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Oxygen Aeration at Newtown Creek

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Oxygen Aeration at Newtown Creek

New York City Environmental Protection Administration

Prepared for

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OXYGEN AERATION AT NEWTOWN CREEK

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FOREWORD

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

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

As part of these activities, a project was undertaken in New York City in mid-1970 to construct and demonstrate a large-scale municipal oxygen activated sludge system as a follow-up to successful feasibility studies completed several months earlier at Batavia, New York. The information documented in this report from that project should be carefully evaluated by design engineers and municipal officials responsible for wastewater treatment process selection.

Francis T. Mayo, Director
Municipal Environmental Research
Laboratory

ABSTRACT

A successful initial feasibility investigation of oxygen aeration at the 0.11-m^3/sec (2.5-mgd) municipal wastewater treatment plant in Batavia, New York, prompted a larger demonstration at New York City's 13.6-m^3/sec (310-mgd) Newtown Creek Plant. The U.S. Environmental Protection Agency desired to further evaluate oxygen aeration on a scale sufficiently large to establish reliable engineering design and cost data, and the City saw the process as a possibility for upgrading the plant's modified aeration process to step aeration efficiency. A 34-mo evaluation was performed in a self-contained set of plant tanks using a 13.6-metric ton/day (15-ton/day) oxygen generator with liquid oxygen backup for oxygen supply and turbine mixers and spargers for oxygen dissolution. For the 34-mo period, at influent flows of 0.44 to 1.53 m^3/sec (10 to 35 mgd), effluent quality averaged 19 mg/l each of BOD and suspended solids (SS) for removal efficiencies of 88 and 86 percent, respectively. Removals were not impaired by intentional hydraulic and BOD overloading of the oxygenation system. During the winter months, a fungus in the influent sewage caused the oxygenation system biomass to become filamentous, resulting in a deterioration of sludge settling and thickening characteristics to varying degrees over the three winters of the testing program. While operating difficulties occurred, this condition had no significant effect on the plant effluent quality. Power and oxygen requirements and sludge production data are presented, and sludge volumes are compared with those of the Newtown Creek diffused air plant and with two New York City step aeration plants.

This report was submitted in fulfillment of Grant No. S802714 by the New York City Environmental Protection Administration, Department of Water Resources, under the partial sponsorship of the U.S. Environmental Protection Agency. This report covers the operating period of May 14, 1972, to March 11, 1975. Also contained in this report in Appendix B is a description and discussion of the current proposal by Union Carbide Corporation for conversion of the Newtown Creek plant to an oxygen system.

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The authors wish to thank Quentin P. Monahan, Superintendent of the Newtown Creek plant, Jerome Degen, Senior Chemist in charge of the Industrial Wastes Control Laboratory at Newtown Creek, and their capable staffs for their invaluable contributions to this project.

Stephen Y. Arella, Assistant Civil Engineer assisted in field supervision and data reduction; Hank Innerfeld, Principal Engineering Technician, and Angelika Forndran, Assistant Civil Engineer, performed some tabulation and reduction of the data.

SECTION 1

INTRODUCTION AND SCOPE OF PROJECT

Plant-scale feasibility studies in 1969 and 1970 at the 0.11-m^3/sec (2.5-mgd) activated sludge plant in Batavia, New York, indicated that significant improvement of the process could be achieved by the use of pure oxygen instead of diffused air, and that considerable capital and operating savings were possible if oxygen was used in the upgrading of existing plants (1). To the City of New York, this offered a means of upgrading its Newtown Creek Water Pollution Control Plant, which was designed to treat 13.6 m^3/sec (310 mgd) by modified aeration from a population of 2.5 million in the boroughs of Manhattan, Brooklyn, and Queens. The plant began operation in September 1967, but with only the flow from Brooklyn and Queens; delays in the construction of a pumping station prevented the delivery of the estimated 7.4-m^3/sec (170-mgd) Manhattan flow through a force main under the East River. During the 34 mo of operation described in this report, the flow to the plant, including that to the oxygen aeration segment, averaged only 7.5 m^3/sec (171 mgd).

The Newtown Creek plant consists of 16 treatment modules 16.8 m (55 ft) wide and 190.5 m (625 ft) long, with flow-through transverse baffles dividing each tank into a pair of aerated grit chambers, an aeration tank, and a settling tank, but with no primary settling tanks (Figure 1). After screening, the raw sewage is pumped and divides north and south to enter channels leading to two sets of eight modules. From this point on, each module is hydraulically separate from the others, except that the return sludge from each battery of eight tanks is combined and returned to the same battery.

For its first 3 yr of service, the plant was operated at a sludge age* averaging 0.35 day, but removals were only 37 percent for BOD and 50 percent for SS, considerably below the respective 60 and 70 percent design levels. In January 1971, the City, upon the recommendation of consulting engineers who had prepared a report on the upgrading of some of the plant's facilities, decided to venture into the usually hazardous sludge age range between 0.7 day and 3.5 days. The results were surprising: by the use of four of the seven engine-generators and five of the

*Defined as kg mixed liquor suspended solids (MLSS) in aeration tank/kg SS in aeration tank influent/day.

