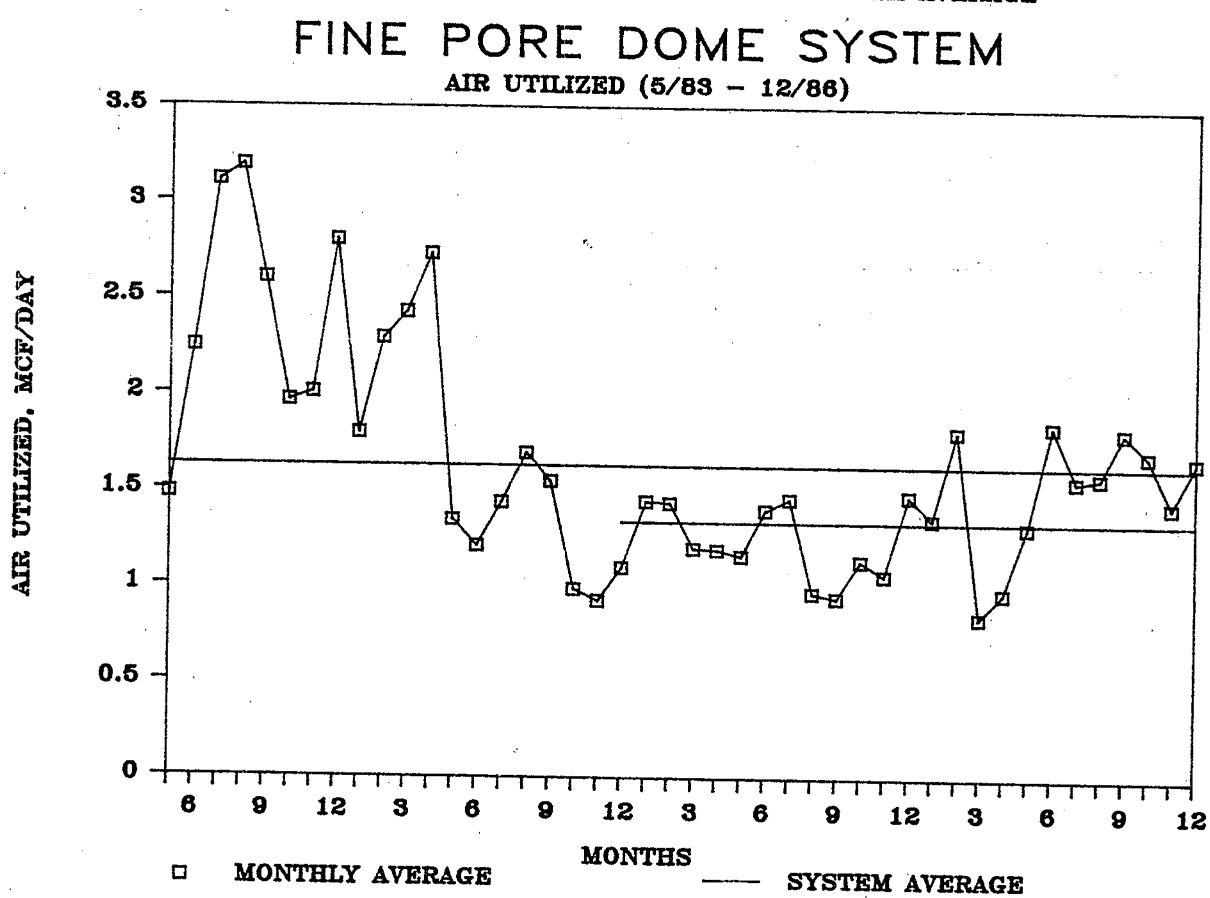
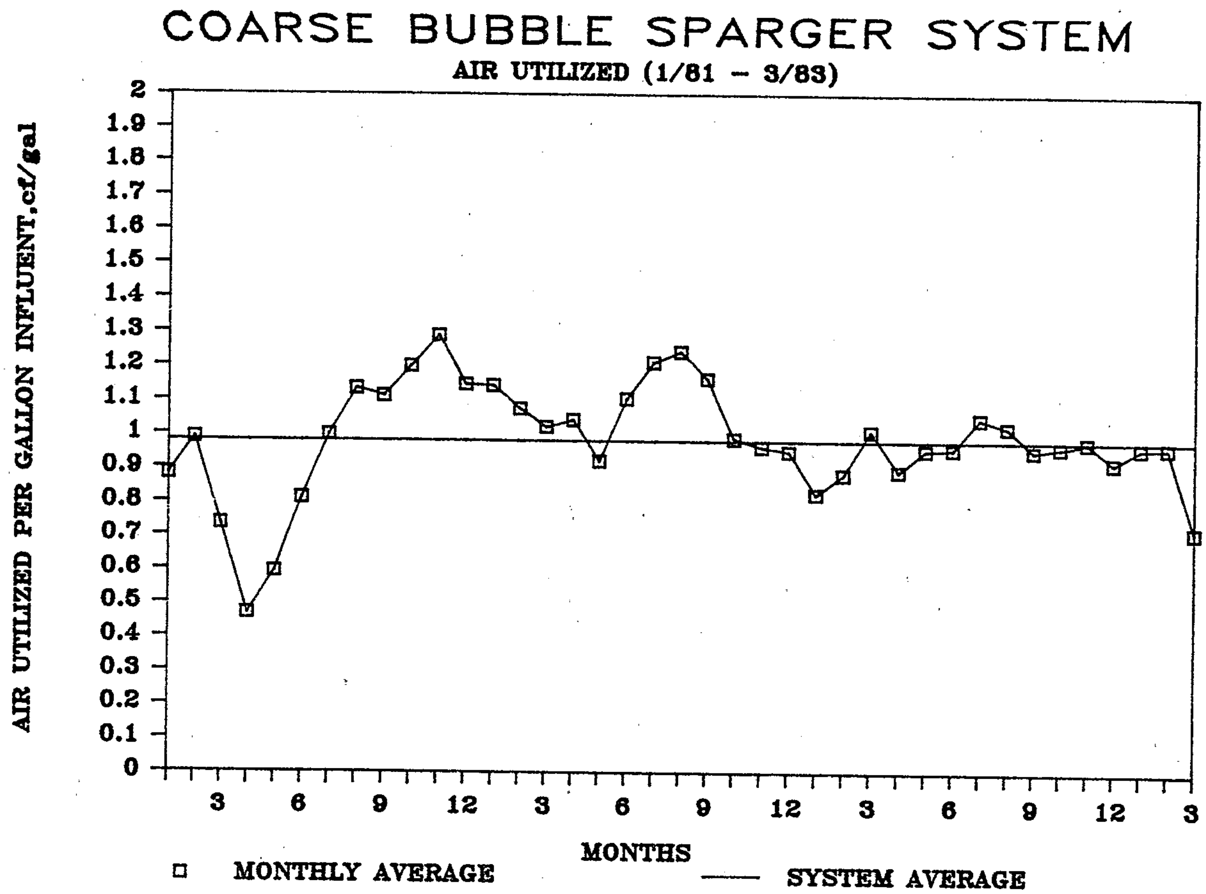


