OXYGEN TRANSFER EFFICIENCY SURVEYS AT THE SOUTH SHORE WASTEWATER TREATMENT PLANT 1985 - 1987

by

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DISCLAIMER

Development of the information in this report has been funded in part by the U.S. Environmental Protection Agency under Cooperative Agreement No. CR812167 by the American Society of Civil Engineers. The report has been subjected to Agency peer and administrative review and approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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

Ceramic plate diffusers were among the earliest forms of fine pore diffusers used for oxygen transfer in activated sludge treatment. They have been successfully used for over 60 years in the Jones Island West Plant of the Milwaukee Metropolitan Sewerage District and, since initial start-up, in the Jones Island East Plant and the South Shore Plant. Surveys of performance of these diffusers in all three plants were included in the EPA/ASCE Fine Pore Aeration Project. This report presents the results of 20 off-gas sampling surveys carried out at the South Shore Wastewater Treatment Plant.

For all 20 basin surveys, the median value of standardized oxygen transfer efficientcy (alpha-F-SOTE) was 18.9%. When evidence of nitrification was present, alpha-F-SOTE values were higher than on other survey dates.

A cleaning history for the basin was obtained at the time of each off-gas survey. However, no correlation between number of months in service since cleaning and alpha-F-SOTE could be identified.

This report was submitted in partial fulfillment of Cooperative Agreement No. CR812167 by the American Society of Civil Engineers under subcontract to the Milwaukee Metropolitan Sewerage District under the partial sponsorship of the U.S. Environmental Protection Agency. The work reported herein was conducted over the period of 1985-1987.

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Joseph Grinker, Process Control Supervisor, for the South Shore Plant gave valuable guidance and support to the project. The initial impetus for the project came from Larry Ernest, who at that time was Manager of Laboratory Services. Thanks are in order to him and to Lloyd Ewing and Dave Redmon of Ewing Engineering Company for continuing guidance and support.

INTRODUCTION

Ceramic plate diffusers, such as those in service at Milwaukee's South Shore Wastewater Treatment Plant, were among the earliest forms of fine pore diffusers used in activated sludge treatment. They have been successfully used for periods of up to fifty years in one of the treatment plants of the Milwaukee Metropolitan Sewerage District (MMSD). Because of this record, surveys of current performance of these diffusers in all three activated sludge plants operated by the MMSD were included in the EPA/ASCE Fine Pore Diffuser Project. This report presents the results of surveys carried out at the South Shore Plant.

The program was planned to include twenty surveys of South Shore Plant basins. Originally, each of five basins was to be tested four times over a two year period. Unfortunately, at the start of testing, the requirements of an ongoing program of rehabilitation and expansion at the Plant necessitated taking each battery out of service for three to four months in succession. The tank surveys were grouped by season, viz., six in Summer, 1985, six in Fall, 1985, four in Summer, 1986, and four in Spring, 1987. Only two basins could be tested on all four occasions; the selection of the remainder was dictated largely by availability of pairs of basins in normal service.

Following the April, 1986 Contractors' meeting, two additional surveys were added to the program. The first was a one-time investigation of the effects of collection hood placement patterns on observed oxygen transfer efficiency. The second was a 24 hour survey with hourly OTE observations for two hood stations in basin No. 12.

CONCLUSIONS

1. The flux weighted alpha-F-SOTE values obtained from 20 South Shore aeration basin surveys ranged from 15.0% to 22.2% with a mean value of 18.9%.

2. The mean sludge age for the South Shore Treatment Plant for the 10 test days in the study period was 6.8 days. The mean F/M ratio was 0.37 days $^{-1}$. Testing at the lower sludge ages (4-6 days) yielded lower estimates of alpha-F-SOTE (15-18%).

3. For survey dates when there was evidence of nitrification, as measured by final effluent ammonia, nitrite, and nitrate concentrations, alpha-F-SOTE values were higher than on the other survey dates.

4. A diurnal OTE survey at the South Shore Plant showed no significant shift in alpha-F-SOTE for the collection hood positions used in the survey (at approximately the 2/3 point of tank length).

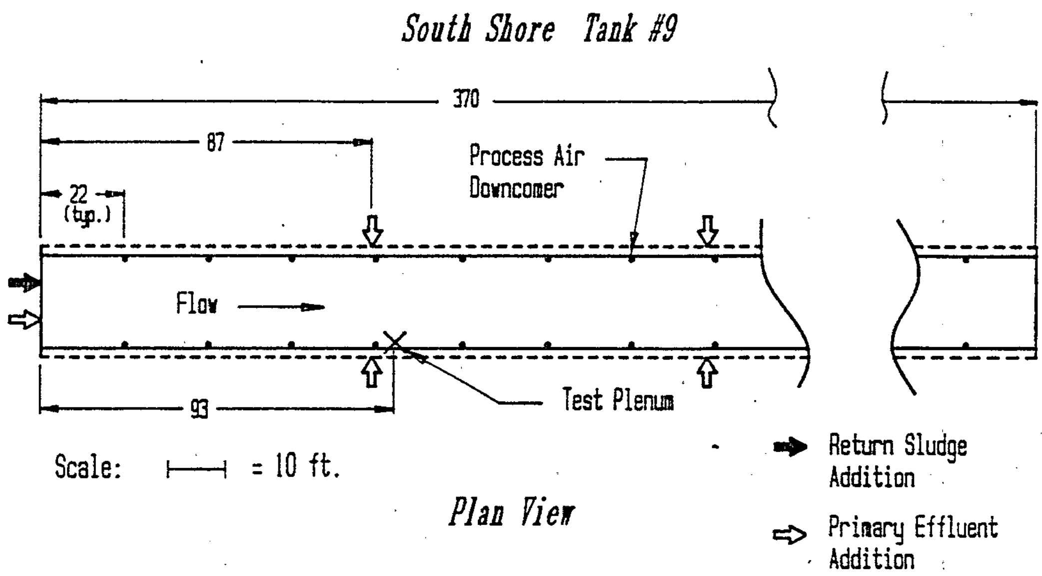
5. Flux-weighted alpha-F-SOTE values were unrelated to the number of months in service following the last previous high pressure hosing or hosing plus acid cleaning.

PLANT DESCRIPTION

The MMSD's South Shore Wastewater Treatment Plant began activated sludge treatment in 1974. There are twenty-four aeration basins arranged in four batteries of six basins each. They are 370 feet long, 30 feet wide, with a water depth of 15 feet. The width at the water surface is approximately 26 feet because of Y-wall construction used to accommodate the process air mains and primary effluent step feed as well as to provide walkways between tanks. Figure 1 shows a plan view and a cross-section of a basin.

The tanks are flat bottom with one foot square, 1-1/2 inch thick ceramic (silica) diffuser plates in 9-plate containers arranged in a longitudinal pattern so that the plates are flush with the floor of the tank. Process air piping to the containers is arranged beneath the tank floor. Containers are placed across the width of the tank in a staggered pattern, eight across. Each downcomer supplies two rows of eight containers or 144 plates. With 17 downcomers, the total number of plates per tank is 2,448. The permeabilities range from 15 to 21. The plates are grouped by permeabilities in ranges of 15-16, 17-19, and 20-21. Each downcomer is fitted with plates of only one range. Return sludge is fed at the head of each tank. Primary effluent is added at the head of the tank and at step feed points on both sides of the tank at approximately the quarter and the halfway points along the length.

