OFF-GAS ANALYSIS RESULTS AND FINE PORE RETROFIT INFORMATION FOR GLASTONBURY, CONNECTICUT

by

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Cooperative Agreement No. CR812167

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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

In the summer of 1984, the Glastonbury, Connecticut Water Pollution Control Plant underwent a retrofit from a spiral roll coarse bubble to a spiral roll fine pore aeration system. Only diffuser replacement was performed in the aeration tanks. From November 1985 through September 1988, on-site studies were performed using off-gas analysis as part of the ASCE/EPA Fine Pore Aeration Project. This report presents the results of over 160 off-gas tests together with a case history of the retrofit to upgrade the aeration system. Historical information, retrofit evolution and implementation, aeration performance after the retrofit, and comparison of performance with pre-retrofit data are included in the report.

This report was submitted in partial fulfillment of Cooperative Agreement No. CR812167 by the American Society of Civil Engineers under subcontract to the Aeration Technologies, Inc. under the partial sponsorship of the U.S. Environmental Protection Agency. The work reported herein was conducted over the period of 1985-1988.

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ACKNOWLEDGEMENTS

This investigation and study would not have been possible without facilities use authorization by the Town of Glastonbury, CT. Messrs. Ralph Mandeville and Michael Bisi together with the Water Pollution Control Plant staff provided information and support which were invaluable to the study. Their cooperation and assistance are greatly appreciated.

1.0 INTRODUCTION

In 1969, the consulting engineering firm of Metcalf & Eddy, Boston, MA, completed the design of secondary wastewater treatment facilities for the Town of Glastonbury, Connecticut. The secondary wastewater treatment facilities included the activated sludge process utilizing coarse bubble spiral-roll aeration. Details of the basic design criteria are contained in Appendix I-B.

The secondary wastewater treatment facilities were completed in 1972. The wastewater plant was designed for an average 1990 hydraulic flow of 3.64 MGD and a peak 1990 hydraulic flow of 8.13 MGD. The activated sludge aeration system consisted of two identical four-pass aeration tanks, each 40 feet wide by 165 feet long with nominal operating liquid depth of 15.0 to 15.5 feet. The original aeration equipment consisted of Walker Process Jacknife Sparjer - Header Diffuser assemblies with Delrin coarse bubble sparjers. The Delrin coarse bubble sparjers contained four 1/4-inch diameter air orifices at 90 degrees to one another. The total airflow capacity per diffuser was 13.1 SCFM at 11 inches of water column headloss. Twenty sparjers were installed on each swing-arm assembly. Each of four aeration passes per aeration tank contained four swing-arm assemblies. The total number of sparjers installed in each aeration tank was 320. The detailed specifications and drawings for the aeration equipment are contained in Appendix I-B.

The centerline of the horizontal air manifold of the swing-arm diffuser assemblies was approximately 2.5 to 3.0 feet above the tank floor and 2.5 feet from the tank sidewall. The sparjers were submerged with liquid to a depth of about 12.0 feet.

A spiral-roll aeration and mixing pattern was established by the aeration equipment placement and tank geometry. The Standard Oxygen Transfer Efficiency (SOTE) of the coarse bubble sparjer aeration system was estimated to be approximately 6 percent as installed new.

Air for the submerged aeration system was supplied by three identical 200 HP Hoffman multistage centrifugal blowers, each with a unit airflow capacity of 2,000 to 4,500 SCFM and an average discharge pressure of 7.0 psig. Operation of only one blower was required at any given time.

As the cost of electrical energy increased in the mid to late 1970's, population growth in the service area lagged initial projections, and the popularity of fine pore aeration equipment increased, strong interest developed on the part of the Town to retrofit the coarse bubble system with a new, more efficient fine pore aeration system.

In early 1983, Town public works engineers began to investigate the feasibility of aeration system retrofit. Bids for new fine pore aeration equipment were received by the Town in October 1983, and a contract for new fine pore tube diffuser aeration equipment was awarded to FMC Corp. in April 1984. The new aeration equipment was installed by Town personnel during the summer of 1984. Start-up of the new fine pore aeration system began immediately at the completion of installation. In the spring of 1985, a smaller, more efficient 100 HP centrifugal blower was installed to replace one of the 200 HP units. Detailed information on the new fine pore tube diffuser equipment are contained in Appendix I-C.

This report contains a detailed presentation of the aeration equipment retrofit project at the Glastonbury Wastewater Treatment Facility together with the results of over 160 off-gas tests conducted during six site visits from November 1985 through

September 1988. Table No. 2, Aeration Equipment Retrofit and Off-Gas Test Chronological Summary, contains the chronological summary of the activities which have taken place from the initial design of secondary wastewater treatment facilities to the completion of off-gas testing of the fine pore tube diffuser equipment in September of 1988. Appendix I-A contains summary tables for all off-gas testing conducted during the field investigation. Table No. 3, Overall Aeration Performance for the Whole Tank, contains a summary of all off-gas tests results for the Glastonbury facility aeration system

This report is divided into the following major topical sections:

1.0 Introduction
2.0 Summary
3.0 Historical Background Information
4.0 Fine Pore Aeration Retrofit Design Description
5.0 Operation Performance and Evaluation
6.0 Economic Considerations for Fine Pore Aeration
7.0 Recommendations
8.0 References

This Report also contains the following three appendices:

I-A Summary of Individual Off-Gas Field Tests and Computations for Airflow-Weight Averaging

I-B Overall Plant Data Sheet Based on Previous Year of Record and Supplemental Information

I-C Manufacturer Data and Information for Diffuser Retrofit

The summary section of the report (2.0) SUMMARY) which immediately follows this section, contains the significant overview results, observations, conclusions, and recommendations based on the detailed findings and evaluations presented in the main body of the report.

2.0 SUMMARY

2.1 GENERAL

The replacement of coarse bubble sparjers with fine pore tube diffusers in the spiral-roll aeration system at the Glastonbury wastewater treatment facility has proven to be cost-effective. Mixed liquor oxygen transfer efficiency (apparent alpha[1]xSOTE) increased from an estimated 4.2 percent to over 6.6 percent (57 percent increase in efficiency), and blower power consumption was reduced by approximately 50 KW after the retrofit with fine pore tube diffusers. The reduced electrical cost resulted in a savings of about $20,000.00 per year. The project payback period was less than 18 months.

A chronological summary of the aeration equipment retrofit project and off-gas testing program is presented in Table No. 2. Plant wastewater characteristic information and operational parameters for the off-gas site visit tests are contained in Table No. 1. Table Nos. 3 through 8 contain overall airflow-weighted aeration performance based on the off-gas test results. These data are presented for the whole tank and for each aeration pass versus test visit and overall performance versus aeration pass.

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[1]includes influence of wastewater characteristics, standard or new diffuser characteristics, and any other effects on oxygen transfer performance due to biofouling, clogging and/or changes in diffuser operation such as air leaks or porous media material changes.

Figure Nos. 1 through 6 contain sketches and details of the secondary treatment process schematic, aeration tank dimensions and details, aeration equipment details, and off-gas sampling plans. Figure Nos. 7 through 10 contain plots of plant performance data and wastewater characteristics for the off-gas test visits. Figure No. 11 contains a plot of aeration equipment performance versus airflow per diffuser for clean water test performance (SOTE) and mixed liquor performance (apparent alpha×SOTE) based on the field off-gas testing and available information on clean water testing. Figure Nos. 12 through 21 contain plots of overall aeration system performance for the whole tank and for each aeration pass versus test visit, and Figure Nos. 22 and 23 contain overall aeration performance versus aeration pass. Aeration performance data is based on airflow-weight averaging of individual off-gas test results.

Significant detailed technical data are contained in the three report appendices. Appendix I-A contains a set of summary tables of individual off-gas test field measurements including computations for airflow-weight averaging of the individual test results. Appendix I-B contains EXHIBIT A.1: Overall Plant Data Sheet Based on Previous Year of Record plus supplemental information on the basic design criteria for the secondary treatment process and original aeration equipment specifications. Appendix I-C contains information and data concerning the retrofit to fine pore tube diffusers. Diffuser technical data, and installation, operation, and maintenance information is included.

2.2 OFF-GAS TESTING RESULTS

The results of the field off-gas measurements were generally consistent with the wastewater characteristics and process operating parameters. There was some variability in all observed and measured values. Off-gas oxygen transfer efficiency varied somewhat from visit to visit, and variability increased from test to test and sample point to sample point measurements. Replicate off-gas results of a single sample location generally varied by a small amount, with few exceptions.

Wastewater flow rate and organic loading varied within a normal range during the test site visits and from visit to visit. Process operating parameters such as MLSS concentration, diffuser airflow, and F/M ratio also varied within a normal range throughout the study.

With the exception of the first site visit in November 1985, off-gas results from visit to visit did not vary by a great amount. A possible reason for the rather low results for the November 1985 testing was that a large amount of coarse bubbling was observed during the visit. It was determined that many of the fine pore tube diffusers were leaking air around the end gasket connections because of loose retaining nuts. This problem was corrected before the second off-gas test in March 1986.

Between March 1986 and September 1987, Aeration Tank No. 2 was taken out of service for extended periods of time to perform maintenance work on the buried air supply main and in-tank maintenance on the concrete work and swing-arm assemblies. In June 1986, a 100-year flood of the Connecticut River totally submerged the plant under several feet of water. The plant was out of operation for several weeks.

The average whole-tank airflow-weighted oxygen transfer efficiency (apparent alpha×SOTE) for all tests was 6.6 percent and ranged from 4.9 to 7.6 percent on a site visit-by-site visit basis. Excluding the initial test in November 1985, the average whole-tank efficiency was 7.2 percent. Average airflow-weighted oxygen transfer efficiencies by aeration pass varied by a small amount as follows:

Aeration Pass	Apparent Alpha × SOTE, %	Aeration Mode
1	5.6	Reaeration
2	7.0	Influent Pass
3	7.2	Second Pass
4	6.9	Third Pass

The average airflow-weighted whole tank apparent alpha for all tests by site visit was 0.55 and ranged from 0.42 to 0.61. Excluding the first test, the average apparent alpha was 0.58. The overall apparent alpha changed very little from test-to-test and from site visit-to-site visit. Pass No. 1, which received all of the return activated sludge, experienced an average apparent alpha of about 0.5, while the remaining three aeration passes had higher apparent alpha values. Generally, the inlet of Pass No. 2 (primary effluent feed point) had lower apparent alpha values than any of the other off-gas sample locations in Aeration Tank No. 2.

2.3 OPERATION AND MAINTENANCE OBSERVATIONS

Operation and maintenance practices for the new fine pore tube diffusers differ very little from those practices used for the coarse bubble sparjer diffusers. Manual measurement of mixed liquor dissolved oxygen concentration and airflow adjustment

are undertaken on a more frequent basis to maximize the opportunity to reduce electrical power usage and thereby reduce costs.

There is no routine, scheduled program for cleaning of the fine pore tube diffusers. Inspection of the diffusers consists of visual observation of the air pattern at the liquid surface. Any turbulence and excessive coarse bubbling are noted. Maintenance is performed on an as-needed basis depending on the airflow pattern and distribution (back pressure on individual or multiple diffusers). Repairs are made by removing a swing-arm assembly from service, hoisting to the raised position, and repairing the diffusers as required.

The swing-arm assembly system allows the aeration tank to remain in service without disruption to the process, while at the same time, providing for complete access to the diffusers at any time. Although the mixed liquor transfer efficiency of this type of system is about 60 to 70 percent of the efficiency of a full floor coverage fine pore system, the accessibility for maintenance and repair is infinitely better, and there is no adverse impact on operation and process control while the equipment is out of service for inspection, cleaning, or repair.

2.4 DIFFUSER CLEANING COMMENTS

The fine pore tube diffusers at Glastonbury have been cleaned once because of internal fouling with mixed liquor solids. No routine cleaning has been done with a goal of improved oxygen transfer efficiency. The only cleaning occurred within weeks after the installation of the new diffusers. At the time of installation of the new diffusers, the drain holes in the swing-arm air manifolds (horizontal air header to which the diffusers are attached) were not plugged. When airflow to the swing-arm unit was disrupted, mixed liquor flowed back into

swing-arm unit was disrupted, mixed liquor flowed back into the air manifold and swing-arm drop leg. Solids in the mixed liquor impacted on the inside of the diffusers when air supply was introduced to the swing-arm assembly.

Correction of the fouling problem involved raising of a swing-arm assembly, removal of the diffusers, disassembly of the diffusers, detergent cleaning of the tube diffuser media, reassembly of the diffusers, installation of the diffusers on the swing-arm assembly, and plugging of the air manifold drain holes. Because of the time required to disassemble, detergent clean, and reassemble each diffuser, the unit cost for diffuser cleaning was relatively high ranging from $5.00 to $7.50 per diffuser.

2.5 DESIGN COMMENTS

The retrofit of this small activated sludge secondary wastewater treatment plant was a project which could be managed by plant and public works personnel without costly outside consulting assistance. Initially, Town Public Works Dept. personnel investigated the various alternate fine pore systems which could be used at the Glastonbury facility. Manufacturers were contacted for product information and equipment recommendations, and visits were made to other wastewater treatment facilities which had retrofitted from coarse bubble to fine pore equipment. Valuable information was gained from these contacts.

In the review and selection of fine pore replacement diffusers on swing-arm assemblies, consideration must be given to the details of attaching the new diffusers and the condition of the swing-arm assembly. Swing-arm assembly piping and fittings should be inspected for service condition and possible modification requirements. Corrosion products must be removed from the air piping. All drain holes must be plugged, and all

locations for potential air leakage must be inspected and repaired as necessary. (The drop leg knee joint is a prime location for air leakage and potential backflow of mixed liquor when air supply to the swing-arm assembly is shut off.) Lastly, air piping must be capable of draining out all liquid which enters through the diffusers when air is off. In most retrofit cases, the new diffusers are mounted on the top of the air manifold. In some cases, the diffusers are mounted on the side(s) of the air manifold. In either case, a low-point drain should be provided on the air manifold. One diffuser should be attached to the low-point drain to ensure that liquid does not become entrapped in the air manifold during operation of the equipment.

Each type of diffuser considered for retrofit on swing-arm assemblies will have unique SOTE, back pressure, and air filtration characteristics. If maximum electrical power savings are to be realized, the diffuser characteristics must be fully considered in conjunction with the existing and/or new air supply equipment. Air filtration requirements will vary from none to full second stage air filtration depending upon the specific diffuser to be used. If existing blower equipment is to be used with the new retrofit equipment, electrical power savings can only be realized by shutting off blowers or, in the case of centrifugal blowers, reducing airflow to some degree. In many cases, existing blowers can be modified to operate at reduced airflow rates efficiently, thus reducing electrical power consumption. In other cases, new blower equipment can be purchased which will match the characteristics of the new diffuser equipment and maximize electrical power savings at the same time.

2.6 RECOMMENDATIONS

Evaluation of field oxygen transfer performance in spiral-roll retrofit aeration systems by off-gas testing is viable and useful. In systems where significant variations in plant loading and process operating modes occur, a greater number of off-gas tests, over a longer time base, provide more accurate average performance information than the results from specific sample point and/or point-in-time testing.

Fine pore retrofit or new applications' design should be based on accurate full-scale Standard Oxygen Transfer Efficiency (SOTE) data and realistic apparent alpha factor values covering the range of process conditions tank spatial location, and wastewater characteristic parameters. Where possible, pilot and/or full scale alpha testing should be undertaken, especially if unique conditions exist (i.e. industrial waste, special process streams, or other factors which could influence the alpha factor value). Pilot tests should use fouled as well as clean diffusers.

In the absence of alpha factor values based on specific testing, a design average range of 0.4 and 0.6 should be used for fine pore tube diffuser spiral-roll aeration systems. The full range of alpha values could be from less than 0.3 to over 0.7, depending on the many factors which effect alpha under operating conditions. Therefore, it is very important to consider these factors carefully when designing a new or retrofit fine pore tube diffuser system.

Mixed liquor apparent alpha×SOTE values of 5 to 8 percent (7 percent average) should be considered for fine pore tube diffuser spiral-roll aeration systems operating at 15.0 to 15.5 feet of liquid depth and 12.0 to 12.5 feet of diffuser submergence in the conventional activated sludge process treating domestic wastewater. The apparent alpha×SOTE values stated above are based on SOTE values of 11.0 to 13.0 percent in

clean tap water, operated under the same conditions of tank geometry, diffuser density and airflow, and diffuser submergence.

In retrofit aeration systems using tube diffusers with retaining nuts, gaskets, and bolts, care must be taken to ensure that diffuser assembly is proper and that air leakage is prevented from occurring around gaskets and retaining hardware. Where existing air piping and swing-arm assemblies are to be used, cleaning of inside piping surfaces and reconditioning knee joints as necessary must be accomplished prior to placing the new fine pore tube diffuser equipment in operation. All drain holes, blow-down legs, and other coarse bubble system openings in the horizontal air manifold and swing-arm assembly must be plugged to prevent backflow or intrusion of mixed liquor into the air piping and diffusers.

Dissolved oxygen monitoring and airflow control instrumentation should only be as sophisticated as necessary. The simpler the control system, the better the results. Routine manual measurement of dissolved oxygen and manual adjustment of airflow are adequate for small plants such as Glastonbury. Air supply equipment should match the aeration system. The airflow range and system pressure requirements of the aeration equipment must integrate with the blower equipment performance characteristics if aeration efficiency is to be optimized. In cases where retrofit of the aeration equipment requires substantial reduction in air supply, blower turndown capabilities, shutdown of incremental units, or replacement of old equipment with new, smaller equipment must be considered and evaluated for maximum power reduction potential.

Dissolved oxygen monitoring instrumentation should be checked and calibrated frequently, if the measurements are to be meaningful.

All operating on-line fine pore aeration equipment should be tested for oxygen transfer efficiency and back pressure on a routine basis. The results of this testing should be used to compare equipment performance with expected values of performance, and to establish maintenance schedules for cleaning the equipment. Air leaks should be repaired as soon as possible to limit intrusion of mixed liquor into the air piping system, thereby reducing the potential for air-side fouling, to minimize deterioration of the aeration system, and to ensure that oxygen transfer efficiency is not reduced unnecessarily.

3.0 HISTORICAL BACKGROUND INFORMATION

3.1 THE TREATMENT FACILITY

The Glastonbury wastewater treatment plant serves the Town of Glastonbury, Connecticut. The secondary activated sludge treatment facility, designed in 1969 and completed in 1972, presently processes an average daily flow of about 1.6 MGD and a maximum daily flow of 2.1 MGD with peaks as high as 2.5 MGD. The secondary treatment facilities are designed for a 1990 average daily flow of 3.6 MGD and a 1990 peak flow of 8.1 MGD. Present plant loading is only a fraction of the design loading values used to size the secondary treatment facilities. Population growth projections and industrial flow projections used for the design did not materialize as anticipated.

The wastewater treatment facility contains preliminary, primary, secondary activated sludge, and waste sludge conditioning unit operations and processes. The conditioned sludge from this plant is trucked to the Hartford MDC treatment facility for final treatment and disposal.

3.2 THE ACTIVATED SLUDGE PROCESS

The activated sludge process is designed to treat a 3.6 MGD average daily flow. However, over the past several years, the average daily flow has been about 1.5 MGD and has not increased due to a lack of growth in the service area as anticipated at the time of design in 1969.

The flow from primary treatment enters the secondary facilities by gravity. Only one of the two identical aeration tanks is used for treatment. Each aeration tank is 166 feet

long and 40 feet wide with a nominal liquid depth of 15.0 to 15.5 feet. Each aeration tank is divided into four passes of equal size. Each pass is 82.5 feet long and 20 feet wide. The normal mode of operation is conventional activated sludge with provision for step-feed. Return activated sludge (RAS) is introduced at the head-end of Pass No. 1, and primary effluent (PE) is introduced at the head-end of Pass No. 2. Figure No. 1 contains a schematic of the secondary treatment process. Schematics of the aeration tank and aeration equipment are contained on Figure Nos. 2, 3, and 4.

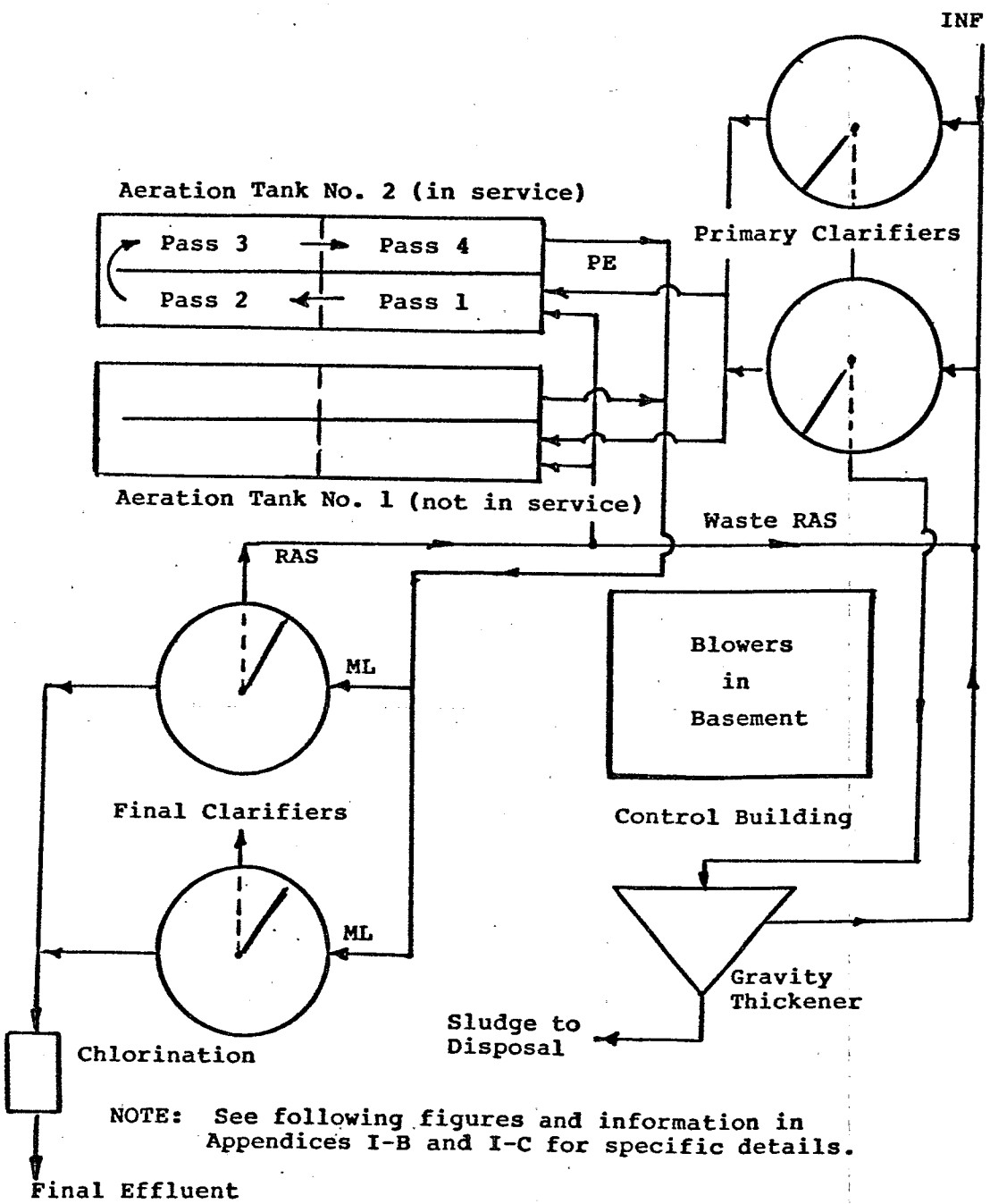
Mixed liquor flows from the aeration tank to two 65-foot diameter circular final clarifiers. The overflow from the final clarifiers is chlorinated and discharged to the Connecticut River. Settled sludge from the final clarifiers is returned to the activated sludge process at an average rate equal to 34 percent of the plant flow. Waste sludge is thickened at the plant and then trucked to the Hartford MDC facility for final treatment and disposal.

3.3 ORIGINAL AERATION SYSTEM

The original aeration equipment installed in 1972 consisted of Walker Process Jacknife Sparjer-Header Diffuser assemblies with Delrin coarse bubble sparjers installed on the air manifolds at the end of each jacknife. The Delrin coarse bubble sparjers contained four 1/4-inch diameter air orifices at 90 degrees to one another. The total airflow capacity per diffuser was 13.1 SCFM at 11 inches of water column headloss. Twenty sparjers were installed on each swing-arm assembly. Each of the four aeration passes per aeration tank contained four swing-arm assemblies. The total number of sparjers installed in each aeration tank was 320 units. The sparjers were uniformly spaced along the air manifolds at 2-foot intervals. No provision for aeration tapering was provided by this orientation of the sparjers in the aeration tanks.

FIGURE NO. 1

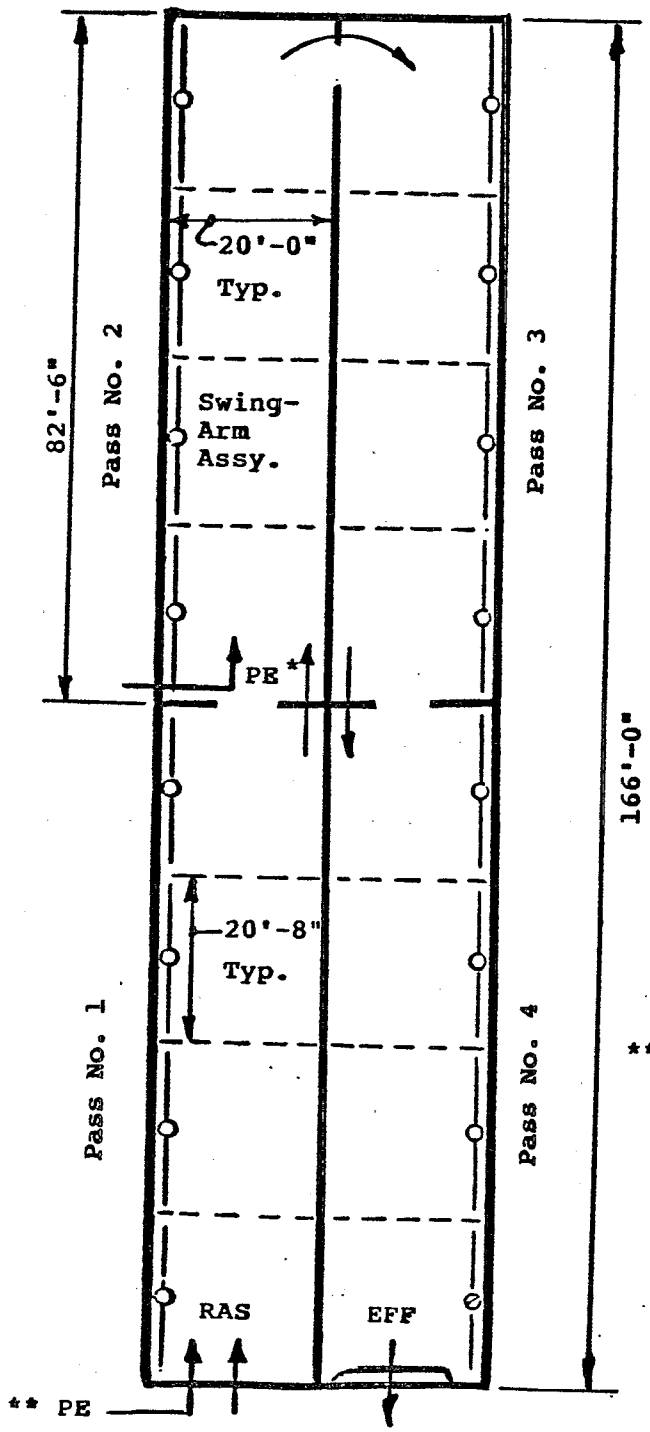
SCHEMATIC OF SECONDARY TREATMENT PROCESS



NOTE: See following figures and information in Appendices I-B and I-C for specific details.

FIGURE NO. 2

PLAN SKETCH WITH TANK DIMENSIONS



NOMINAL LIQUID VOLUME PER PASS:

25,500 cu. ft.
191,000 gal.

NOMINAL TOTAL LIQUID VOLUME:

102,000 cu. ft.
764,000 gal.

NOMINAL LIQUID SIDE WATER DEPTH:

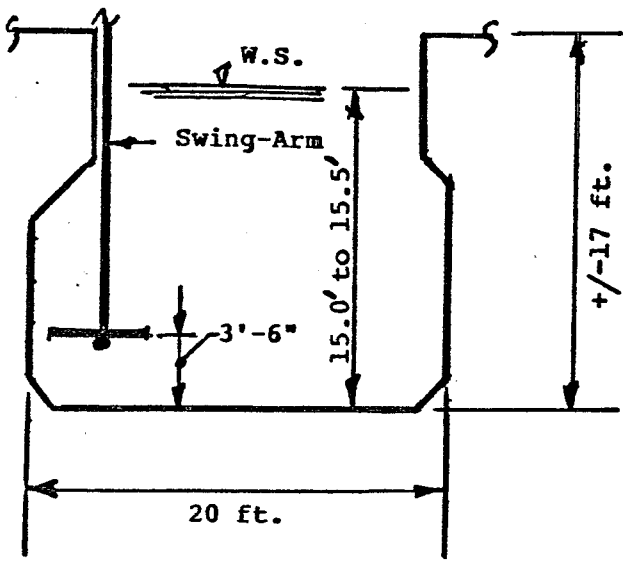
15.0 to
15.5 ft.