Figure 49. Air Utilized Per Gallon Influent - Coarse and Fine



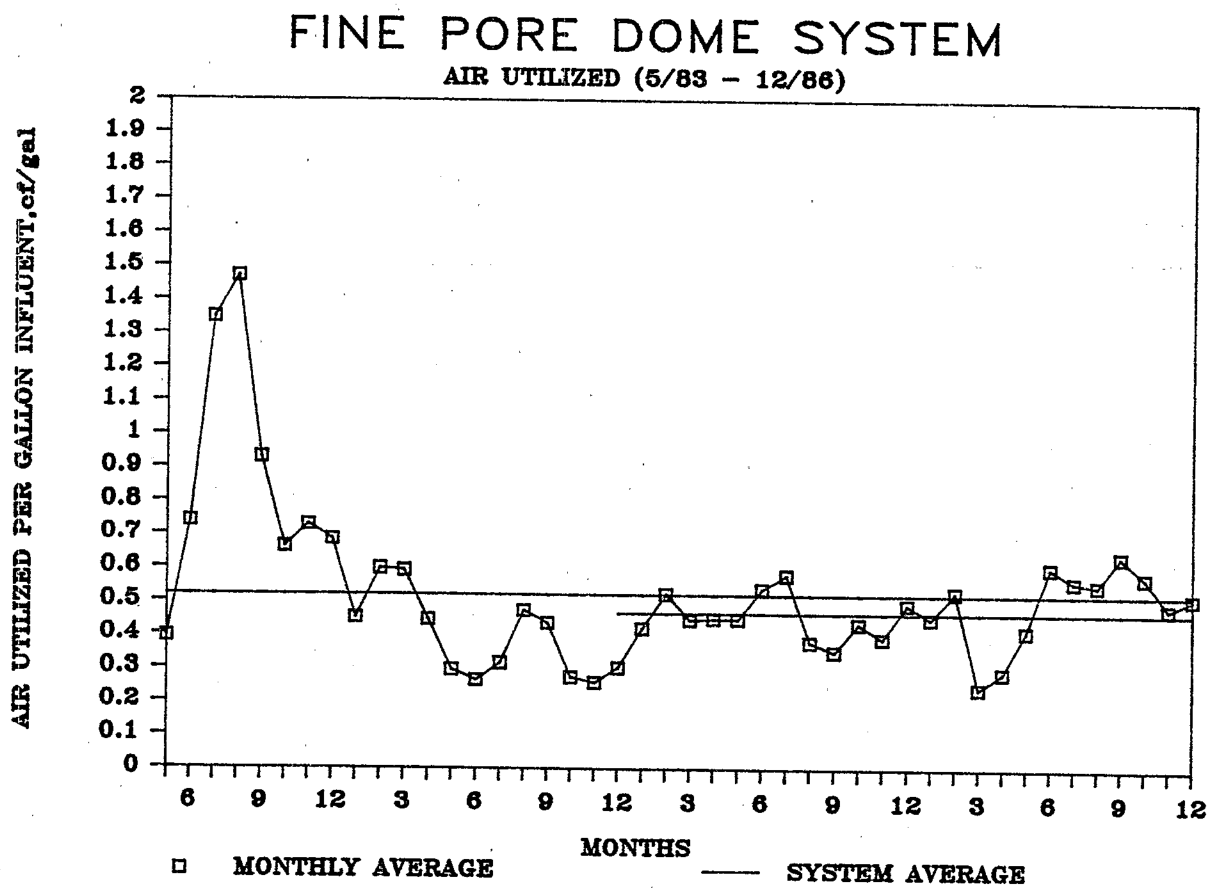