More detailed information concerning the historical record, aeration basin and process air supply design, and plant operation and maintenance are presented in the Report on South Shore Plant History prepared by Larry Ernest under this EPA contract (1).



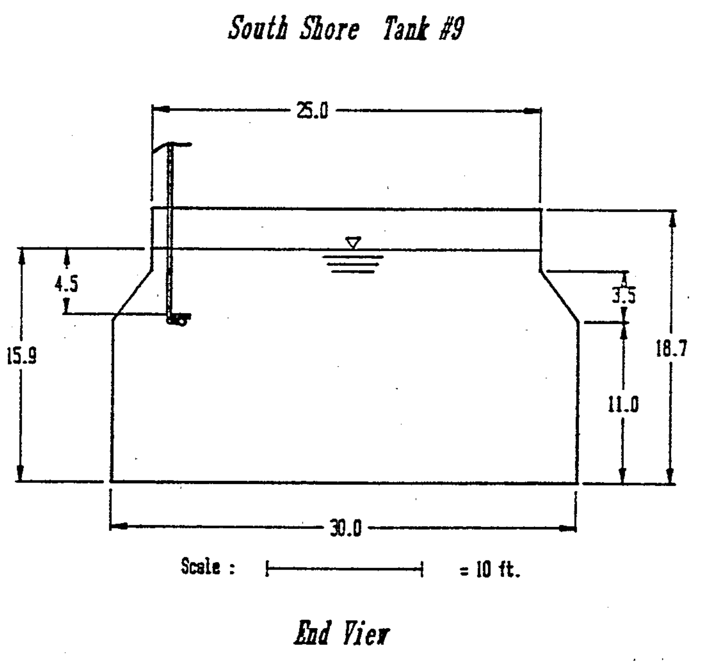


Figure 1. Plan and cross section views of an original South Shore aeration basin.

CONDUCT OF THE SURVEYS

OFF GAS SURVEY METHODS

The MMSD purchased an "Aerator-Rator, Mark IV" off-gas analyzer from Ewing Engineering Company in June, 1985. This provided the opportunity to use the off-gas method for measurement of oxygen transfer efficiency as described by Redmon, et al. (2). The off-gas monitoring unit was used with two gas collection hoods, designed and built by Ewing Engineering Company. The hoods, constructed of fiber glass and PVC pipe reinforcing, each had a collection area of dimensions 2 feet by 16.5 feet or 33 square feet. The volume under the hood was approximately 30 cubic feet and depended on the hood position in the mixed liquor. The connection between each hood and the Aerator-Rator was made with 50 feet of 1-1/4 inch vacuum cleaner hose.

Carbon dioxide content in the off-gas was measured using a Dwyer CO_2 indicator. The Aerator-Rator came equipped with a drying column, so humidity data were not collected for either off-gas or reference air. At least two gas samples were collected for CO_2 determination for every collection hood position. Mixed liquor dissolved oxygen concentration was also measured at every collection hood station using YSI dissolved oxygen meters and field probes. Readings were taken at depths of approximately four feet and ten feet and averaged. These two readings rarely varied by more than 0.1 mg/l.

Before a survey was begun, twelve test stations were located at equal distances along the length of the tank to be tested. With a hood collecting off-gas from 33 square feet at each station, the total area sampled was 396 square feet or 4.3 percent of tank surface area. For the South Shore surveys, all basins were tested in pairs with one collecting hood in each basin and the Aerator-Rator set up between basins. Stations were sampled in sequence from the inlet to the outlet. At each station, the hood was positioned lengthwise across the width of the tank, approximately in the center, and secured with ropes. As soon as a station was sampled, the hood was moved to the next location while a measurement was completed for the adjacent tank.

The traverse from inlet to outlet for a pair of basins usually required 6 hours. The average time on a station was 15 minutes, with the oxygen sensor millivolt output recorded for the latter half of that period. After data for a station were recorded, the hood was moved immediately to the next station where about 20 minutes elapsed before off-gas readings were taken.

The lowest air flow tested was 1,300 scfm or an average flux rate of 0.14 scfm/sq. ft. This would yield an off-gas collection rate of 4.6 scfm, and a residence time for the off-gas in the hood of about seven minutes. Thus, approximately three residence times elapsed between set-up of the collection hood and recording of the off-gas millivolt output. Higher air flows provided additional flow-through before readings were taken. These readings were recorded at one minute intervals, and the data were accepted when 4 readings had been obtained with a range not exceeding 4 millivolts.

AERATION BASIN OPERATION

In normal operation, the air flow is controlled by a central computer responding to a dissolved oxygen concentration reading obtained near the effluent end of the tank. During 1985, the test basins were left on computer control in order to represent normal operation. This typically resulted in airflow variation of plus or minus 20 to 30 percent. For the 1986 surveys, the air flow valves to the test basins were controlled locally, and the air flow variation was held between 5 and 10 percent of the mean air flow for the survey.

The 17 downcomers are equipped with knife gate values requiring manual adjustment. These were not adjusted during the surveys. At times, Operations Staff had set the valves for most basins to provide positive dissolved oxygen readings over as much of the basin length as possible. These were, of course, settings related to the air flow and loadings occurring at the time of the adjustments. It was not feasible to relate airflows to the downcomers during these surveys except to note that a great variety of dissolved oxygen profiles was observed, and measured flux rates varied widely along most tanks.

For basins in service, valves controlling primary effluent addition were normally fully open, so that flow variation reflected variation in flow to the entire plant. The South Shore aeration basins were operated in the step-feed mode during the entire period covered in this testing program. About a third of the primary effluent was added at the head of the tank, a third at the one-quarter point, and a third at the half-way point. The valves regulating return sludge flow to the basins were under computer control with the objective of maintaining desired mixed liquor solids concentrations. These valves were left on computer control during all surveys. Changes were usually gradual and within a 20% range from lowest readings to the highest for both primary effluent and return sludge flows.

TREATMENT PLANT OPERATION

Measurements of primary effluent 5 day BOD, mixed liquor suspended solids, sludge wasting rates, and sludge solids inventories were obtained from plant monthly reports that provided analytical data from 24-hour composite samples and operations data based on the same 24-hour periods. The BOD sample was collected from the flow to the entire plant while the remaining values were obtained for the battery that included the tanks surveyed.

Nitrogen related measurements were all compiled from plant monthly reports and based upon 24 hour composite samples of primary effluent and final effluent.

PRESENTATION OF SURVEY DATA

Survey data were recorded on the "Offgas Field Data Sheet" (3). The value of beta, the ratio of the saturation oxygen concentration in process water to that in clean water, was assumed to be 0.99 throughout the South Shore Plant testing. A value of 10.6 mg/l was selected for the clean water dissolved oxygen saturation concentration at 20^{0} C for a 15 foot deep aeration basin equipped with fine pore diffusers (4). An effective saturation depth of 43% of submergence was assumed in obtaining the pressure correction factor used to calculate the field dissolved oxygen saturation value and the deficit or driving force at each station.