* Primary effluent inlet for Contact Stabilization Mode. (Site visitation 1 through 3).

** Primary effluent inlet for Conventional Mode. (Site visitations 4 through 6).

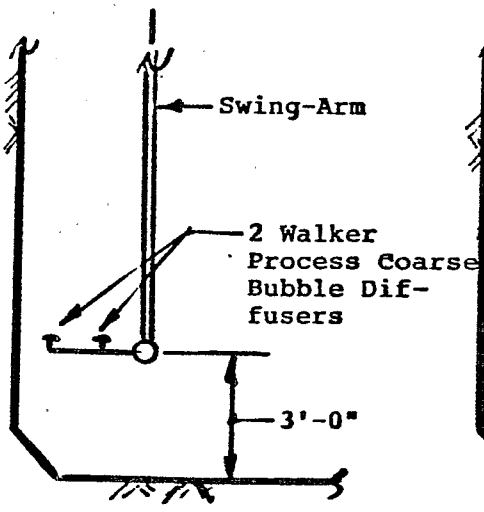
FIGURE NO. 3

TYPICAL CROSS SECTION AND DETAIL



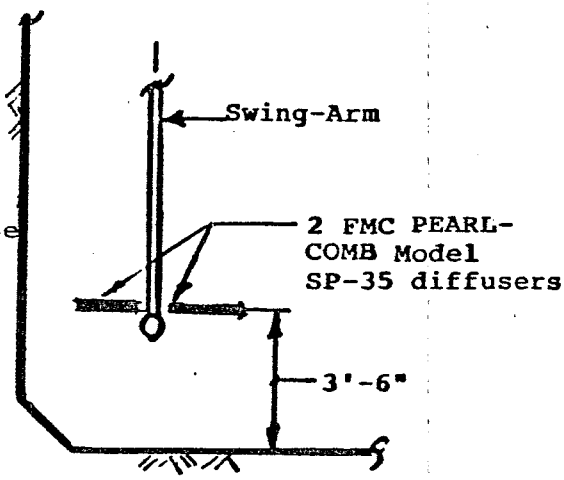
CROSS SECTION THROUGH AERATION TANK
NTS

Preretrofit Diffuser Arrangement



For details see Appendix I-B

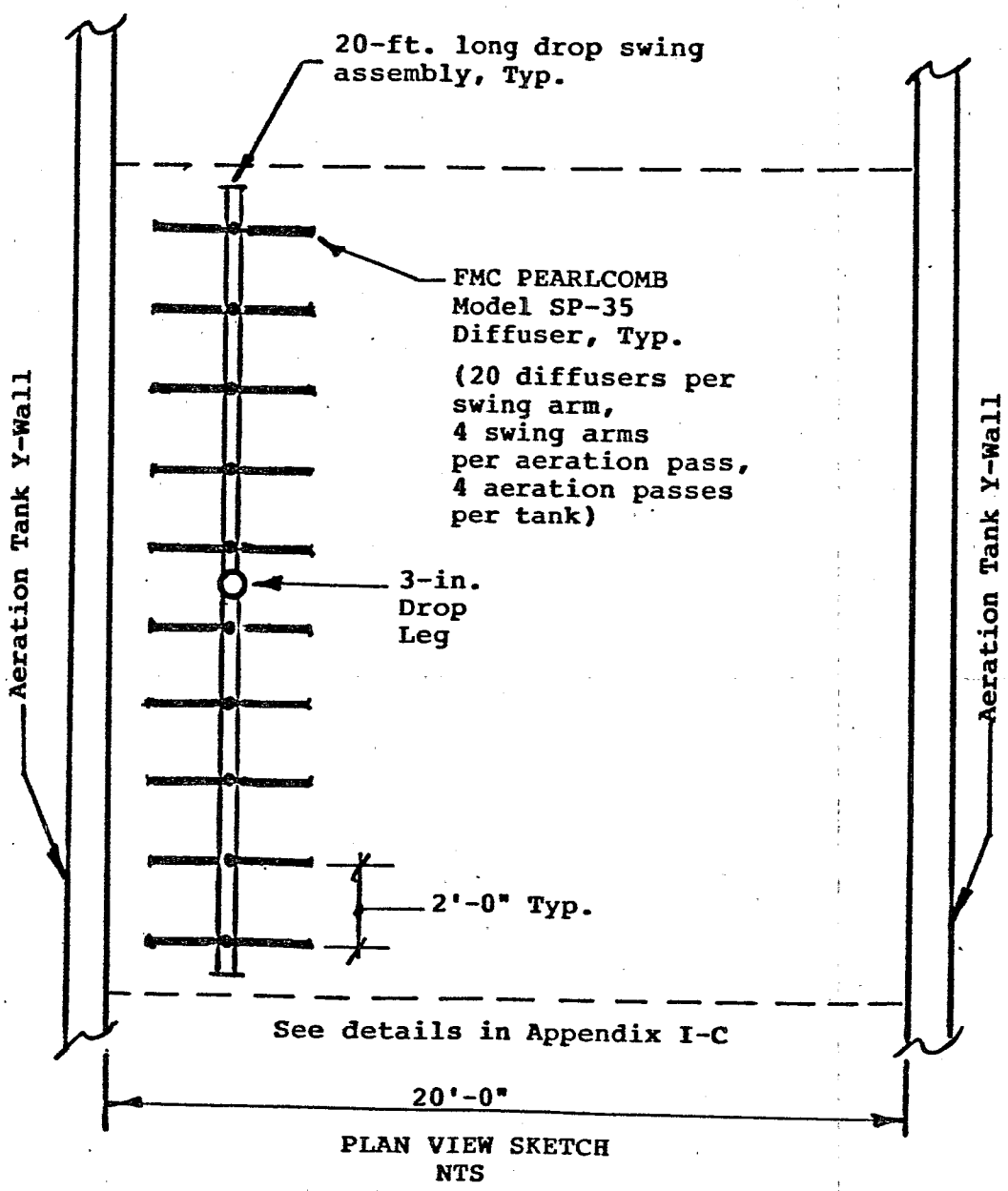
Retrofit Diffuser Arrangement



For details see Appendix I-C

FIGURE NO. 4

TYPICAL DIFFUSER LAYOUT



PLAN VIEW SKETCH
NTS

Detailed specifications and drawings for the original aeration equipment are contained in Appendix I-B. Figure Nos. 2, 3, and 4 contain dimensions and tank details regarding the aeration equipment placement.

The centerline of the horizontal air manifold of each swing-arm assembly was positioned 2.5 to 3.0 feet above the aeration tank floor and 2.5 feet from the tank sidewall. The sparjers were submerged with liquid to a depth of about 12.0 to 12.5 feet. The sparjers were oriented between the drop-leg of the swing-arm and the tank sidewall, creating a very narrow band of aeration.

A spiral-roll aeration and mixing pattern was created by the aeration equipment placement and tank geometry. The Standard Oxygen Transfer Efficiency (SOTE) of this coarse bubble sparjer aeration system was estimated to be approximately 6 percent as installed new.

Air for the original submerged aeration system was supplied by three identical 200 HP Hoffman multistage centrifugal blowers, each with an airflow capacity range of 2,000 to 4,500 SCFM and an average discharge pressure of 7.0 psig. Operation of only one blower was required at any given time, and airflow rate adjustment was accomplished by inlet valve throttling at the blower suction.

Dissolved oxygen and air supply control were carried out with manual measurement of dissolved oxygen and manual adjustment of airflow to Pass Nos. 1 and 2 and Pass Nos. 3 and 4 with in-line valves. In addition, each swing-arm assembly contained an isolation valve which could be used to throttle airflow to the individual swing-arm assembly.

3.4 OPERATIONAL PROBLEMS

As the cost of electrical energy increased in the mid-to-late 1970's, and as population growth in the early 1980's lagged far behind the initial design estimates, the Town of Glastonbury developed a strong interest in saving electrical power costs for aeration. During this same period of time, the popularity of fine pore aeration equipment was increasing due to aeration efficiency and power cost considerations. Several Connecticut communities had retrofitted with fine pore operation equipment and were experiencing electrical power cost savings as a result of the retrofits.

Prior to the full retrofit feasibility study, the No. 2 blower was modified by the manufacturer to provide reduced capacity and power draw. The blower modification allowed airflow turndown from the original surge point of 1,900 SCFM to under 1,600 SCFM, thus providing additional throttling and reduced power consumption.

Glastonbury's interest in retrofitting to fine pore aeration equipment was solely based on a desire to reduce electrical power costs. Both new in-tank equipment and blower modifications to reduce airflow supply would be investigated.

3.5 RETROFIT OBJECTIVES

With electrical power savings as a primary objective for retrofitting to fine pore equipment, several important considerations were also made a part of the overall retrofit objectives. They were:

1. payback of capital cost of the project in as short a time as possible (24 months desirable).
2. minimize any additional operational and maintenance costs over the existing aeration equipment.

3. provide the same operational flexibility as the existing equipment afforded.
4. keep process results and effluent water quality standards the same as before the retrofit.
5. avoid the need the use multiple blower units as much as possible to keep electrical demand charges as low as possible.

3.6 BASIS FOR CHANGING TO FINE PORE AERATION

In early 1983, the Town of Glastonbury public works engineers began to investigate the feasibility of aeration system retrofit. Initially, various alternate fine pore systems were investigated. Manufacturers were contacted for product information and equipment recommendations, and visits were made to other wastewater treatment facilities which had retrofitted from coarse bubble to fine pore equipment.

It was determined that significant electrical power savings could be realized by replacing the coarse bubble aeration equipment with fine pore equipment and perform some modifications to the air supply equipment to render it compatible with the new in-tank equipment and, generally, improve aeration efficiency.

Since the Town did not want to contract with a consultant to undertake a costly feasibility study, only proven fine pore technology was considered. Other types of aeration equipment with high efficiency claims were not considered. Also, the continued use of the existing swing-arm assemblies was a strong consideration, because the equipment was in good repair, and the operational flexibility afforded was superior to full-floor coverage equipment which would require that the aeration tank be taken out of service and dewatered for cleaning and maintenance of the diffuser system. For a small plant

like Glastonbury with only one on-line aeration tank, the switchover of the entire activated sludge process to a standby tank was a significant operational consideration.

4.0 FINE PORE AERATION RETROFIT DESIGN DESCRIPTION

4.1 BASIS FOR DESIGN

The design basis for retrofitting from the existing swing-arm coarse bubble diffuser assemblies to fine pore equipment is contained in the Invitation to Bid documents and attachments prepared by the Town of Glastonbury. These documents (BID #GL-2283) are contained in Appendix I-C. The Invitation to Bid and supporting documents were sent to several manufacturers of both fine pore tube diffuser aeration equipment and fine pore dome/disc diffuser aeration equipment.

The detailed specification prepared by the Town requested proposals for "evaluation and equipment recommendations for modifications to the aeration system at its Water Pollution Control Facility which is presently operating conventional activated sludge with capability of step-feed." The purpose for the request for proposals was as follows: "The Town is interested in reducing its energy consumption from generating compressed air for an aeration system as part of its activated sludge process." The proposal scope for aeration system modifications which the Town would consider and evaluate included the centrifugal blower(s), controls, valving, piping, and diffuser system(s).

Evaluation parameters used by the Town to compare the various bids for aeration system modifications were as follows:

1. Energy savings over the current aeration process, broken down by major components (i.e., blower, control valve, controls, diffuser).
2. Expected equipment life.
3. Operating energy costs-system life.

4. Operating/maintenance system costs-system life.
5. System cost.
6. Equipment flexibility within system life to varying flow and biochemical demands.
7. Why vendor recommends the proposed system.
8. Equipment manufacturer resume with the proposed type of system.
9. Location(s) of proposed equipment/system currently in use.

The system life was to be taken as 10 years or the actual life of the proposed equipment if less than 10 years.

Potential bidders were provided with detailed information and data concerning the existing aeration system. This information included:

1. Basic design data (1970 and 1990).
2. Current operating data (1983).
3. Air compressor performance curves for original and modified equipment.
4. Aeration tank details.
5. Air header diffuser specifications, sparjer assembly details, and sparjer back-pressure curves.

Much of the information listed above is contained in Appendix I-B of this report.

Several bids were received from fine pore tube manufacturers, both flexible membrane and various rigid media types. At least one bid was received from the manufacturer of fine pore dome diffuser equipment.

4.2 DESCRIPTION OF FINE PORE DIFFUSER EQUIPMENT PURCHASED

Bids were received in October 1983 and an equipment selection and award was made in April 1984. The successful bidder was FMC Corp. for the supply of 320 Pearlcomb Diffusers, Model SP-35.

The Pearlcomb Diffuser is a fine pore tube-type diffuser with a porous cylindrical tube composed of modified acrylonitrile styrene copolymer material in the form of uniformly-sized spheres linked to their points of contact. Each diffuser assembly consists of:

- one tube adapter manufactured from an ABS polymer provided with a stainless steel insert suitable for connection to a 3/4-inch NPT thread and control orifice.
- one diffuser tube.
- one end cap manufactured from an ABS polymer.
- one stainless steel rod threaded at both ends with PVC nut.
- one set of Neoprene gaskets and polyethylene washes.

The diffusers are shipped unassembled and require assembly at the job site by the installing contractor.

Details of the technical specification for the diffuser; installation, operation and maintenance instructions; and diffuser detail drawing and diffuser installation drawing are included in Appendix I-C of this report.

The existing 3-inch diameter air manifold on each swing-arm assembly was rotated 90 degrees to orient the air release holes and pipe clamp assemblies in an upright position. A 1-inch pipe nipple was inserted in each clamp assembly. A 3/4x3/4x1-inch tee was attached to the top of the nipple. A Pearlcomb Diffuser was attached to each 3/4-inch tee opening.

The purchase of air filtration equipment and a new 100 HP Hoffman multistage centrifugal blower to replace one of the three existing 200 HP units was not part of the diffuser and in-tank work. The existing blowers could not be throttled to a low enough discharge volume for the new diffuser equipment, and a smaller capacity unit was needed to accomplish the reduction in electrical power usage sought as the major objective of the project.

5.0 OPERATIONAL PERFORMANCE AND EVALUATION

5.1 SYSTEM START-UP

Prior to the start-up of Aeration Tank No. 2 with the new fine pore tube diffusers in the summer of 1984, the average air supply rate to the activated sludge process was 2,250 SCFM. After installation of all 320 Pearlcomb Diffusers, the airflow was adjusted downward to the surge point on the modified 200 HP blower (about 1,600 SCFM). The purchase of a smaller, more efficient 100 HP blower in 1985 permitted airflow adjustment to a range of 1,000 to 1,200 SCFM with airflow rate control based on manual measurement of the mixed liquor dissolved oxygen concentration.

Installation of all equipment was performed by Town Public Works employees. Aeration Tank No. 2 was dewatered and cleaned prior to the retrofit installation work. Modification of the swing-arm air manifolds and installation of the new Pearlcomb Diffusers was accomplished from the bottom of the aeration tank to avoid lifting and lowering of each individual swing-arm which would be necessary if the installation work was done topside.

After a few weeks of operation, it was noted that several diffusers appeared to be clogged or plugged, and airflow patterns indicated a smaller amount of air was being released from many diffusers. Investigation of the problem revealed that mixed liquor was backflowing into the blow-down holes in the air manifolds on each swing-arm assembly and plugging the inside of the diffusers. Steps were taken to correct this problem and to thoroughly clean the diffusers.

5.2 OPERATING CONDITIONS

Average operating conditions for the period from the retrofit implementation through the off-gas testing program are contained in Table No. 1 and in Appendix I-B. The average BOD loading to the plant was 230 mg/l and approximately 120 mg/l to the secondary treatment system. Wastewater flow averaged 1.5 MGD with maximum day flows of over 2.0 MGD and peaks to over 2.5 MGD. MLSS concentration ranged from under 1,500 mg/l to over 3,000 mg/l. The average detention time in aeration was 11 hours, and sludge age averaged 12 days.

5.3 OPERATIONAL CONTROL

Operational control for the new aeration equipment involved manual measurement of the dissolved oxygen concentration of the mixed liquor and manual airflow adjustment of the on-line blower to a flow rate which would achieve a dissolved oxygen concentration in the mixed liquor of approximately 2.0 mg/l. Dissolved oxygen measurements were taken two to three times each day.

5.4 TREATMENT PERFORMANCE

The water quality of the plant effluent remained consistently high after the implementation of the fine pore aeration system retrofit. Effluent BOD and suspended solids concentrations nearly always remained below 10 mg/l.

TABLE NO. 1

WASTEWATER CHARACTERISTICS INFORMATION FOR
OFF-GAS VISITS

DATE	PLANT FLOW, MGD	INFLUENT BOD5, MG/L	PRI. EFF. BOD5, MG/L	FINAL EFF. BOD5, MG/L	MLSS, MG/L	MLVSS, MG/L	FINAL EFF. SS, MG/L	RETURN SLUDGE, %	WASTE SLUDGE, LBS.	F/M RATIO	SVI
11-21-85*	1.70	258	135	28	2,137	1,848	15	24	1262	0.17	87
03-26-86*	1.80	215	113	2	2,893	2,401	12	46	298	0.11	221
09-17-87*	1.80	260	156	6	1,751	1,541	2	43	1003	0.25	366
01-11-88**	1.80	403	176	29	3,003	2,603	8	52	841	0.16	313
05-17-88**	1.98	305	142	6	2,230	1,919	4	51	1426	0.20	381
09-07-88**	1.56	245	124	7	1,389	1,194	5	65	1192	0.22	436

* CONTACT STABILIZATION MODE

** CONVENTIONAL MODE

5.5 AERATION SYSTEM EVALUATION

5.5.1 General

An extensive aeration system performance evaluation has been undertaken at the Glastonbury treatment facility as part of the ASCE/EPA Oxygen Transfer Study. From November 1985 through September 1988, Aeration Technologies, Inc. conducted off-gas testing during six separate site visits. Over 160 individual off-gas tests were performed in Aeration Tank No. 2 to measure and record aeration performance over time. The results of the field off-gas measurements were compared with plant water quality data and operating conditions for the periods in which testing was performed.

Table No. 2 contains a listing of the six site visits together with test designation identification. Other key event dates for the Glastonbury retrofit project are contained in the table.

The initial off-gas test visit in November 1985 and the second off-gas test visit in March 1986 used a sampling plan consisting of two sets of replicate tests at each of the influent and effluent quarter points of each aeration pass. Each replicate test set consisted of two individual off-gas tests, one taken with the hood positioned half way across the aeration pass width and one taken with the hood placed at the remaining half-width position. In the first position, the collection hood airflow was very high compared to the very low airflow collected at the half-width position furthest from the swing-arm assembly. (The sampling designation for this sequence of testing is Sampling Plan "A" and is shown graphically on Figure No. 5).

For the remaining four off-gas test visits, a sampling plan using one replicate at each sample point, but with three sets of tests for each site visit, was adopted. This sampling plan

TABLE NO. 2

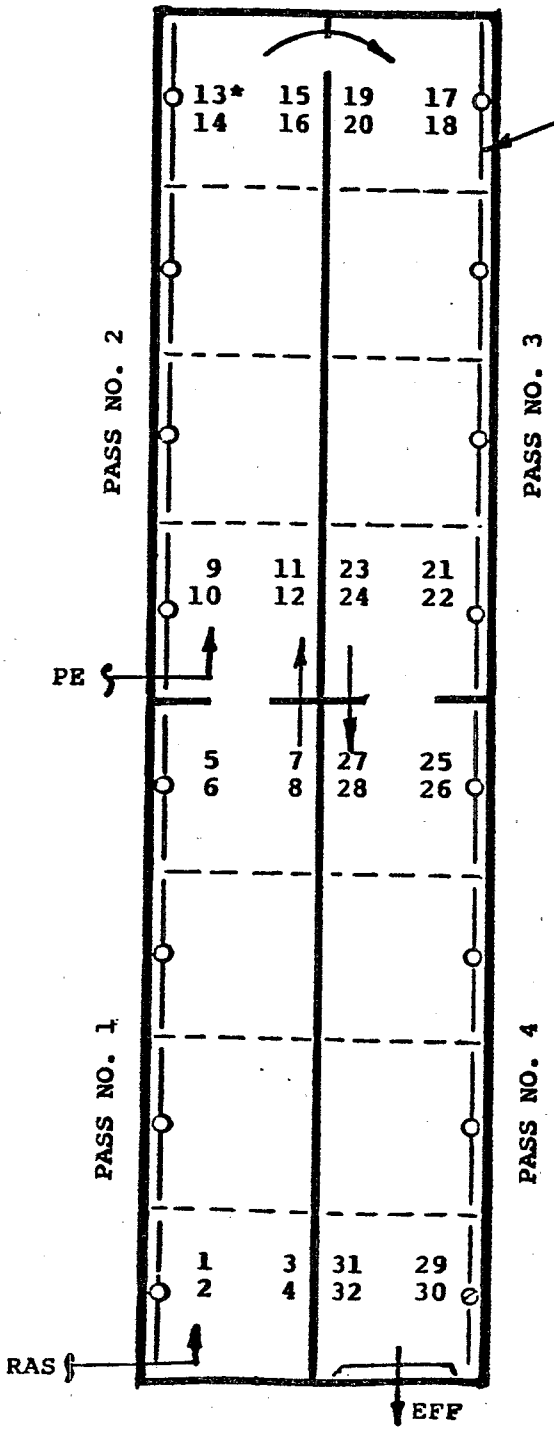
AERATION EQUIPMENT RETROFIT AND
OFF-GAS TEST CHRONOLOGICAL SUMMARY

TIME/DATE	DESCRIPTION
Late 1969	Final design of Secondary Treatment Facilities
Late 1972	Completion of Secondary Treatment Facilities
Early 1982	Investigate feasibility of retrofitting the coarse bubble aeration equipment
Oct. 1982	Modification of one 200 HP blower to reduce capacity
Oct. 1983	Bids received for fine pore retrofit equipment
April 1984	Contract let for new fine pore aeration equipment
June 1984	100-year flood shuts plant down for several weeks
Fall 1984	Installation of new fine pore aeration equipment
Feb. 1985	Installation of new 100 HP blower
May 1985	Start-up and operation of new fine pore aeration system
Nov. 21 & 22, 1985*	Full Tank Testing - Designated 1A
Mar. 26 & 28, 1986*	Full Tank Testing - Designated 2A
Sept. 17, 1987**	Full Tank Testing - Designated 3B
Jan. 11, 1988**	Full Tank Testing - Designated 4B
May 17, 1988**	Full Tank Testing - Designated 5B
Sept. 7, 1988**	Full Tank Testing - Designated 6B

* Four replicate tests per sample location and one excursion through the aeration tank.
** One test per sample location and three excursions through the aeration tank.

FIGURE NO. 5

OFF-GAS SAMPLING PLAN "A"



NOTE: half-width hood used throughout

* denotes test number and sample location for tests conducted on November 21 and 22, 1985 and on March 26 and 28, 1986. Four replicate tests at each sample location (one excursion through the aeration tank per site visit).

(designated as Sampling Plan "B" and shown graphically on Figure No. 6) utilized a collection hood which extended across the full width of the aeration pass. It was believed that the reduced time necessary to test the total aeration tank on a once-through basis would be more representative of actual performance conditions in the aeration tank. Also, the use of a full-width hood eliminated the need to airflow weight-average the results from two widely differing test conditions (high airflow and low OTE versus low airflow and high OTE).

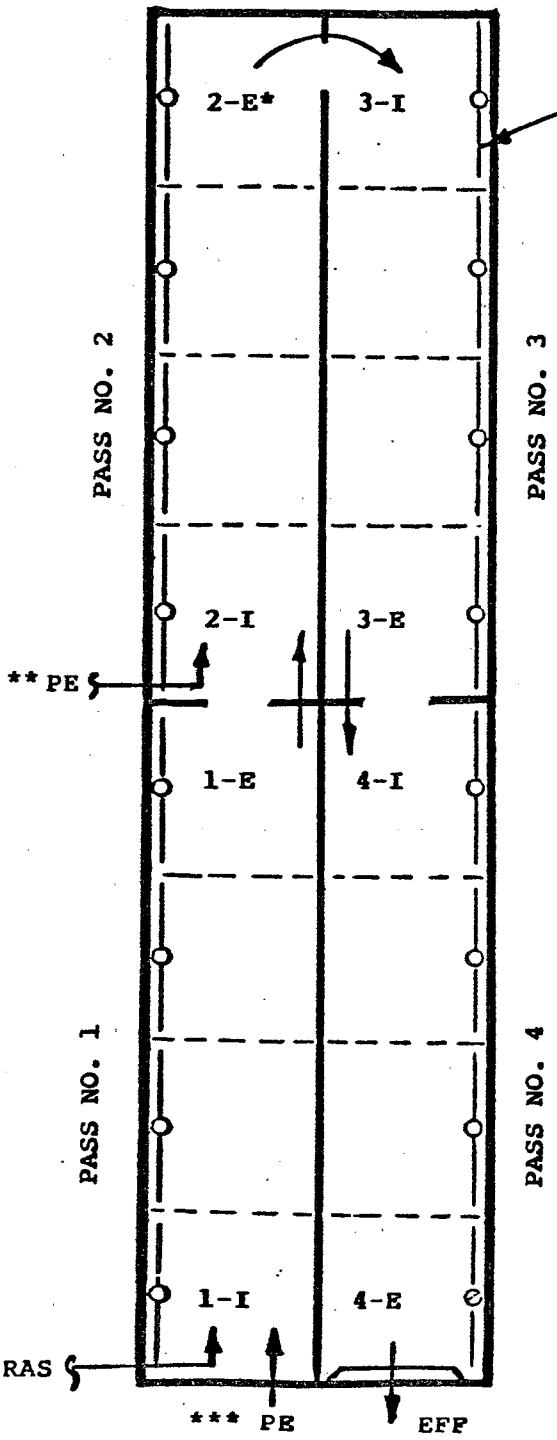
The off-gas test equipment and analysis procedures are in accordance with the project "Manual of Methods for Fine Bubble Diffused Aeration Field Studies." The results of all off-gas testing are summarized in the tables and on the figures. Appendix I-A contains a summary of the individual test run results plus the whole-pass and whole-tank airflow weighted results and the overall airflow weight-averaged results by aeration pass and for the whole tank for the six test visits.

Plant wastewater and process characteristics for the test site visits are contained in Table No. 1. These data are plotted on Figure Nos. 7 through 10 versus elapsed time, starting with the site visit in November 1985.

The results of the oxygen transfer performance tests are summarized in Table Nos. 3 through 8. Table No. 3 contains the overall aeration performance data by site visit for the whole tank based on airflow weight-averaged results from 24 to 32 individual test runs per site visit. Table Nos. 4 through 7 contain the overall aeration performance data by site visit for each aeration pass based on airflow weight-averaged results from 6 to 8 individual test runs per site visit. Table No. 8 contains the overall aeration performance data by aeration pass for all six site visits. Figure Nos. 11 through 22 contain plots of aeration performance in terms of apparent alphax SOTE and apparent alpha for the whole tank, for each aeration pass, and by aeration pass based on the airflow

FIGURE NO. 6

OFF-GAS SAMPLING PLAN "B"



NOTE: full-width hood used throughout

* denotes sample location for all tests conducted after March 28, 1986. One replicate test at each sample location (three excursions through the aeration tank per site visit).