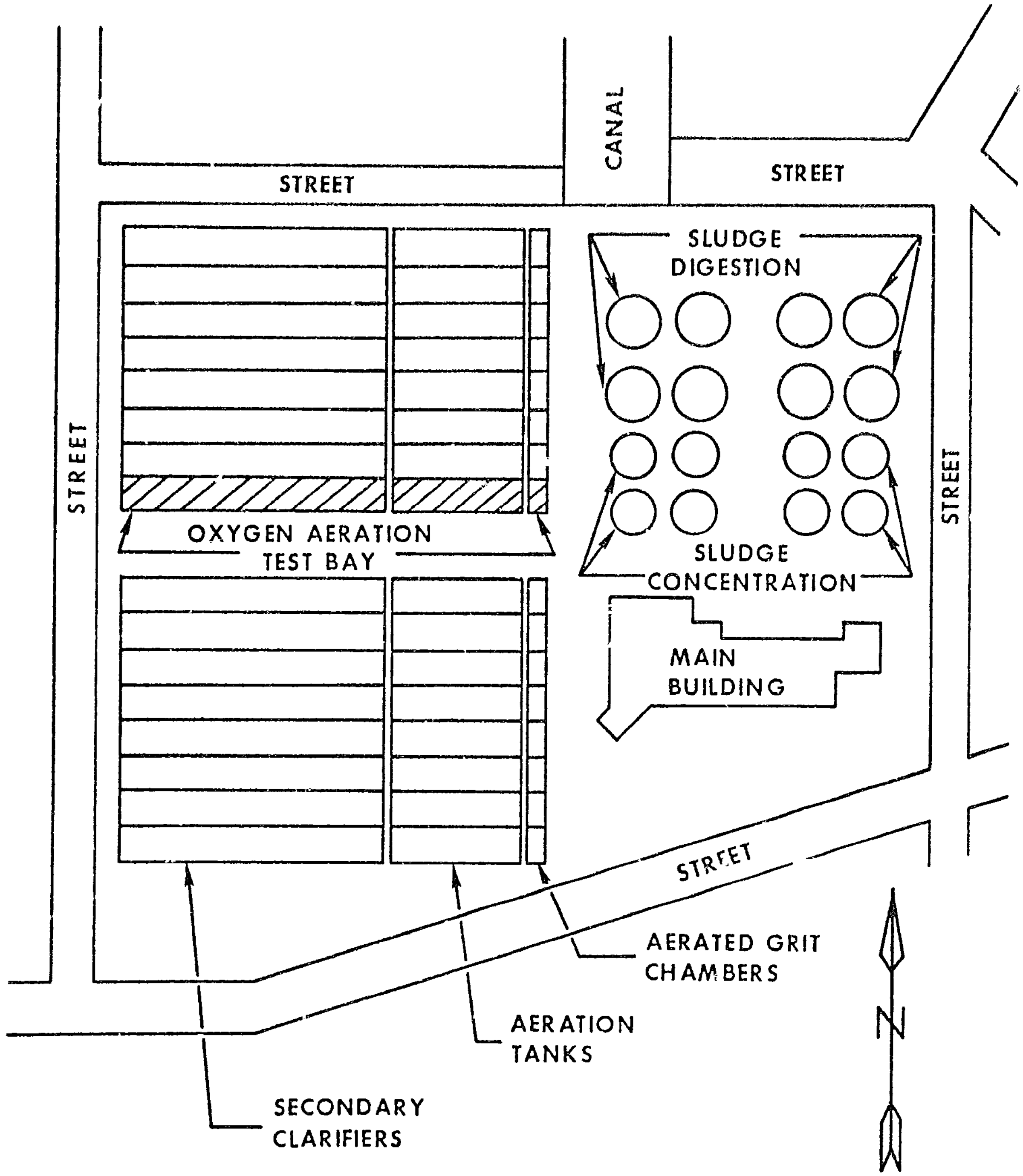

Figure 1. Plant layout.

six blowers, by supplying an air to influent wastewater ratio of 9.0 m^3/m^3 (1.2 ft^3/gal), and by maintaining mixed liquor suspended solids (MLSS) concentrations at 1800 mg/l (equivalent to a sludge age of 1.0 day), efficiencies were greatly increased to average BOD and SS removals of 81 and 74 percent, respectively. However, this could only be viewed as a temporary success; the inevitable arrival of 7.4 m^3/sec (170 mgd) of additional sewage from Manhattan would double the flow, halve the aeration time, double the final tank overflow rate, and make it impossible to maintain the higher air to influent wastewater ratio and sludge age. Some method of improving the plant's efficiency was necessary, and conversion to oxygen aeration offered a potential solution. Therefore, in June 1970, the City applied for Federal support for a 0.88-m^3/sec (20-mgd) test of the UNOX system*.

The unique layout of the plant was helpful. One module could be isolated from the rest of the plant by the installation of its own influent pumps and its own return sludge pump. Two 0.88-m^3/sec (20-mgd) pumps were provided, one constant-speed and one variable from 0.44 to 0.88 m^3/sec (10 to 20 mgd) to take suction from the grit chamber, along with a 0.66-m^3/sec (15-mgd) variable-speed, return sludge pump to recycle settled sludge to the head of the aeration tank. Thus, the oxygen activated sludge system would be a separate plant within the Newtown Creek plant. Provisions were made for the measurement of all important physical and chemical characteristics by an elaborate array of instrumentation. Alum storage and feeding equipment# was installed for a test of phosphorus removal. The initially budgeted cost of the project was $2,796,465, of which the Federal government provided $1,574,625 and the City $1,221,840. Additional overrun costs of approximately $900,000 were shared by the City and Union Carbide.

The program was designed to answer these questions:

1. Would the use of oxygen enable Newtown Creek to increase its BOD and SS removals to those of conventional activated sludge within the existing tank volume?

2. Would the plant's secondary clarifier design overflow rate of 35.9 $m^3/day/m^2$ (880 gpd/ft^2) be adequate? (As a precaution, the adjoining Module 10 was kept out of service to be used for additional settling capacity if necessary.)

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*A proprietary oxygen aeration system of the Union Carbide Corporation.

#This equipment was never used because a detergent phosphate ban implemented by the State of New York reduced influent phosphorus at Newtown Creek to a level consistently below 3 mg/l.

3. Were the claims of lower sludge production and lower power requirements for oxygeneration** valid?

4. Could mixed liquor dissolved oxygen (DO) concentrations of 8-10 mg/l be obtained without economic penalty?

5. Could mixed liquor volatile suspended solids (MLVSS) concentrations of 4500 mg/l or greater be maintained?

6. Would the activated sludge concentrate to 3 percent total solids or more in the sedimentation tank and permit low sludge return rates?

**Oxygenation and oxygen aeration are used interchangeably in this report.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

During the nearly 3-yr operating period of this project, some problems were encountered which have made it difficult to draw the type of broad conclusions that investigators hope for. These problems included failure of the single return sludge pump during two of the three winters, which required shutdowns and restarts of the process at low wastewater temperatures; the presence in the Newtown Creek influent of a fungal organism which proliferated in both the air and oxygen aeration tanks; lower removal efficiencies following the two cold-weather startups, but satisfactory removals during the third uninterrupted winter despite the continued presence of the fungi; a wide variety of loading rates; and a number of mechanical, electrical, and instrumentation problems. Therefore, the data have been separated into several groups with different operating conditions and are discussed in the light of those conditions.

1. Over the life of the project, BOD and SS removal efficiencies were 88 and 86 percent, respectively. The effluent averaged 19 mg/l for both BOD and SS.

2. During one phase of the test when the fungi were not present (hereafter "non-filamentous"), and the flow was at the design point of 0.88 m^3/sec (20 mgd) (uniform rate, not diurnal), effluent quality averaged 9 mg/l of BOD and 12 mg/l of SS, for removals of 94 and 92 percent, respectively.

3. During two non-filmamentous phases at 0.88-m^3/sec (20-mgd) diurnal flows, effluent quality averaged 21 and 22 mg/l of BOD and SS, for removals of 87 and 86 percent, respectively.

4. During non-filamentous phases at volumetric aerator loadings of 4.95 to 5.64 kg BOD/day/m^3 (309 to 352 lb/day/1000 ft^3) and overflow rates of 47.3 to 65.6 m^3/day/m^2 (1160 to 1610 gpd/ft^2), the effluent BOD ranged from 21 to 24 mg/l and the effluent SS from 17 to 26 mg/l, representing average removals of 90 and 85 percent, respectively. These removals were obtained at BOD loading rates of 123 to 140 percent of design and influent flows of 128 to 177 percent of design.

5. Slightly less successful efficiencies were obtained during three phases, totaling nearly 6 mo, each following a shutdown of the process and at low sewage temperatures. Effluent quality

averaged 21 mg/l of BOD and 22 mg/l of SS, for removals of 86 and 84 percent, respectively. Operation during these three low-temperature process startup periods was characterized by the presence of the influent fungi which caused varying degrees of difficulty with sludge settling and wasting and with maintenance of the desired MLSS concentration. However, effluent quality was not significantly affected.

6. Removals during a fourth low-temperature phase extending over 3 mo averaged 87 percent for both BOD and SS, with effluent concentrations of 18 mg/l of BOD and 13 mg/l of SS, at the design diurnal flow of 0.88 m^3/sec (20 mgd). The fungi were present in the influent, as they were during the preceding two winters, but their concentration in the mixed liquor did not appear to be as great. Fungi concentrations were determined numerically during this last period, but were only visually estimated during other phases.

This was the only winter operation that was not halted by a failure of the return sludge pump. There is reason to believe, therefore, that the lower efficiencies and larger volumes of excess sludge during the first two winter periods were caused by the combination of startups of the process at low sewage temperatures and the presence of the influent fungi.

7. Excess solids production on a total suspended solids (TSS) basis during non-filamentous periods averaged 0.93 kg/kg BOD removed, and 1.27 kg/kg BOD removed during filamentous periods. For the Newtown Creek modified aeration plant at comparable sludge ages, the averages were 1.27 and 1.71 kg TSS/kg BOD removed, 37 and 35 percent greater, respectively.