A FORTRAN program was written to accept the data obtained from an off-gas survey, complete the required calculations, and print a report displaying the data and the calculated efficiencies for each station as well as flux weighted values for the field efficiency (FOTE) and the standardized efficiency for a dissolved oxygen concentration of zero (alpha-F-SOTE). Figure 2 is an illustration of a survey summary report using Tank 20 on July 26, 1985, as an example.

Figure 2. Report format used to summarize data obtained from oxygen transfer efficiency surveys using the off-gas method.

TEST SITE: SOUTH SHORE   TEST DATE: 7-26-85   AERATION TANK #: 20   AERATION SYSTEM: CERAMIC PLATE   SUBMERGENCE(ft): 15

TANK VOL(MG): 1.24   AIR RATE(SCFM): 1900   WASTEWATER FLOW(MGD): 4.2   RETURN SLUDGE(MGD): 1.5   TOTAL FLOW(MGD): 5.7

RET.TIME(hrs): 5.2   MLSS(mg/l): 2000   EST LOAD(#BOD/#MLVSSday): 0.31   EST SLUDGE AGE(days):6.3

TEST CREW: RW   LOCAL AIR TEMP(deg F): 81   C*20(mg/l): 10.6   SOURCE: EWING ENGINEERING CO

TIME	STA.	MOG	MVR	ML TEMP	DO	DEFICIT	ROTAM 1	ROTAM 2	FOTE	SPOTE	FLUX	STOTE	BAROM	ROT TEMP	ROT PRES	FCO2
11:17	1	867.	995.	18.00	0.40	10.38	0.0	55.0	0.143	0.0140	0.200	0.150	29.43	88.00	7.00	.0135
11:54	2	830.	1000.	18.00	1.55	9.23	0.0	72.0	0.195	0.0220	0.247	0.232	29.43	90.00	8.00	.0115
12:21	3	845.	1001.	18.00	1.15	9.63	0.0	48.0	0.180	0.0190	0.181	0.206	29.43	86.50	7.00	.0095
13:52	4	847.	1000.	18.00	0.20	10.58	95.0	0.0	0.176	0.0170	0.077	0.184	29.43	83.00	6.00	.0095
14:20	5	853.	1001.	18.00	0.40	10.38	115.0	0.0	0.171	0.0170	0.091	0.182	29.43	79.00	7.00	.0086
14:50	6	864.	997.	18.00	0.35	10.43	0.0	69.0	0.156	0.0160	0.240	0.165	29.43	83.00	7.50	.0065
15:16	7	867.	998.	18.00	0.55	10.23	192.0	0.0	0.152	0.0150	0.146	0.164	29.43	80.00	8.50	.0080
5:45	8	863.	997.	18.00	1.15	9.63	218.0	0.0	0.152	0.0170	0.165	0.174	29.43	81.00	12.50	.0115
16:15	9	816.	999.	18.00	1.85	8.93	159.0	0.0	0.205	0.0240	0.123	0.252	29.43	77.00	7.50	.0170
16:45	10	852.	999.	18.00	1.45	9.33	0.0	53.0	0.160	0.0180	0.196	0.189	29.43	78.00	7.50	.0185
17:12	11	827.	998.	18.00	1.90	8.88	0.0	37.0	0.187	0.0220	0.152	0.232	29.43	80.00	6.50	.0210
17:44	12	803.	999.	18.00	1.90	8.88	208.0	0.0	0.214	0.0250	0.158	0.265	29.43	79.00	13.50	.0235
							WEIGHTED AVERAGES :		0.173	0.0188	0.165					

EXPLANATION OF THE VARIABLES

STA: STATION NUMBER   MOG: MILLIVOLTS OFF GAS   MVR: MILLIVOLTS REFERENCE AIR   DO: DISSOLVED OXYGEN (mg/l)

ML TEMP: MIXED LIQUOR TEMPERATURE (deg C)   ROTAM 1 OR 2: ROTAMETER READING   FOTE: FIELD OXYGEN TRANSFER EFFICIENCY

SPOTE: OXYGEN TRANSFER EFFICIENCY AT 20 deg C PER mg/l OF DO DEFICIT   STOTE: OXYGEN TRANSFER EFFICIENCY AT 20 deg C AND ZERO DO

FLUX: AIR FLOW AT SURFACE (scfm/sq ft)   BAROM: BAROMETRIC PRESSURE (in of mercury)

ROT TEMP: AIR TEMPERATURE AT THE ROTAMETER (deg F)   ROT PRESS: PRESSURE AT THE ROTAMETER (in of water)

FCO2: FRACTION OF CO2 IN OFF-GAS

SURVEY RESULTS

Twenty surveys were completed for the South Shore Plant. Table 1 is an overall summary of test dates, test conditions, and flux weighted average field and standard OTE values. Also shown are tank cleaning information, sludge age and loading estimates for the test dates. Table 2 contains nitrogen related data taken from plant laboratory records for the ten test dates. Detailed information concerning treatment plant facilities and operation are included in the Overall Plant Data Sheet (Appendix A) and in the monthly averages of data for South Shore primary effluent and South Shore activated sludge basins that were compiled in connection with the EPA/ASCE Interplant Fouling Study (Appendix B).

Figure 3 shows the profiles obtained from the first pair of surveys for this project. The average air flow for tank 13 was 2600 scfm, and for tank 14 it was 1500 scfm. This difference is reflected in the lower dissolved oxygen measured in tank 14. The basins had nearly the same average standard efficiency, 19.4 percent for tank 13 and 18.8 percent for tank 14.

DIURNAL STUDY

The results of a diurnal test for 2 stations located in tank 12 are shown in Figure 4. The test ran from noon on July 22, to noon on July 23, 1986. The air flow to the basin was controlled manually at 1900 scfm plus or minus 10 percent. Dissolved oxygen profiles were similar for the 2 stations with an unexplained peak occurring at both stations at about 6 p.m. FOTE values were higher at station 7 than station 8, possibly reflecting a decrease in the BOD load between stations since both stations were beyond the second step-feed point and plant data gave no indication of nitrification.

No explanation is at hand for the decrease in alpha-F-SOTE between station 7 and station 8. In any event, alpha-F-SOTE varied less than 10 percent at either position, indicating little or no variation in alpha with clock time for those stations on that date.

COLLECTION HOOD ORIENTATION

A study of the effects of hood placement on weighted average OTE and off-gas flux was carried out on July 15, 1986. Since South Shore aeration basins had Y-wall construction along the entire length, it appeared that flux rates at the edge could exceed those at the center, because flow patterns for the rising bubbles might cause a build-up under the Y-wall.