** Primary effluent inlet for Contact Stabilization Mode. (Site visitations 1 through 3).

*** Primary effluent inlet for Conventional Mode. (Site visitations 4 through 6).

FIGURE NO. 7

PLANT PERFORMANCE DATA
PLANT FLOW VS. ELAPSED TIME

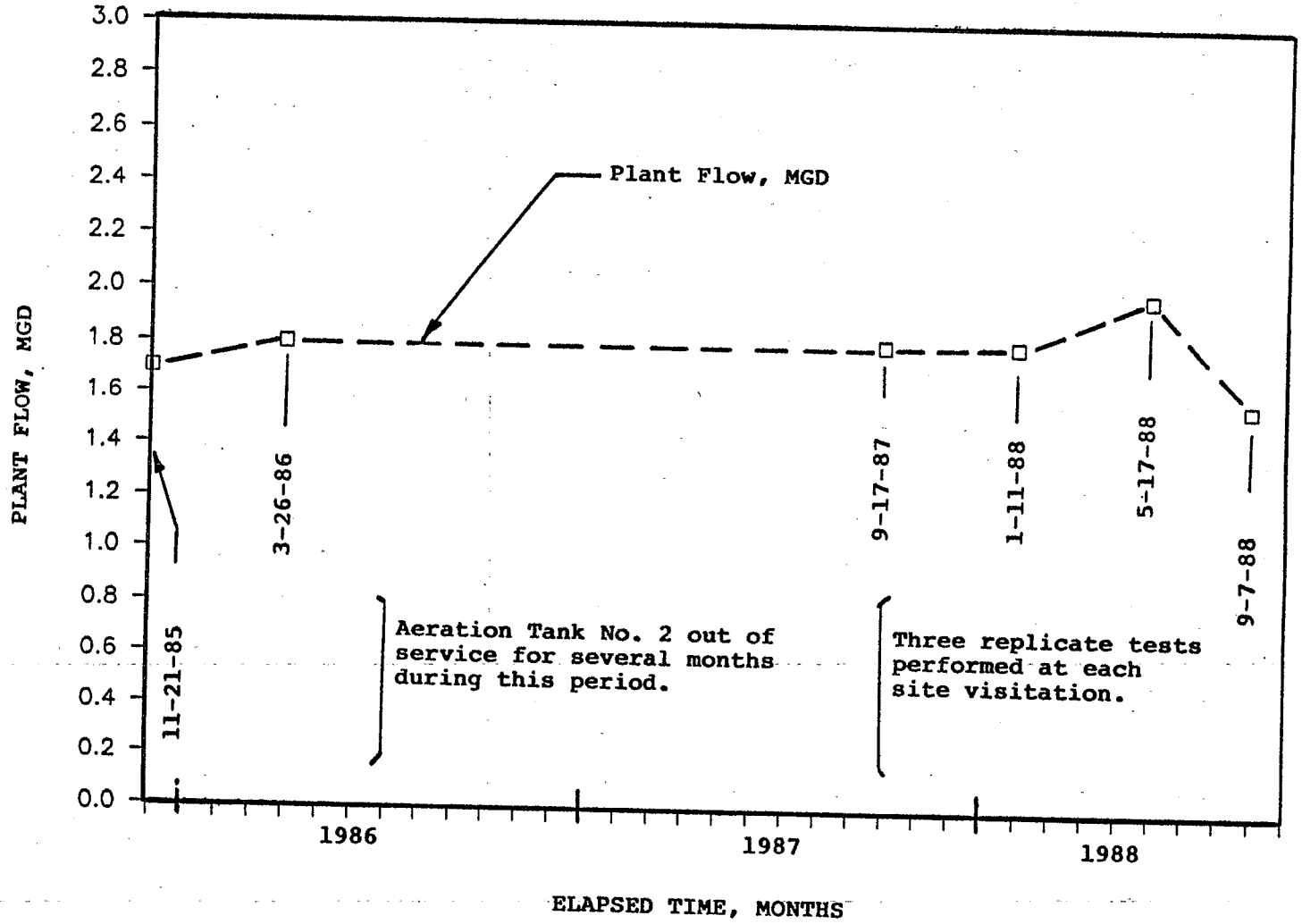


FIGURE NO. 8

PLANT PERFORMANCE DATA
CARBONACEOUS BOD_5 VS. ELAPSED TIME

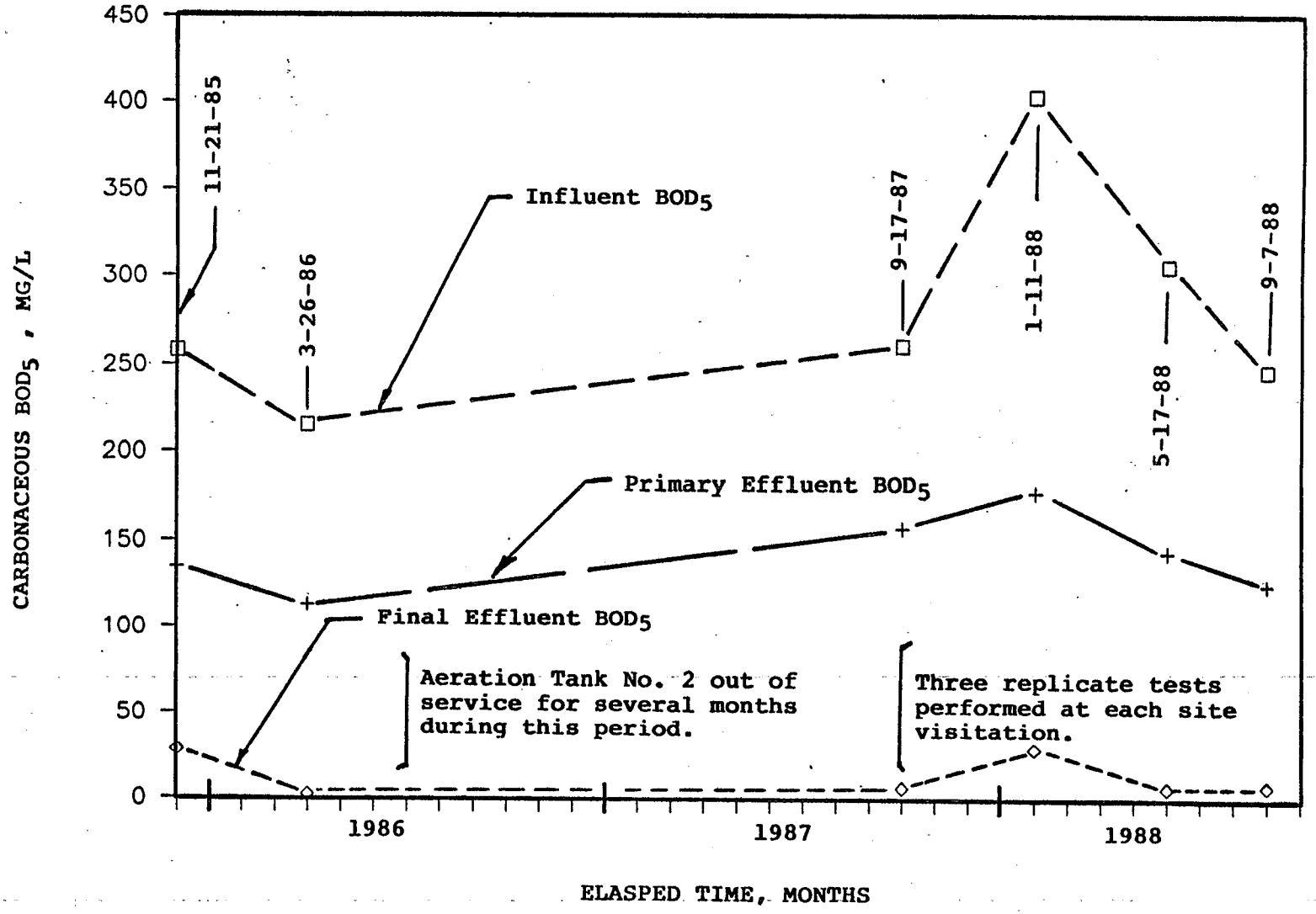


FIGURE NO. 9

PLANT PERFORMANCE DATA
MLSS & MLVSS VS. ELAPSED TIME

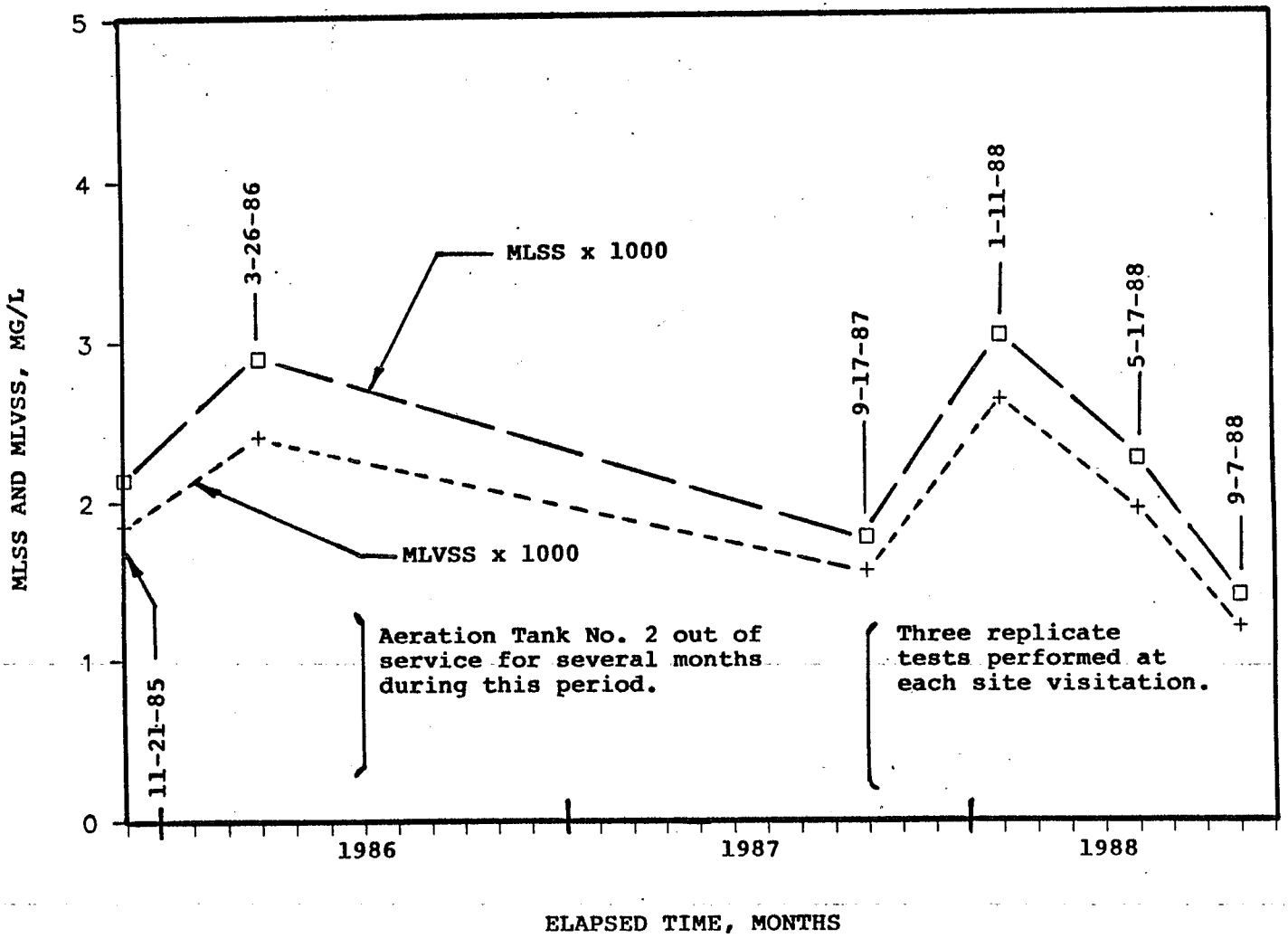


FIGURE NO. 10

PLANT PERFORMANCE DATA
F/M AND SVI VS. ELAPSED TIME

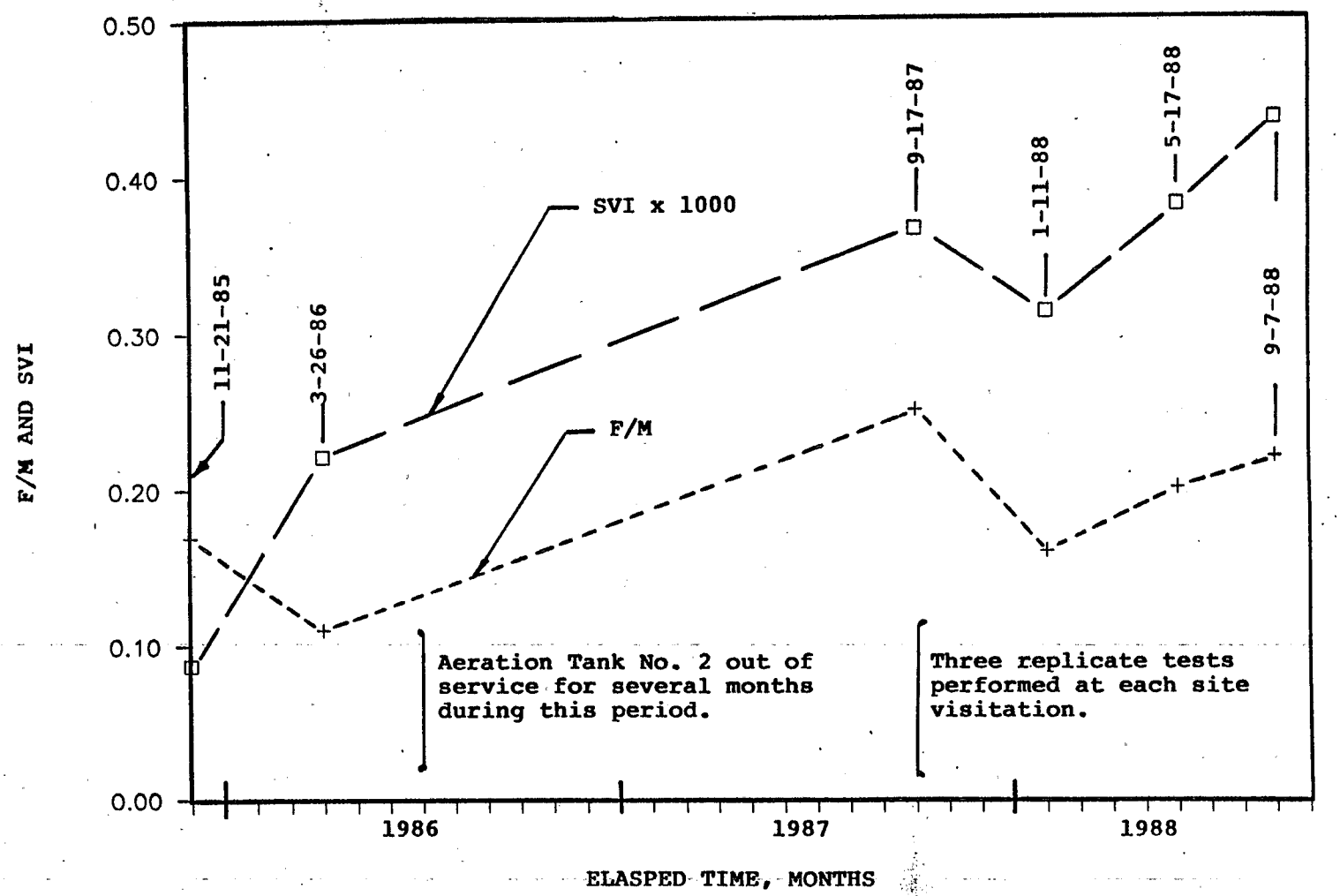


TABLE NO. 3

OVERALL AERATION PERFORMANCE FOR THE WHOLE TANK

TEST DATE	TEST NO.	ALPHA x SOTE, %	AIRFLOW/ DIF., SCFM	TOTAL AIRFLOW, SCFM	NEW SOTE, %	APPARENT ALPHA	ALPHA x SOTR, LBS.02/HR.	NEW SOTR, LBS.02/HR.
11-21-85	1A *	4.86	5.28	1688.0	11.4	0.42	84.99	200.12
3-26-86	2A	6.65	6.03	1928.0	11.2	0.59	132.79	223.21
9-17-87	3B1	7.58	3.30	1056.0	12.5	0.61	82.94	136.79
9-17-87	3B2	7.03	3.36	1076.0	12.5	0.56	78.33	139.38
9-17-87	3B3	7.29	2.88	920.0	12.5	0.58	69.45	119.17
9-17-87	3B AVG.	7.30	3.18	1017.3	12.5	0.58	76.91	131.78
1-11-88	4B1	7.33	2.91	932.0	12.5	0.59	70.76	120.73
1-11-88	4B2	7.49	3.06	980.0	12.5	0.60	76.10	126.94
1-11-88	4B3	8.01	3.19	1020.0	12.5	0.64	84.67	132.12
1-11-88	4B AVG.	7.62	3.05	977.3	12.5	0.61	77.18	126.60
5-17-88	5B1	6.67	3.14	1004.0	12.5	0.54	69.43	129.71
5-17-88	5B2	7.71	3.23	1032.0	12.5	0.62	82.50	133.17
5-17-88	5B3	7.59	3.26	1044.0	12.5	0.61	82.07	135.06
5-17-88	5B AVG.	7.33	3.21	1026.7	12.5	0.59	78.00	132.65
9-7-88	6B1	6.82	3.03	968.0	12.5	0.55	68.44	125.30
9-7-88	6B2	6.90	3.04	972.0	12.5	0.55	69.52	125.76
9-7-88	6B3	6.76	2.96	948.0	12.5	0.54	66.38	122.35
9-7-88	6B AVG.	6.83	3.01	962.7	12.5	0.55	68.11	124.47
AVG. FOR ALL TESTS		6.58	3.96	1266.7	11.9	0.55	86.33	156.47

NOTES: 1A - "A" TESTS DESIGNATE FOUR REPLICATE TESTS PER SAMPLE LOCATION AND ONE EXCURSION THROUGH THE AERATION TANK.

3B1 - "B" TESTS DESIGNATE ONE TEST PER SAMPLE LOCATION AND THREE EXCURSIONS THROUGH THE AERATION TANK. THE NUMBER FOLLOWING THE LETTER DESIGNATION IS THE EXCURSION NUMBER.

* Loose diffuser connections.

TABLE NO. 4

OVERALL AERATION PERFORMANCE FOR PASS NO. 1

TEST DATE	TEST NO.	ALPHA x SOTE, %	AIRFLOW/ DIF., SCFM	TOTAL AIRFLOW, SCFM	NEW SOTE, %	APPARENT ALPHA	ALPHA x SOTR, LBS.02/HR.	NEW SOTR, LBS.02/HR.
11-21-85	1A *	3.04	7.70	616.0	10.5	0.29	19.37	67.03
3-26-86	2A	6.91	8.40	672.0	10.3	0.67	48.14	71.73
9-17-87	3B1	6.11	3.60	288.0	12.5	0.49	18.23	37.31
9-17-87	3B2	6.17	4.10	328.0	12.5	0.49	20.98	42.49
9-17-87	3B3	6.03	4.05	324.0	12.5	0.48	20.25	41.97
9-17-87	3B AVG.	6.10	3.92	313.3	12.5	0.49	19.82	40.59
1-11-88	4B1	6.16	2.95	236.0	12.5	0.49	15.07	30.57
1-11-88	4B2	7.19	3.50	280.0	12.5	0.58	20.87	36.27
1-11-88	4B3	8.26	3.55	284.0	12.5	0.66	24.30	36.79
1-11-88	4B AVG.	7.27	3.33	266.7	12.5	0.58	20.08	34.54
5-17-88	5B1	5.87	4.00	320.0	12.4	0.47	19.47	41.11
5-17-88	5B2	6.97	4.05	324.0	12.3	0.56	23.40	41.46
5-17-88	5B3	6.58	4.05	324.0	12.5	0.53	22.08	41.80
5-17-88	5B AVG.	6.47	4.03	322.7	12.4	0.52	21.65	41.46
9-7-88	6B1	5.71	4.15	332.0	12.3	0.46	19.64	42.48
9-7-88	6B2	5.63	4.10	328.0	12.3	0.46	19.15	41.96
9-7-88	6B3	4.81	4.15	332.0	12.2	0.39	16.54	42.14
9-7-88	6B AVG.	5.38	4.13	330.7	12.3	0.44	18.44	42.19
AVG. FOR ALL TESTS		5.65	5.25	420.2	11.4	0.50	24.58	49.59

NOTES: 1A - "A" TESTS DESIGNATE FOUR REPLICATE TESTS PER SAMPLE LOCATION AND ONE EXCURSION THROUGH THE AERATION TANK.

3B1 - "B" TESTS DESIGNATE ONE TEST PER SAMPLE LOCATION AND THREE EXCURSIONS THROUGH THE AERATION TANK. THE NUMBER FOLLOWING THE LETTER DESIGNATION IS THE EXCURSION NUMBER.

*Loose diffuser connections.

TABLE NO. 5

OVERALL AERATION PERFORMANCE FOR PASS NO. 2

TEST DATE	TEST NO.	ALPHA x SOTE, %	AIRFLOW/ DIF., SCFM	TOTAL AIRFLOW, SCFM	NEW SOTE, %	APPARENT ALPHA	ALPHA x SOTR, LBS.02/HR.	NEW SOTR, LBS.02/HR.
11-21-85	1A	7.47	5.80	464.0	11.3	0.66	35.92	54.33
3-26-86	2A	4.74	6.30	504.0	11.1	0.43	24.74	57.97
9-17-87	3B1	6.96	3.80	304.0	12.5	0.56	21.91	39.38
9-17-87	3B2	8.02	3.70	296.0	12.5	0.64	24.61	38.34
9-17-87	3B3	8.51	2.40	192.0	12.5	0.68	16.93	24.87
9-17-87	3B AVG.	7.73	3.30	264.0	12.5	0.62	21.15	34.20
1-11-88	4B1	8.38	3.30	264.0	12.5	0.67	22.92	34.20
1-11-88	4B2	8.60	3.15	252.0	12.5	0.69	22.45	32.64
1-11-88	4B3	8.35	3.35	268.0	12.5	0.67	23.18	34.72
1-11-88	4B AVG.	8.44	3.27	261.3	12.5	0.67	22.85	33.85
5-17-88	5B1	6.86	3.30	264.0	12.5	0.55	18.77	34.20
5-17-88	5B2	7.81	3.40	272.0	12.5	0.62	22.01	35.23
5-17-88	5B3	8.15	3.50	280.0	12.5	0.66	23.64	36.27
5-17-88	5B AVG.	7.62	3.40	272.0	12.5	0.61	21.47	35.23
9-7-88	6B1	7.45	3.05	244.0	12.5	0.60	18.83	31.61
9-7-88	6B2	7.68	3.10	248.0	12.5	0.61	19.72	32.12
9-7-88	6B3	8.33	3.05	244.0	12.5	0.67	21.05	31.61
9-7-88	6B AVG.	7.81	3.07	245.3	12.5	0.63	19.87	31.78
AVG. FOR ALL TESTS		7.01	4.19	335.1	11.9	0.59	24.33	41.23

NOTES: 1A - "A" TESTS DESIGNATE FOUR REPLICATE TESTS PER SAMPLE LOCATION AND ONE EXCURSION THROUGH THE AERATION TANK.

3B1 - "B" TESTS DESIGNATE ONE TEST PER SAMPLE LOCATION AND THREE EXCURSIONS THROUGH THE AERATION TANK. THE NUMBER FOLLOWING THE LETTER DESIGNATION IS THE EXCURSION NUMBER.

TABLE NO. 6

OVERALL AERATION PERFORMANCE FOR PASS NO. 3

TEST DATE	TEST NO.	ALPHA x SOTE, %	AIRFLOW/ DIF., SCFM	TOTAL AIRFLOW, SCFM	NEW SOTE, %	APPARENT ALPHA	ALPHA x SOTR, LBS.02/HR.	NEW SOTR, LBS.02/HR.
11-21-85	1A *	4.79	3.80	304.0	12.5	0.38	15.10	39.38
3-26-86	2A	7.80	4.70	376.0	12.0	0.65	30.39	46.76
9-17-87	3B1	9.62	3.10	248.0	12.5	0.77	24.71	32.12
9-17-87	3B2	6.34	3.00	240.0	12.5	0.51	15.76	31.09
9-17-87	3B3	8.12	2.45	196.0	12.5	0.65	16.50	25.39
9-17-87	3B AVG.	8.04	2.85	228.0	12.5	0.64	18.99	29.53
1-11-88	4B1	7.52	2.65	212.0	12.5	0.60	16.51	27.46
1-11-88	4B2	6.95	2.75	220.0	12.5	0.56	15.84	28.50
1-11-88	4B3	7.44	2.90	232.0	12.5	0.59	17.88	30.05
1-11-88	4B AVG.	7.30	2.77	221.3	12.5	0.58	16.74	28.67
5-17-88	5B1	7.18	2.50	200.0	12.5	0.57	14.89	25.91
5-17-88	5B2	8.90	2.70	216.0	12.5	0.71	19.92	27.98
5-17-88	5B3	8.73	2.80	224.0	12.5	0.70	20.27	29.02
5-17-88	5B AVG.	8.31	2.67	213.3	12.5	0.66	18.36	27.64
9-7-88	6B1	6.96	3.35	268.0	12.5	0.56	19.33	34.72
9-7-88	6B2	7.62	3.40	272.0	12.5	0.61	21.49	35.23
9-7-88	6B3	7.34	3.10	248.0	12.5	0.59	18.87	32.12
9-7-88	6B AVG.	7.31	3.28	262.7	12.5	0.58	19.90	34.02
AVG. FOR ALL TESTS		7.18	3.34	267.6	12.4	0.58	19.91	34.33

NOTES: 1A - "A" TESTS DESIGNATE FOUR REPLICATE TESTS PER SAMPLE LOCATION AND ONE EXCURSION THROUGH THE AERATION TANK.

3B1 - "B" TESTS DESIGNATE ONE TEST PER SAMPLE LOCATION AND THREE EXCURSIONS THROUGH THE AERATION TANK. THE NUMBER FOLLOWING THE LETTER DESIGNATION IS THE EXCURSION NUMBER.

*Loose diffuser connections.

TABLE NO. 7

OVERALL AERATION PERFORMANCE FOR PASS NO. 4

TEST DATE	TEST NO.	ALPHA x SOTE, %	AIRFLOW/ DIF., SCFM	TOTAL AIRFLOW, SCFM	NEW SOTE, %	APPARENT ALPHA	ALPHA x SOTR, LBS.02/HR.	NEW SOTR, LBS.02/HR.
11-21-85	1A *	4.64	3.80	304.0	12.5	0.37	14.60	39.38
3-26-86	2A	7.58	4.70	376.0	12.0	0.63	29.52	46.76
9-17-87	3B1	8.08	2.70	216.0	12.5	0.65	18.09	27.98
9-17-87	3B2	7.73	2.65	212.0	12.5	0.62	16.99	27.46
9-17-87	3B3	7.32	2.60	208.0	12.5	0.59	15.78	26.94
9-17-87	3B AVG.	7.72	2.65	212.0	12.5	0.62	16.95	27.46
1-11-88	4B1	7.13	2.75	220.0	12.5	0.57	16.26	28.50
1-11-88	4B2	7.17	2.85	228.0	12.5	0.57	16.93	29.53
1-11-88	4B3	7.89	2.95	236.0	12.5	0.63	19.30	30.57
1-11-88	4B AVG.	7.41	2.85	228.0	12.5	0.59	17.50	29.53
5-17-88	5B1	7.15	2.75	220.0	12.5	0.57	16.30	28.50
5-17-88	5B2	7.53	2.75	220.0	12.5	0.60	17.17	28.50
5-17-88	5B3	7.18	2.70	216.0	12.5	0.57	16.08	27.98
5-17-88	5B AVG.	7.29	2.73	218.7	12.5	0.58	16.52	28.33
9-7-88	6B1	8.27	1.55	124.0	12.8	0.64	10.63	16.50
9-7-88	6B2	7.12	1.55	124.0	12.8	0.56	9.15	16.44
9-7-88	6B3	7.72	1.55	124.0	12.8	0.60	9.92	16.48
9-7-88	6B AVG.	7.70	1.55	124.0	12.8	0.60	9.90	16.47
AVG. FOR ALL TESTS		6.93	3.05	243.8	12.4	0.56	17.50	31.32

NOTES: 1A - "A" TESTS DESIGNATE FOUR REPLICATE TESTS PER SAMPLE LOCATION AND ONE EXCURSION THROUGH THE AERATION TANK.

3B1 - "B" TESTS DESIGNATE ONE TEST PER SAMPLE LOCATION AND THREE EXCURSIONS THROUGH THE AERATION TANK. THE NUMBER FOLLOWING THE LETTER DESIGNATION IS THE EXCURSION NUMBER.

*Loose diffuser connections.