Compared to the 1 available yr of data from the Jamaica step aeration plant, oxygen produced 20 percent less solids during non-filamentous periods, but 9 percent more during filamentous periods, at sludge ages about one-third of those under step aeration. Compared to the first 17 mo of operation of the recently-upgraded 26th Ward step aeration plant, oxygen produced 33 percent less solids during non-filamentous periods and 9 percent less during filamentous periods, at half the sludge age. However, it must be noted that these plants were operated at significantly lower loading rates and on much weaker wastewaters than the Newtown Creek plant.

8. During the three periods of above design BOD loading rates, when the equipment was fully stressed, oxygen system power requirements averaged 0.95 kWh/kg BOD removed (0.58 hp-hr/lb). For the single year at the Jamaica plant, the range was 1.21 to 1.96 kWh/kg BOD removed (0.74 to 1.19 hp-hr/lb). In addition, the first 17 mo of operation at the recently upgraded 26th Ward step aeration plant produced a range of 0.71 to 1.05 kWh/kg BOD removed (0.43 to 0.64 hp-hr/lb). Caution should be exercised in

directly comparing these numbers since the wastewater characteristics and plant loadings were different for these two facilities relative to Newtown Creek.

9. At or above the design flow of 20 mgd, oxygen supply averaged 1.0 kg/kg BOD removed. At flows below design, oxygen supply ranged from 1.2 to 1.6 kg/kg BOD removed.

10. The fungal organisms which affected cold weather operation entered the plant in the influent sewage and concentrated in the mixed liquor. The Newtown Creek air plant, in which the organisms were also present, was less seriously affected during the first two winters, but more seriously in the third.

11. Foam (probably of Nocardia origin) twice developed in the aeration tank, and once required a halt to the oxygen feed. Some means of suppressing or removing foam should be provided.

SECTION 3

SYSTEM DESCRIPTION

An oxygen aeration system is a high-rate activated sludge process which employs oxygen instead of air for the biological removal of organic pollutants from wastewater. In any system, the rate of oxygen transfer is directly proportional to the concentration of oxygen in the aerating gas; thus, pure oxygen should support a more concentrated biomass by making more oxygen available. Because higher MLSS concentrations imply higher concentrations of microorganisms, reduced detention times and, thus, smaller aerator volumes are claimed to result for a given level of organic removal.

DESIGN FOR NEWTOWN CREEK

Tank No. 9 (Figure 1) was selected for the demonstration because its location adjacent to a wide plant road allowed room for the installation of the oxygen generator, liquid backup tank, and the control building. The existing aerator piping and diffusers were removed, and three full-width, reinforced-concrete baffle walls and a lightweight, precast-concrete, gas-tight cover were installed. A 0.9-m (3-ft) gas space was obtained between the mixed liquor surface and the cover, and separate openings in the walls permitted the flow of mixed liquor and gas from one stage to the next. Thus, four co-current gas and liquid stages were created, each 15.2 m long x 16.8 m wide x 5.5 m high (50 ft x 55 ft x 18 ft) with a 4.6-m (15-ft) side water depth (SWD) and a total liquid volume of 75,700 m^3 (1.23 mil gal). The equipment was designed for an average flow of 0.88 m^3/sec (20 mgd) at an influent strength of 250 mg/l of BOD.

A system of reinforced concrete beams and girders was installed to support the mixers, and additional columns were installed in the tank to transmit the static and dynamic loads to the existing foundation. The cover was designed to sustain an internal positive pressure of 15.2 cm (6 in) of water and an external negative pressure of 10.2 cm (4 in), and to support a live load of 488 kgf/m^2 (100 lb/ft^2). The cover was free to expand and contract with changes in temperature.

The primary oxygen supply for the UNOX system was a Union Carbide pressure swing adsorption (PSA) air separation facility which was designed to produce 473 std m^3/hr (16,700 scfh) of gas containing 425 std m^3/hr (15,000 scfh) of pure oxygen. The unit consisted essentially of an air compressor, aftercooler and attendant cooling tower, adsorption beds and valve skid, and automatic flow controls. The PSA unit was backed up by a liquid oxygen storage tank with an electric water bath vaporizer capable of supplying up to 510 std m^3/hr (18,000 scfh) of pure oxygen. Flow from the liquid oxygen storage tank was automatically controlled by the pressure in the line, which fell when either the PSA was not supplying oxygen or when the system called for more oxygen than the PSA could supply. Evaporation losses from the liquid oxygen storage tank were recovered by piping gaseous oxygen which escaped from the tank into the oxygen feed line.

Each stage contained two mixer-spargers suspended from the cover for oxygen dissolution. A total of five compressors were provided at the side of the tank, two for the first stage and one each for the second, third, and fourth stages, to recirculate the gas. The compressed gas was pumped through the hollow rotating shafts of the mixers and sparged into the liquid from the bottom of the shafts. Three-bladed, 1.8-m (6-ft) diameter, marine propellers attached to each shaft dispersed the oxygenated wastewater and kept the solids in suspension. The mixers were equipped with automatic controls for shutdown if the oil level was too low, the vibration too extreme, or the seal air pressure too low.

Degritted influent sewage entered Stage 1 of the tank from the grit chambers, which acted as a well for the two 112-kw (150-hp) influent pumps. A magnetic flow meter monitored the influent flow, which was recorded and totalized.

The oxygen feed to Stage 1 was controlled by the pressure in the stage gas space; if the pressure dropped below a pre-set limit, an automatic valve opened further to admit more oxygen. This flow was monitored by a temperature-compensated orifice meter and recorded and totalized. The gas in Stage 1 passed first through a trap to remove particulate matter and then into a 18.4-std m^3/hr (650-scfm) recirculation compressor. Two compressors were provided for Stage 1; either or both could be used if required. The recirculation systems for the second and succeeding stages were the same as for Stage 1, except that manual adjustment of a bypass valve controlled the recirculation rate in these stages. The gas leaving the fourth and final stage was analyzed for oxygen content and metered.

In anticipation of denser sludge, the final clarifier sludge collector drive was modified to increase its speed to 1.65 m/min (5.4 ft/min) [before the alteration, two-speed operation was possible, 0.61 m/min (2.0 ft/min) and 0.91 m/min (3.0 ft/min)]. Later, to decrease wear on the mechanism, the speed was reduced to 1.34 m/min (4.4 ft/min), the minimum possible after the modification.

A 0.66-m^3/sec (15-mgd), variable-speed, return sludge pump and a 1.14-m^3/min (300-gpm) waste sludge pump were provided, along with magnetic flow meters and recording and totalizing equipment.

Section and plan views of the Newtown Creek oxygen test bay, including both reactor and secondary clarifier, are shown in Figure 2. A perspective illustration of the oxygenation equipment and oxygen reactor are presented in Figure 3. The reactor deck and turbine-sparger drives are shown photographically in Figure 4.

CONTROL SYSTEM

Safety

Sensing devices were installed in Stages 1 and 4 to monitor the concentration of volatile hydrocarbon gases in the reactor gas space. In the event of a hydrocarbon entering the reactor with the influent wastewater and reaching a concentration in the gas space of 25 percent of the lower explosive limit (LEL) of hexane, an alarm would sound and automatically halt the feed oxygen flow. The PSA compressor would then supply purge air at a rate to completely renew the reactor gas space within 15 min. If the gas space hydrocarbon concentration continued to rise, another alarm would sound at 50 percent LEL and the recirculation compressors would be shut down to eliminate them as a potential ignition source. After any hydrocarbon alarm situations, the equipment could be returned to operation only manually and only after the hydrocarbon level decreased to below the 25 percent LEL concentration.