Table 1

South Shore Wastewater Treatment Plant
Summary of Oxygen Transfer Survey Data
July, 1985 - April, 1987

Date	Basin Number	Time in Service (mos.)	Cleaning Method	Airflow (scfm)	FOTE %	alpha-F-SOTE %	Sludge Age (Days)	Loading #BOD5 per #MLVSS - day
7/24/85	13	15	W	2600	12.6	19.4	9.8	0.17
7/24/85	14	15	W	1500	15.4	18.8	9.8	0.20
7/26/85	19	49	W	2100	16.7	21.5	6.3	0.34
7/26/85	20	22	W	1900	17.3	19.7	6.3	0.31
7/29/85	9	37	A	1300	20.4	22.1	7.2	0.20
7/29/85	10	50	A	1800	20.2	22.2	7.2	0.22
10/17/85	9	40	A	1300	15.8	18.6	12.0	0.54
10/17/85	10	53	W	1700	18.3	20.4	12.0	0.58
10/28/85	13	18	W	1300	15.3	17.6	6.1	0.24
10/28/85	14	18	W	1500	11.9	18.6	6.1	0.22
10/31/85	19	52	W	1300	17.1	20.7	12.0	0.31
10/31/85	20	25	W	1400	14.9	19.1	12.0	0.28
7/24/86	1	6	W	1900	15.9	18.0	2.7	0.31
7/24/86	2	7	W	1800	11.8	15.9	2.7	0.34
7/28/86	9	49	A	1800	16.1	20.2	9.1	0.49
7/28/86	10	9	W	1900	15.5	19.1	9.1	0.51
3/20/87	9	57	A	1500	14.8	17.5	4.3	0.82
3/20/87	10	17	W	1600	11.9	15.0	4.3	0.74
4/17/87	11	46	W	1500	10.4	16.7	5.5	0.34
4/17/87	12	46	W	1500	11.8	17.3	5.5	0.33

W denotes washing with a high pressure (100 psi) hose.

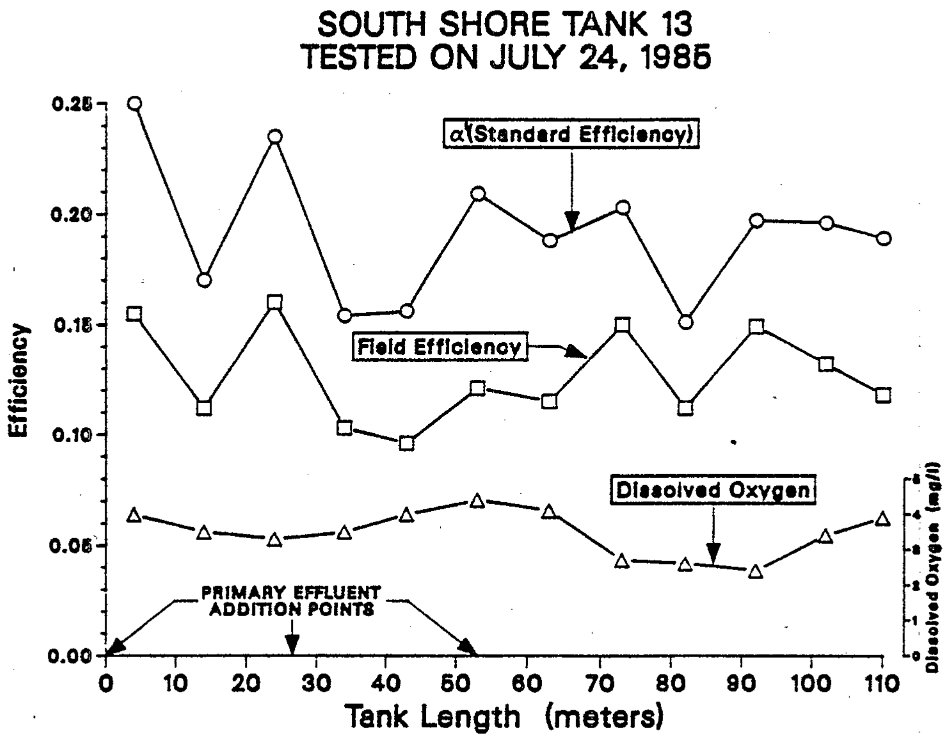
A denotes washing followed by acid cleaning.

Table 2

Secondary Treatment Nitrogen Data (1)
South Shore Wastewater Treatment Plant
July, 1985 - April, 1987

Date	Primary Effluent TKN	Primary Effluent NH_3	Final Effluent TKN	Final Effluent NH_3	Final Effluent NO_2	Final Effluent NO_3
7/24/85	-	26	8	7	0.7	7.8
7/26/85	34	20	6	-	1.0	6.1
7/29/85	31	23	4	4	0.5	11.0
10/17/85	34	36	20	20	0.2	0.7
10/28/85	24	15	13	11	0.8	1.9
10/31/85	27	21	16	14	1.0	2.5
7/24/86	24	15	13	11	0.7	2.1
7/28/86	15	9	10	8	0.7	1.4
3/20/87	24	-	15	-	0.1	0.2
4/17/87	16	-	9	-	0.3	0.7

(1) All values in mg/l; (-) denotes missing value.



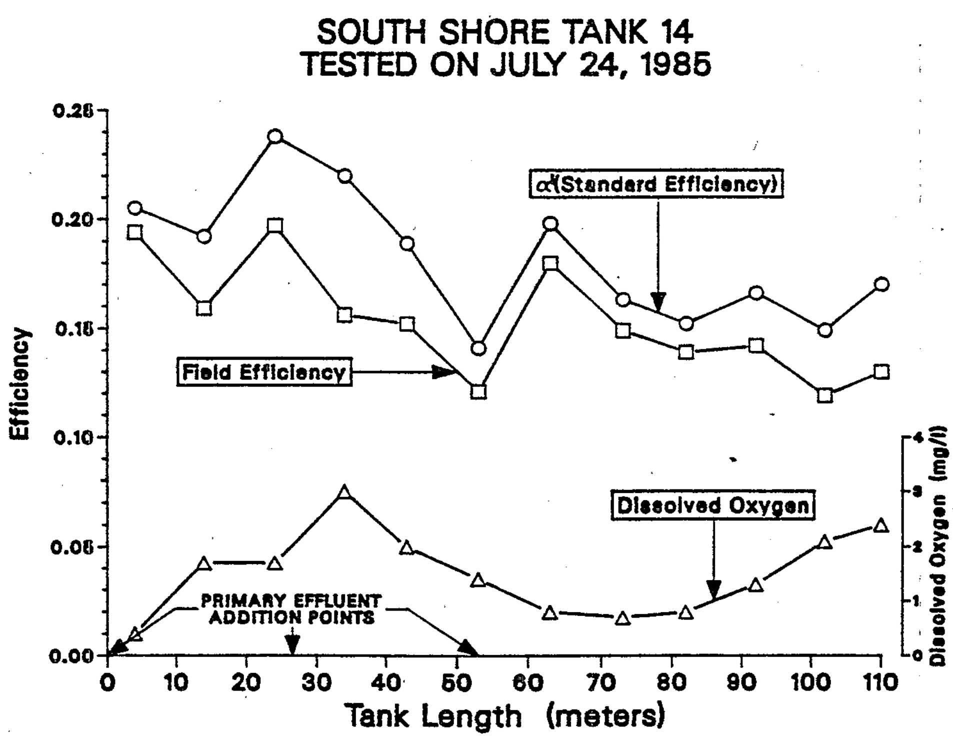
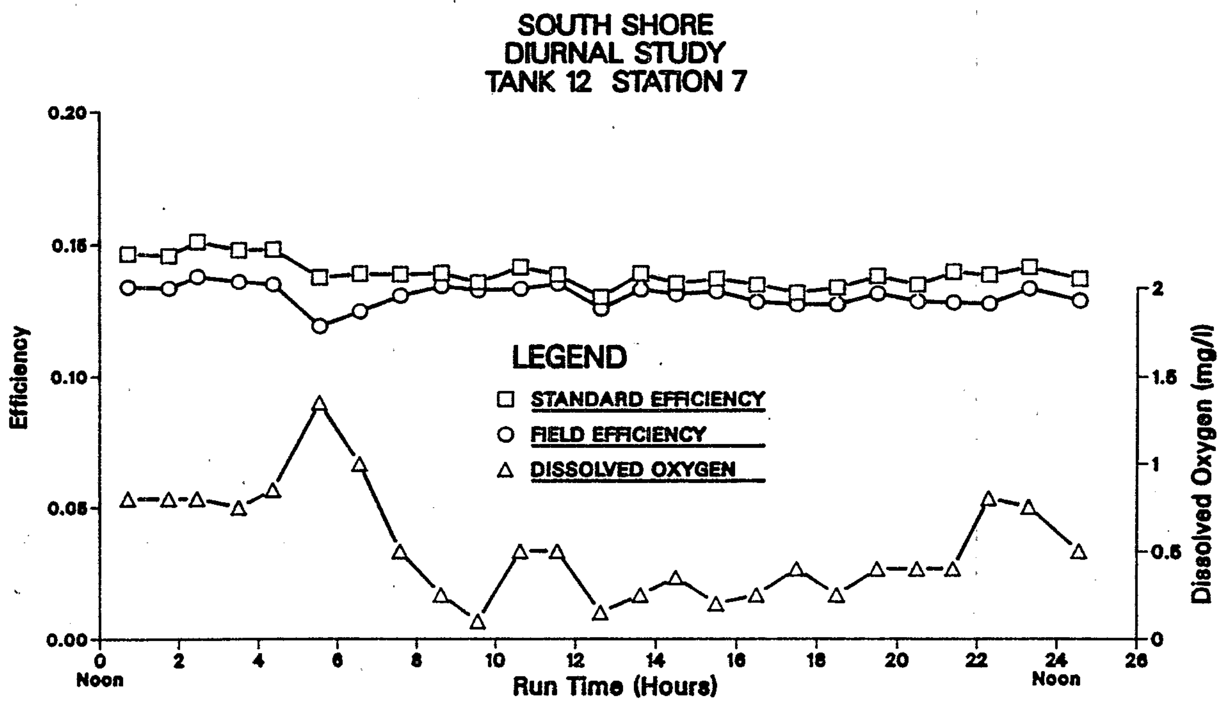