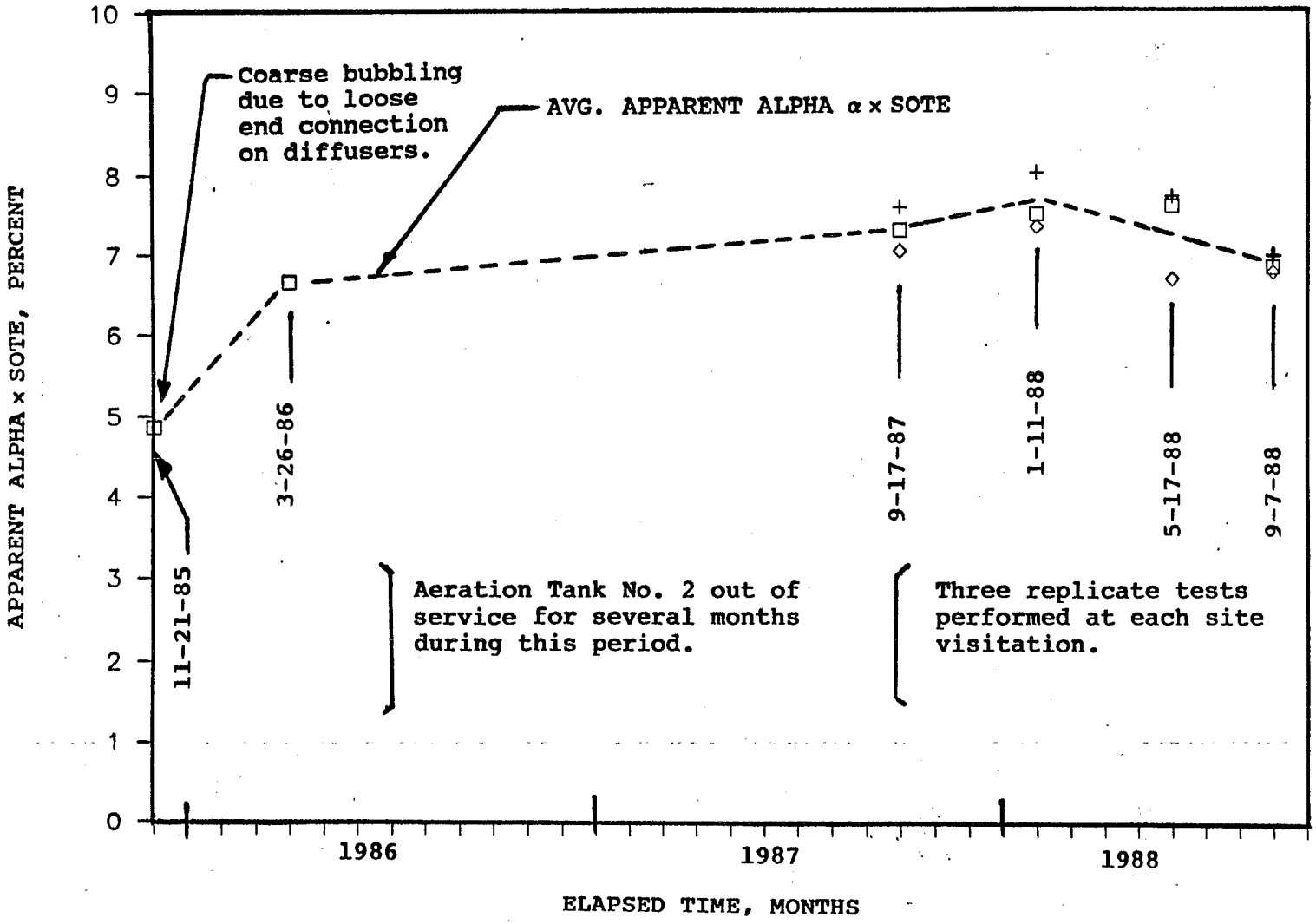
TABLE NO. 8

OVERALL AERATION PERFORMANCE BY PASS

LOCATION	CONDITION	ALPHA x SOTE, %	AIRFLOW/ DIFFUSER SCFM	TOTAL AIRFLOW, SCFM	NEW SOTE, %	APPARENT ALPHA
PASS NO. 1	AVG.	5.65	5.25	420.2	11.4	0.50
	MIN.	3.04	3.33	266.7	10.3	0.29
	MAX.	7.27	8.40	672.0	12.5	0.58
PASS NO. 2	AVG.	7.01	4.19	355.1	11.9	0.59
	MIN.	4.74	3.07	245.3	11.1	0.43
	MAX.	8.44	6.30	504.0	12.5	0.66
PASS NO. 3	AVG.	7.18	3.35	267.6	12.4	0.58
	MIN.	4.79	2.67	213.3	12.0	0.38
	MAX.	8.31	4.70	376.0	12.5	0.66
PASS NO. 4	AVG.	6.93	3.05	243.8	12.4	0.56
	MIN.	4.64	1.55	124.0	12.0	0.37
	MAX.	7.72	4.70	376.0	12.8	0.63
WHOLE TANK	AVG.	6.58	3.96	1266.7	11.9	0.55
	MIN.	4.86	3.01	962.7	11.2	0.42
	MAX.	7.62	6.03	1928.0	12.5	0.61