Oxygen Feed

Oxygen feed flow to the system was automatically controlled by the gas pressure in the first stage. If the organic load increased, the oxygen uptake rate rose, the pressure in the gas space decreased, and a pressure-regulating device compensated to allow increased oxygen feed. If the PSA could not supply enough oxygen to maintain system pressure, liquid oxygen was automatically vaporized and added. If the organic loading decreased, the oxygen uptake rate would fall and the system pressure would rise, causing suction throttling of the PSA compressor and a reduced flow of oxygen to the system.

Oxygen Vent

As the organic loading to the system changed, the fourth stage vent gas purity changed and adjustments had to be made to return the purity to the desired level. An increased organic loading caused the vent gas purity to decrease, and a decreased loading caused the purity to increase. Adjustments to the vent

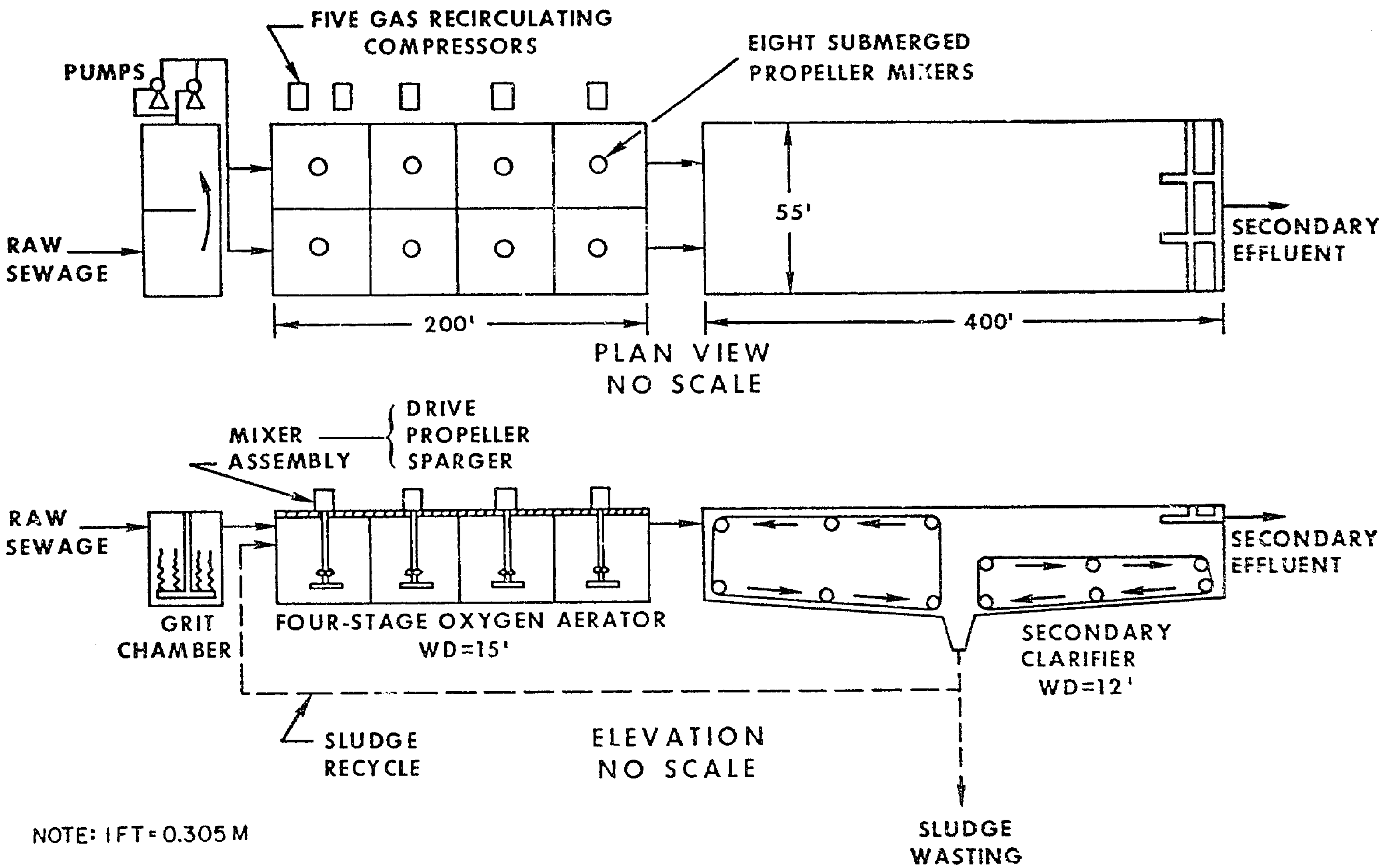

Figure 2. Plan and evaluation views of oxygen test bay.

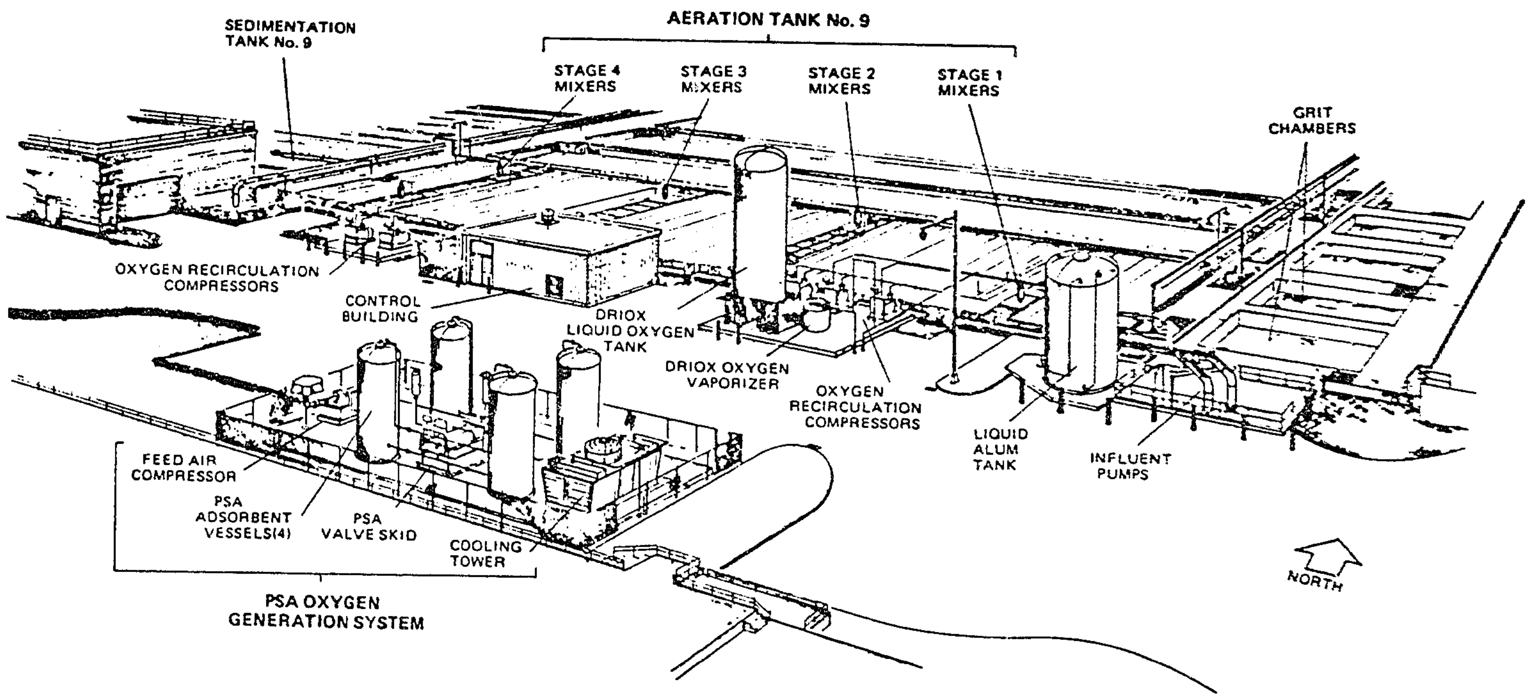

Figure 3. Perspective illustration of oxygenation equipment.