Figure 3. Profiles for dissolved oxygen, FOTE, and alpha-F-SOTE for basins 13 and 14 surveyed on July 24, 1985.



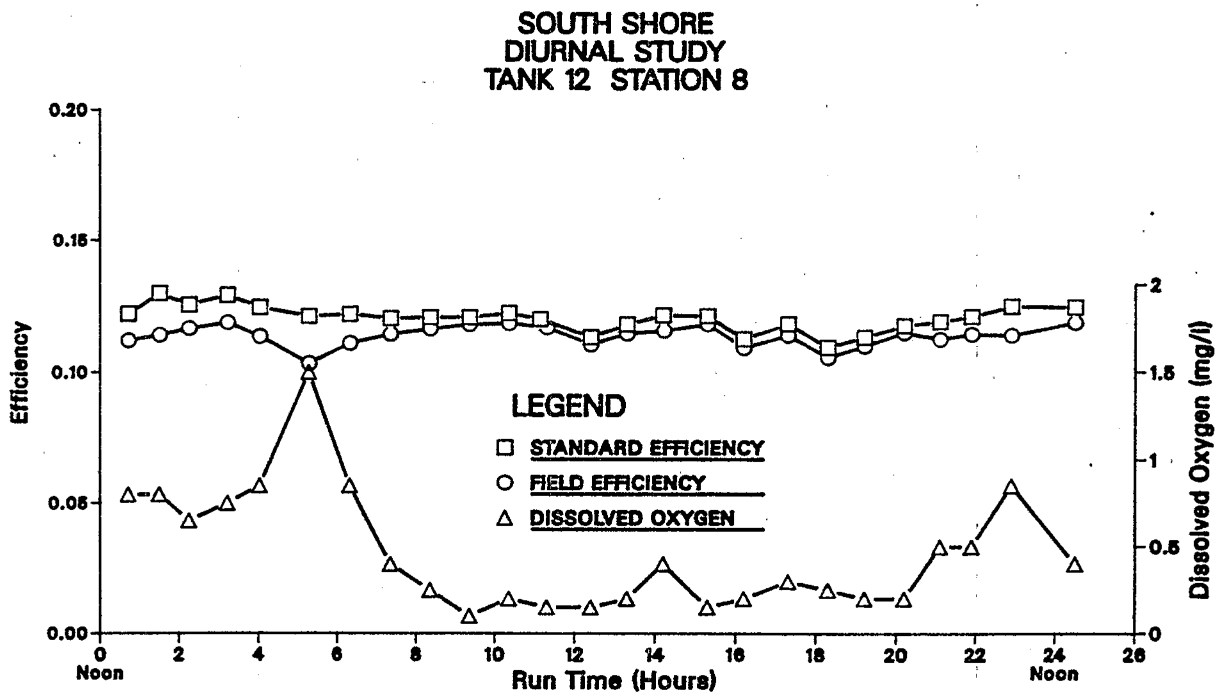


Figure 4. Diurnal test results for South Shore tank 12 on July 22 and 23, 1986.

A survey was carried out with 2 collection hoods in Basin 12. One hood was placed lengthwise along the east edge of the basin while the other was placed across the width of the tank at the usual test positions. The air flow was maintained manually during the survey at 1100 scfm plus or minus 10 percent. The 12 edge positions were lined up as nearly as possible so that the hood in the edge position formed a "T" with the hood in the cross-tank position. The average results from this comparison survey are shown in Table 3.

Table 3

Average Results for the Hood Position Study
South Shore Wastewater Treatment Plant

Hood Position	alpha-F-SOTE %	Flux Rate scfm/sq ft
Across the tank in the center	13.6	0.107
Longitudinally along east edge	12.6	0.113

The results of this exercise showed no significant difference between the edge and center hood for average flux or for flux weighted average alpha-F-SOTE. At any given distance along the tank, however, there were large differences between the center and edge values for both flux and alpha-F-SOTE.

DISCUSSION

The standardized oxygen transfer efficiency under process conditions (alpha-F-SOTE) has been proposed by the ASCE oxygen transfer committee for characterizing performance of aeration basins equipped with fine pore diffusers (5). SOTE refers to clean water performance which is unknown in this case. Alpha is the ratio of oxygen transfer rate under process conditions to that in clean water. With time, diffusers operating under process conditions may suffer fouling and loss of efficiency. This effect is incorporated in the modified transfer efficiency term, alpha-F-SOTE.

The average value of alpha-F-SOTE for all 20 South Shore surveys was 18.9% with a range of 15.0 to 22.2%. For the South Shore tanks the average efficiency per meter of depth was 4.4%, a very high value in comparison with the values in the interim data base presented by Brenner and Boyle (5).