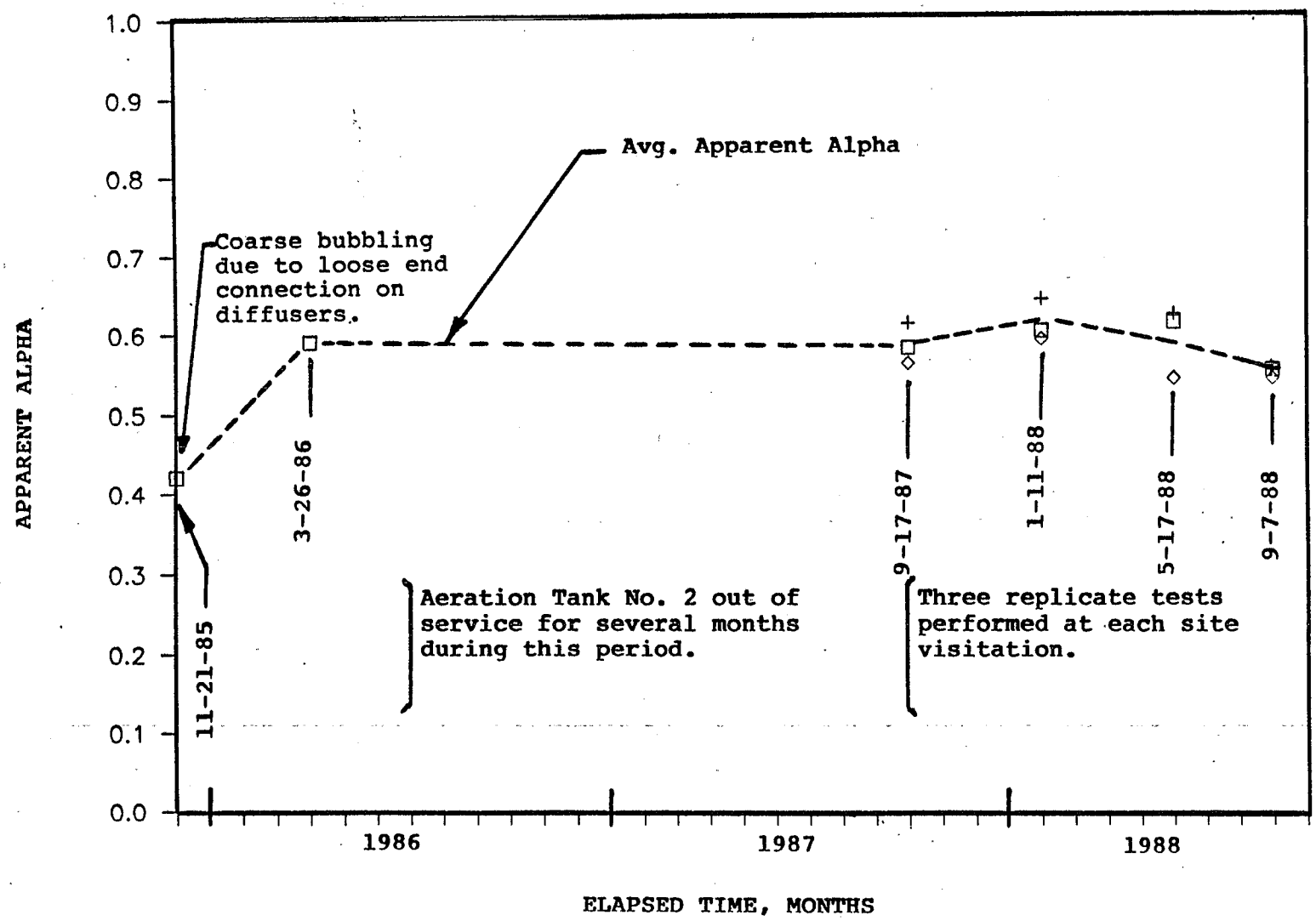
OVERALL TANK PERFORMANCE

FIGURE NO. 11



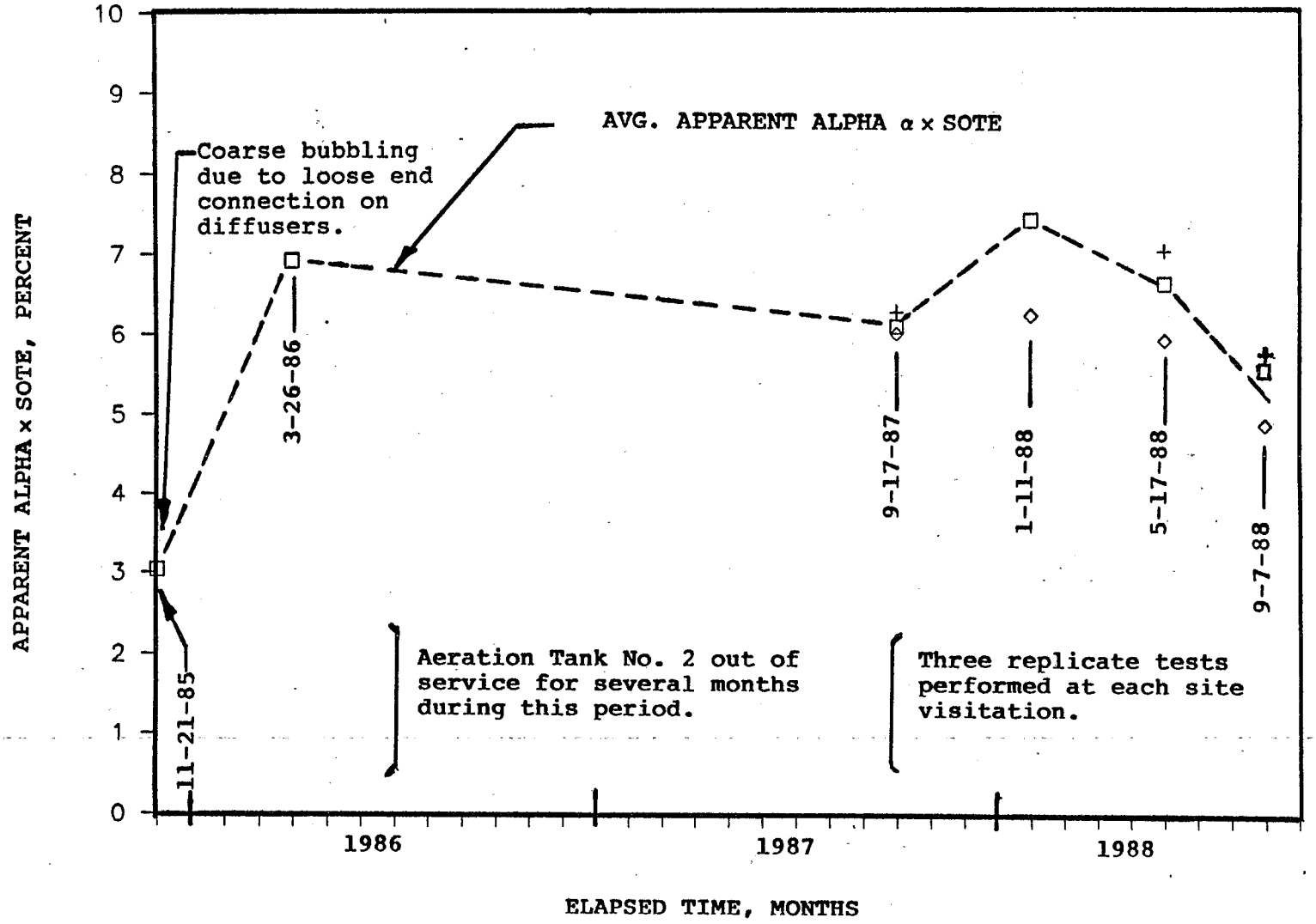
OVERALL TANK PERFORMANCE

FIGURE NO. 12



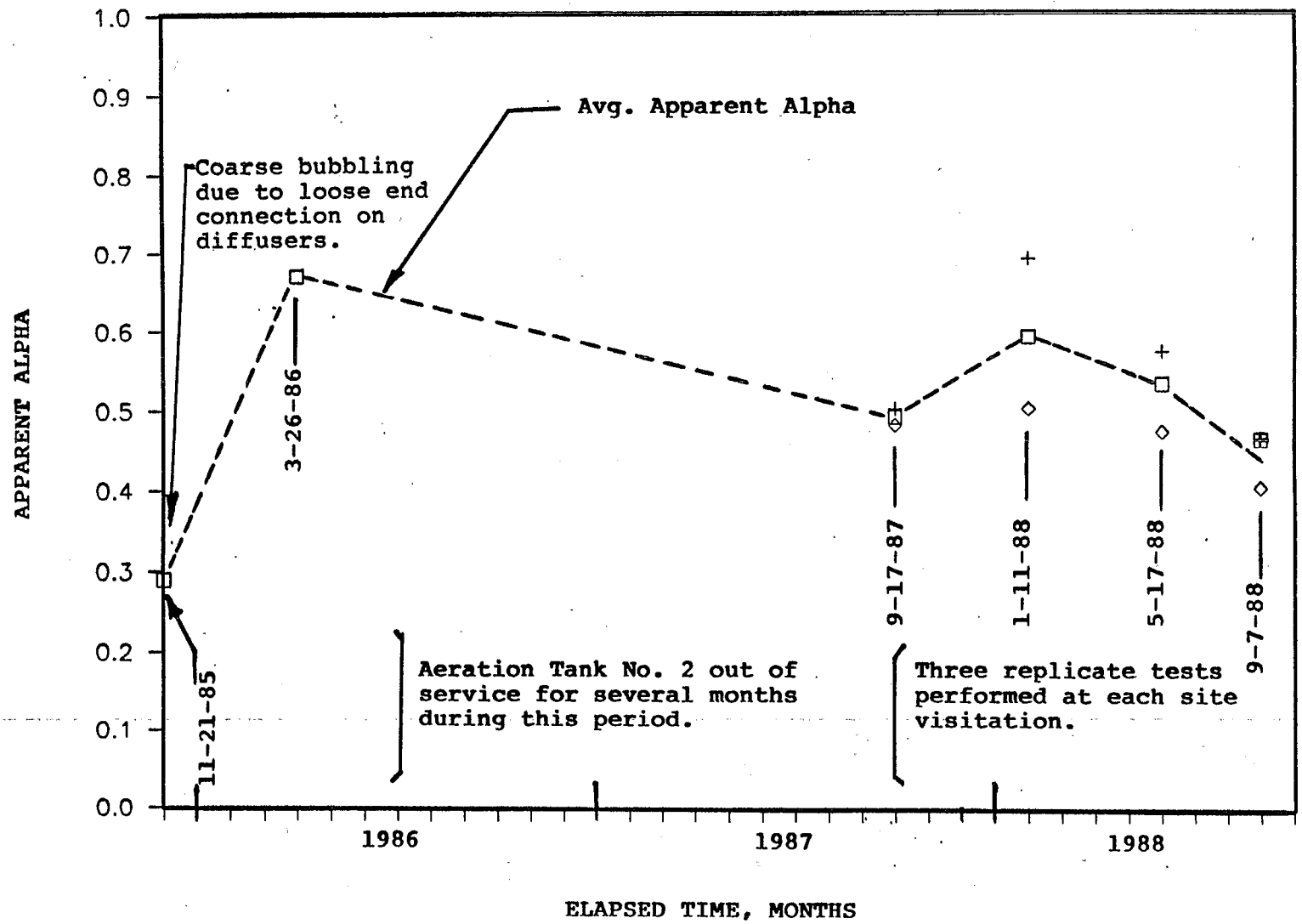
AERATION PERFORMANCE - PASS NO. 1

FIGURE NO. 13



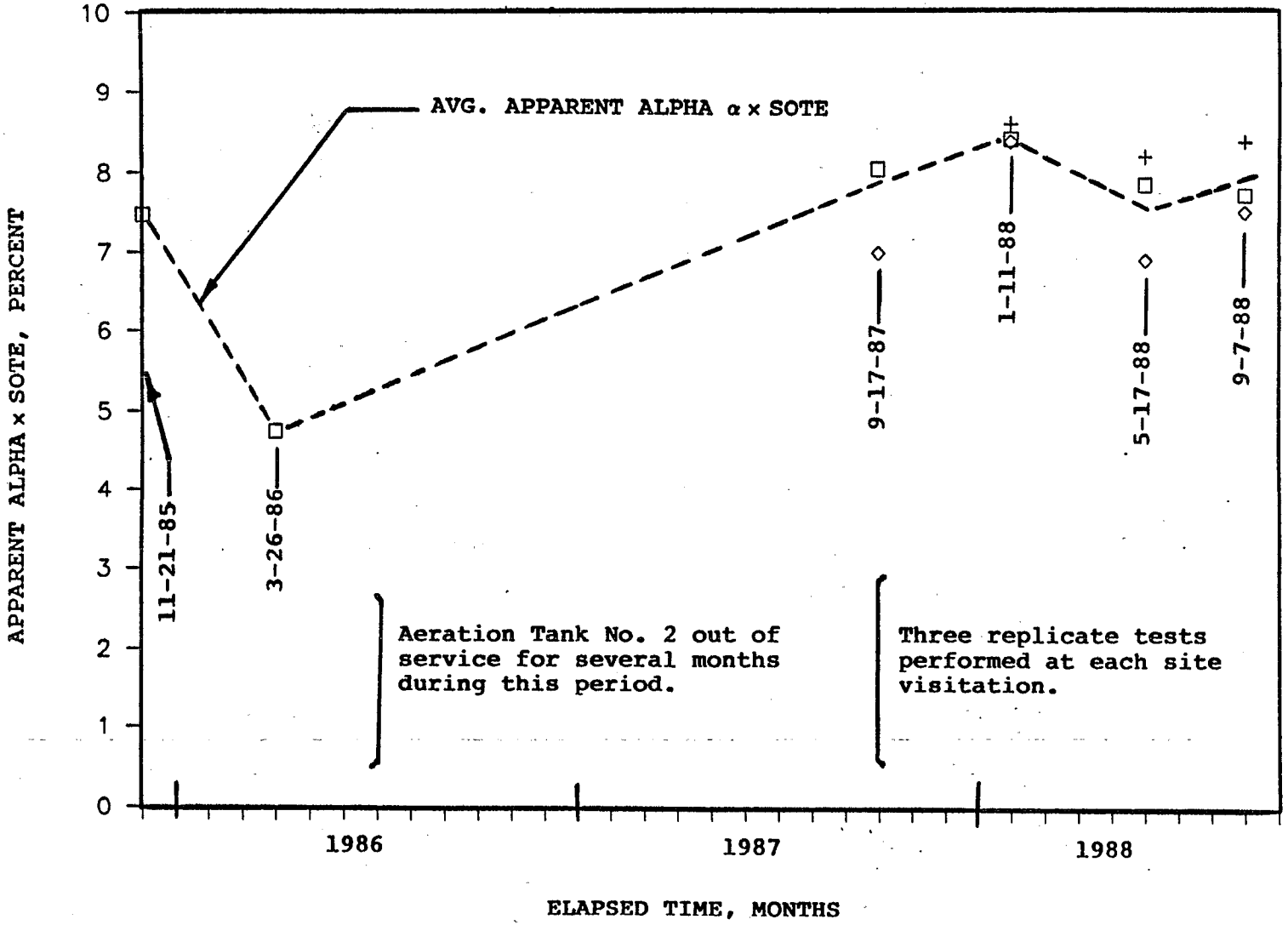
AERATION PERFORMANCE - PASS NO. 1

FIGURE NO. 14



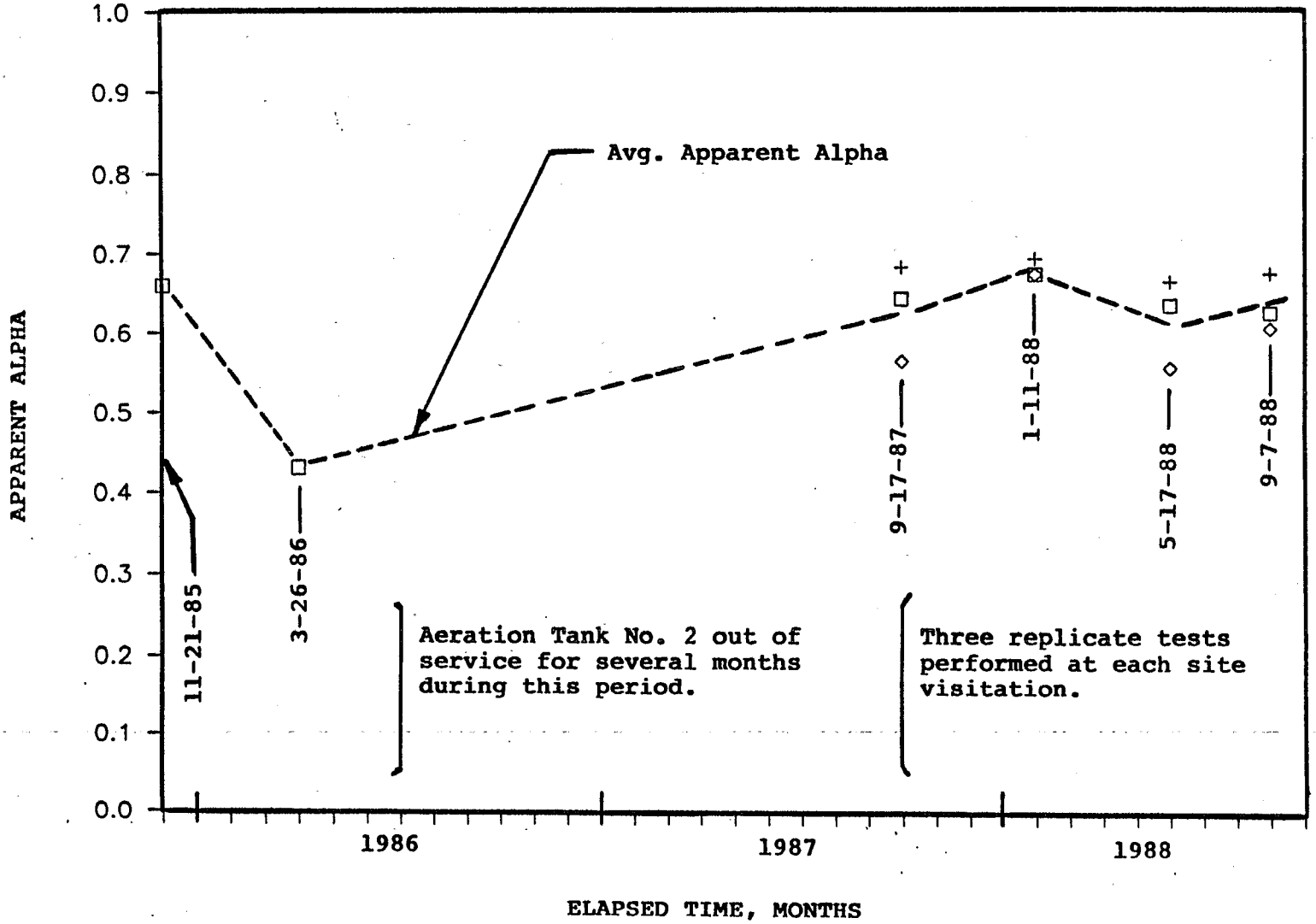
AERATION PERFORMANCE - PASS NO. 2

FIGURE NO. 15



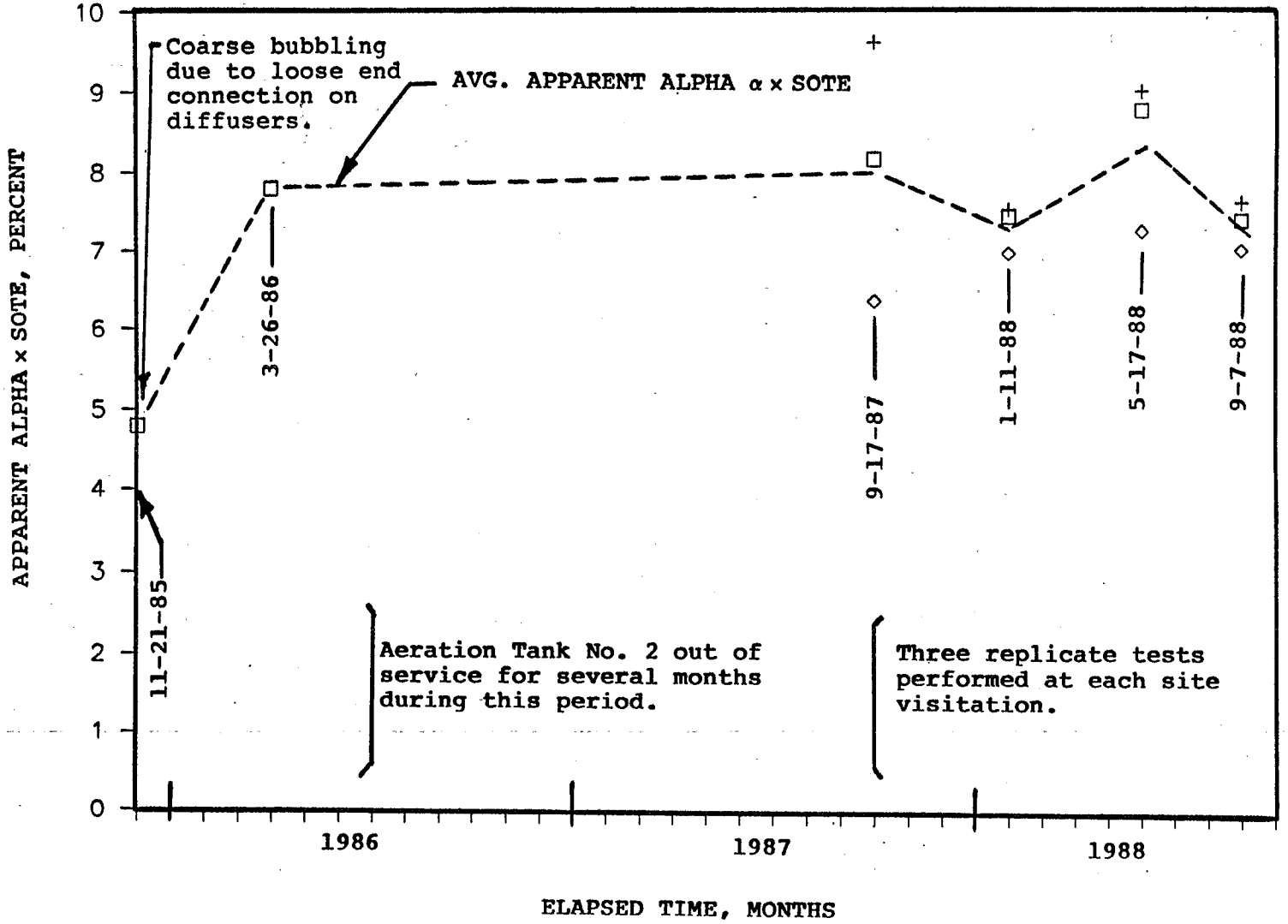
AERATION PERFORMANCE - PASS NO. 2

FIGURE NO. 16



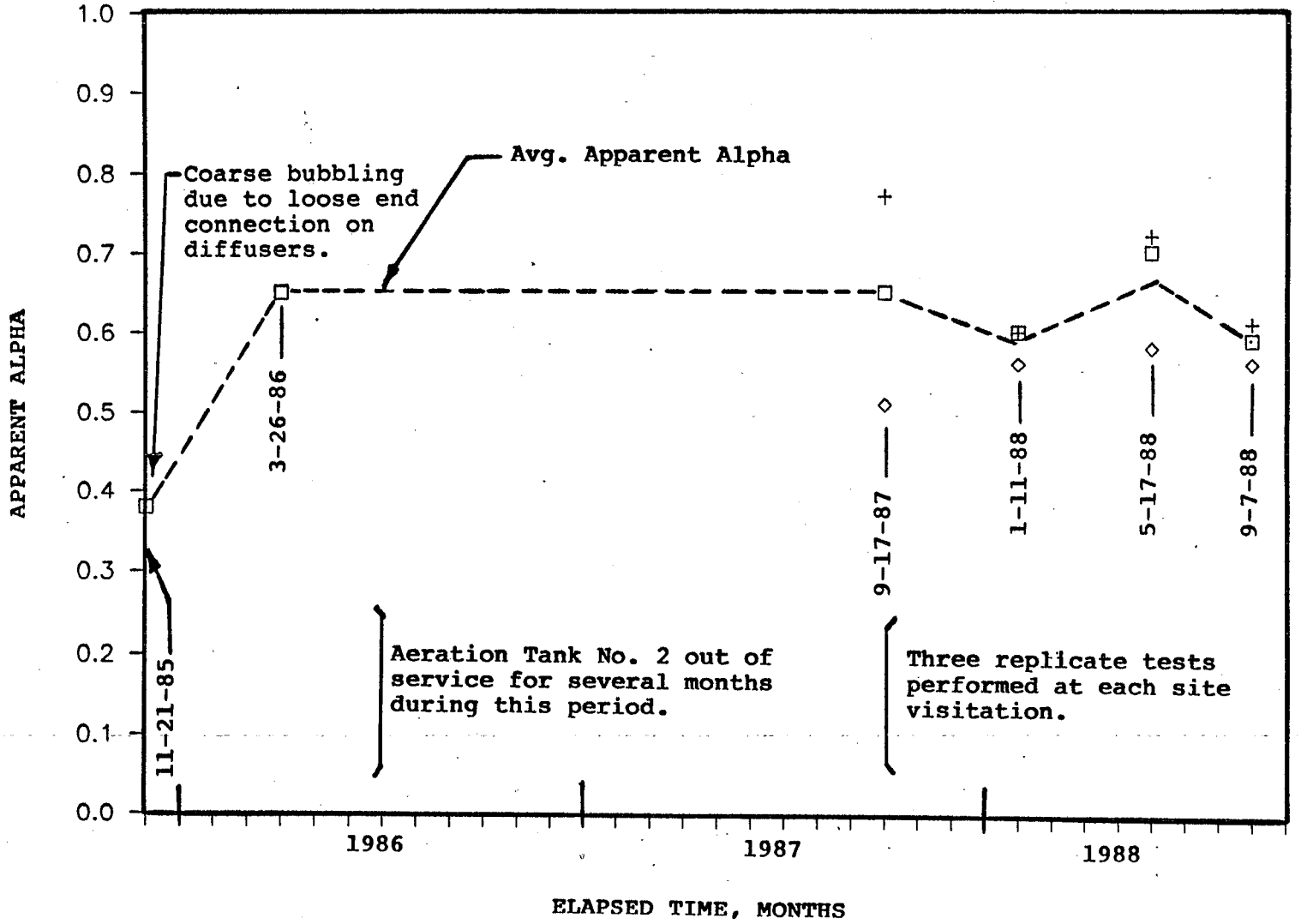
AERATION PERFORMANCE - PASS NO. 3

FIGURE NO. 17



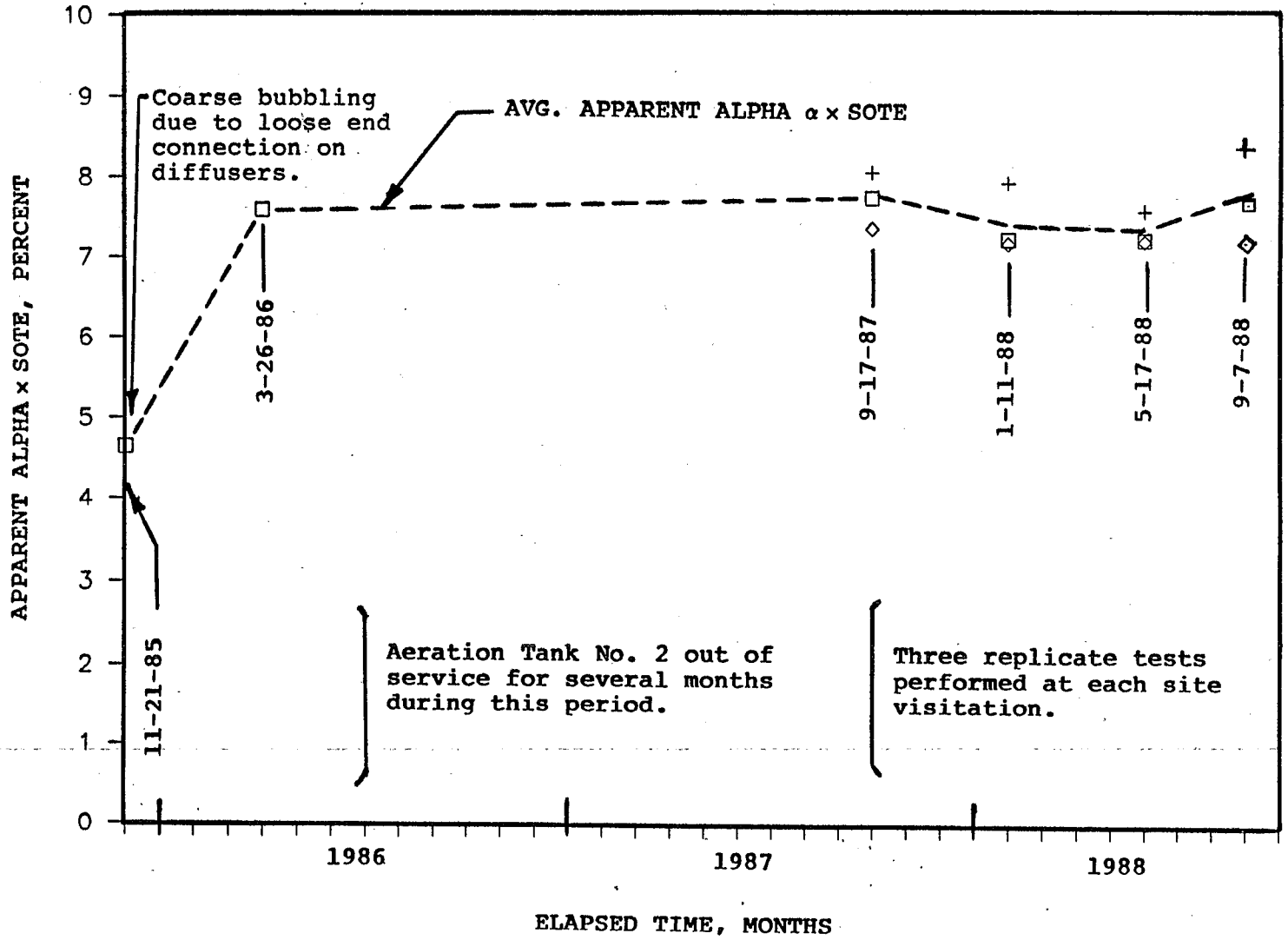
AERATION PERFORMANCE - PASS NO. 3

FIGURE NO. 18



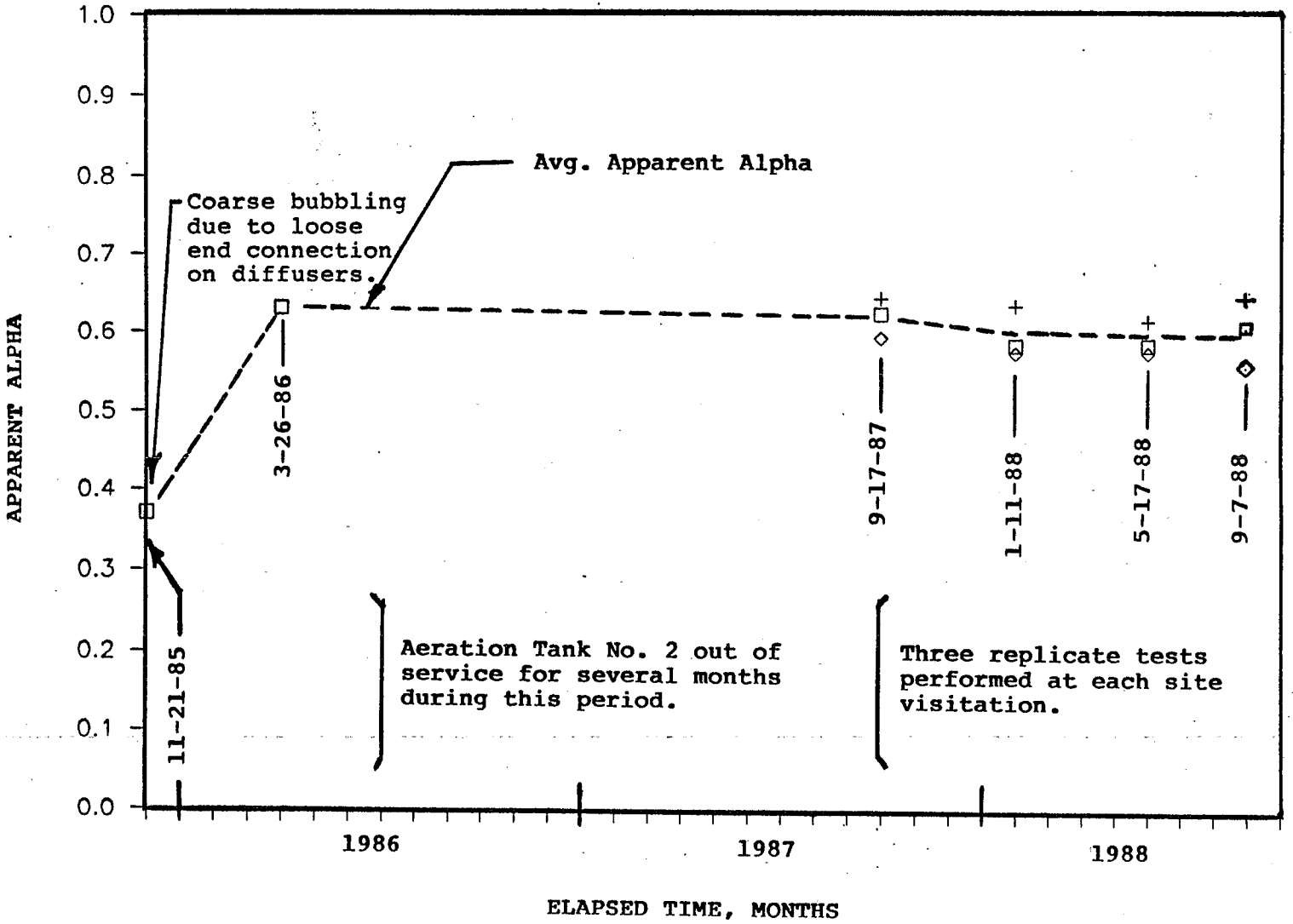
AERATION PERFORMANCE - PASS NO. 4

FIGURE NO. 19



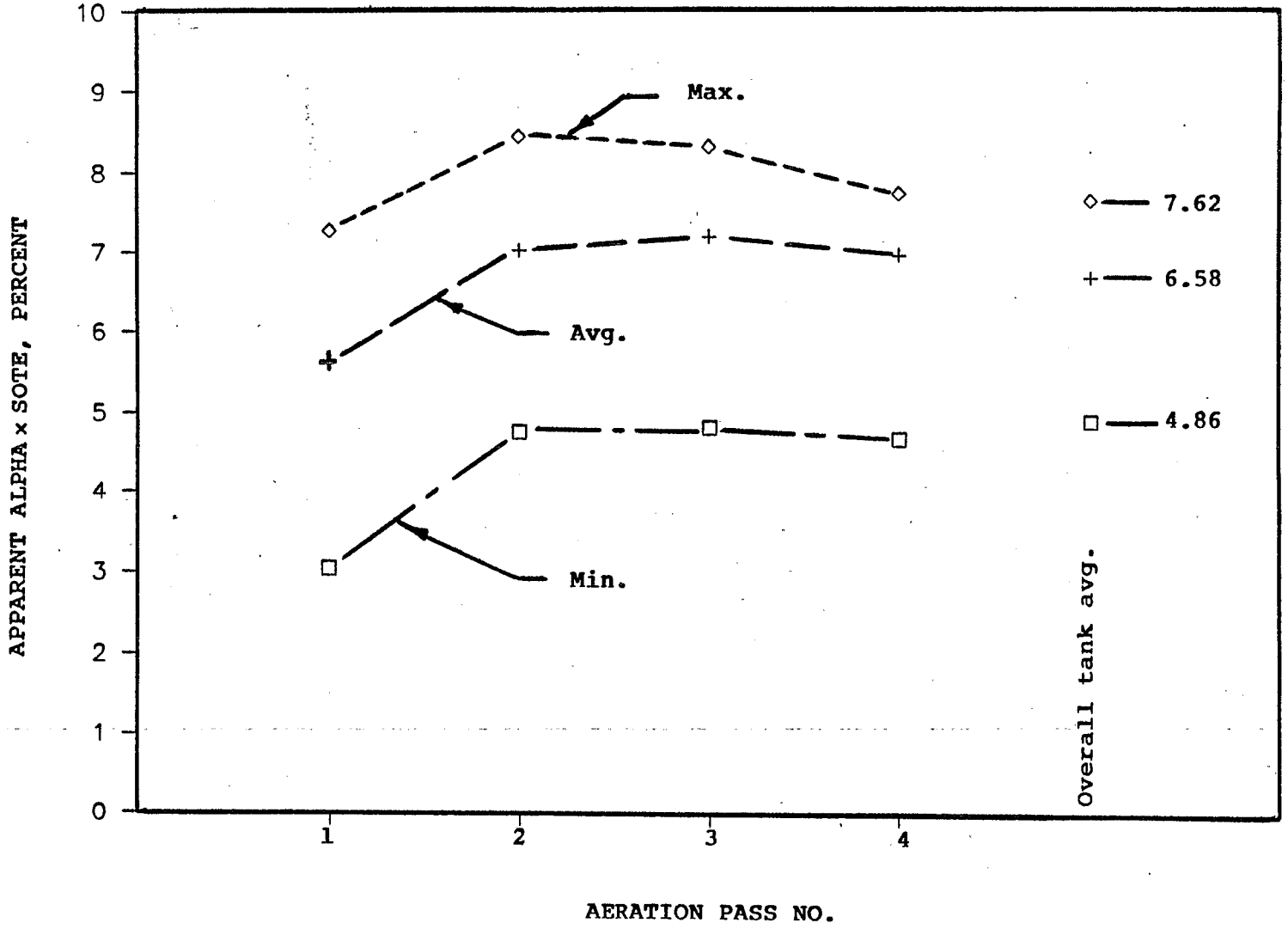
AERATION PERFORMANCE - PASS NO. 4

FIGURE NO. 20



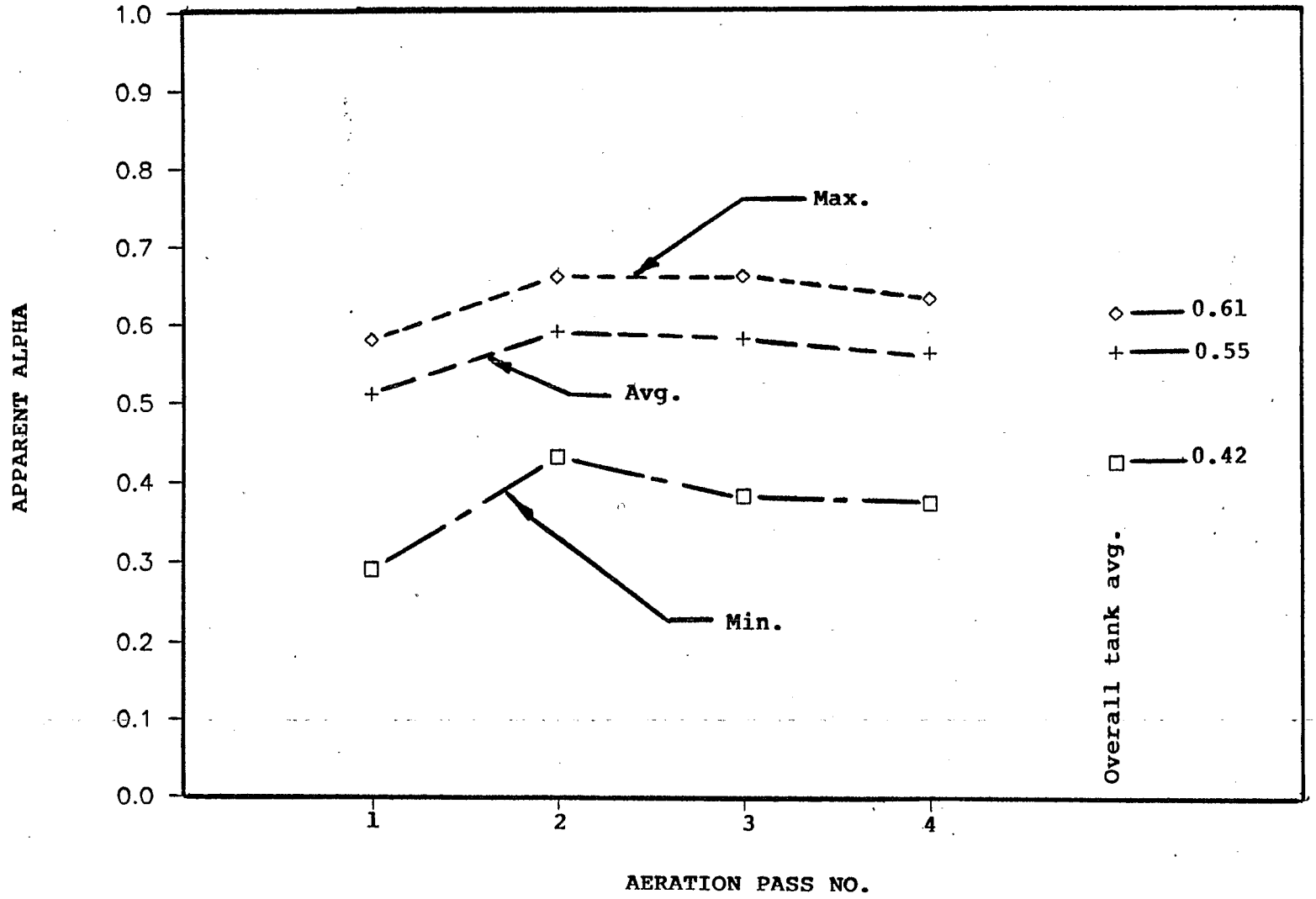
OVERALL AERATION PERFORMANCE BY PASS

FIGURE NO. 21



OVERALL APPARENT ALPHA BY PASS

FIGURE NO. 22



weight-averaged results contained in Table Nos. 3 through 8. These data are plotted versus elapsed time starting with the first site visit in November 1985.

5.5.2 Oxygen Transfer Efficiency

The overall whole-tank oxygen transfer efficiency, expressed as apparent alpha×SOTE, averaged 6.6 percent for the two-year, ten- month study period. The average whole-tank apparent alpha×SOTE test results varied from a high of 7.62 percent to a low of 4.86 percent throughout the study. The whole-tank average values are based on six site visits from November 1985 to September 1988 and represent the summary of over 160 individual test runs. During each site visit, each aeration pass was tested at the influent and effluent quarter points. Sampling Plan "A" replicated each sample location two times consecutively, and Sampling Plan "B" replicated overall whole-tank off-gas results three times for each site visit.

Evaluation and comparison of all test results by specific parameter indicates that oxygen transfer efficiency varied within a small range over the study period with the exception of the first site visit where test results were influenced by coarse bubbling due to air leaks at the diffuser gaskets.

A summary of the variation in apparent alpha×SOTE at various times and sample locations is illustrated below. The first site visit (November 1985) is not represented in these data.

Sampling Criteria	apparent alphaxSOTE, Percent		
	Average	Minimum	Maximum
Average whole-tank airflow weight-averaged results for five site visits	7.15	6.65	7.62
(individual test)	-	6.65	8.01
Average whole-pass 1 airflow weight-averaged results for five site visits	6.43	5.38	7.27
(individual test)	-	4.81	8.26
Average whole-pass 2 airflow weight-averaged results for five site visits	7.27	4.74	8.44
(individual test)	-	4.74	8.60
Average whole-pass 3 airflow weight-averaged results for five site visits	7.75	7.30	8.31
(individual test)	-	6.34	9.62
Average whole-pass 4 airflow weight-averaged results for five site visits	7.54	7.29	7.72
(individual test)	-	7.12	8.27

From the above summary, it can be seen that the range in oxygen transfer efficiency varies over a relatively narrow range for the whole tank and for each aeration pass. Replicate test-run results at a single sample location and for a single site visit were relatively close. Average whole-tank airflow weight-averaged results for a site visit were also relatively close. The average overall whole-tank airflow

weight-averaged results for the two-year, ten-month study period ranged from ±21 percent of the average value for all six site visits and from ±7 percent of the average value for the last five site visits.

Although the test result variability at Glastonbury was narrow, a large number of tests and wide time base are necessary for accurate estimation of overall average performance characteristics which are representative of the general aeration system performance over time.

5.5.3 Clean Water and Mixed Liquor Performance Criteria

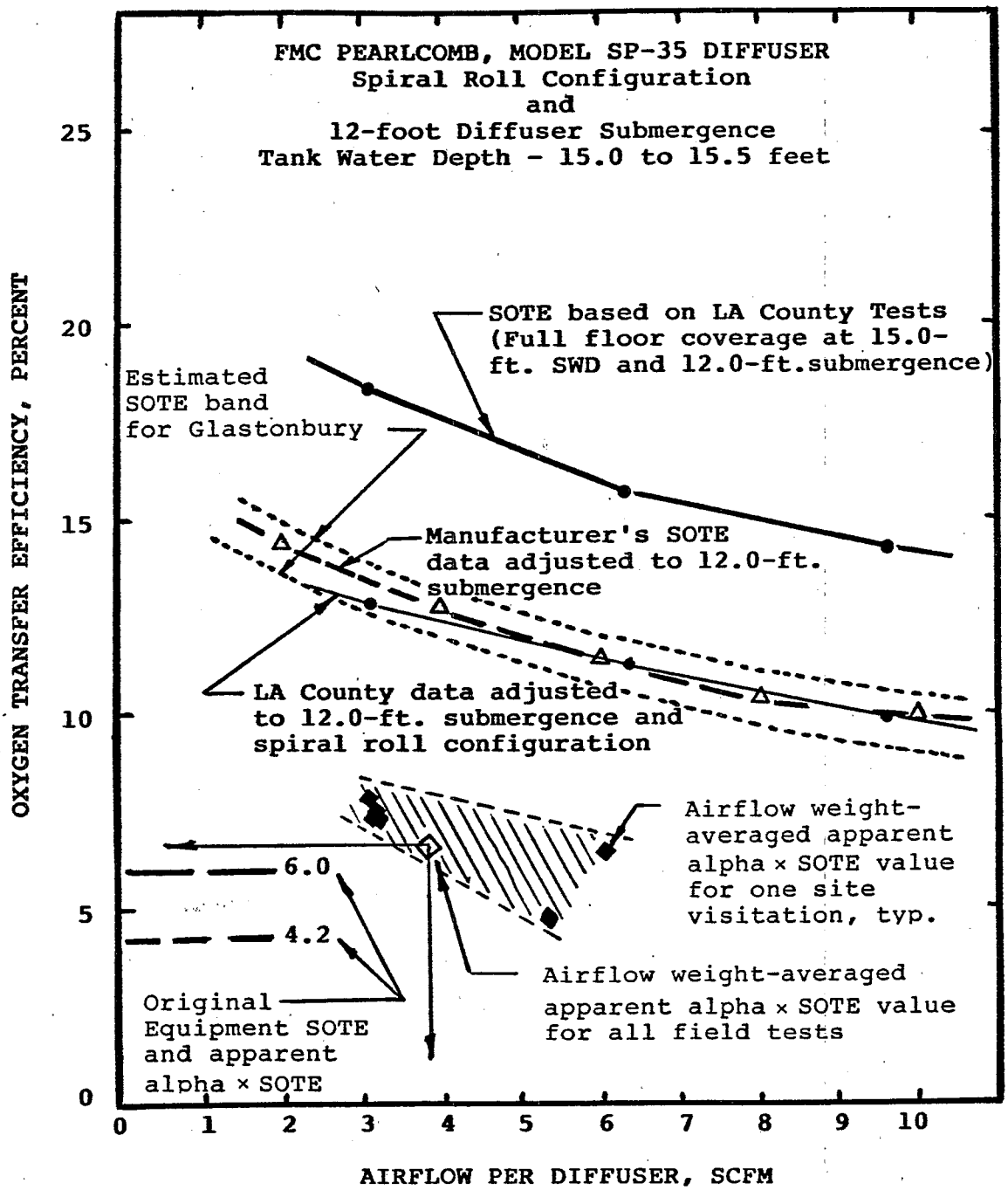
Each off-gas test result was compared with the expected clean water performance value based on Standard Oxygen Transfer test data and manufacturer information. The Standard Oxygen Transfer Efficiency (SOTE) information for the Glastonbury aeration system was based on work by Yunt at L. A. County, Rooney at Rexnord, and FMC product information.

Figure No. 23 contains a plot of clean water and apparent alpha×SOTE performance versus airflow per diffuser for the average whole-tank test results. Reported clean water test data are also plotted on the figure together with performance estimates for the original coarse bubble aeration equipment.

The expected average SOTE value for the Glastonbury aeration system after retrofit is 11.9 percent. The average whole-tank apparent alpha×SOTE as measured by off-gas testing is 6.6 percent. The original coarse bubble aeration equipment SOTE is estimated to be about 6.0 percent, with an apparent alpha×SOTE of 4.2 percent based on an apparent alpha value of 0.7.

OXYGEN TRANSFER EFFICIENCY CHARACTERISTICS

FIGURE NO. 23



5.5.4 Measured Apparent Alpha

The measured apparent alpha factor value for the average whole-tank off-gas test results was 0.55 with a range of 0.42 to 0.61. Individual sample point apparent alpha values ranged from less than 0.3 to over 0.8. Usually the very low apparent alpha values were measured at the influent ends of the aeration passes near the wastewater inlet points.

The apparent alpha factors measured in the spiral-roll aeration system at Glastonbury are much higher than for a full-floor coverage fine pore aeration system (nearly 0.6 at Glastonbury versus 0.4 at Hartford). It is interesting to note from Figure No. 23 that if the fine pore tube diffusers were arranged on a full-floor coverage matrix and if the off-gas results were the same for this matrix as for the spiral-roll, then the apparent alpha would be approximately 0.4 (6.6/17.5), or the same as measured at Hartford for full-floor coverage fine pore dome diffuser aeration equipment.

5.5.5 Physical Observations

The effect of diffuser cleaning on oxygen transfer performance and laboratory testing of diffusers were not undertaken in the Glastonbury study. However, physical observations of the liquid surface revealed useful information. Initially, it was determined by plant personnel that the diffusers were clogging from mixed liquor intrusion into the air manifolds because the air manifold blow-down holes had not been plugged. The air-side clogging of the tube diffusers prevented air from exiting the diffusers. This reduction in airflow (and in some cases stoppage of airflow) was observed at the liquid surface directly above the affected swing-arm assemblies.

During the off-gas testing program (and particularly during the initial off-gas site visit in November 1985), significant coarse bubbling was observed at the liquid surface directly

above the diffusers. It was determined that, in several cases, air was leaking around the gaskets at the ends of the tube media. Tightening of the retaining nut on the diffuser eliminated the leaking air problem in most cases.

As with the dome diffuser equipment which utilizes bolts and gaskets to retain the diffuser dome, the fine pore tube diffusers which have gaskets, bolts and nuts also are susceptible to air leakage. The potential for reduced oxygen transfer efficiency and fouling due to backflow of mixed liquor are very real. Observation of the liquid surface pattern is one way to monitor equipment operation and to check for possible air leaks.

6.0 ECONOMIC CONSIDERATIONS FOR FINE PORE AERATION

6.1 POWER USE

Although no long-term baseline information exists for the preretrofit blower electrical power usage, the measured power reduction, on a spot-check basis, after retrofit and installation of the new 100 HP blower is approximately 50 KW. This value represents about a 40 percent reduction in electrical power usage for blower operation. Although most of the power reduction is due to in-tank equipment improvements, there is significant improvement in air compression efficiency due to the installation of a new blower.

6.2 OXYGEN TRANSFER EFFICIENCY COMPARISON

The original coarse bubble spiral-roll aeration system is estimated to have an SOTE performance of about 6.0 percent. This value is based on test data from the manufacturer and test results from the L. A. County oxygen transfer work done by Yunt. The efficiency of the coarse bubble aeration equipment is lowered to 4.2 percent (apparent alpha×SOTE) when an alpha value of 0.7 is assumed. The estimated OTE in mixed liquor with a dissolved oxygen concentration of 2.0 mg/l is 3.0 percent for the original equipment.

The average value for apparent alpha×SOTE for all the whole-tank tests conducted on the fine pore tube diffuser aeration system in Aeration Tank No. 2 was 6.6 percent transfer. This value is 1.6 times greater than the estimated transfer efficiency of the original equipment. The reduction in airflow after retrofit was at least, and probably more than, 50 percent of the preretrofit airflow. The airflow reduction trend is in general agreement with the increased oxygen transfer efficiency value.

A comparison of SOTE and the whole-tank off-gas test results for the fine pore tube diffuser system is contained on Figure No. 23. The average value of apparent alphaxSOTE is approximately 55 percent of the estimated clean water SOTE value for a spiral-roll fine pore tube diffuser system, and is 38 percent of the estimated clean water SOTE value for a full-floor coverage fine pore tube diffuser system. These data would suggest that the apparent alpha factor value may be a function of the diffuser placement (layout pattern or geometry) within the aeration tank.

6.3 INCREASE IN ACTUAL EFFICIENCY

Based on more than 160 off-gas tests conducted at Glastonbury, it seems reasonable to assume that the average whole-tank apparent alphaxSOTE ranges from 6.5 to 7.0 percent. The original coarse bubble spiral-roll system apparent alphaxSOTE is estimated to be in the range of 4.0 to 4.5 percent. The increase in efficiency due to the retrofit is 155 to 165 percent of the original equipment performance.

There was no initial assumption for aeration system performance improvement other than the manufacturer's claims and estimates based on the information provided in the Invitation to Bid. Although there was no actual before and after transfer efficiency information to compare, before-retrofit airflow ranged from 2,200 to 2,500 SCFM and after-retrofit airflow ranged from less than 1,000 SCFM to more than 1,900 SCFM, with an average rate of approximately 1,250 SCFM.

An increase in oxygen transfer efficiency of 160 percent of the original equipment for this retrofit project is probably realistic based on the reported values for both power consumption and airflow before and after the retrofit. Also, the apparent alphaxSOTE values measured in this system agree reasonably well with the reported results from other fine pore

tube diffuser systems tested in the recent past using the off-gas method (ref. Stenstrom testing of spiral-roll retrofit systems).