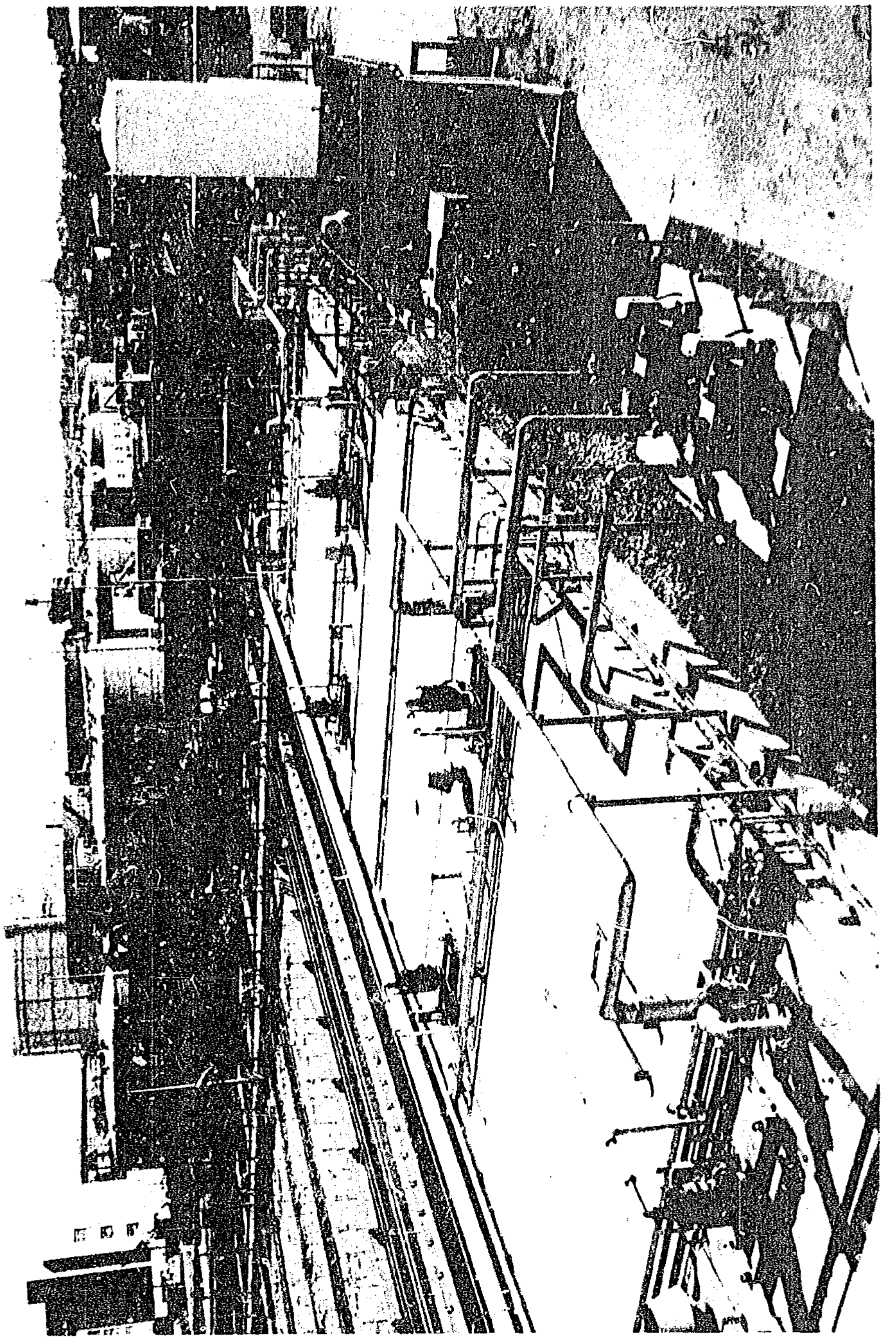

Figure 4. Photograph of oxygen reactor deck.

gas purity were accomplished by controlling the flow rate through the vent valve. If the purity fell below the desired level, the vent flow was manually increased; if the purity rose above the desired level, the vent flow was manually decreased. The entire oxygen system gas flow and control network is diagrammed in Figure 5.

Liquid Flows

The influent sewage flow rate was automatically maintained at an operator-selected level. An automatic flow variation pattern could be achieved by the use of a programmer to simulate the diurnal flow variations of the existing air activated sludge plant. The return sludge flow rate could be set at a constant rate or at a pre-set fraction of the influent flow, and the waste sludge flow rate was manually controlled using a variable-speed pump.