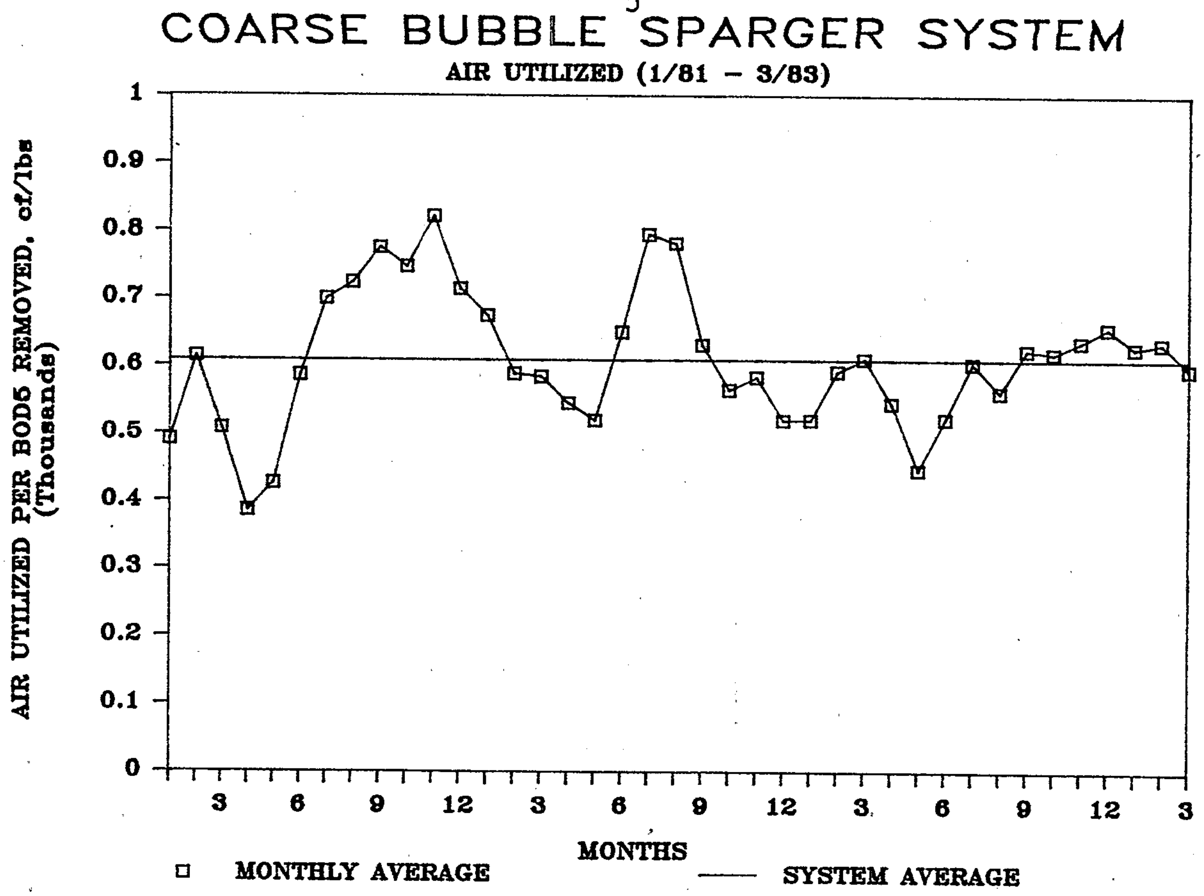
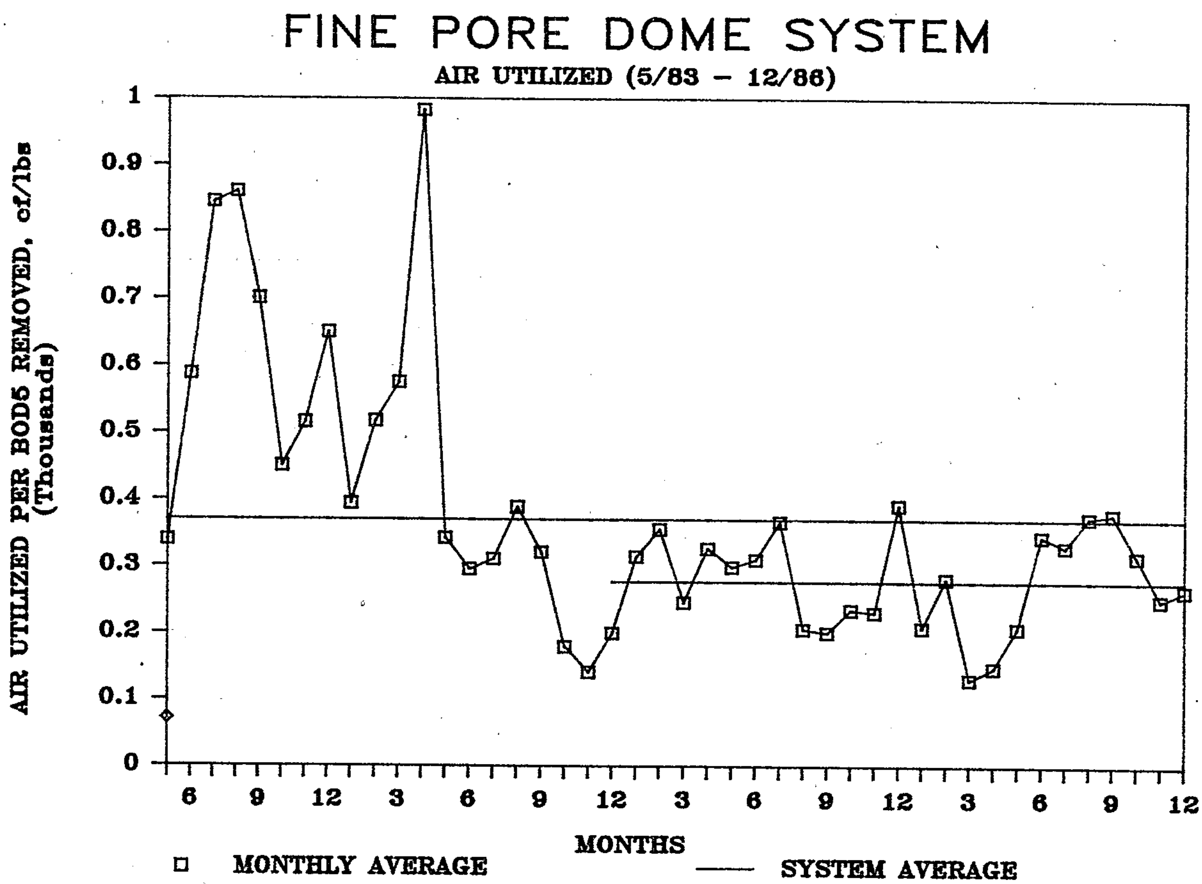