6.4 COST CONSIDERATIONS

The approximate total capital cost for the Glastonbury retrofit project was $28,000.00. The price of the diffusers was about $30.00 each, unassembled. The time required for town employees to remove the old diffusers, recondition the swing-arm assemblies and install the new diffusers was about 0.75 man-hours per diffuser. At a rate of $20.00 per man-hour, the installation cost was approximately $6,500.00. Miscellaneous pipe fittings and hardware cost about $2,500.00. The estimated total cost of the new blower was $10,000.00, including air filtration equipment and installation costs.

Electrical power savings are estimated to be about $50.00 per day based on a 50 KWH reduction in power usage. The annual operating savings range from $15,000.00 to $18,000.00 per year depending on blower usage and maintenance performed on the in-tank equipment.

Annual maintenance costs for the fine pore tube diffuser system have not increased significantly over the maintenance costs for the coarse bubble system. The diffusers at Glastonbury have been cleaned only once due to diffuser clogging caused by mixed liquor intrusion into the air piping through blow-down holes in the air manifold which were not blocked off during the conversion to fine pore diffusers.

Cleaning consisted of removing the diffusers from an entire swing-arm assembly, disassembling the diffusers, detergent washing the diffuser media per the manufacturer's instructions, reassembly of the diffusers, and reinstallation of the diffusers on the swing-arm assembly.

The time required for this cleaning operation is much greater than routine in-place cleaning of the exterior surface of diffusers. The time required to disassemble and clean each diffuser ranges from 20 to 30 minutes with a cost of $5.00 to $7.50 per diffuser.

Exterior cleaning was not performed at Glastonbury, but hosing and brushing should take no more than 2 to 3 minutes per diffuser. Annual maintenance should include at least one exterior cleaning of the diffusers with an inspection and tightening of retaining nuts and gaskets to ensure that coarse bubbling does not occur due to air leaks. The estimated cost for annual exterior cleaning is $500.00 for the Glastonbury system.

Based on the estimated total capital costs and electrical power savings, the payback period at Glastonbury was between 18 and 21 months. Payback periods of less than 2 years can be expected for replacement of spiral-roll coarse bubble aeration equipment with spiral-roll fine pore tube diffuser aeration equipment. The actual payback period will be a function of the total capital cost and the ability to reduce blower power usage through turndown and/or shutdown of blower units after retrofitting with the new equipment. For the Glastonbury type of retrofit, in-tank equipment modifications are generally inexpensive if air piping and swing-arm assemblies are in good working condition. However, blower modifications can range from simple and inexpensive to complex and costly.

7.0 RECOMMENDATIONS

7.1 GENERAL

Based on a thorough review of the Glastonbury Water Pollution Control Facility retrofit history and evaluation of over two years operating and oxygen transfer performance data as part of the ASCE/EPA Oxygen Transfer Study, several recommendations can be made with regard to retrofit considerations for similar other facilities. These recommendations are categorized as follows:

1. Engineering Design
2. Equipment Design
3. Operation
4. Maintenance
5. Efficiency Considerations
6. Clogging Potential
7. Mechanical Reliability
8. Overall Advantages and Disadvantages

7.2 ENGINEERING DESIGN

The proposed retrofit diffuser arrangement and other in-tank air piping should be designed for operational flexibility for delivery of oxygen as required to specific sections of the aeration tank or process. Spare or excess diffuser connections should be provided for in the retrofit design. Other methods of tapering air supply should be provided for in the design as well.

Dissolved oxygen measurement and control instrumentation design should be kept as simple and reliable as possible. Only proven technologies with a history of low maintenance

should be considered. The complexity of the dissolved oxygen control system should be a function of potential power savings, which for small plants is generally limited.

Air supply should be sized for capacity considerations throughout the design life cycle of the proposed retrofit system. Piping should provide for operational flexibility and tapering of the air supply. All existing pipe which could be used in the retrofit system must be inspected for serviceability and suitability with the proposed retrofit equipment. Knee joints, blow-down legs and other air piping equipment which could contain points of leakage or openings must be repaired. All corrosion products and other debris inside air piping and air delivery assemblies must be removed prior to installation of new fine pore equipment.

Air distribution considerations should include an understanding of the oxygen demand profile in the system and methods for accomplishing necessary tapering, either by the quantity of diffusers per swing-arm assembly or by control valves, or a combination of both.

Blower design or modification must be considered whenever changing from coarse bubble to fine pore aeration. Airflow, discharge pressure, and power consumption relationships must be evaluated and understood with regard to the new operating conditions. Net operating savings will be a direct result of the reduced electrical power usage of the blower system and not solely as a result of increased oxygen transfer efficiency of the new in-tank aeration equipment.

7.3 EQUIPMENT DESIGN

The fine pore tube diffuser equipment should be durable and functionally simple. Equipment using gaskets and plastic bolts, nuts and hardware should be evaluated carefully. Cur-

rently available gasketing systems are prone to leaks and do not hold up for long periods of time (far less than the life-cycle). Plastic bolts and nuts are subject to total failure if overtightened or if temperature stresses develop after installation. Problems with either gaskets or plastic hardware lead to coarse bubbling (loss of oxygen transfer efficiency), maldistribution of air, and intrusion of mixed liquor into the diffusers and air piping when air supply is shut off or cut back significantly.

In-tank air piping should be totally corrosion resistant and designed to prevent air leaks. All air piping should contain a low point moisture blow-off device to ensure that liquid completely drains from all air piping in a short time after start-up of air supply to the aeration system.

7.4 OPERATION

The fine pore tube diffuser aeration system should be operated within the airflow range of the design. Minimum airflow rates for solids suspension and mixing of the mixed liquor and minimum airflow rates per diffuser to assure uniform distribution of air throughout the system must be maintained.

Minimum dissolved oxygen concentrations should be established based on process and effluent quality considerations. Monitoring of dissolved oxygen should be based on maintaining accurately measuring dissolved oxygen measurement equipment.

MLSS concentrations should be maintained within design ranges insofar as possible. Increased MLSS inventories in the aeration system increase oxygen demand per unit of BOD oxidized and probably lower the apparent alpha values.

7.5 MAINTENANCE

All fine pore aeration systems must be properly maintained to ensure high operational efficiency. Routine inspection, cleaning, and repair must be carried out as necessary. Diffuser headloss, or dynamic wet pressure, and oxygen transfer efficiency measurements provide useful information for cleaning frequency requirements. Observation of surface patterns can provide information concerning coarse bubbling (possibly due to biofouling of the diffusers or from gasket leaks) and obvious air leaks. Major coarse bubbling problems should be checked out immediately and repairs made as soon as possible. Not only is oxygen transfer efficiency reduced as a result of coarse bubbling, but diffuser system clogging is possible from mixed liquor backflow into the air system.

7.6 EFFICIENCY CONSIDERATIONS

Aeration system or equipment retrofit design should be predicated upon sound performance data. Valid Standard Oxygen Transfer information should only be used in the design. Diffuser airflow rates, water depth, and diffuser density should be the same for test result information as for the proposed design conditions.

Apparent alpha factors in the range of 0.4 to 0.6 should be used for spiral-roll fine pore tube diffuser systems. Higher values of the apparent alpha factor should not be used unless specific apparent alpha factor testing has been carried out, and the results verify that less conservative values could be used. Any apparent alpha factor testing should include results for fouled or dirty diffusers as well as results for the new, clean diffusers.

For plug-flow systems where diffuser tapering is required to match changing oxygen demand, both clean water transfer efficiency and apparent alpha factor value selection must take into consideration the need to select different values for SOTE and apparent alpha at different points along the taper.

In many fine pore aeration systems, oxygen transfer efficiency will diminish from a high value immediately after cleaning to lower values as operating time increases. These changes in oxygen transfer efficiency should be taken into consideration for determining cleaning frequency and assessing overall operating cost.

7.7 CLOGGING POTENTIAL

Regardless of operating mode, fine pore diffusers may clog or foul over time. Both operating mode and wastewater characteristics effect the degree and frequency of clogging. Fine silt and other inorganic materials carried in the primary effluent stream can and do end up on the diffusers, causing an increase in diffuser headloss. Biological materials which develop on the surface of the diffusers also cause clogging problems to exist.

Air-side fouling can occur from particles in the air supply or from backflow of mixed liquor into the diffuser piping through leaking gaskets and bolts, broken bolts, and leaks in the air piping. The major air-side fouling potential is from leaks in equipment components and not from particles in the air supply.

7.8 MECHANICAL RELIABILITY

Mechanical reliability is always a concern when using plastic components in severe duty applications such as aeration. Materials must be handled more carefully during installation. Temperature variations must be accounted for with the thermal expansion and contraction of the plastic components.

Diffuser attachment to the air piping system should be simple and positive. Plastic bolts and nuts should not be used because of high potential for failure. Gaskets should be manufactured of materials which will have long service life and not leak shortly after installation. Gaskets can be replaced as required, and plastic hardware can be replaced with stainless steel bolts. Replacement and repair of the diffuser components is costly, however.

7.9 OVERALL ADVANTAGES AND DISADVANTAGES

The most significant advantage of any fine pore retrofit is increased oxygen transfer efficiency. In some cases, the increased efficiency allows for reduction of power consumption, and in other cases, additional aeration capacity is achieved without additional power consumption.

Although spiral-roll fine pore tube diffuser systems are not as energy efficient as full-floor coverage dome/disc diffuser systems (average apparent alpha×SOTE 0.7:1.0, respectively), the spiral-roll fine pore tube diffuser systems generally have lower operating and maintenance costs. Swing-arm systems usually operate at 0.5 to 1.0 psig less air pressure than full-floor coverage dome/disc systems because of diffuser submergence and diffuser headloss differences. Aeration tank accessibility is not a concern with diffuser systems utilizing swing-arm assemblies, and there should be no tank downtime which could effect process and plant effluent quality.

The disadvantages of spiral-roll fine pore tube aeration systems are not significant as long as the overall objectives of power savings or additional aeration capacity are being achieved. The main disadvantages include: 1.) need for higher level of maintenance of the aeration equipment, and 2.) shorter equipment life-cycle than for coarse bubble aeration systems.

In spite of higher levels of maintenance and operational care, spiral-roll fine pore tube aeration retrofit systems which are properly operated and maintained will have life-cycle costs which are significantly less than continuing with the existing coarse bubble equipment.

8.0 REFERENCES

1. Manual of Methods for Fine Bubble Diffused Aeration Field Studies, ASCE/EPA Project, July 1985.

2. Contract Documents, Town of Glastonbury, CT, Water Pollution Control Plant and Appurtenant Work, Metcalf & Eddy Engineers, December 1969.

3. Pearlcomb Diffuser product literature and Contract Specifications, FMC Corporation, May 1984.

APPENDIX I-A

Summary of Individual Off-Gas
Field Tests and Computations
for Airflow-Weight Averaging

OFF-GAS TEST RESULTS FOR NOVEMBER 21 AND 22, 1985*
(TEST 1A)

TEST LOCATION	PASS NO.	DATE	RUN NO.	ALPHA x SOTE, %	NO. OF TUBES	AIRFLOW SCFM	TOTAL AIRFLOW, SCFM	NEW SOTE, %	APPARENT ALPHA	ALPHA x SOTR, LBS. 02/HR	NEW SOTR, LBS. 02/HR
1-I	1	11-21-85	1 & 3	2.72	20	7.70	154.0	10.5	0.26	4.34	16.76
1-I	1	11-21-85	2 & 4	2.30	20	7.70	154.0	10.5	0.22	3.67	16.76
1-E	1	11-21-85	5 & 7	3.31	20	7.70	154.0	10.5	0.32	5.28	16.76
1-E	1	11-21-85	6 & 8	3.81	20	7.70	154.0	10.5	0.36	6.08	16.76
PASS 1 AVG.	-	-	-	3.04	80	7.70	616.0	10.5	0.29	19.37	67.03
2-I	2	11-21-85	9 & 11	6.17	20	5.80	116.0	11.3	0.55	7.42	13.58
2-I	2	11-21-85	10 & 12	7.04	20	5.80	116.0	11.3	0.62	8.46	13.58
2-E	2	11-21-85	13 & 15	7.28	20	5.80	116.0	11.3	0.64	8.75	13.58
2-E	2	11-21-85	14 & 16	9.39	20	5.80	116.0	11.3	0.83	11.29	13.58
PASS 2 AVG.	-	-	-	7.47	80	5.80	464.0	11.3	0.66	35.92	54.33
3-I	3	11-21-85	17 & 19	5.33	20	3.80	76.0	12.5	0.43	4.20	9.84
3-I	3	11-21-85	18 & 20	5.04	20	3.80	76.0	12.5	0.40	3.97	9.84
3-E	3	11-21-85	21 & 23	4.02	20	3.80	76.0	12.5	0.32	3.17	9.84
3-E	3	11-21-85	22 & 24	4.78	20	3.80	76.0	12.5	0.38	3.76	9.84
PASS 3 AVG.	-	-	-	4.79	80	3.80	304.0	12.5	0.38	15.10	39.38
4-I	4	11-22-85	25 & 27	4.46	20	3.80	76.0	12.5	0.36	3.51	9.84
4-I	4	11-22-85	26 & 28	4.63	20	3.80	76.0	12.5	0.37	3.65	9.84
4-E	4	11-22-85	29 & 31	4.25	20	3.80	76.0	12.5	0.34	3.35	9.84
4-E	4	11-22-85	30 & 32	5.20	20	3.80	76.0	12.5	0.42	4.10	9.84
PASS 4 AVG.	-	-	-	4.64	80	3.80	304.0	12.5	0.37	14.60	39.38
TANK 2 AVG.	-	-	-	4.86	320	5.28	1688.0	11.4	0.42	84.99	200.12

*Coarse bubbling due to loose end connections on diffusers.

OFF-GAS TEST RESULTS FOR MARCH 26 AND 28, 1986
(TEST 2A)

TEST LOCATION	PASS NO.	DATE	RUN NO.	ALPHA x SOTE, %	NO. OF TUBES	AIRFLOW SCFM	TOTAL AIRFLOW, SCFM	NEW SOTE, %	APPARENT ALPHA	ALPHA x SOTR, LBS. 02/HR	NEW SOTR, LBS. 02/HR
1-I	1	3-26-86	1 & 3	8.35	20	8.40	168.0	10.3	0.81	14.54	17.93
1-I	1	3-26-86	2 & 4	7.69	20	8.40	168.0	10.3	0.75	13.39	17.93
1-E	1	3-26-86	5 & 7	6.29	20	8.40	168.0	10.3	0.61	10.95	17.93
1-E	1	3-26-86	6 & 8	5.32	20	8.40	168.0	10.3	0.52	9.26	17.93
PASS 1 AVG.	-	-	-	6.91	80	8.40	672.0	10.3	0.67	48.14	71.73
2-I	2	3-26-86	9 & 11	3.46	20	6.30	126.0	11.1	0.31	4.52	14.49
2-I	2	3-26-86	10 & 12	4.06	20	6.30	126.0	11.1	0.37	5.30	14.49
2-E	2	3-26-86	13 & 15	5.35	20	6.30	126.0	11.1	0.48	6.99	14.49
2-E	2	3-26-86	14 & 16	6.08	20	6.30	126.0	11.1	0.55	7.94	14.49
PASS 2 AVG.	-	-	-	4.74	80	6.30	504.0	11.1	0.43	24.74	57.97
3-I	3	3-28-86	17 & 19	7.95	20	4.70	94.0	12.0	0.66	7.74	11.69
3-I	3	3-28-86	18 & 20	6.90	20	4.70	94.0	12.0	0.58	6.72	11.69
3-E	3	3-28-86	21 & 23	8.14	20	4.70	94.0	12.0	0.68	7.93	11.69
3-E	3	3-28-86	22 & 24	8.21	20	4.70	94.0	12.0	0.68	8.00	11.69
PASS 3 AVG.	-	-	-	7.80	80	4.70	376.0	12.0	0.65	30.39	46.76
4-I	4	3-28-86	25 & 27	9.00	20	4.70	94.0	12.0	0.75	8.77	11.69
4-I	4	3-28-86	26 & 28	7.35	20	4.70	94.0	12.0	0.61	7.16	11.69
4-E	4	3-28-86	29 & 31	6.90	20	4.70	94.0	12.0	0.58	6.72	11.69
4-E	4	3-28-86	30 & 32	7.05	20	4.70	94.0	12.0	0.59	6.87	11.69
PASS 4 AVG.	-	-	-	7.58	80	4.70	376.0	12.0	0.63	29.52	46.76
TANK 2 AVG.	-	-	-	6.65	320	6.03	1928.0	11.2	0.59	132.79	223.21

OFF-GAS TEST RESULTS FOR SEPTEMBER 17, 1987
(TEST 3B, TESTING FROM 10:15 TO 11:30)

TEST LOCATION	PASS NO.	DATE	TIME	RUN NO.	MEAS. OTE, %	DO, MG/L	ALPHA x SOTE, %	NO. OF TUBES	AIRFLOW SCFM	TOTAL AIRFLOW, SCFM	NEW SOTE, %	APPARENT ALPHA	ALPHA x SOTR, LBS. O2/HR	NEW SOTR, LBS. O2/HR
1-I	1	9-17-87	1015	1	4.80	0.18	4.84	40	3.10	124.0	12.5	0.39	6.22	16.06
1-E	1	9-17-87	1025	2	7.01	0.17	7.07	40	4.10	164.0	12.5	0.57	12.02	21.24
PASS 1 AVG.	-	-	-	-	-	-	6.11	80	3.60	288.0	12.5	0.49	18.23	37.31
2-I	2	9-17-87	1035	3	5.96	0.40	6.16	40	3.80	152.0	12.5	0.49	9.70	19.69
2-E	2	9-17-87	1045	4	7.46	0.45	7.75	40	3.80	152.0	12.5	0.62	12.21	19.69
PASS 2 AVG.	-	-	-	-	-	-	6.96	80	3.80	304.0	12.5	0.56	21.91	39.38
3-I	3	9-17-87	1055	5	10.89	0.30	11.16	40	3.10	124.0	12.5	0.89	14.34	16.06
3-E	3	9-17-87	1110	6	7.96	0.20	8.07	40	3.10	124.0	12.5	0.65	10.37	16.06
PASS 3 AVG.	-	-	-	-	-	-	9.62	80	3.10	248.0	12.5	0.77	24.71	32.12
4-I	4	9-17-87	1120	7	8.06	0.46	8.40	40	3.10	124.0	12.5	0.67	10.79	16.06
4-E	4	9-17-87	1130	8	7.54	0.20	7.65	40	2.30	92.0	12.5	0.61	7.29	11.92
PASS 4 AVG.	-	-	-	-	-	-	8.08	80	2.70	216.0	12.5	0.65	18.09	27.98
TANK 2 AVG.	-	-	-	-	-	-	7.58	320	3.30	1056.0	12.5	0.61	82.94	136.79

OFF-GAS TEST RESULTS FOR SEPTEMBER 17, 1987
(TEST 3B, TESTING FROM 11:40 TO 12:50)

TEST LOCATION	PASS NO.	DATE	TIME	RUN NO.	MEAS. OTE, %	DO, MG/L	ALPHA x SOTE, %	NO. OF TUBES	AIRFLOW SCFM	TOTAL AIRFLOW, SCFM	NEW SOTE, %	APPARENT ALPHA	ALPHA x SOTR, LBS. O2/HR	NEW SOTR, LBS. O2/HR
1-I	1	9-17-87	1250	16	4.80	0.23	5.79	40	4.60	184.0	12.5	0.46	11.04	23.83
1-E	1	9-17-87	1240	15	6.65	0.09	6.66	40	3.60	144.0	12.5	0.53	9.94	18.65
PASS 1 AVG.	-	-	-	-	-	-	6.17	80	4.10	328.0	12.5	0.49	20.98	42.49
2-I	2	9-17-87	1230	14	7.47	0.15	7.53	40	3.60	144.0	12.5	0.60	11.24	18.65
2-E	2	9-17-87	1220	13	8.39	0.18	8.49	40	3.80	152.0	12.5	0.68	13.37	19.69
PASS 2 AVG.	-	-	-	-	-	-	8.02	80	3.70	296.0	12.5	0.64	24.61	38.34
3-I	3	9-17-87	1210	12	6.78	0.27	6.93	40	3.00	120.0	12.5	0.55	8.62	15.54
3-E	3	9-17-87	1200	11	5.57	0.35	5.74	40	3.00	120.0	12.5	0.46	7.14	15.54
PASS 3 AVG.	-	-	-	-	-	-	6.34	80	3.00	240.0	12.5	0.51	15.76	31.09
4-I	4	9-17-87	1150	10	7.62	0.40	7.89	40	3.00	120.0	12.5	0.63	9.81	15.54
4-E	4	9-17-87	1140	9	7.42	0.20	7.53	40	2.30	92.0	12.5	0.60	7.18	11.92
PASS 4 AVG.	-	-	-	-	-	-	7.73	80	2.65	212.0	12.5	0.62	16.99	27.46
TANK 2 AVG.	-	-	-	-	-	-	7.03	320	3.36	1076.0	12.5	0.56	78.33	139.38

OFF-GAS TEST RESULTS FOR SEPTEMBER 17, 1987
(TEST 3B; TESTING FROM 13:00 TO 14:30)

TEST LOCATION	PASS NO.	DATE	TIME	RUN NO.	MEAS. OTE, %	DO, MG/L	ALPHA x SOTE, %	NO. OF TUBES	AIRFLOW SCFM	TOTAL AIRFLOW, SCFM	NEW SOTE, %	APPARENT ALPHA	ALPHA x SOTR, LBS. O2/HR	NEW SOTR, LBS. O2/HR
1-I	1	9-17-87	1300	17	5.82	0.23	5.91	40	4.60	184.0	12.5	0.47	11.27	23.83
1-E	1	9-17-87	1310	18	6.18	0.10	6.19	40	3.50	140.0	12.5	0.50	8.98	18.13
PASS 1 AVG.	-	-	-	-	-	-	6.03	80	4.05	324.0	12.5	0.48	20.25	41.97
2-I	2	9-17-87	1325	19	7.30	0.20	7.39	40	2.40	96.0	12.5	0.59	7.35	12.44
2-E	2	9-17-87	1335	20	9.51	0.19	9.63	40	2.40	96.0	12.5	0.77	9.58	12.44
PASS 2 AVG.	-	-	-	-	-	-	8.51	80	2.40	192.0	12.5	0.68	16.93	24.87
3-I	3	9-17-87	1345	21	9.47	0.13	9.54	40	2.40	96.0	12.5	0.76	9.49	12.44
3-E	3	9-17-87	1355	22	6.68	0.17	6.76	40	2.50	100.0	12.5	0.54	7.01	12.95
PASS 3 AVG.	-	-	-	-	-	-	8.12	80	2.45	196.0	12.5	0.65	16.50	25.39
4-I	4	9-17-87	1415	23	6.43	0.22	6.54	40	2.60	104.0	12.5	0.52	7.05	13.47
4-E	4	9-17-87	1430	24	8.03	0.14	8.10	40	2.60	104.0	12.5	0.65	8.73	13.47
PASS 4 AVG.	-	-	-	-	-	-	7.32	80	2.60	208.0	12.5	0.59	15.78	26.94
TANK 2 AVG.	-	-	-	-	-	-	7.29	320	2.88	920.0	12.5	0.58	69.45	119.17

OFF-GAS TEST RESULTS FOR JANUARY 11, 1988
(TEST 4B; TESTING FROM 10:30 TO 11:45)

TEST LOCATION	PASS NO.	DATE	TIME	RUN NO.	MEAS. OTE, %	DO, MG/L	ALPHA x SOTE, %	NO. OF TUBES	AIRFLOW SCFM	TOTAL AIRFLOW, SCFM	NEW SOTE, %	APPARENT ALPHA	ALPHA x SOTR, LBS. O2/HR	NEW SOTR, LBS. O2/HR
1-I	1	1-11-88	1030	1	6.04	0.24	6.33	40	2.70	108.0	12.5	0.51	7.08	13.99
1-E	1	1-11-88	1040	2	5.65	0.43	6.02	40	3.20	128.0	12.5	0.48	7.99	16.58
PASS 1 AVG.	-	-	-	-	-	-	6.16	80	2.95	236.0	12.5	0.49	15.07	30.57
2-I	2	1-11-88	1050	3	8.26	0.38	8.77	40	3.40	136.0	12.5	0.70	12.36	17.62
2-E	2	1-11-88	1100	4	7.46	0.45	7.96	40	3.20	128.0	12.5	0.64	10.56	16.58
PASS 2 AVG.	-	-	-	-	-	-	8.38	80	3.30	264.0	12.5	0.67	22.92	34.20
3-I	3	1-11-88	1115	5	6.71	0.53	7.21	40	2.60	104.0	12.5	0.58	7.77	13.47
3-E	3	1-11-88	1125	6	7.23	0.59	7.81	40	2.70	108.0	12.5	0.62	8.74	13.99
PASS 3 AVG.	-	-	-	-	-	-	7.52	80	2.65	212.0	12.5	0.60	16.51	27.46
4-I	4	1-11-88	1135	7	6.44	0.48	6.89	40	2.70	108.0	12.5	0.55	7.71	13.99
4-E	4	1-11-88	1145	8	6.92	0.42	7.37	40	2.80	112.0	12.5	0.59	8.55	14.51
PASS 4 AVG.	-	-	-	-	-	-	7.13	80	2.75	220.0	12.5	0.57	16.26	28.50
TANK 2 AVG.	-	-	-	-	-	-	7.33	320	2.91	932.0	12.5	0.59	70.76	120.73

OFF-GAS TEST RESULTS FOR JANUARY 11, 1988
(TEST 4B; TESTING FROM 11:55 TO 13:20)

TEST LOCATION	PASS NO.	DATE	TIME	RUN NO.	MEAS. OTE, %	DO, MG/L	ALPHA x SOTE, %	NO. OF TUBES	AIRFLOW SCFM	TOTAL AIRFLOW, SCFM	NEW SOTE, %	APPARENT ALPHA	ALPHA x SOTR, LBS. O2/HR	NEW SOTR, LBS. O2/HR
1-I	1	1-11-88	1320	16	5.54	0.32	5.85	40	3.90	156.0	12.5	0.47	9.46	20.21
1-E	1	1-11-88	1310	15	8.48	0.22	8.88	40	3.10	124.0	12.5	0.71	11.41	16.06
PASS 1 AVG.	-	-	-	-	-	-	7.19	80	3.50	280.0	12.5	0.58	20.87	36.27
2-I	2	1-11-88	1255	14	7.57	0.36	8.02	40	2.90	116.0	12.5	0.64	9.64	15.03
2-E	2	1-11-88	1245	13	8.46	0.53	9.09	40	3.40	136.0	12.5	0.73	12.81	17.62
PASS 2 AVG.	-	-	-	-	-	-	8.60	80	3.15	252.0	12.5	0.69	22.45	32.64
3-I	3	1-11-88	1235	12	6.02	0.92	6.70	40	2.70	108.0	12.5	0.54	7.50	13.99
3-E	3	1-11-88	1225	11	6.62	0.65	7.19	40	2.80	112.0	12.5	0.58	8.34	14.51
PASS 3 AVG.	-	-	-	-	-	-	6.95	80	2.75	220.0	12.5	0.56	15.84	28.50
4-I	4	1-11-88	1215	10	6.04	0.48	6.46	40	2.90	116.0	12.5	0.52	7.77	15.03
4-E	4	1-11-88	1155	9	7.30	0.61	7.90	40	2.80	112.0	12.5	0.63	9.17	14.51
PASS 4 AVG.	-	-	-	-	-	-	7.17	80	2.85	228.0	12.5	0.57	16.93	29.53
TANK 2 AVG.	-	-	-	-	-	-	7.49	320	3.06	980.0	12.5	0.60	76.10	126.94

OFF-GAS TEST RESULTS FOR JANUARY 11, 1988
(TEST 4B; TESTING FROM 13:35 TO 15:20)

TEST LOCATION	PASS NO.	DATE	TIME	RUN NO.	MEAS. OTE, %	DO, MG/L	ALPHA x SOTE, %	NO. OF TUBES	AIRFLOW SCFM	TOTAL AIRFLOW, SCFM	NEW SOTE, %	APPARENT ALPHA	ALPHA x SOTR, LBS. O2/HR	NEW SOTR, LBS. O2/HR
1-I	1	1-11-88	1335	17	5.69	0.39	6.04	40	4.00	160.0	12.5	0.48	10.01	20.73
1-E	1	1-11-88	1345	18	10.54	0.31	11.12	40	3.10	124.0	12.5	0.89	14.29	16.06
PASS 1 AVG.	-	-	-	-	-	-	8.26	80	3.55	284.0	12.5	0.66	24.30	36.79
2-I	2	1-11-88	1355	19	7.33	0.41	7.80	40	3.30	132.0	12.5	0.62	10.67	17.10
2-E	2	1-11-88	1415	20	8.08	0.78	8.88	40	3.40	136.0	12.5	0.71	12.51	17.62
PASS 2 AVG.	-	-	-	-	-	-	8.35	80	3.35	268.0	12.5	0.67	23.18	34.72
3-I	3	1-11-88	1425	21	6.43	0.63	6.97	40	2.80	112.0	12.5	0.56	8.09	14.51
3-E	3	1-11-88	1450	22	7.33	0.52	7.87	40	3.00	120.0	12.5	0.63	9.79	15.54
PASS 3 AVG.	-	-	-	-	-	-	7.44	80	2.90	232.0	12.5	0.59	17.88	30.05
4-I	4	1-11-88	1500	23	7.80	0.50	8.36	40	3.00	120.0	12.5	0.67	10.40	15.54
4-E	4	1-11-88	1520	24	6.90	0.52	7.41	40	2.90	116.0	12.5	0.59	8.91	15.03
PASS 4 AVG.	-	-	-	-	-	-	7.89	80	2.95	236.0	12.5	0.63	19.30	30.57
TANK 2 AVG.	-	-	-	-	-	-	8.01	320	3.19	1020.0	12.5	0.64	84.67	132.12