Among the operating variables presented in Table 1, sludge age varied from 2.7 days to 12 days, air flow from 1300 scfm (0.53 scfm/diffuser) and 2600 scfm (1.06 scfm/diffuser), and time in service since previous cleaning from 6 months to nearly 5 years. The influence of these variables on alpha-F-SOTE was examined by applying stepwise multiple regression. With a 5% level of significance, neither air flow nor time in service could be included in the final equation. The influence of sludge age was significant at the 5 percent level; however, it is important to note that wide daily variations occur in sludge age both on a plant basis and a battery basis. While the average sludge age of 7.5 days for 10 survey dates is probably a useful estimate of sludge age for the 20 month period over which OTE surveys were conducted, any individual daily value can be greatly affected by requirements of plant operations. An obvious example is temporary cessation of sludge wasting which produces a high, but not meaningful, value of sludge age for that day.

Maintenance of a South Shore aeration basin consists of taking the basin out of service, draining it, and flushing the bottom and sides using a high pressure hose. Occasionally, 50 percent muriatic acid is applied to the diffusers followed by a second rinsing of the basin floor with the high pressure hose. These procedures have been used when the operator is unable to maintain a desired air flow to the basin at the header pressure for the plant or they have been required by circumstances unrelated to aeration basin performance (e.g., taking basins in and out of service to accommodate contractors participating in plant expansion and upgrading). As expected, no relationship was found between efficiency and time in service since cleaning.

From Table 2, it appears that nitrification was taking place during July, 1985 when 6 of the OTE surveys were made. The mean value of alpha-F-SOTE was 20.6% while the mean value for the remaining 14 surveys was 18.2%. While this represented only about a 10% difference - close to the experimental error in the measurement of alpha-F-SOTE - it was consistent with the findings summarized in the status report of Brenner and Boyle that showed higher values of alpha-F-SOTE associated with nitrifying as opposed to non-nitrifying systems.

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1. Ernest, L. A. Case History Report on Milwaukee Ceramic Plate Aeration Facilities. Study conducted under Cooperative Agreement CR812167, Risk Reduction Engineering Laboratory, U.S. E.P.A., Cincinnati, OH (to be published).

2. Redmon, D. T., W. C. Boyle and L. Ewing. Oxygen Transfer Efficiency Measurements in Mixed Liquor Using Off-Gas Techniques. Journal WPCF, 55(11): 1338-1347, November, 1983.

3. Cooperative Agreement CR812167, Risk Reduction Laboratory, U.S. E.P.A., Cincinnati, OH: Manual of Methods for Fine Bubble Diffused Aeration Field Studies, Appendix A, July, 1985.

4. Personal communication from David T. Redmon, Ewing Engineering Co., Milwaukee, WI, September 27, 1985.

5. Brenner, R. C. and W. C. Boyle. Status of Fine Pore Aeration in the United States. In: Proceedings of the 11th United States/Japan Conference on Sewage Treatment Technology, EPA 600/9-88/010, NTIS No. PB88-214986, U.S. E.P.A., Cincinnati, OH, April, 1988.

APPENDIX A

EXHIBIT A.1: OVERALL PLANT DATA SHEET
BASED ON PREVIOUS YEAR OF RECORD

Plant Name South Shore Wastewater Treatment Plant **Location** Oak Creek, Wisconsin

Flow Through Secondary Treatment: Average 100 **MGD Max.Day** 322 **MGD**

WASTEWATER CHARACTERISTICS- BASED ON MONTHLY AVERAGES

Temperature, deg. C: Average 15 **Min** 10.5 **Max** 18.9

	Raw Influent mg/l			Sec. Effl. mg/l		
	Ave	Min	Max	Ave	Min	Max
5 day BOD	153	90	226	18	12	26
COD (opt)	--	--	--	--	--	--
TSS	213	124	306	13.9	6.3	25
TDS **	835	697	954	808	709	922
TKN	30	17	47	13.7	6.9	20
Total P	4.6	2.7	5.9	.69	.45	1.2
pH (not mg/l)	7.8	7.4	8.0	7.2	7.0	7.3
Alkalinity*						
Hardness*						
Nitrate-N	--	--	--	3.5	.26	11

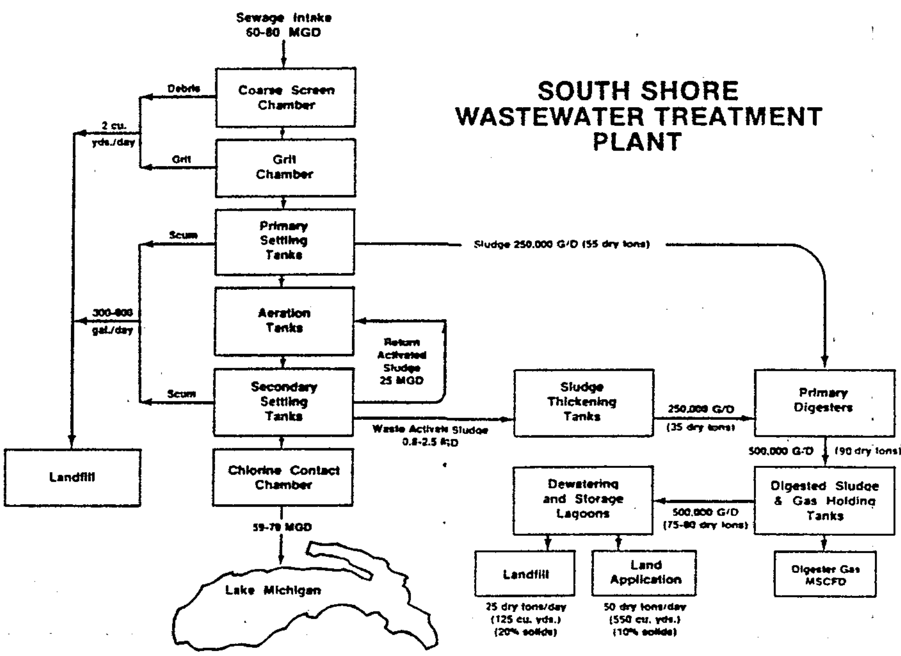
*as calcium carbonate equivalent

** For 7 years: 1975-1981

PROCESS FLOW DIAGRAM INCLUDING TANK SIZES AND RETURN FLOWS FROM SLUDGE PROC.