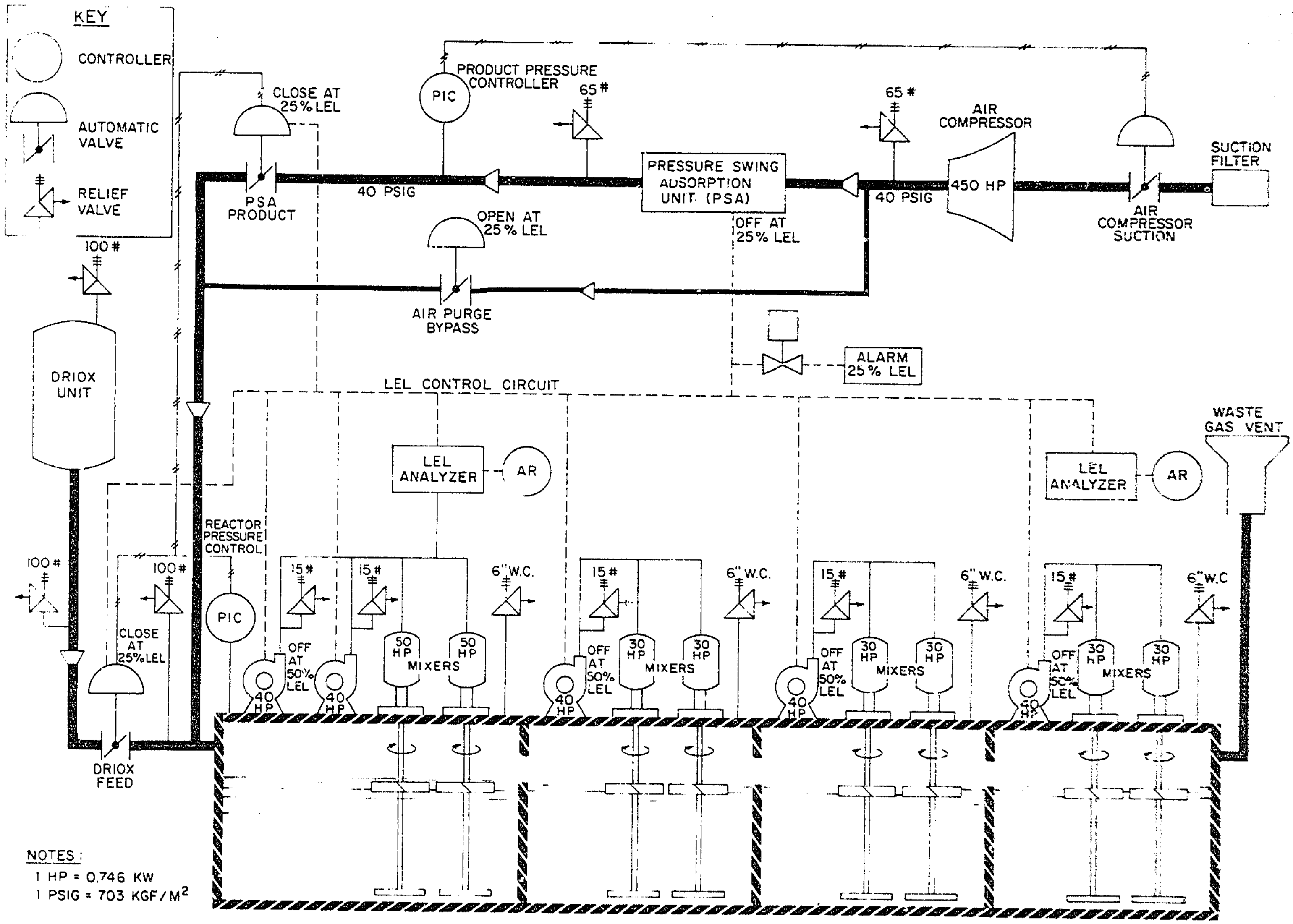

Figure 5. Oxygen system gas flow and control diagram.

SECTION 4

ANALYTICAL METHODS

BOD

Total and filtrate BOD analyses, in two dilutions, were performed daily on influent and effluent samples. Samples for filtrate BOD were filtered through Whatman No. 1 paper. Beginning in January 1973, dissolved oxygen readings for BOD were taken with a DO meter and probe (Weston and Stack Model 300 meter with Model 3A probe, and Model 350 meter with Model 33 probe) instead of the Winkler titration method previously used. Winkler titrations were used to calibrate the meter daily. DO readings by meter saved time and proved to be reliable.

The procedures outlined in Standard Methods for the Examination of Water and Wastewater (2) were used, except in the determinations of initial DO levels of the sample dilutions, which were done according to the practice of the New York City Department of Water Resources as described in the following paragraph.

DO measurements of the dilution water were taken on the day the dilutions were prepared. The post-incubation DO levels of the seed controls (5 and 10 percent seed incubated for 5 days) were applied to those measurements to calculate the DO of the dilution water (1 percent seed) after 5 days of incubation. The final DO levels of the incubated sample dilutions were then subtracted from this calculated blank to obtain the depletions due to the samples. An extensive comparison was performed of this method and the standard method of taking the initial DO reading of each sample dilution. BOD values obtained by the two techniques were very close, well within the accuracy of the BOD test.

Although the final effluent often was supersaturated, handling, compositing, and shaking dissipated the supersaturation by the time the BOD analysis was begun. The dilutions, therefore, had essentially the same initial DO level as the dilution water, despite the high percentage of effluent used in the dilutions.

Laboratory work generally was not performed on weekends; Saturday and Sunday samples were refrigerated until Monday. Dilutions which normally would have been removed from the incubator on Saturday and Sunday were removed on Friday and Monday, and the resulting BOD values adjusted to 5-day values according to Streeter & Phelps (3). The validity of applying the factors was confirmed by experiment.

SOLIDS

Suspended solids analyses were performed on daily influent, effluent, Stage-4 mixed liquor, and return sludge samples. Glass fiber filters (Whatman GF/C with Gooch crucibles, permitted by Standard Methods (2) as an alternate) were initially used for all samples. Mixed liquor and return sludge samples were diluted prior to withdrawing an aliquot for filtration.

Starting in May 1973, Buchner funnels were used instead of Gooch crucibles for mixed liquor and return sludge samples because their larger filtration area permitted larger aliquots to be filtered without dilution. Some ceramic mateial was cut from the funnels to keep their weight within the capacity of the analytical balance. Volatile suspended solids were determined after ignition at 550 C.

Total solids and total volatile solids determinations were performed in accordance with Standard Methods (2). Suspended solids and volatile suspended solids values were substracted from these to obtain dissolved solids and volatile dissolved solids values. Dissolved solids analyses were performed twice a week on influent and effluent samples, but were discontinued in June 1973.

SETTLING DATA

Two 1000-ml graduated cylinders, one equipped with a 1-rpm mechanical stirrer, were filled with well-dispersed, fresh, Stage-4 mixed liquor. Readings of the volume of settled sludge were taken after 1,2,3,5,7,10,15,20,25, and 30 min.

The settling rate in ml/min was determined for each time increment, and the highest of these rates was taken as the initial settling rate (ISR) and reported as m/hr (ft/hr).

The 30-min settled volume was used to calculate the sludge volume index (SVI) and sludge density index (SDI) as specified in Standard Methods (2).

pH AND ALKALINITY

pH analyses were performed on daily influent and effluent samples and, starting in March 1973, on Stage-4 mixed liquor settling test samples, using a Hach Model 2075 pH meter with a combination electrode. Alkalinity determinations were performed twice a week on influent and effluent samples by potentiometric titration to pH 4.5.

Turbidity determinations were made twice a week on the supernatant liquor from settled influent and effluent samples using a Hach Model 2100 turbidimeter. Both samples required 15 min of settling to remove large particles which caused erratic meter readings. Commercial Jackson Turbidity Unit (JTU) standards were used for calibration. These analyses were discontinued in July 1973.

COD

COD analyses were performed on daily influent, effluent, effluent filtrate (Whatman No. 1 paper), and return sludge samples. Mercuric sulfate was added to the digestion flask to inhibit the interfering effect of chlorides. Fifty-ml samples or aliquots diluted to 50 ml were used. Influent and return sludge samples were digested in the presence of a strong dichromate solution (0.25N); a weaker solution (0.025N) was used for the effluent samples. Refluxing for 1½ hours was found to be sufficient for complete digestion.

NUTRIENTS

Total Kjeldahl nitrogen (TKN), ammonia nitrogen, total phosphate, and soluble orthophosphate analyses were performed on influent and effluent samples, but not every day. The analyses were alternated so that total Kjeldahl and ammonia nitrogen analyses were run daily one week, and total and soluble orthophosphate analyses were performed daily the following week. The samples were preserved with 40 mg/l of mercuric chloride and refrigerated until analysis. Nitrate and nitrite nitrogen analyses were performed on fresh influent and effluent samples twice a month until March 1973, after which they were done only once a month.

All nutrient analyses were performed with a Technicon Autoanalyzer system. An Autoanalyzer I was used until November 1973, and the Autoanalyzer II system thereafter.

Ammonia nitrogen analyses were performed according to the automated method in Methods for Chemical Analysis of Water and Wastes (MCAWW) (4). Samples were not distilled prior to analysis.

Samples for total Kjeldahl nitrogen analysis were digested and distilled according to Standard Methods (2), except that 0.02N sulfuric acid was used for collection instead of boric acid. Following distillation, the ammonia nitrogen analysis, described above, was performed.

Total phosphate and soluble orthophosphate analyses were performed by the automated stannous chloride method until November 1973, when it was replaced by the automated single reagent method (ascorbic acid method). Both methods are described in MCAWW (4).

The automated hydrazine reduction method in MCAWW (4) was used for nitrate and nitrite nitrogen analyses.

TOC

Beginning in October 1972, total organic carbon analyses were performed on daily influent and effluent samples with a Beckman Model 915 TOC analyzer using the procedure recommended by the manufacturer. The samples were preserved by adding mercuric chloride to a concentration of 40 mg/l and then refrigerated. Before analysis, they were acidified and purged with nitrogen to remove inorganic carbon and then homogenized in a blender for 5 min for greater uniformity and reproducibility.