OFF-GAS TEST RESULTS FOR MAY 17, 1988
(TEST 5B; TESTING FROM 10:35-11:50)

TEST LOCATION	PASS NO.	DATE	TIME	RUN NO.	MEAS. OTE, %	DO, MG/L	ALPHA x SOTE, %	NO. OF TUBES	AIRFLOW SCFM	TOTAL AIRFLOW, SCFM	NEW SOTE, %	APPARENT ALPHA	ALPHA x SOTR, LBS. O2/HR	NEW SOTR, LBS. O2/HR
1-I	1	5-17-88	1035	1	4.92	0.35	5.18	40	3.90	156.0	12.5	0.41	8.37	20.21
1-E	1	5-17-88	1045	2	6.16	0.43	6.53	40	4.10	164.0	12.3	0.53	11.10	20.90
PASS 1 AVG.	-	-	-	-	-	-	5.87	80	4.00	320.0	12.4	0.47	19.47	41.11
2-I	2	5-17-88	1055	3	6.18	0.68	6.71	40	3.30	132.0	12.5	0.54	9.18	17.10
2-E	2	5-17-88	1110	4	6.44	0.70	7.01	40	3.30	132.0	12.5	0.56	9.59	17.10
PASS 2 AVG.	-	-	-	-	-	-	6.86	80	3.30	264.0	12.5	0.55	18.77	34.20
3-I	3	5-17-88	1120	5	7.57	0.75	8.27	40	2.40	96.0	12.5	0.66	8.23	12.44
3-E	3	5-17-88	1130	6	5.64	0.78	6.18	40	2.60	104.0	12.5	0.49	6.66	13.47
PASS 3 AVG.	-	-	-	-	-	-	7.18	80	2.50	200.0	12.5	0.57	14.89	25.91
4-I	4	5-17-88	1140	7	6.15	1.30	7.09	40	2.70	108.0	12.5	0.57	7.93	13.99
4-E	4	5-17-88	1150	8	6.67	0.64	7.21	40	2.80	112.0	12.5	0.58	8.37	14.51
PASS 4 AVG.	-	-	-	-	-	-	7.15	80	2.75	220.0	12.5	0.57	16.30	28.50
TANK 2 AVG.	-	-	-	-	-	-	6.67	320	3.14	1004.0	12.5	0.54	69.43	129.71

OFF-GAS TEST RESULTS FOR MAY 17, 1988
(TEST 5B; TESTING FROM 12:00 TO 13:20)

TEST LOCATION	PASS NO.	DATE	TIME	RUN NO.	MEAS. OTE, %	DO, MG/L	ALPHA x SOTE, %	NO. OF TUBES	AIRFLOW SCFM	TOTAL AIRFLOW, SCFM	NEW SOTE, %	APPARENT ALPHA	ALPHA x SOTR, LBS. O2/HR	NEW SOTR, LBS. O2/HR
1-I	1	5-17-88	1320	16	6.13	0.42	6.50	40	4.10	164.0	12.3	0.53	11.05	20.90
1-E	1	5-17-88	1310	15	6.99	0.48	7.45	40	4.00	160.0	12.4	0.60	12.35	20.56
PASS 1 AVG.	-	-	-	-	-	-	6.97	80	4.05	324.0	12.3	0.56	23.40	41.46
2-I	2	5-17-88	1255	14	6.89	0.90	7.64	40	3.30	132.0	12.5	0.61	10.45	17.10
2-E	2	5-17-88	1245	13	7.51	0.43	7.97	40	3.50	140.0	12.5	0.64	11.56	18.13
PASS 2 AVG.	-	-	-	-	-	-	7.81	80	3.40	272.0	12.5	0.62	22.01	35.23
3-I	3	5-17-88	1235	12	9.53	0.68	10.35	40	2.50	100.0	12.5	0.83	10.73	12.95
3-E	3	5-17-88	1225	11	6.91	0.89	7.65	40	2.90	116.0	12.5	0.61	9.20	15.03
PASS 3 AVG.	-	-	-	-	-	-	8.90	80	2.70	216.0	12.5	0.71	19.92	27.98
4-I	4	5-17-88	1215	10	6.64	1.25	7.62	40	2.80	112.0	12.5	0.61	8.84	14.51
4-E	4	5-17-88	1200	9	6.93	0.56	7.44	40	2.70	108.0	12.5	0.60	8.33	13.99
PASS 4 AVG.	-	-	-	-	-	-	7.53	80	2.75	220.0	12.5	0.60	17.17	28.50
TANK 2 AVG.	-	-	-	-	-	-	7.71	320	3.23	1032.0	12.5	0.62	82.50	133.17

OFF-GAS TEST RESULTS FOR MAY 17, 1988
(TEST 5B; TESTING FROM 13:30 TO 15:10)

TEST LOCATION	PASS NO.	DATE	TIME	RUN NO.	MEAS. OTE, %	DO, MG/L	ALPHA x SOTE, %	NO. OF TUBES	AIRFLOW SCFM	TOTAL AIRFLOW, SCFM	NEW SOTE, %	APPARENT ALPHA	ALPHA x SOTR, LBS. O2/HR	NEW SOTR, LBS. O2/HR
1-I	1	5-17-88	1330	17	6.38	0.78	6.99	40	4.10	164.0	12.4	0.56	11.88	21.07
1-E	1	5-17-88	1340	18	5.89	0.25	6.15	40	4.00	160.0	12.5	0.49	10.20	20.73
PASS 1 AVG.	-	-	-	-	-	-	6.58	80	4.05	324.0	12.5	0.53	22.08	41.80
2-I	2	5-17-88	1350	19	7.55	0.56	8.11	40	3.60	144.0	12.5	0.65	12.10	18.65
2-E	2	5-17-88	1415	20	7.67	0.50	8.19	40	3.40	136.0	12.5	0.66	11.54	17.62
PASS 2 AVG.	-	-	-	-	-	-	8.15	80	3.50	280.0	12.5	0.65	23.64	36.27
3-I	3	5-17-88	1425	21	8.50	0.51	9.08	40	2.60	104.0	12.5	0.73	9.79	13.47
3-E	3	5-17-88	1435	22	7.05	1.65	8.43	40	3.00	120.0	12.5	0.67	10.48	15.54
PASS 3 AVG.	-	-	-	-	-	-	8.73	80	2.80	224.0	12.5	0.70	20.27	29.02
4-I	4	5-17-88	1445	23	6.11	0.94	6.80	40	2.60	104.0	12.5	0.54	7.33	13.47
4-E	4	5-17-88	1510	24	7.02	0.56	7.54	40	2.80	112.0	12.5	0.60	8.75	14.51
PASS 4 AVG.	-	-	-	-	-	-	7.18	80	2.70	216.0	12.5	0.57	16.08	27.98
TANK 2 AVG.	-	-	-	-	-	-	7.59	320	3.26	1044.0	12.5	0.61	82.07	135.06

OFF-GAS TEST RESULTS FOR SEPTEMBER 7, 1988
(TEST 6B; TESTING FROM 11:15 TO 12:30)

TEST LOCATION	PASS NO.	DATE	TIME	RUN NO.	MEAS. OTE, %	DO, MG/L	ALPHA x SOTE, %	NO. OF TUBES	AIRFLOW SCFM	TOTAL AIRFLOW, SCFM	NEW SOTE, %	APPARENT ALPHA	ALPHA x SOTR, LBS. O2/HR	NEW SOTR, LBS. O2/HR
1-I	1	9-7-88	1115	1	6.34	0.24	6.52	40	4.20	168.0	12.2	0.53	11.35	21.24
1-E	1	9-7-88	1125	2	4.79	0.15	4.88	40	4.10	164.0	12.5	0.39	8.29	21.24
PASS 1 AVG.	-	-	-	-	-	-	5.71	80	4.15	332.0	12.3	0.46	19.64	42.48
2-I	2	9-7-88	1135	3	6.77	0.39	7.07	40	3.10	124.0	12.5	0.57	9.08	16.06
2-E	2	9-7-88	1145	4	7.42	0.51	7.84	40	3.00	120.0	12.5	0.63	9.75	15.54
PASS 2 AVG.	-	-	-	-	-	-	7.45	80	3.05	244.0	12.5	0.60	18.83	31.61
3-I	3	9-7-88	1155	5	4.72	0.71	5.09	40	3.40	136.0	12.5	0.41	7.17	17.62
3-E	3	9-7-88	1210	6	7.16	1.97	8.89	40	3.30	132.0	12.5	0.71	12.16	17.10
PASS 3 AVG.	-	-	-	-	-	-	6.96	80	3.35	268.0	12.5	0.56	19.33	34.72
4-I	4	9-7-88	1220	7	6.79	0.26	7.00	40	2.40	96.0	12.5	0.56	6.96	12.44
4-E	4	9-7-88	1230	8	12.36	0.17	12.63	40	0.70	28.0	14.0	0.90	3.66	4.06
PASS 4 AVG.	-	-	-	-	-	-	8.27	80	1.55	124.0	12.8	0.64	10.63	16.50
TANK 2 AVG.	-	-	-	-	-	-	6.82	320	3.03	968.0	12.5	0.55	68.44	125.30

OFF-GAS TEST RESULTS FOR SEPTEMBER 7, 1988

(TEST 6B; TESTING FROM 12:40 TO 14:15)

TEST LOCATION	PASS NO.	DATE	TIME	RUN NO.	MEAS. OTE, %	DO, MG/L	ALPHA x SOTE, %	NO. OF TUBES	AIRFLOW SCFM	TOTAL AIRFLOW, SCFM	NEW SOTE, %	APPARENT ALPHA	ALPHA x SOTR, LBS. O2/HR	NEW SOTR, LBS. O2/HR
1-I	1	9-7-88	1415	16	4.89	0.16	4.99	40	4.20	168.0	12.2	0.41	8.69	21.24
1-E	1	9-7-88	1400	15	6.19	0.15	6.31	40	4.00	160.0	12.5	0.50	10.46	20.73
PASS 1 AVG.	-	-	-	-	-	-	5.63	80	4.10	328.0	12.3	0.46	19.15	41.96
2-I	2	9-7-88	1350	14	7.09	0.21	7.27	40	3.10	124.0	12.5	0.58	9.34	16.06
2-E	2	9-7-88	1320	13	7.72	0.41	8.08	40	3.10	124.0	12.5	0.65	10.38	16.06
PASS 2 AVG.	-	-	-	-	-	-	7.68	80	3.10	248.0	12.5	0.61	19.72	32.12
3-I	3	9-7-88	1310	12	6.38	0.35	6.64	40	3.30	132.0	12.5	0.53	9.08	17.10
3-E	3	9-7-88	1300	11	7.49	1.24	8.55	40	3.50	140.0	12.5	0.68	12.40	18.13
PASS 3 AVG.	-	-	-	-	-	-	7.62	80	3.40	272.0	12.5	0.61	21.49	35.23
4-I	4	9-7-88	1250	10	5.50	0.50	5.81	40	2.50	100.0	12.5	0.46	6.02	12.95
4-E	4	9-7-88	1240	9	12.36	0.15	12.60	40	0.60	24.0	14.0	0.90	3.13	3.48
PASS 4 AVG.	-	-	-	-	-	-	7.12	80	1.55	124.0	12.8	0.56	9.15	16.44
TANK 2 AVG.	-	-	-	-	-	-	6.90	320	3.04	972.0	12.5	0.55	69.52	125.76

OFF-GAS TEST RESULTS FOR SEPTEMBER 7, 1988
(TEST 6B; TESTING FROM 14:25 TO 15:40)

TEST LOCATION	PASS NO.	DATE	TIME	RUN NO.	MEAS. OTE, %	DO, MG/L	ALPHA x SOTE, %	NO. OF TUBES	AIRFLOW SCFM	TOTAL AIRFLOW, SCFM	NEW SOTE, %	APPARENT ALPHA	ALPHA x SOTR, LBS. O2/HR	NEW SOTR, LBS. O2/HR
1-I	1	9-7-88	1425	17	5.02	0.13	5.11	40	4.10	164.0	12.3	0.42	8.68	20.90
1-E	1	9-7-88	1435	18	4.36	0.29	4.51	40	4.20	168.0	12.2	0.37	7.85	21.24
PASS 1 AVG.	-	-	-	-	-	-	4.81	80	4.15	332.0	12.2	0.39	16.54	42.14
2-I	2	9-7-88	1445	19	8.13	0.34	8.45	40	3.10	124.0	12.5	0.68	10.86	16.06
2-E	2	9-7-88	1455	20	7.84	0.41	8.20	40	3.00	120.0	12.5	0.66	10.20	15.54
PASS 2 AVG.	-	-	-	-	-	-	8.33	80	3.05	244.0	12.5	0.67	21.05	31.61
3-I	3	9-7-88	1510	21	6.27	0.65	6.72	40	3.20	128.0	12.5	0.54	8.91	16.58
3-E	3	9-7-88	1520	22	7.34	0.82	8.01	40	3.00	120.0	12.5	0.64	9.96	15.54
PASS 3 AVG.	-	-	-	-	-	-	7.34	80	3.10	248.0	12.5	0.59	18.87	32.12
4-I	4	9-7-88	1530	23	7.88	0.25	8.10	40	2.10	84.0	12.5	0.65	7.05	10.88
4-E	4	9-7-88	1540	24	6.8	0.15	6.92	40	1.00	40.0	13.5	0.51	2.87	5.60
PASS 4 AVG.	-	-	-	-	-	-	7.72	80	1.55	124.0	12.8	0.60	9.92	16.48
TANK 2 AVG.	-	-	-	-	-	-	6.76	320	2.96	948.0	12.5	0.54	66.38	122.35

APPENDIX I-B

Overall Plant Data Sheet Based on
Previous Year of Record
and Supplemental Information

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

Plant Name: GLASTONBURY WATER POLLUTION CONTROL PLANT

Location: GLASTONBURY, CT

Flow Through Secondary Treatment:

Average: 1.6 MGD
Maximum: 2.1 MGD

1. WASTEWATER CHARACTERISTICS - BASED ON MONTHLY AVERAGES

Temperature, Deg. C:

Average: 15.5
Minimum: 10.5
Maximum: 22.0

	Raw Influent, mg/l			Sec. Eff., mg/l		
Parameter	Avg.	Min.	Max.	Avg.	Min.	Max.
BOD_5	240	195	345	18	4	47
COD	*	*	*	*	*	*
TSS	225	160	340	10	1	40
TDS	*	*	*	*	*	*
TKN	*	*	*	*	*	*
Total P	*	*	*	*	*	*
pH (units)	*	*	*	*	*	*
Alk	*	*	*	*	*	*
Hardness	*	*	*	*	*	*
Nitrate-N	*	*	*	*	*	*

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*not available and/or not determined

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

Process Flow Diagram: See attached design data sheets

Primary Sed. Area:

Each tank, 2 @ 2,826 sq. ft.

Final Clar. Area:

Each tank, 2 @ 2,826 sq. ft.

Aeration Tank Vol.:

Each tank, 2 @ 0.74 mil. gal. (99,000 cu. ft.)
(only one tank in operation)

Aeration Tank Water Depth:

Nominal: 15.5 ft.

3. MAJOR INDUSTRIAL WASTES

- no major industrial streams
- less than 10 percent of flow is commercial or industrial

4. RETURN FLOWS FROM SLUDGE PROCESSING - AVERAGES

(no information available)

5. PRIMARY EFFLUENT CHARACTERISTICS - AVERAGE INCLUDING RETURN FLOWS

Flow:	1.6 MGD
BOD:	120 mg/l
TSS	60 mg/l
TKN	*
TDS	*
Oil and Grease	*

*not available and/or not determined

6. PROCESS PARAMETERS - BASED ON AVERAGE CONDITIONS

(no percent variability data available)

Primary Overflow rate:	566 gpd/sf
Aeration Detention Time (V/Q):	11 hours
MLSS Conc.:	2,000 mg/l
Ratio, MLVSS/MLSS:	0.82
MLSS Inventory:*	13,000 lbs.
Solids Wasting Rate:	600 lbs. MLSS/day
Sludge Volume Index:	220
Recycle Ratio, R/Q:	34 percent
Sludge Age:*	12 days
F/M Ratio:*	0.12 (est.)

*estimated clarifier holdup included in solids inventory

7. AIR DIFFUSION SYSTEM

- Tank Designation: Aeration Tank No. 2

- Diffusers, Type and Number:
  FMC PEARLCOMB Diffusers, Model SP-35, total of 320 installed in Aeration Tank No. 2 (80 diffusers per pass, 20 diffusers per drop leg).

For tank configuration and diffuser placement, see attached information and information in Appendix I-C.

- Recommended Air Rates for this Diffuser:

  Minimum: 2 SCFM
  Maximum: 20 SCFM

- Typical Wet Resistance for this Diffuser over the Recorded Air Rate Range:

  See data in Appendix I-C
  (no information available for dirty diffuser conditions)

- Year Installed: Summer 1984
- Submergence: 12.0 feet
- Water Depth: 15.5 feet

- Cleaning Practice and History:

  Diffusers have never been cleaned to improve oxygen transfer efficiency. All diffusers were cleaned once during late 1984 due to internal clogging from biosolids entering drain holes in the drop leg manifold which were not plugged at the time of retrofit. The procedure used to clean the diffusers was the "Detergent Method" as described in the IO & M Manual (Appendix I-C). The diffuser cleaning was necessary due to the reduced airflow passage through clogged diffusers.

8. BLOWERS AND AIR SUPPLY PIPING

Blower No.	Type, Brand, Model	Yr.	HP	RPM	SCFM	Op.Time Hr./Yr.
1	Multistage Centrifugal Hoffman, 74105A2	1985	100	3,600	1,200 to 2,200	full time
2	Multistage Centrifugal Hoffman, 38506B	1973 (modified in 1983)	200	3,600	1,500 to 3,200	stand-by
3	Multistage Centrifugal Hoffman, 38506B	1973	200	3,600	2,000 to 4,750	stand-by

Total Installed Blower HP: 500
Total Installed Blower SCFM: 10,150
Blower Rating Curve: See attached information and data sheets
Description of Air Filtration System:

The existing air filtration equipment was modified to accept standard cartridge filter elements of a size suitable to remove 95 percent of all particles 0.3 microns or larger in size. The air filtration system uses twenty 24-inch by 24-inch by 2-inch Best Air Model 440 filters.

Supplemental Information on Blower Drives:

Drive No.	Drive Type	Brand	Model	Yr.	Design RPM	HP at Design RPM
1	Squirrel Cage Induction	GE	Energy Saver	1985	3,600	100
2	"	GE	-	1973	3,600	200
3	"	GE	-	1973	3,600	200

Typical Blowers Used at Average Operating Conditions:

Blower Numbers: 1 (small)
Total Horsepower: 100
Measured Pressure at Blower Discharge: 6.85 psig
Measured Dynamic Wet Pressure at Diffuser: N/A
Nominal Airflow per Diffuser: 4 SCFM

Typical Blowers Used at Maximum Operating Conditions:

Blower Numbers: 1 (large)
Total Horsepower: 200
Measured Pressure at Blower Discharge: 7.15 psig
Nominal Airflow per Diffuser: 7 SCFM

Blower Turndown Capability:

New: 100 HP blower surge point is 1,200 SCFM
Modified: 200 HP blower surge point is 1,500 SCFM
Original: 200 HP blower surge point is 2,000 SCFM

Strategy Used to Manage Blowers:

Manual control maintaining a positive DO in all aeration passes at all times. Adjustments in airflow made by inlet throttling valve positioning. Large blower turned on only when the small blower cannot provide sufficient airflow to meet DO demand. Under this condition, the large blower is turned on and the small blower turned off.

Arrangement of Blowers and Transmission Piping:

Blowers are located in a basement room of the control building. Only enough room exists for three blowers. Discharge piping travels through the basement pump room and then under ground to the aeration tanks, approximately 100 feet away.

Data Base for Aeration Tank Dissolved Oxygen:

Frequency of Measurement: All passes two to three times each day. Portable probe and meter are used by an operator.

Number of Locations: Continuously moved along each aeration pass.

Length of Record: Instantaneous

Typical Aeration Tank DO Values:

Period	Maximum	Minimum
Winter	4.5	1.5
Summer	1.2	0.5

9. RESULTS OF PREVIOUS OXYGEN TRANSFER TESTS AT THIS PLANT

- none conducted -

Manufacturer information and L. A. County work by Yunt used for establishment of SOTE values.

10. ADDITIONAL COMMENTS

- see attached supplemental information -

******

ATTACHMENT 2

CURRENT OPERATING DATE - (JULY 1983)

Flow: Average 1.5 MGD Peak 2.5 MGD

Raw Influent Bod_5 (average) 180-320 mg/l

Aeration Basin BOD_5 (primary effluent) 60-150 mg/l

Retention Time (at average flow) 12 hours

DO in Aeration Tank: Range = 0.5-3.0 mg/l,
Average = 1.5 mg/l

Average Influent Temperature 52-68°F

Average Effluent Temperature 54-72°F

Mixed Liquor Suspended Solids: Range = 1000-2000 mg/l,
Average = 1600 mg/l

Percent Removal 95% (NPDES Permit 85% minimum)

ATTACHMENT 1a

Table 1.1 Base Design Data

	Initial	Design
Year	1970	1990
Type of Treatment	Conventional activated sludge with provisions for step aeration	
Population served	10,000	35,000
Domestic sewerage		
Average flow, mgd		
Domestic	0.60	2.27
Infiltration	0.11	0.04
Commercial allowance @ 400 gcd	0.02	0.18
Industrial allowance @ 325 gcd	0.04	0.35
Total	0.77	3.22
Peak flow, mgd		
Domestic, commercial & industrial	1.91	6.72
Infiltration	0.11	0.42
Total	2.02	7.14
Per capita contributions		
Average flow, gcd	77	92
5-day BOD, lb./capita/day	0.16	0.20
Suspended solids, lb./capita/day	0.18	0.23
Characteristics, mg/l, average		
5-day BOD	249	261
Suspended solids	280	300
Industrial wastes		
* Herman Rosar & Sons Tannery, Inc.		
Flow, mgd		
Average (equalized 24 hr.)	0.12	0.12
Peak	0.24	0.24
5-day BOD, mg/l	905	905
Suspended solids, mg/l	855	855
* Glastonbury Dyeing & Finishing Co.		
Flow, mgd		
Average daytime rate (12 hr.)	0.30	0.30
Peak	0.75	0.75
5-day BOD, mg/l	270	270
Suspended solids, mg/l	50	50
Total flows, mgd		
Average		
Domestic	0.77	3.22
Rosar Tannery	0.12	0.12
Glastonbury Dyeing & Finishing Co.	0.30	0.30
TOTAL	1.19	3.64

*Both contributors no longer in service as of 1983.

ATTACHMENT 1b

Table 1.1 (Continued) Basic Design Data

	Initial	Design
Peak		
Domestic	2.02	7.14
Rosar Tannery	0.24	0.24
Glastonbury Dyeing & Finishing Co.	0.75	0.75
Total	3.01	8.13
* 5-Day BOD loadings, lb./day, average		
Domestic	1,600 (161 mg/l)	7,000 (231 mg/l)
Rosar Tannery	905 (91 mg/l)	905 (30 mg/l)
Glastonbury Dyeing & Finishing Co.	670 (68 mg/l)	670 (22 mg/l)
Total	3,175	8,575
* Suspended solids, lb./day, average		
Domestic	1,800 (181 mg/l)	8,050 (265 mg/l)
Rosar Tannery	855 (86 mg/l)	855 (28 mg/l)
Glastonbury Dyeing & Finishing Co.	125 (13 mg/l)	125 (4 mg/l)
Total	2,780	9,030
Composite waste characteristics, mg/l., Average		
5-day BOD	320	283
Suspended solids	281	298
Plant Components:		
Comminution equipment		
Number of units	1	1
Size, in.	25	25
Unit capacity, mgd	9	9
Emergency bypass rack - 36 in.	Manually cleaned	
Flow metering equipment		
Type	Parshall flume	
Size, in.	12	12
Capacity, mgd	10	10
Primary settling tanks		
No. of tanks	2	2
Diameter, ft.	65	65
Sidewall water depth, ft.	10	10
Bottom slope, in./ft.	1	1
Unit volume, cu. ft.	33,200	33,200
Total volume, cu. ft.	66,400	66,400
No. of tanks in service	1	2

* IN BOTH LBS./DAY AND MG/L - BASED ON INITIAL FLOW OF 1.19 MGD DESIGN OF 3.64 MGD.

ATTACHMENT 1c

Table 1.1 (Continued) Basic Design Data

	Initial	Design
Detention time, hr.		
At average flow	5.0	3.3
At instantaneous peak	2.0	1.5
Overflow rate gal./sq. ft./day		
At average flow	359	549
At instantaneous peak flow	907	1,226
Weir overflow rate gal./lin. ft./day		
At average flow	6,320	9,660
At instantaneous peak flow	16,000	21,560
Grit facilities	Cyclone-type separator	
Aeration tanks		
No. of tanks	2	2
Length, ft.	165	165
Width, ft.	40	40
Depth, ft.	15.0	15.0
No. of channels per tank	2	2
Channel width	20	20
Unit volume, cu. ft.	99,000	99,000
Total volume, cu. ft.	198,000	198,000
No. of tanks in service	1	2
Detention time, hr.		
At average flow (incl. 25% return sludge)	12.0	7.8
At maximum flow (incl. 55% return sludge)	4.1	3.0
MLSS concentration, mg/l	1,600	2,000
BOD to aeration tanks, lb./day average	2,384	6,420
F/M ratio, lb. BOD/lb. MLSS	0.24	0.26
BOD to volume ratio, lb./day/1,000 cu. ft.	24.0	32.4
Aeration equipment		
No. of blowers	3	3
Unit of capacity range, cfm	2,000-4,500	2,000-4,500
Air, cu. ft./lb. BOD applied	1,000	1,000
BOD applied, lb./day	2,380	6,420
Air required, million cu. ft./day	2.38	6.42
Air required, cfm	1,650	4,450
Air to aeration tanks, cfm (150%)	2,475	6,675
No. of blowers in service	1	2
Final settling tanks		
No. of tanks	2	2
Diameter, ft.	65	65
Sidewall water depth, ft.	12.1	12.1
Bottom slope, in./ft.	0.25	0.25
Unit volume, cu. ft.	40,200	40,200
Total volume, cu. ft.	80,400	80,400
No. of tanks in service	1	2

GLASTONBURY, CONN.
SEWAGE TREATMENT PLANT
SPECIFICATIONS
AIR DIFFUSION SYSTEM
JACKKNIFE SPARJER -HEADER DIFFUSER

Application ----------	Aeration
Tank Size ----------	8 @ 82'-6" x 20'-0" x 15'-6" A.W.D.
Type ----------	JK-DH

SPARJER-HEADER ASSEMBLIES

Arrangement ----------	Spiral roll aeration.
Sparjer-Header	
Number & Length ------	Thirty Two @ 19'-6" long.
Size & Material ------	3" steel pipe hot-dipped galvanized after fabrication with drilled holes as required for feeding Sparjer assemblies. All flange bolts and nuts for header connection and header end plates are type 302 stainless steel.
Sparjer	
Quantity ----------	20 per header, 640 total.
Arrangement ----------	Saddle-mounted from side of header with stainless steel U-bolts & Neoprene gasket.
Material ----------	Corrosive-resistant Delrin Sparjer, threaded into galv. M.I. tees & elbows. Sparjers to be assembled to headers in field
Air Rate ----------	Approx. 13.1 cfm per Sparjer, at 11" W.C. headloss.
JackKnife Assembly	
Pivot Joint ----------	Lubricated knee pivot joint near mid-point of riser consisting of galv. cast iron assembly fitted with bronze wearing rings and "O" ring seals for watertight connection. Lubricated pivot joint at top of riser consisting of a cast iron assembly containing bronze wearing rings, "O" ring seal and shut-off valve.
Risers ----------	4" steel hot-dipped galvanized after fabrication. Riser sections flange-connected to pivot assemblies.
Base Elbows ----------	Special galv. C.I. elbows set in concrete cop to support entire assembly, complete with mechanical joint inlet, flanged outlet and anchorage parts.

Air Main Connections Material ----------	Cast iron, double-X, mechanical joint connector in air main, with flanged, galvanized, steel cross manifold for connection to top pivot joint assembly.
Air Main ----------	Air main from blower to connections and between connections - NOT BY WPE.
Painting and Finishing -	See separate shop painting specs.
Anchorage ----------	Hot-dipped galvanized steel bolts.
Cathodic Protection ----	Thirty Two (32) magnesium anodes, Dow "Galvomag" type 32D5, attached to air risers.
Spare Parts ----------	Six (6) Sparjers.