Primary Sed. Area, sq ft. 16@ 6400 Ft^2 .... **Final Clar. Area, sq ft** 16 @ 10,392 Ft^2

Aeration Tank Vol. cu ft. 24@ 166,500 Ft^2 **Aeration Tank Water Depth ft.** 15 ft



MAJOR INDUSTRIAL WASTES- Averages

Glue	**Flow** 3.1 **MGD**	**BOD** 460 **mg/l**
Machinery, including plating	**Flow** 2.0 **MGD**	**BOD** 80 **mg/l**
Food	**Flow** 0.7 **MGD**	**BOD** 1160 **mg/l**
Tanning	**Flow** 0.2 **MGD**	**BOD** 1430 **mg/l**
Landfill (Leachate)	**Flow** 0.1 **MGD**	**BOD** 2300 **mg/l**

RETURN FLOWS FROM SLUDGE PROCESSING– Averages

Source	Flow MGD	BOD mg/1	TSS mg/1	TKN mg/1	pH	...
Incinerator Recycle	.05-.10	--	--	--	--	
DAF underflow	1.0 (.7-1.4)					

Notes:

PRIMARY EFFLUENT CHARACTERISTICS– AVERAGE INCLUDING RETURN FLOWS

Flow 96 MGD BOD 97 mg/1 TSS 73 mg/1 TKN 27 mg/1

TDS -- mg/1 Total Raw Influent ~~Oil and~~ Grease 36 mg/1 COD 200 mg/1

PROCESS PARAMETERS– Based on Average Conditions

		+/– percent variability max. month to min. month	
		Min.	Max.
Primary Overflow Rate, gpd/sf	1197	797	1759
Aeration Detention Time, V/Q	4.8	3.4	6.4
MLSS Concentration mg/1	1730	1400	2100
Ratio, MLVSS/MLSS	.73	.68	.77
MLSS Inventory lb*	352,000	282,000	412,000
Solids Wasting Rate, lb MLSS/day	59,648	37,947	108,587
Sludge Volume Index	235	117	396
Recycle Ratio, R/Q	.39	.23	.46

	Avg.	Max	Min
Sludge Age, Days*	7.85	11.0	4.9
F/M Ratio, per day* of monthly averages (based on MLVSS)	0.36	0.44	0.26

*estimated clarifier holdup included in solids inventory

AIR DIFFUSION SYSTEM: For Each Tank Studied, Tank Designation.............

Diffusers, Type and Number. 2,448 12-inch sq. by 1.5-inch thick Fine Bubble FILTROS GLASS BONDED SILICA CERAMIC POUROUS PLATES

Recommended Air Rates for this Diffuser, SCFM Min. 0.9 Max. 1.95

Typical Wet Resistance for this Diffuser over the Rec. Air Rate Range

	at Min Rate	at Max Rate
Orifice Resistance, inches water :	Very Low; orifice for 9 plate container is one inch diameter.	
Clean Diffuser, inches water	These data unavailable for South Shore.	
Dirty Diffuser, inches water (if available)		

Year Installed 1974 Submergence, ft. 15 Water Depth, ft. 15

Cleaning Practice and History: Please see the plant history report by Larry Ernest.

Sketch of Diffuser Arrangement in Tank. Give Essential Dimensions for Diffuser Spacing and Air Distribution Piping. Indicate Tapering. Begin with Downcomer.

Please see the South Shore Plant History Report by Larry Ernest.

BLOWERS AND AIR SUPPLY PIPING

Blower Number	Type, Brand, Model	Year	HP	RPM	SCFM	Op. Time Hr/Year
1	Allis-Chalmers Single Stage Centrifugal Compressors		1375	900	35000	3294
2	"				35000	694
3	"				35000	3686
4	"				35000	3307
5						
6						

Total Installed Blower HP....................... SCFM....................

Include the Rating Curve for Each Blower if Available

SEE ATTACHMENT

Describe the Air Filtration System:

Inlet air to the aeration system is filtered through a Fuller Company ATMOS Filter System. These non-abestos bag type filters have a rated design capacity of 200,000 cfm. The filters are equipped with a shaker cleaning mechanism.

Supplemental Information on Blower Drives

Drive Number	Drive Type, Brand, Model	Year	Design RPM	HP at Design RPM
1	White Superior 12 Cylinder Dual Gas Engine	1973	900	1,375
2	"	1973	900	1,375
3	"	1973	900	1,375
4	"	1973	900	1,375
5				
6				

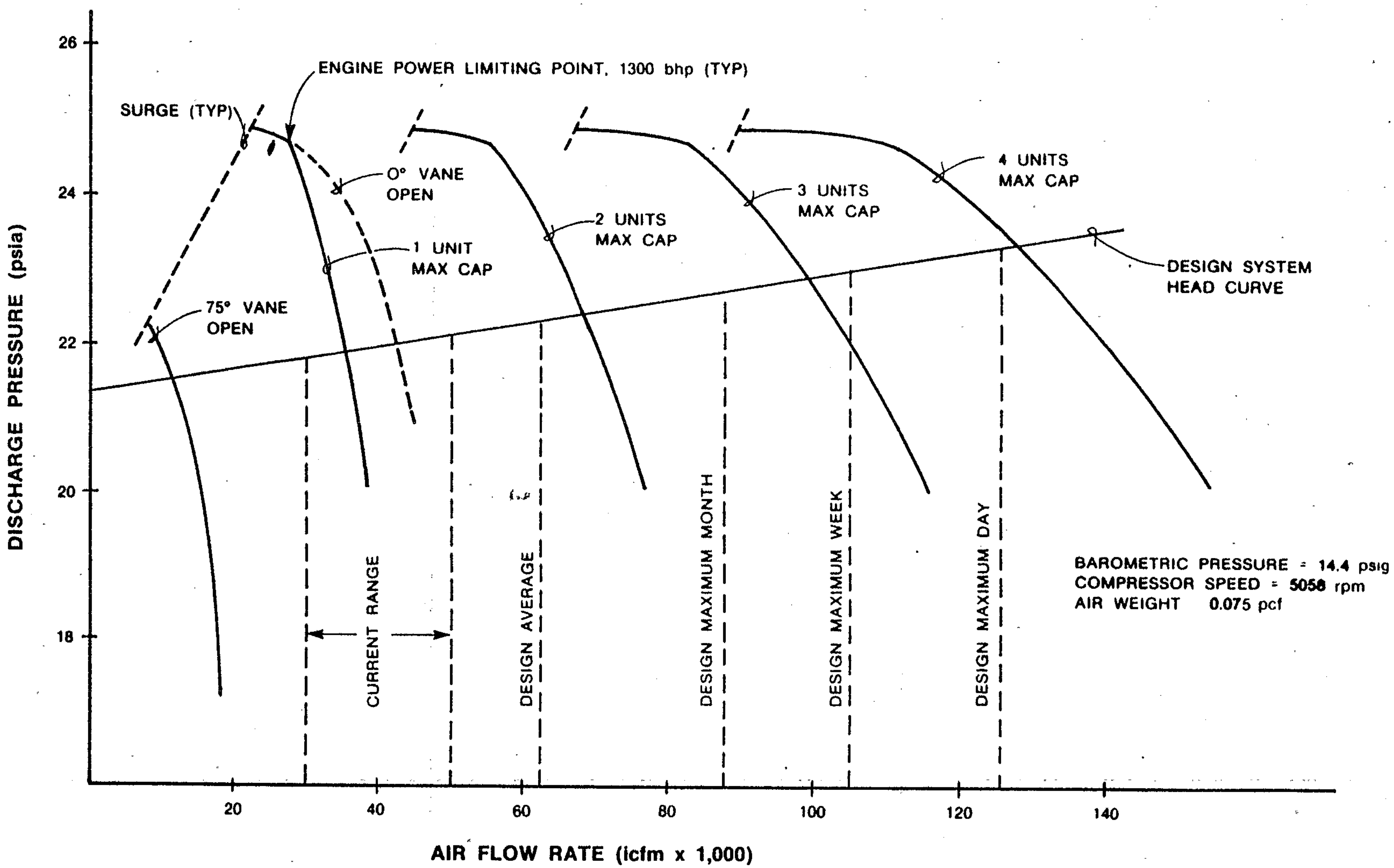


FIGURE 3
EXISTING COMPRESSOR SYSTEM CHARACTERISTICS AT 70°F

Typical Blowers Used at Average Operating Conditions:

Blower Numbers....2....Total Horsepower....2750....