Figure 50. Air Utilized Per BOD_5 Removed - Coarse and Fine





VIII. ECONOMIC ANALYSIS

Preliminary assessment indicates that fine pore aeration retrofit would enable Ridgewood to reduce their blower power consumption by 50% (Burde, Phase I, 1982). Actual power reduction is approximately 28%, as shown in Table 36. The values presented in Table 36 are averages from 1984 through 1986. Table 37 presents a breakdown of the yearly dome cleaning and repair costs incurred with fine pore diffuser retrofit. The yearly labor costs are based on 1 man day = $175, derived from an average salary of $20,000 per year divided by 230 workdays per year multiplied by 2 for overhead. The lack of cleaning initially was balanced by the extensive cleaning performed in 1985 to attempt to evaluate the cleaning effect on oxygen transfer efficiency and therefore, 1985 values do not represent typical cleaning costs. No additional manpower requirements were needed for foam cleanup. Table 39 summarizes the maintenance costs incurred with the fine pore system. Total maintenance costs per year since April 1983 have been $2780/year for the fine pore system, while essentially no maintenance was required for the coarse bubble system.

Figure 51 illustrates the savings in power consumption obtained by the fine pore aeration system. Two blower operation requires 89700 kwhr/month, while average actual power consumption is about 63400 kwhr/month. Figure 52 shows the cumulative power consumption costs and savings. The projected cost for the coarse bubble system is based on continuous two blower operation. Approximately 40% of the bid price has been paid off from April 1983 to December 1986. The bid price for retrofitting the plant with fine pore diffusers was $218,000 to be paid off monthly from the power savings incurred with the new aeration system. The bid price is a present worth value including capital costs and anticipated interest charges over a payoff period of 7 years at 9%. Based on a 50% power consumption reduction and 1982 power costs, the payoff period was projected at 6.1 years. Based on actual payments the predicted payoff period is approximately 9.7 years. If the increased dome maintenance cost is included, the projected payoff period is 11.1 years as shown in Table 40.

TABLE 36

Average Blower Power Reduction for Fine Pore System at Ridgewood

Average Parameters[1]	Unit	1st Blower	2nd Blower	Total	Reduction[2]
Monthly On Time	hrs/month	730	313	1043	417
Unit Power Cost	$/kwhr	0.0746	0.0746		
Monthly Power Consumption	kwhr/month	44840	18583	63423	26257
Yearly Power Cost	$/year	39950	17550	57550	22400

[1] Based on average values over a 3 year period (1984 through 1986)

[2] Reduction = 1st Blower - 2nd Blower

% Yearly Power Cost Reduction = (22,400 x 100)/2x39950 = 28%

TABLE 37

Yearly Dome Cleaning and Repair Costs

Dome System Cleaning

Year	Type of Cleaning	# of Cleanings	\$/cleaning[3]	Yearly Cost
4/83–12/83	Hose[1]	0	0	0
	Acid[2]	0	0	0
1984	Hose	2	175	350
	Acid	0	0	0
1985	Hose	8	175	1400
	Acid	3	375	1125
1986	Hose	3	175	525
	Acid	1	375	375
			Total	\$3775
			Average[4]	\$1005/year

Dome System Repairs

Year	Description	Yearly Cost
4/83–12/83	No repairs performed	0
1984	Adjust and replace domes and bolts, increase dome density, ∿ 4 man days	\$700
1985	Tighten bolts and seal cracks with hot glue gun, ∿ 2 man days	\$350
1986	No repairs performed	0
	Total	\$1050
	Average	\$280/year

[1] 1 man/day for 1 tank = 1 man day
[2] 2 men/day for 1 tank = 2 man days
[3] Based on \$175/man•day
[4] Based on 3-3/4 years