MANUALLY-OPERATED HYDRAULIC HOIST

Application ----------	Hoisting JackKnife Sparjer-Headers.
Number of Units --------	One (1).

Each unit shall conform to the following specifications:

Type ----------	Hydraulic cylinder hoist with hand-operated pump.
Description ----------	Hand-operated hydraulic pump with built-in lever operated directional control valve. Hydraulic cylinder circuit includes combination flow control and check valve. Complete hoisting mechanism mounted on rugged welded steel frame and ball bearing swivel casters with composition wheels, soft rubber treads, and self-lubricating bearings.
Painting ----------	See separate shop painting specs.
Cover ----------	One (1) heavy weatherproof tarpaulin furnished to cover complete hoist for storage.

APPENDIX I-C

Manufacturer Data and Information
for Diffuser Retrofit

FMC

SECTION 7824.80
SERVICE INSTRUCTIONS
OCTOBER, 1977
PAGE 1

PEARLCOMB DIFFUSERS

Installation, Operating and Maintenance Instructions

DIFFUSER DESCRIPTION

The Pearlcomb Diffuser is a fine bubble diffuser which is available in two configurations, the Simplex and Duplex arrangements. The diffuser consists of a diffuser tube(s), threaded adapter, threaded rod, end cap(s), washers, and gaskets. See FMC Drawings K-6314 and K-6315. In some cases, the adapter will be fitted with a control orifice.

The diffuser tube consists of minute styrene copolymer spheres linked together to form a porous diffusion medium. The end cap and adapter are Cycolac. The operating characteristics of the Pearlcomb Diffuser are similar to ceramic diffusers, except that Pearlcomb Diffusers are light-weight, non-abrasive, and generally more durable.

For normal operation, the Pearlcomb Diffusers are rated for 8-12 cubic feet of standard free air per minute per diffuser tube.

When installed on aeration headers, the recommended maximum spacing between diffusers is 2'0", and the recommended minimum is 6". Pearlcomb Diffusers can be added to or removed from the headers to maintain the above recommended minimums and maximums.

DIFFUSER ASSEMBLY

The Pearlcomb Diffuser is shipped unassembled. Upon the arrival of the shipment, check the contents of the shipment for damages.

For the Simplex Diffuser, begin assembly by placing a washer and gasket, in that order, on the threaded adapter. Next, thread the rod into the adapter, using the end with the shorter threaded portion. Slip on the Pearlcomb Diffuser tube, centering it on the adapter. Holding the assembly in a vertical position, place a gasket on the diffuser tube, and then another washer. Thread on the end cap, being careful to center the gasket and washer as the cap is tightened down. Tighten the end cap firmly by hand, and complete the assembly by threading on the end nut, also hand tight.

NOTE: The proper order of assembly must be followed. The gaskets must always be placed against the diffuser tube to provide an air seal. The washers must be placed against the adapter and end cap to prevent the gaskets from gathering as the assembly is tightened.

For the Duplex Diffusers, begin assembly by placing the threaded rod through the adapter tee. Place one washer against each side of the tee, and then follow with a gasket on each side. Slip on a Pearlcomb Diffuser over each end, centering each on the tee over the washers and gaskets. Add a gasket on the end of each tube, and follow with a washer on each side. Thread on an end cap on each side, being careful to center the gaskets and washers as the caps are tightened down. Tighten the end caps firmly by hand, and complete the assembly by threading on the end nuts, also hand tight.

INSTALLATION OF DIFFUSERS

Before the diffusers are installed, the air system (piping, Swingfuser Aerators, air headers) must be thoroughly cleaned. For details on this procedure, see the Instructions for the Swingfuser Aerators. If dirt, dust, rust or pipe scale is left in the system prior to the installation of the diffusers, this debris will clog the diffusers after the operation is started.

Install the diffusers just prior to placing aeration tanks in service. Avoid exposing diffusers for long periods to sunlight and environmental elements. Mount the Pearlcomb Diffusers in the positions shown on the aeration header drawings. HAND TIGHTEN ONLY.

STARTING UP A NEW PLANT

To avoid the possibility of damaging the aeration equipment, it is better to first fill the aeration tank. If the Swingfuser Aerator headers are lowered in the tank prior to the tank filling operation, to avoid damage, make certain the liquid flow will not fall directly over the diffusers. If there is more than one tank, all tanks being placed in operation should be filled to the same level. The aeration headers should be carefully lowered into the liquid and the air should be introduced no sooner than after the diffusers are submerged at least three feet. From this point on, the air headers can be lowered at a much faster rate.

OPERATION OF THE PEARLCOMB DIFFUSER

In general, the fine bubble Pearlcomb Diffuser requires very little attention. Once the normal plant operation is started and the normal air rates are used, the simple daily recording of the blower discharge air pressures and a check of previously recorded discharge pressures will show if anything abnormal occurs. If the back pressure increases above the normal at the respective air rate, an inspection of the diffusers is recommended. Also, if a change in the normal circulation pattern of the aeration tank occurs, the diffusers should be inspected.

To inspect the diffusers, raise the Swingfuser Aerator from the tank. When the diffusers are raised to approximately 3 feet below the liquid surface, shut off the air and then complete the raising operation. (If the air is not controlled, the other aerators will not be supplied sufficient air and might not diffuse, and mixed liquor will enter the diffusers and air headers and cause additional problems.) After raising the air header, it is recommended that the headers and diffusers be washed with a spray of water from a hose to facilitate inspection. Remove and dispose of any rags or debris that may have become attached to the headers or diffusers. Inspect all diffusers and open the header end covers. If sludge or debris is found inside the header, use a combination of air and water to clean the header. If there is a damaged diffuser, it should be replaced. After completing the inspection and/or cleaning, return the air header to operation. Do not open the air valve until the diffusers are submerged at least 3 feet.

PEARLCOMB DIFFUSER MAINTENANCE

During routine operation, a gradual buildup in back pressure will be noted, which will eventually exceed the design pressure of the system. When this occurs, diffuser tube cleaning is required. Depending upon the degree of diffuser tube blinding, the diffuser can be cleaned in one of two ways. Cleaning with mild detergent can be performed when the deposits are relatively light. For heavy deposits, chemical cleaning provides the best results.

The recommended procedure for determining which method to use is to begin by cleaning one header of diffusers using the detergent. If this first batch is cleaned satisfactorily, then the remaining diffusers can be cleaned in the same manner. If cleaning with detergent does not thoroughly remove the deposits, chemical cleaning will be required.

A. Cleaning with Detergent

Working with one header at a time, raise the header from the tank and rinse the diffusers as previously described. Remove each Pearlcomb Diffuser from the header using a pipe wrench; being careful to place the wrench on the pipe nipple and not the Cycolac adapter.

Once the diffusers have been removed, each should be disassembled for inside and outside cleaning. Begin by removing the end nut(s) from the assembly; remove the end cap(s), gaskets, and washers. Note the order of assembly. Remove the Pearlcomb Diffuser tube from the adapter, using caution not to force the tube if the parts should stick together.

Soak the diffuser tubes for one-half hour in a solution of warm water and commercial grade detergent. Wash the inner and outer surfaces of the diffuser tube using a firm bristle brush to loosen

deposits. Rinse the tubes thoroughly with clean water. A convenient way to rinse the tubes is to place them in a barrel with fresh water flowing through it. The use of compressed air applied uniformly along the surface can aid in rinsing the tube by driving out all the water.

B. Cleaning with Chemicals

When heavy deposits cannot be removed with detergent, soaking and cleaning in an acid bath can usually provide excellent results. Experience with acid baths has indicated that the Pearlcomb Diffuser can regain up to 97% of its original efficiency when cleaned in this manner.

A rubber lined barrel or tank should be prepared, so that the diffuser tubes can be soaked in a vertical position. Rubber gloves, boots, safety glasses, and apron should be worn for protection against acid burns. Prepare the cleaning solution of sulfuric acid and potassium perchromate as follows:

1. Prepare 10%, by weight, aqueous potassium perchromate, $K_2Cr_2O_7$.
2. While stirring the aqueous potassium perchromate, add 1/4 or 1/5, by volume, concentrated H_2SO_4 gradually.
3. To avoid dangerous reactions, always add H_2SO_4 into aqueous potassium perchromate, not vice versa.

Immerse diffuser tubes for soaking, the duration of which will vary depending upon the degree of blinding. Twenty-four hours is usually sufficient for light deposits, and one to two weeks for heavy deposits. When fresh, the color of the mixture of sulfuric acid and potassium perchromate is red. If the color changes to dark green as a result of decomposition of deposits, prepare a new mixture.

If desired, the tubes can be scrubbed with a firm brush to loosen deposits. Rinse the tubes thoroughly in clean water, using the method previously described.

Reassemble the Pearlcomb Diffusers, being careful to place the gaskets against the diffuser tube to provide an air seal. If necessary, replace those gaskets and washers which are torn or cracked.

Install the Pearlcomb Diffusers on the header, and place the Swingfuser Aerator back in service using the above mentioned procedure.

LIST OF EQUIPMENT FURNISHED BY E.E.D.

(QTY.) GRADE SP_____ DUPLEX PEARLCOMB DIFFUSER ASSEMBLY(IES) EACH CONSISTING OF:

ONE (1) ADAPTER TEE

TWO (2) PEARLCOMB DIFFUSER TUBES

ONE (1) ROD (THREADED BOTH ENDS) WITH RETAINING NUTS

TWO (2) END CAPS

ONE (1) ITEM OF GASKETS AND WASHERS

NOTE:

UNIT MUST BE FIELD ASSEMBLED BY OTHERS

CHICAGO PUMP-PRODUCTS

SECTION 7824.7

INSTALLATION DWG NO K-6315

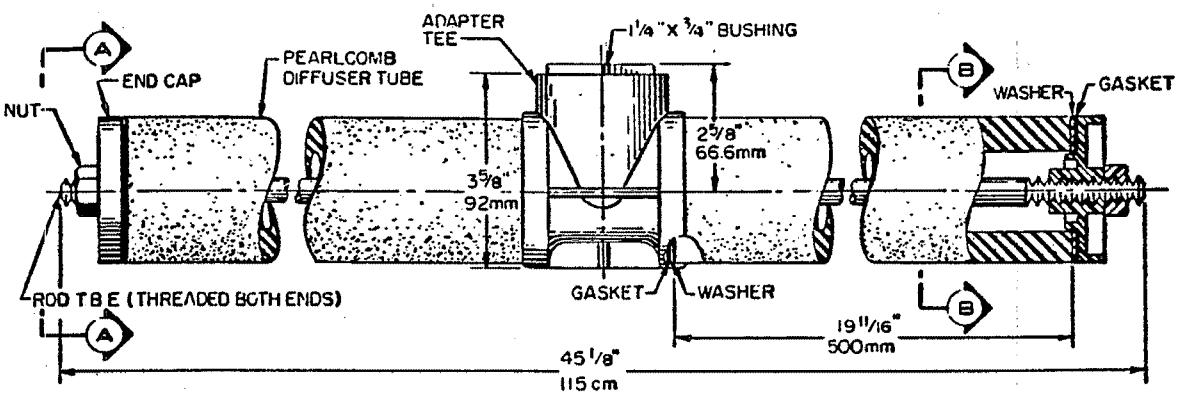
SHEET 1 OF 1 SHEETS

DUPLEX PEARLCOMB® DIFFUSER ASSEMBLY

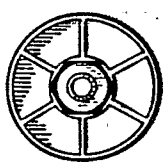
FMC CORPORATION
ENVIRONMENTAL EQUIPMENT DIVISION

E.E.D. ORDER NUMBER

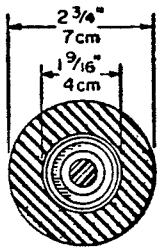
ISSUE	REVISION	DATE



SIDE VIEW



VIEW A-A



SECTION B-B

DWG NO K-6315	ISSUE	A	CHKD
DRN BY M.K.	DATE	2-73	E.J.M.G.G.

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LIST OF EQUIPMENT FURNISHED BY E.E.D.

(QTY 1) GRADE SP____SIMPLEX PEARLCOMB DIFFUSER ASSEMBLY (IES) EACH CONSISTING OF:

ONE (1) ADAPTER WITH____INCH CONTROL ORIFICE

ONE (1) PEARLCOMB DIFFUSER TUBE

ONE (1) ROD (THREADED BOTH ENDS) WITH RETAINING NUT

ONE (1) END CAP

ONE (1) ITEM OF GASKETS AND WASHERS

ORIFICE SIZE					
	11/32"	13/32"	15/32"	17/32"	NONE
✓					

NOTE:

UNIT MUST BE FIELD ASSEMBLED BY OTHERS

CHICAGO PUMP-PRODUCTS

SECTION 7824.7

INSTALLATION DWG NO K-6314

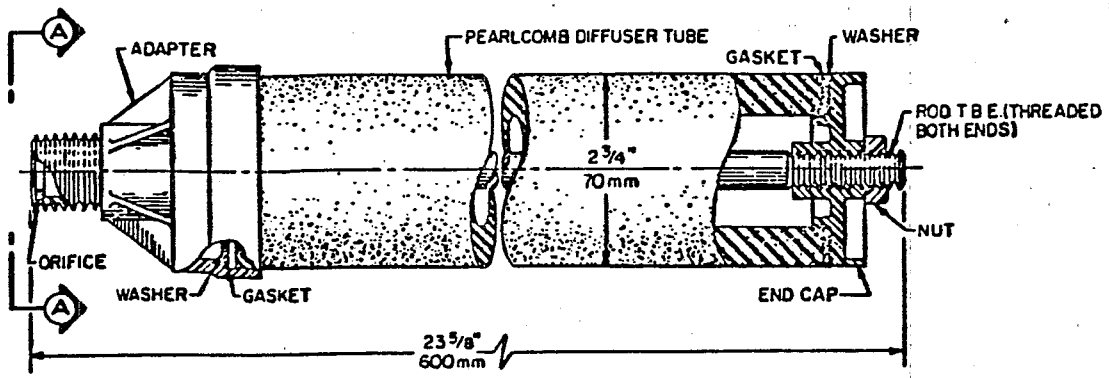
SHEET 1 OF 1 SHEETS

SIMPLEX PEARLCOMB™ DIFFUSER ASSEMBLY

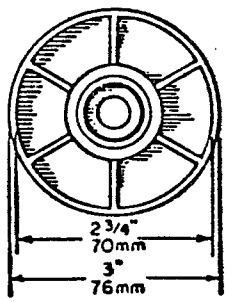
FMC Environmental Equipment Division

E.E.D ORDER NUMBER

ISSUE	REVISION	DATE



SIDE VIEW



VIEW A-A

DWG NO K-6314	ISSUE	4	CHKD	B	CHKD
DRN BY M.K.	DATE	2-73	EJM GCG	10-77	WMP EJM

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SECTION
7824.4

PEARLCOMB®
DIFFUSER

engineering data sheet

APPLICATION DATA

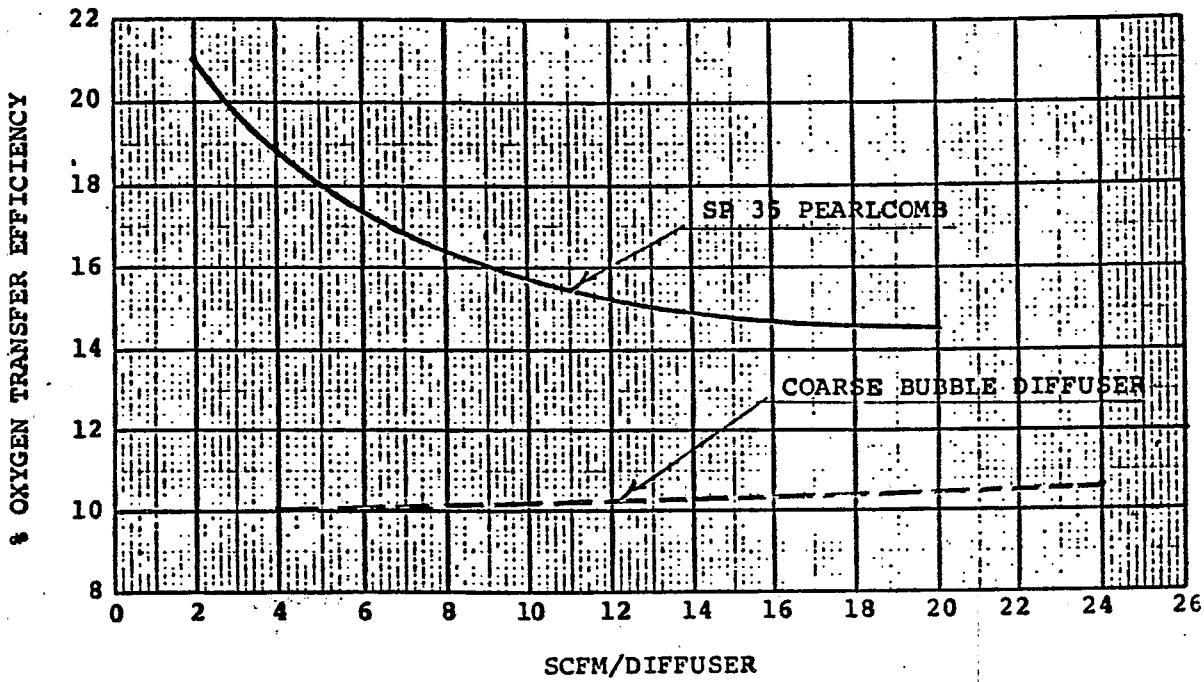
TRANSFER EFFICIENCY COMPARISON

PEARLCOMB® SP35

FINE BUBBLE DIFFUSER

VS

COARSE BUBBLE DIFFUSER



Note:

Typical curve for clear water.
Zero dissolved oxygen concentration.
15 ft. water depth by 15 ft. wide tank.
13 ft. submergence.
Wide band, one side.

engineering data sheet

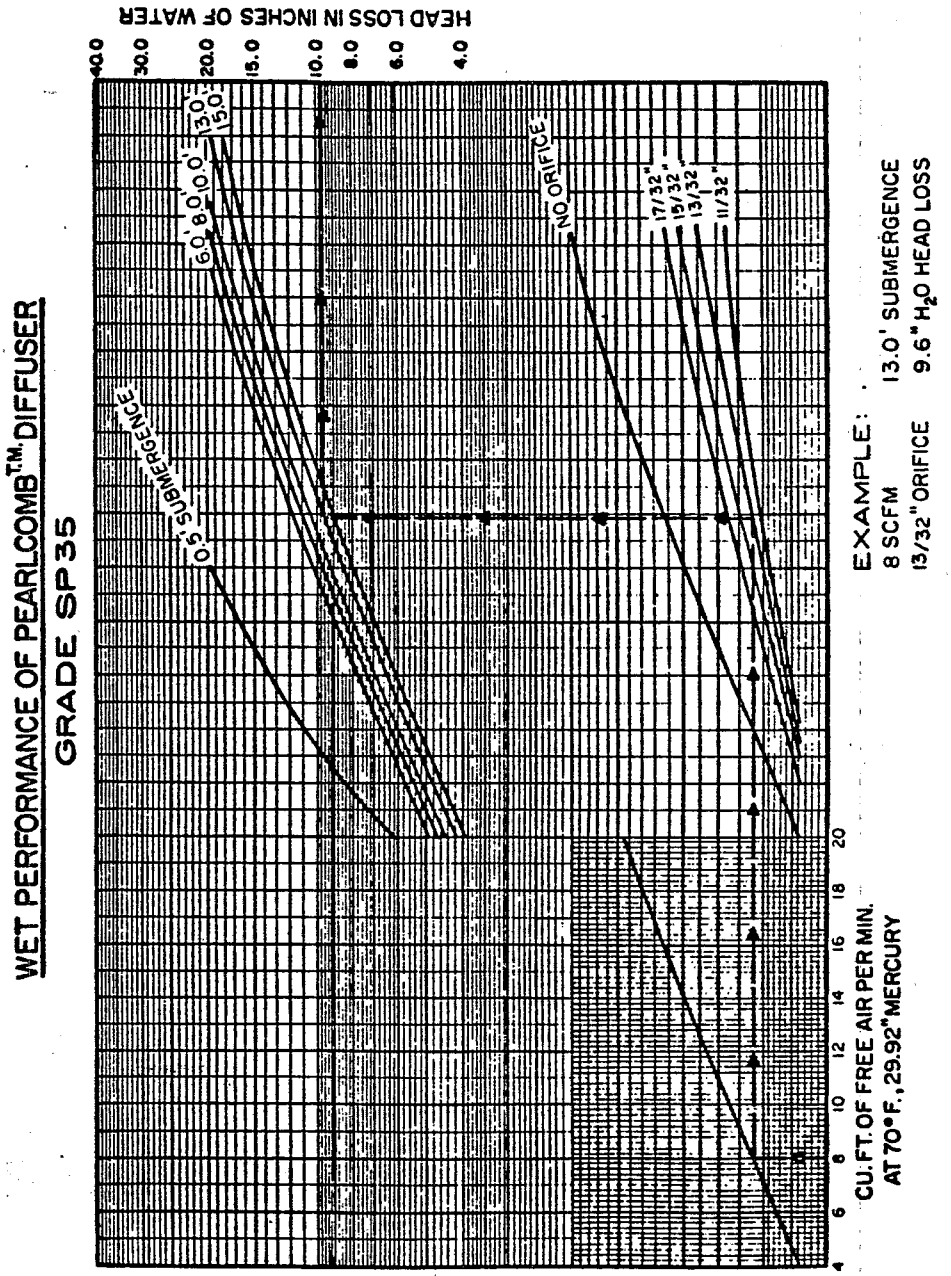
CHICAGO PUMP PRODUCTS

SECTION 7824.4

JULY, 1973 K-6318

PEARLCOMB™
SIMPLEX DIFFUSER
GRADE SP35

SIMPLEX ASSEMBLY HEAD LOSS CURVES



WET PERFORMANCE OF PEARLCOMB™ DIFFUSER GRADE SP35

EXAMPLE:
8 SCFM 13.0' SUBMERGENCE
13/32" ORIFICE 9.6" H_2O HEAD LOSS

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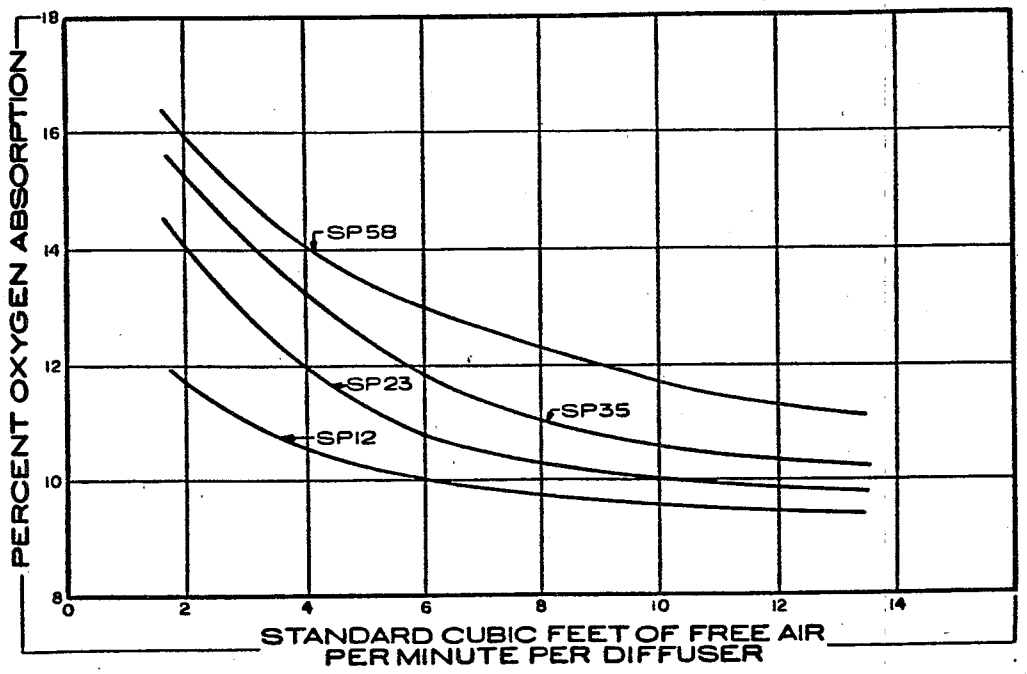
engineering data sheet

APPLICATION DATA

SECTION 7824.4

PEARLCOMB® DIFFUSER

PEARLCOMB®
DIFFUSER TUBE
WIDE BAND DIFFUSER EFFICIENCY



NOTE:

FOR TUBES 70 mm O.D. x 40 mm I.D. x 500 mm L.G.
TEST RUN IN 10,000 GAL. TANK AT P.F. MORGAN SANITARY ENGINEERING LABORATORY, UNIVERSITY OF IOWA, IOWA CITY, IOWA.
10-23 TO 10-24-70.
6 TUBES OF EACH GRADE MOUNTED ON HEADER IN WIDE BAND
TUBE SUBMERGENCE 12'-6"

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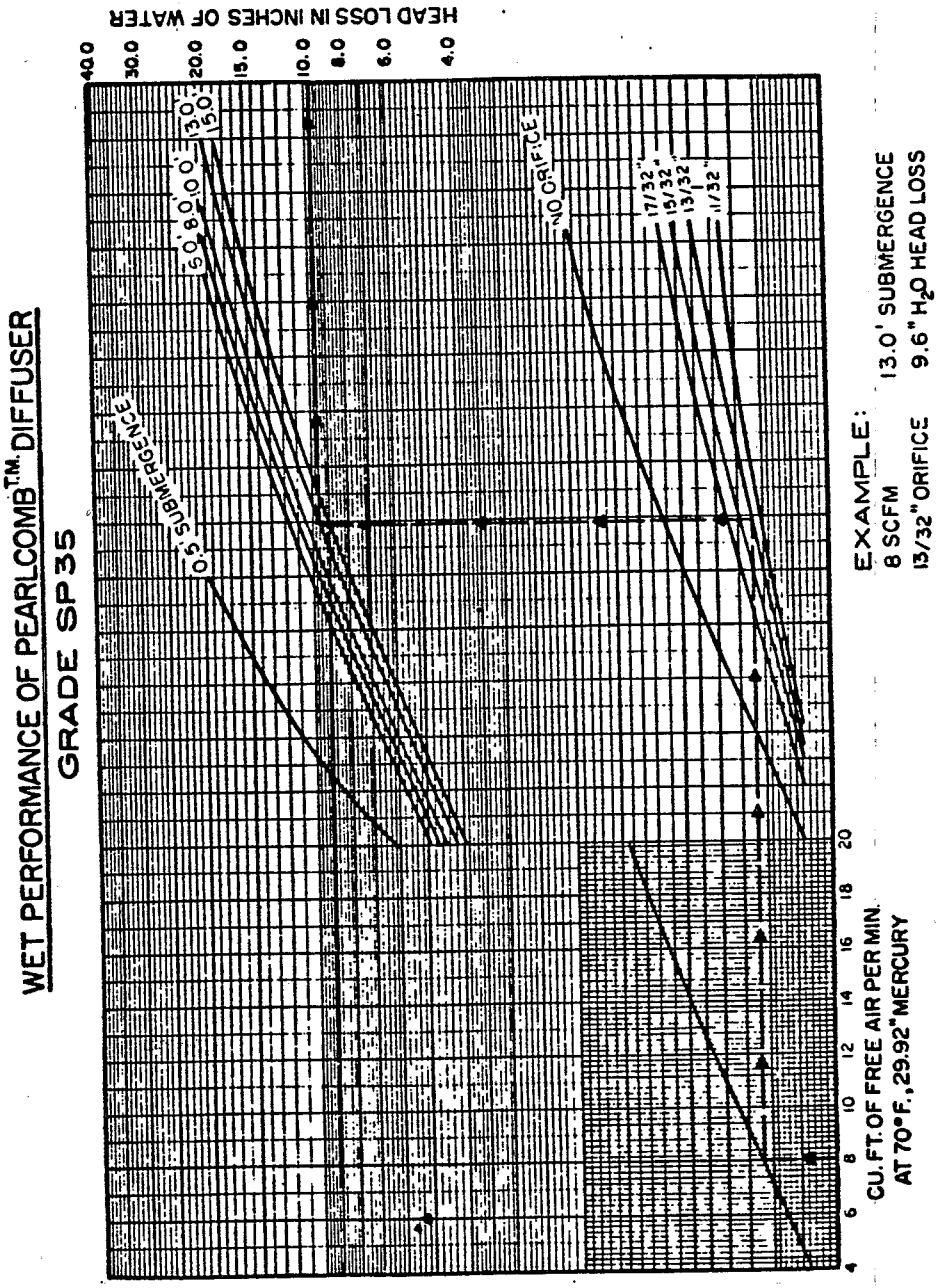
engineering data sheet

SECTION 7824.4

JULY, 1973 K-6318

PEARLCOMB™
SIMPLEX DIFFUSER
GRADE SP35

SIMPLEX ASSEMBLY HEAD LOSS CURVES



WET PERFORMANCE OF PEARLCOMB™ DIFFUSER GRADE SP35

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