SECTION 5

SUMMARY OF OPERATIONS

The Newtown Creek oxygen system was placed in operation May 14, 1972. The testing program was concluded on March 11, 1975. In the intervening 34 mo, a broad range of operating conditions comprising a total of 12 evaluation phases was imposed on the system. Throughout, an extensive array of data were collected daily.

The chronology of events is summarized in Table 1. Each operating phase, shutdown, and restart is discussed individually below. Operating and performance data generated on the oxygen aeration system for Phases 1-12 are presented in phase-average form in Tables 2-9 at the end of this section. For comparative purposes, operating and performance data developed for the same period of time for the Newtown Creek conventional air aeration plant are also recorded at the end of this section in Tables 10-14, along with power consumption and sludge production data for two City step aeration air plants (Jamaica and 26th Ward) in Tables 15-18.

STARTUP (MAY 14-SEPTEMBER 16, 1972)

The intent was to break in the process while collecting data at a flow of 0.44 m^3/sec (10 mgd) for 1 to 2 mo, and then at 0.66 m^3/sec (15 mgd) and possibly one other intermediate point before reaching the design flow of 0.88 m^3/sec (20 mgd) in late summer 1972. The summer, however, was characterized by many equipment and instrumentation problems; these are discussed in Section 6 of this report. In mid-September 1972, with the flow at 0.88 m^3/sec (20 mgd), it was found that most of the data already collected to that point were unusable; large errors were discovered in the metered influent sewage flow, return sludge flow, and oxygen feed flow. The data collected through mid-September 1972 are, therefore, not presented.

PHASE 1 (SEPTEMBER 17-NOVEMBER 25, 1972)

With the flow at 0.88 m^3/sec (20 mgd) and the instrumentation considered reliable, Phase 1 was begun. Waste sludge data, however, are not presented until Phase 3, after the defective magnetic flow meter was replaced (see Section 6). The flow was kept at a constant 0.88 m^3/sec (20 mgd) until the last week, when a diurnal variation based on the air plant influent pattern and

TABLE 1. PROJECT CHRONOLOGY

Dates	Phase	No. of Days	Influent Flow Rate (mgd)*	Remarks
5/14-9/16/72		126	11-20	Startup; faulty meters
9/17-11/25/72	1	70	20.8	Warm weather; design flow (constant)
11/26-12/9/72		14		Shutdown for return sludge pump repair
12/10/72-2/1/73	2	54	17.7	Restart; winter operation; variable flows (constant); fungus
2/2-2/24/73		23		Shutdown for tank cleaning; restart
2/25-4/5/73	3	40	15.1	Winter operation; 75% design flow (constant); fungus
4/6-5/31/73	4	56	20.3	Warm weather; design flow (diurnal)
6/1-6/30/73	5	30	25.6	Overload; diurnal flow
7/1-7/7/73		7		Flow increased; process unstable; PSA difficulties
7/8-8/11/73	6	35	30.0	Overload; diurnal flow
8/12-9/1/73	7	21	35.4	Overload; diurnal flow
9/2-9/15/73		14		Flow reduction due to PSA compressor motor bearing failure; process recovery
9/16-10/8/73	8	23	10.1	Underload; diurnal flow

(continued on next page)

TABLE 1. (continued)

Dates	Phase	No. of Days	Influent Flow Rate (mgd)*	Remarks
10/9-10/13/73		5		Flow reduction due to sludge collector repair; process recovery.
10/14-10/25/73	9	12	14.6	Foam problem; underload; diurnal flow
10/26/73-2/5/74		103		Shutdown for foam problem and return sludge pump repair; restart
2/6-4/30/74	10	84	19.7	Winter operation; design flow (diurnal); fungus
5/1-8/5/74	11	97	19.1	Spring & summer operation; design flow (diurnal); recover from fungus
8/6-8/25/74		20		Flow changed previous to shutdown
8/26-12/12/74		109		Shutdown for PSA rehabilitation; restart
12/13/74-3/11/75	12	89	20.1	Winter operation; design flow (diurnal); fungus

*1 mgd = 0.044 m^3/sec = 3785 m^3/day ranging from 0.61 to 1.05 m^3/sec (14 to 24 mgd) was introduced. The flow for the period averaged 0.91 m^3/sec (20.8 mgd). The aerator detention time, including return sludge flow, was 1.1 hr; the volumetric organic loading was 2.61 kg BOD/day/m^3 (163 lb/day/1000 ft^3); and the food-to-microorganism (F/M) loading was 0.63 kg BOD/day/kg MLVSS (see Table 3). The MLSS concentration was 4860 mg/l, and the SDI averaged 2.2 g/100 ml. The final tank detention time (Table 4) was 2.3 hr and, at an average return sludge flow of 30 percent, the return sludge concentration was 16,200 mg/l. The overflow rate was 39 m^3/day/m^2 (950 gpd/ft^2), and the solids loading 244 kg/day/m^2 (50 lb/day/ft^2). Process performance (Table 2) was excellent: 94 percent total BOD removal, 95 percent filtrate BOD, 83 percent COD, 92 percent suspended solids, and 77 percent TOC.

SHUTDOWN (NOVEMBER 26-DECEMBER 9, 1972)

During the week of November 9, 1972, it became apparent that the return sludge pump would have to be taken out of service for replacement of its bearings. Since the repairs were expected to take only 2 to 3 days, the aeration tank was not drained; raw sewage addition was halted on November 26, but some oxygen feed was maintained, about 3.2 metric tons/day (3.5 tons/day). The job, however, required 10 days to complete because the bearings in stock proved to be the wrong size and it took the manufacturer a week to locate and deliver the proper bearings. The result was that Phase 2 began with the handicap of anaerobic return sludge.

PHASE 2 (DECEMBER 10, 1972-FEBRUARY 1, 1973)

The influent flow was resumed on December 6, 1972, initially at 0.22 m^3/sec (5 mgd) and increasing to the design 0.88 m^3/sec (20 mgd) by December 19. Performance during this period was not as good as it had been before the shutdown. Total and filtrate BOD and SS removals fell to 83-87 percent and COD removal to 76 percent. Sludge compaction also deteriorated with the SDI averaging 1.8 g/100 ml compared to 2.2 before the shutdown.

In January 1973, a microscopic examination told the story: filamentous organisms had become established in the system. An attempt was made to stabilize the process by reducing the influent flow, but the filamentous forms persisted. It was, therefore, decided to shut down the process, empty the tanks, and then start up again and establish a new culture.

SHUTDOWN (FEBRUARY 2-24, 1973)

Advantage was taken of this otherwise unhappy event to inspect the interior of the aerator. No noticeable corrorsion and only an insignificant accumulation of grit was found. No rags were wrapped around the mixer blades and shafts; this was an unexpectedly happy development because Newtown Creek has a heavy rag load. Some repairs and minor modifications also were made, and on February 15, 1973, the system was restarted at a flow of 0.22 m^3/sec (5 mgd).

PHASE 3 (FEBRUARY 25-APRIL 5, 1973)

The purpose of this phase was to continue the collection of winter operating data at 0.88 m^3/sec (20 mgd) which was begun in Phase 2, but with diurnal flow variations. The defective waste sludge magnetic flow meter had been replaced on March 2 1973, and so the data would be complete for the first time. The intention was to maintain a sludge age of 3.5 days and slowly move from an initial 0.22-m^3/sec (5-mgd) flow to 0.88 m^3/sec (20 mgd). It was believed that at the higher sludge age, competition would favor a healthy biomass over any intruding forms. However, almost from startup, filamentous organisms became apparent and, by the first days of March, with the flow at 0.53 m^3/sec (12 mgd), operation had become impaired. The filamentous forms, which were at this time identified as a fungal species (5), had become so prevalent that observable deterioration in sludge settling and compactability were experienced with attendant decreases in SDI's to 1.3 - 1.4 g/100 ml and upward extension of the clarifier sludge blanket beyond the preferred operating limit. Wasting was increased to pull the blanket down and prevent heavy solids losses over the effluent weirs.