TABLE 38

Nocardia Foam Chlorination and Cleanup Costs

Foam Chlorination

Year	Description	Yearly Cost
4/83-12/83	Not required	0
1984	Not required	0
1985	6 drums (∿ \$67/drum) of 15% NaOCℓ	\$1825
	∿ 3 man days	
	Automatic Surface Spray ∿ \$900 - pump setup - hoses with lawn sprinklers - pump replacement motor - ∿ 4 man days	
1986	Construct Permanent Spray System - nozzles - piping - ∿ 5 man days	\$875
	Total	\$2700
	Average[1]	\$720/year

Foam Cleanup

Year	Weeks of Foam	Cleanup Frequency #/week	Yearly Cost[2]
4/83-12/83	∿ 0	0	0
1984	10	0	0
1985	26	1	2275
1986	18	0.4	630
		Total	\$2905
		Average[1]	\$775/year

[1] Based on 3-3/4 years

[2] Based on ½ man day/cleanup

TABLE 39

Summary of Dome System Maintenance Yearly Costs

Year	Yearly Cost for Cleaning	Repairs	Foam Chlorination	Foam Cleanup	Total
4/83-12/83	0	0	0	0	0
1984	350	700	0	0	1050
1985	2525	350	1825	2275	6975
1986	900	0	875	630	2405
Average[1]	1005	280	720	775	2780

[1] Based on 3-3/4 years

Figure 51.

SAVINGS IN POWER CONSUMPTION

APRIL 1983 through DECEMBER 1986

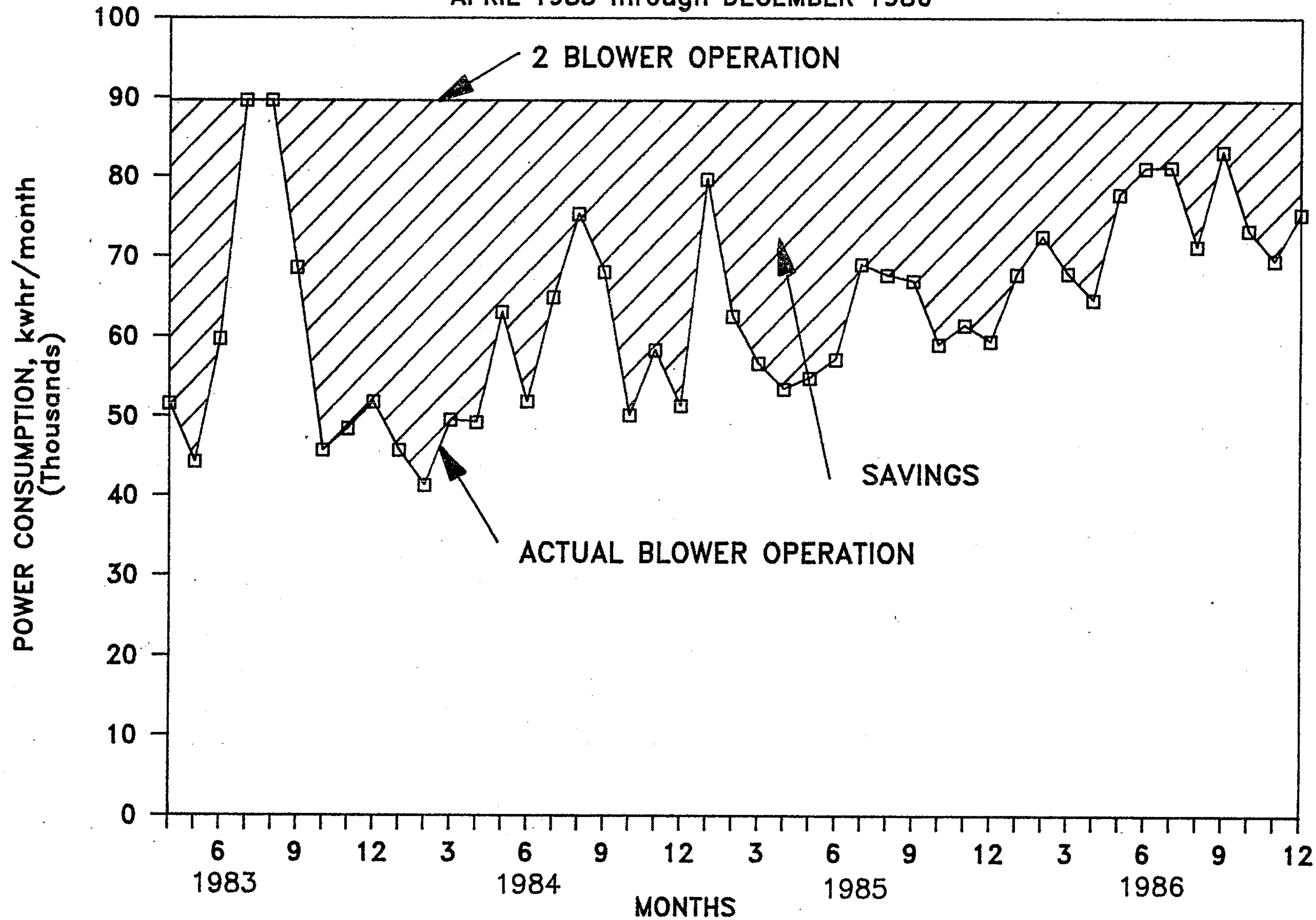


Figure 52.