Measured Pressure at Blower Discharge, psi....7.5-8.0....

Measured Dynamic Wet Pressure at Diffuser, psi....--....

Nominal SCFM per Diffuser....1.0....

Typical Blowers Used at Maximum Operating Conditions:

Blower Numbers....2.... Total Horsepower....2750....

Measured Pressure at Blower Discharge, psi....7.5-8.0....

Nominal SCFM per Diffuser....1.0....

Describe Blower Turndown Capability........

....

....

....

Describe Strategy Used to Manage Blowers....At present, oxygen demand is far below design levels. One blower is often sufficient. A second blower is added whenever header pressure falls below a predetermined level....

Provide a Sketch Showing the Arrangement of Blowers and Transmission Piping. If possible, Show Sufficient Detail so that Friction Loss Calculations Could be Made. Show Pipe Sizes, Lengths, Control Valves and Number of Bends from the Blowers to the Aeration Tanks.

Please see page 25.

Describe the Data Base for Aeration Tank Dissolved Oxygen:

Frequency of Measurement. Three minute intervals--as part of computer control loop.

Number of Locations...... One probe at tank outlet.

Length of Record...

Typical Aeration Tank D.O. Values (From 1985 Off-Gas OTE Testing)

	Maximum	Minimum	Avg. (8 tanks)
First Quarter	3.61	.27	1.27
Second Quarter	3.96	.32	1.38
Third Quarter	3.11	.68	1.52
Fourth Quarter	4.40	1.92	2.15

RESULTS OF PREVIOUS OXYGEN TRANSFER TESTS AT THIS PLANT : Three partial tank surveys were carried out by Dave Redmon of Ewing Engineering in October, 1981. The following values for alpha'SOTE were obtained: Tank 16, 14.8%; Tank 19, 19.7%; Tank 21, 21.7%

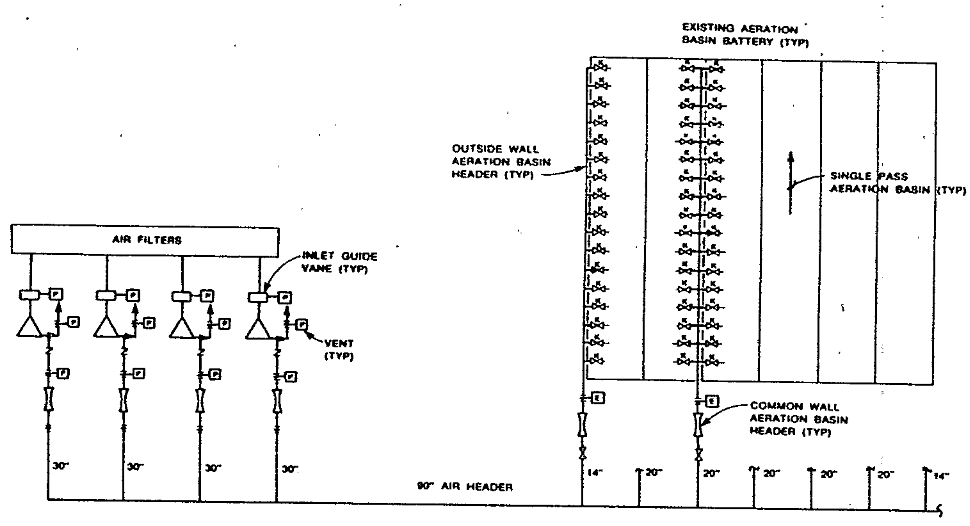


FIGURE 1
EXISTING AIR SUPPLY SYSTEM SCHEMATIC

APPENDIX B-1

Additional Plant Operating Data from the Interplant Fouling Study

SOUTH SHORE ACTIVATED SLUDGE

MONTHLY DATA

DATE	RETURN SLUDGE FLOW (MGD)	MLSS (mg/l) (BATT2)	RSSS (mg/l) (BATT2)	% VSS IN RSSS	MIXED LIQUOR pH	SRT IN DAYS	F/M
June 1986	2.4	1400	4200	74	7.9 - 7.6	6.0	.26
July 1986	2.4	1600	5500	72	7.9 - 7.7	5.4	.39
August 1986	2.4	1700	5100	72	7.9 - 7.6	5.5	.29
September 1986	2.3	1800	6300	69	7.9 - 7.6	7.6	.30
October 1986	2.0	1700	6800	69	7.8 - 7.6	5.4	.43
November 1986	1.7	1700	6600	73	8.1 - 7.4	5.0	.43
December 1986	2.6	1800	4500	74	7.9 - 7.7	7.1	.32
January 1987	2.0	1800	5200	75	8.0 - 7.8	6.9	.26
February 1987	1.3	1500	5100	74	8.0 - 7.8	5.9	.28
March 1987	1.3	1400	7600	68	8.1 - 7.5	3.8	.44
April 1987	1.3	1500	7800	67	7.7 - 7.5	4.4	.42
May 1987	1.8	1500	5900	69	7.7 - 7.4	6.0	.43
June 1987	2.0	1500	4500	72	7.8 - 6.8	6.5	.37
July 1987	2.5	1500	4100	69	7.5 - 6.9	5.4	.43
August 1987	--	--	--	--	--		

APPENDIX B-2

Additional Plant Operating Data from the Interplant Fouling Study

SOUTH SHORE PRIMARY EFFLUENT

MONTHLY DATA

DATE	FLOW (MGD)	5-DAY BOD (mg/l) Tot	5-DAY BOD (mg/l) Sol	pH RANGE (INF)	ALK. (mg/l)	HARDNESS AS $CaCO_3$ (mg/l)	TKN (mg/l)	NH_3 (mg/l)
June 1986	5.0	67	--	7.9-7.6	--	304	22	17
July 1986	6.2	89	38	7.9-7.7	290	--	20	13
August 1986	6.0	73	38	7.9-7.6	270	--	19	13
September 1986	6.8	68	--	7.9-7.6	--	--	17	12
October 1986	7.0	89	--	7.8-7.6	--	--	20	13
November 1986	5.3	124	--	8.1-7.4	--	--	25	18
December 1986	4.9	109	--	7.9-7.7	--	--	26	19
January 1987	4.5	98	--	8.0-7.8	--	--	27	21
February 1987	3.9	97	--	8.0-7.8	--	--	29	22
March 1987	6.0	87	--	8.1-7.5	--	--	23	16
April 1987	6.4	81	--	7.7-7.5	--	--	20	14
May 1987	6.1	90	--	7.7-7.4	--	--	22	16
June 1987	5.3	93	--	7.8-6.8	--	--	24	18
July 1987	6.3	88	--	7.5-6.9	--	--	21	14
August 1987	--	--	--	--	--	--	--	--