FINE PORE POWER COSTS & SAVINGS

APRIL 1983 through DECEMBER 1986

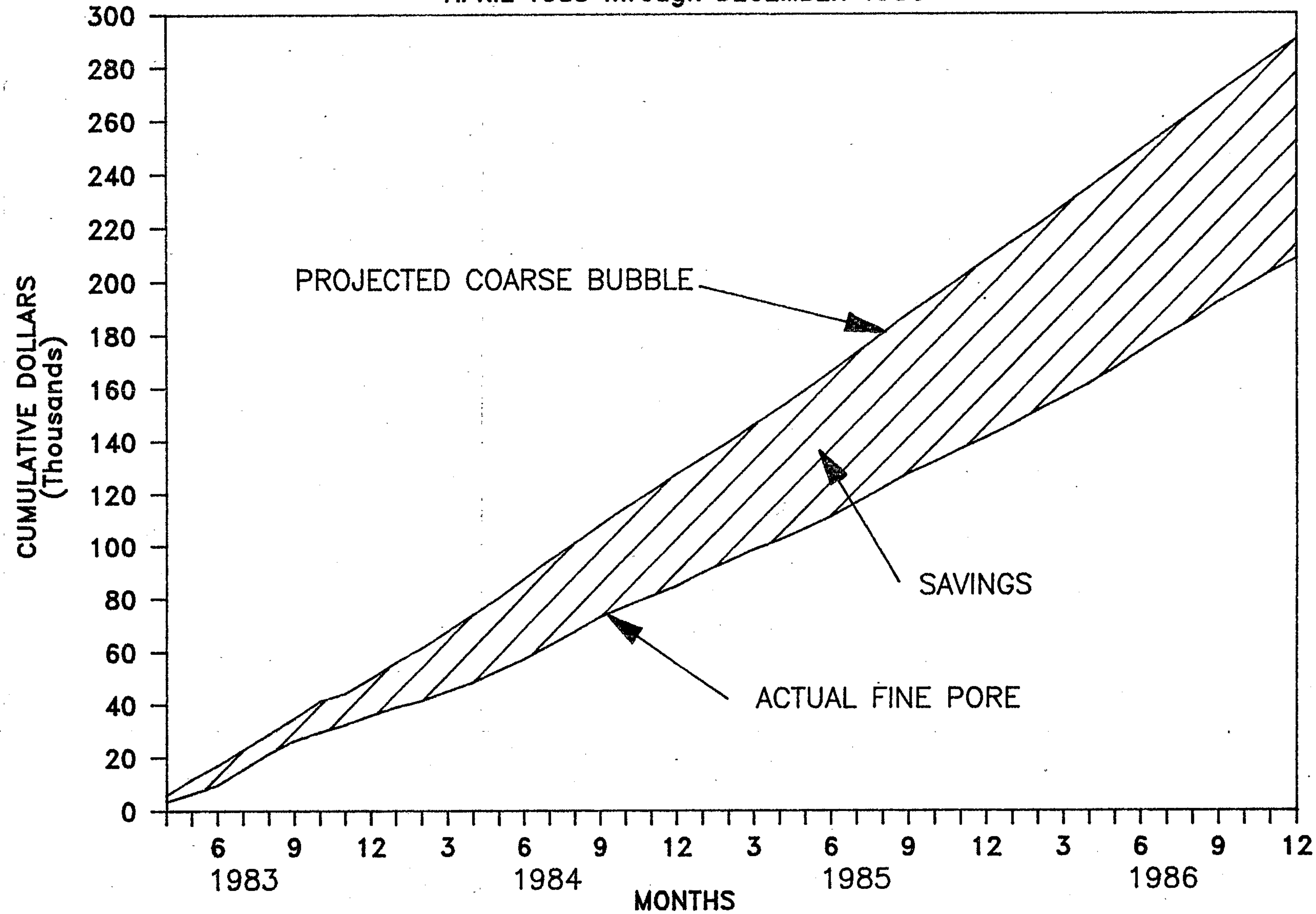


TABLE 40

Dome System Economic Summary at Ridgewood (1983-1986)

	$/year
Power Savings from Retrofit	22400
Increased Maintenance	2780
Net Savings from Retrofit	19620
Fine Pore System Bid Price*	218000
Projected Payoff Period (Based on Average Power Savings & Maintenance Costs	11.1 years
Actual Payoff Period (Based on Actual Payments 4/83-12/86)	9.7 years

* Capital cost + interest expenses (7 years, 9%).

Installation of the fine pore dome system has produced a significant improvement in effluent quality with respect to nitrogen oxidation. Although BOD and suspended solids quality has deteriorated slightly, the high degree of nitrification obtained in the summer months significantly reduced the overall oxygen demand on the HoHo-Kus brook. This increased effluent quality is not taken into account in the economic analysis. Starting in May 1987, Ridgewood will require seasonal nitrification and thus the oxygen demand will be consistently higher on the fine pore system during the summer months than it was on the coarse bubble system. Due to the improved effluent quality obtained by the fine pore system, the Village of Ridgewood is paying off the remainder of the capital cost in a lump sum payment.

IX. CONCLUSIONS

1. In the Ridgewood retrofit from coarse bubble to a fine pore aeration system the process was also modified from a contact stabilization system to a conventional activated sludge system. The coarse system had an average F/M of 0.13 lb BOD_5/day-lb MLVSS and an SRT of 17.7 days while the fine pore system operated at an F/M of 0.25 lb BOD_5/day-lb MLVSS and an SRT of 7.2 days. The sludge handling system was also modified during the retrofit in that on-site lagoons were no longer available for sludge disposal. This resulted in a net secondary sludge increase of approximately 8% and about a 70% increase in sludge haulage.

2. A significant improvement in effluent quality with respect to nitrification occurred in the fine pore system where during summer months 85 to 95% nitrification could be obtained compared to none for the coarse bubble system. Thus fine pore system installation provided the capability to obtain improved effluent quality and reduce the oxygen demand on the receiving stream at Ridgewood. Since this will become a permanent requirement in 1987 for Ridgewood, no additional retrofit should be required. Greater BOD_5 and suspended solids removal was obtained with the coarse bubble system, 96 and 94% respectively, compared to the 91 and 92% obtained for the fine pore system. To a large extent it is felt that this decrease in effluent quality is due to the inability of the sludge handling system at Ridgewood to remove sludge effectively from the system without usage of the onsite lagoons.

3. Over the six years of study at Ridgewood the coarse bubble system, being in operation for 25 years, exhibited an average OTE20 of 4.8% with an average alpha value of 0.55 requiring the usage of two blowers for plant operation. In operation for 3-3/4 years the fine pore system, during normal operation with two tanks in service, provided an average OTE20 of approximately 9.5% during daytime high load periods with an alpha value of 0.40.

4. The Ridgewood retrofit to the fine pore system provided a 28% reduction in aeration power consumption. Based on an average power cost of 0.0746 $/kwhr, the resulting power savings is $22,400/yr. Increased maintenance cost of $2780/year were also incurred for the fine pore

system. Using the net savings of $19,620/year with a capital cost of $218,000 provided a projected payoff period of 11.1 years. Based only on savings in blower power, the actual payoff period was projected at 9.7 years. Both estimates are significantly greater than the 6.1 years projected in the original design. However, the Village of Ridgewood is paying off the remainder of the capital costs after approximately 4 years of operation, due to the ability of the fine pore system to nitrify and meet new permit requirements.

5. After two years of operation with the fine pore system, a significant Nocardia foam problem resulted. Its onset occurred in the early summer months and lasted through the fall. At times foam overflowing the aeration tank caused operational problems with respect to foam cleanup on the site. It is suspected that foam developed when significant organic loads from the sludge recycle streams were discharged to the aeration tank resulting in periods of septic conditions. Minimization of plant overload in 1986 delayed the onset of foaming back from May to the end of June.

6. During periods of dome cleaning, one tank was taken out of service for anywhere from a few days to a two-week period, resulting in a higher organic loading rate and oxygen demand on the aeration tank in operation. Also, during summer months in 1983 through 1985, nitrification control was attempted by taking one aeration tank out of service thus increasing the F/M of the system. Both of these situations caused significant overload on the tank, probably aiding in Nocardia growth, and definitely yielded lower oxygen transfer efficiencies and alpha values for the dome system. This caused a reduction in tank OTE20 from the 1986 average value at high gas flows of 9.9% with an alpha of 0.42 to 7.1% with an alpha value of 0.36.

7. A 24-hour sampling study at Ridgewood in June 1986 showed OTE20 to range from 9.5% to 13.1%, resulting in alphas of 0.43 to 0.59. The latter value occurred during low load early morning hours. The daily value occurred during low load early morning hours. The daily average OTE20 for this study was 10.7% with an alpha of 0.46. This was a period of good plant operation with no Nocardia foam present on the tanks.

8. Both OTE20 and alpha showed statistically significant correlations with oxygen uptake rate and influent TOC load. The greater the uptake rate, the lower the OTE20 and alpha value. For both clean and dirty water, OTE20 correlated well with gas flows. The higher the gas flow, the lower the OTE20 value.

9. Alpha values are based on manufacturer's OTE data using new diffusers and the measured field values where most diffusers are in service for a considerable amount of time. Thus the alpha values incorporate the effects of both wastewater characteristics and any diffuser deterioration. True alpha values can only be determined by clean water testing of the existing plant diffusers.

10. The impact of acid cleaning and simple diffuser hosing at Ridgewood was difficult to evaluate. Changing wastewater characteristics and process conditions at the plant masked any significant improvements due to cleaning. It appears that inspection and maintenance on the aeration system should be accomplished at least once a year at which time hosing would be employed. The best time is in the spring, prior to the onset of the summer high temperature conditions when both aeration tanks should be maintained in service to minimize overload.

11. Both offgas and nonsteady state testing appear reliable at Ridgewood, the offgas testing providing oxygen transfer efficiencies at specific locations in the tank while nonsteady state testing provides only an overall average tank value. The steady state testing technique markedly overestimates oxygen transfer efficiency during oxygen limiting conditions when portions of the aeration tank are septic. From the 24-hour study results, the steady state technique underestimates the oxygen transfer efficiency during food limiting periods. However, oxygen uptake rates, obtained for the steady state technique, are useful in correlating results. Also, the steady state results provided an indication of the accuracy of the offgas tests during high foam conditions when significant oxygen uptake rates occurred in the foam layer above the aeration tank.

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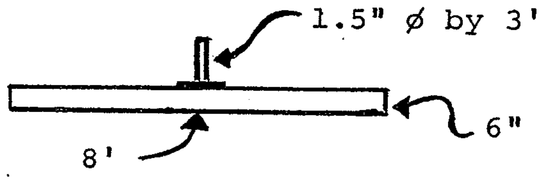
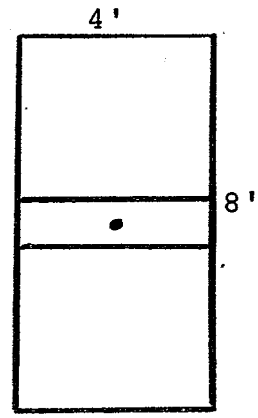
APPENDIX A

NOCARDIA FOAM EFFECT ANALYSIS

A. Hood Foam Volume



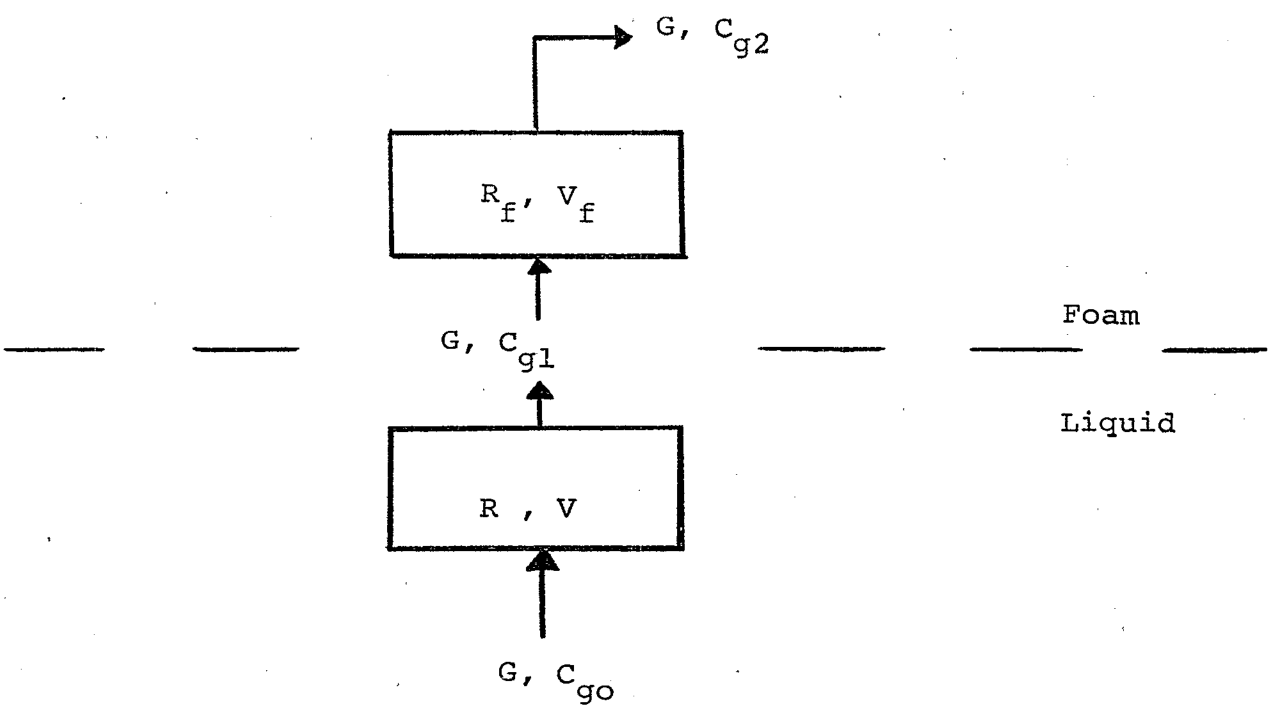


Hood Volume = 1/2 x 4 x 8 = 16 ft^3

$$\text{Pipe Volume} = \frac{\pi(\frac{1.5}{12})^2}{4}\ 3' = 0.037\ ft^3 \quad \text{(neglect pipe volume)}$$

B. Mass Balance

(1) Free Body Diagram



(2) OTE Definition

$$OTE_\ell = \frac{G(Cg_o - Cg_1)}{GCg_o} \quad - \quad \text{Eqn 1}$$

$$OTE_m = \frac{(Cg_o - Cg_2)}{Cg_o}$$

$$Cg_2 = (1 - OTE_m)Cg_o \quad - \quad \text{Eqn 2}$$

OTE_ℓ = oxygen transfer efficiency in liquid

OTE_m = oxygen transfer efficiency measured in liquid and foam

(3) Foam Mass Balance

$$GCg_1 - GCg_2 = R_f V_f$$

$$GCg_1 = R_f V_f + GCg_2$$

$$Cg_1 = \frac{R_f V_f}{G} + Cg_2 \quad - \quad \text{Eqn 3}$$

Substitute Equation 2 into Equation 3

$$Cg_1 = \frac{R_f V_f}{G} + (1 - OTE_m)Cg_o \quad - \quad \text{Eqn 4}$$

Substitute Equation 4 into Equation 1

$$OTE_\ell = \frac{Cg_o - [\frac{R_f V_f}{G} + (1 - OTE_m)Cg_o]}{Cg_o}$$

$$= 1 - (1 - OTE_m) - \frac{R_f V_f}{Cg_o G}$$

$$OTE_{\ell} = OTE_m - \frac{R_f V_f}{Cg_o G}$$

$$OTE_{\ell} = OTE_m - \frac{R_f to_f}{Cg_o} \qquad - \quad \text{Eqn 5}$$

$to_f = \frac{V_f}{G}$ detention time (minutes)

R_f = Foam oxygen uptake rate (mg/ℓ/min)

C_{go} = initial oxygen concentration (mg/ℓ)