It was then theorized that there was an operating range, either considerably above or well below a 3.5-day sludge age, where the fungus would not be able to compete with a healthy biomass. However, with the return sludge pump going out on overload at less than half its capacity and limiting the return rate to only 50 percent, and with the necessity of heavy wasting to control the sludge blanket, operation at the high age was impossible.

The only feasible move was to reduce the sludge age. By increasing both the waste and influent flows, the age was gradually decreased to 2.0 days, but the fungus persisted and the SDI dropped to less than 1.0 g/100 ml. However, even with the fungus present, efficiencies were not adversely affected. Average removals for March were SS-89 percent, total BOD-90 percent, filtrate BOD-87 percent, and COD-80 percent. This was at flows of only 0.22 to 0.70 m^3/sec (5 to 16 mgd), not the design flow of 0.88 m^3/sec (20 mgd). Therefore, with the winter almost over, it was decided that rather than lose additional time searching for an operating range inimical to the fungus, its existence would be accepted as a cold weather phenomenon and a determination made whether 0.88 m^3/sec (20 mgd) could be successfully treated. By the end of March, 1973, influent flow had been increased to 0.88 m^3/sec (20 mgd) with no apparent reduction in process efficiency.

PHASE 4 (APRIL 6-MAY 31, 1973)

With the flow at the design point, a diurnal variation from 0.61 to 1.05 m^3/sec (14 to 24 mgd) and averaging 0.88 m^3/sec (20 mgd) was instituted on April 6, 1973, and Phase 4 was under way. For the next 3 wk, with the fungus still present and the sludge age dropping even farther to 1.3-1.4 days, treatment efficiency remained good. Total BOD, filtrate BOD, and SS removals hovered around 90 percent, and COD removal was in the 75-80 percent range. By the end of April, as the sewage temperature topped 60 F indicating the end of the winter temperatures, the fungus in the sludge diminished and finally, in early May, disappeared.

But some questions remained. If the shutdown had not occurred and required a winter restart, would the healthy culture have prevented the intrusion of filamentous forms? If the fungus was indeed a cold weather occurrence that would have to be tolerated, could the design flow be treated throughout the winter? To answer these questions, another full winter of operation would be required. With the mutual concurrence of the City and EPA, the project was, therefore, extended to the end of April 1974.

PHASE 5 (JUNE 1-30, 1973)

One of the program's objectives was to stress the process to performance breakdown. Therefore, since the plant was performing well at 0.88 m^3/sec (20 mgd), influent flow was increased on June 1, 1973, to 1.10 m^3/sec (25 mgd) with diurnal variations from 0.74 to 1.31 m^3/sec (17 to 30 mgd). The increased flow decreased the aerator detention time, including return sludge flow, to only 0.81 hr. A sharp increase in BOD strength to 240 mg/l more than doubled the volumetric organic loading to 4.95 kg BOD/day/m^3 (309 lb/day/1000 ft^3) and also doubled the F/M loading to 1.38 kg BOD/day/kg MLVSS. The final tank detention time dropped to 1.85 hr, and the final tank solids loading and overflow rate increased to 308 kg/day/m^2 (63 lb/day/ft^2) and 47 m^3/day/m^2 (1160 gpd/ft^2), respectively. Process efficiencies for this phase were very respectable: 90 percent total BOD removal, 89 percent filtrate BOD removal, and 77 percent COD removal. SS removal, however, fell appreciably to 26 mg/l and 83 percent removal. TOC removal was 68 percent, about the average of Phases 1-4.

PROCESS STABILIZATION (JULY 1-JULY 7, 1973)

Flow was increased; process disruption was caused by PSA problems, and efforts were made to stabilize conditions.

PHASE 6 (JULY 8-AUGUST 11, 1973)

Encouraged by the results at 1.10 m^3/sec (25 mgd), influent flow was increased to 1.31 m^3/sec (30 mgd) with a diurnal variation from 0.92 to 1.58 m^3/sec (21 to 36 mgd). Aerator detention time, including return, decreased to 0.74 hr; the volumetric organic loading increased to 519 kg BOD/day/m^3 (324 lb/day/1000 ft^3); and the F/M loading increased to 1.53 kg BOD/day/kg MLVSS. The final tank detention time decreased to 1.6 hr, and the overflow rate rose to 55 m^3/day/m^2 (1360 gpd/ft^2). Removals were 90 percent for total BOD, 88 percent for filtrate BOD, 86 percent for SS, and 71 percent for TOC.

PHASE 7 (AUGUST 12-SEPTEMBER 1, 1973)

After 5 wk and no process deterioration at 1.31 m^3/sec (30 mgd), influent flow was increased to 1.53 m^3/sec (35 mgd) on August 12, 1973, but with a modified diurnal pattern. Since the peak flow of 1.84 m^3/sec (42 mgd) that would have been required exceeded the combined capacities of both influent pumps, the diurnal variation was altered somewhat to obtain the average flow of 1.53 m^3/sec (35 mgd) by means of a sustained peak flow of 1.62 m^3/ sec (37 mgd), which was the combined capacity of the two pumps, and a minimum flow of 1.05 m^3/sec (24 mgd). This latest flow increase represented the greatest stress that could be applied to the system. If the biological process could not be broken at this flow, the maximum tolerable loading would remain unknown.

Things went very well until September 1 when a bearing on the PSA compressor failed, shutting down the oxygen generator. Therefore, this phase, which was intended to last for a month, had to be cut short. Nevertheless, the 3 wk of operation proved very successful. At an average flow of 1.55 m^3/sec (35.4 mgd), effluent total BOD and SS concentrations were only 21 and 17 mg/l, respectively, for removal efficiencies of 89 and 87 percent. COD and TOC removals increased to 80 and 75 percent, respectively. Filtrate BOD removal fell to 83 percent, but the influent strength was 15 percent lower too. These results were obtained at an aerator detention time, including return sludge flow, of only 0.67 hr; a volumetric organic loading rate of 5.64 kg BOD/day/m^3 (352 lb/day/1000 ft^3); and an F/M loading of 2.22 kg BOD/day/kg MLVSS. Settling tank detention time was 1.3 hr, and the overflow rate averaged 66 m^3/day/m^2 (1610 gpd/ft^2).

PROCESS RECOVERY (SEPTEMBER 2-15, 1973)

The bearing failure which shut down the PSA on September 1, 1973, reduced the total oxygen supply capacity to the 16.3 metric tons/day (18 tons/day) of the Driox vaporizer. Then on September 3, the motor operating the automatic liquid oxygen feed valve burned out, preventing automatic control of oxygen feed to maintain a predetermined gas space pressure. The reduced oxygen supply capacity and the crude manual control on the liquid oxygen feed required a cutback in influent flow from 1.53 to 0.53 m3/sec

(35 to 12 mgd). A return to 1.53 m^3/sec (35 mgd) was not imminent, and so on September 7, a diurnal pattern designed to yield an average flow of 0.44 m^3/sec (10 mgd) was implemented in preparation for Phase 8. On September 10, the PSA was returned to service once again allowing automatic control of oxygen feed.

PHASE 8 (SEPTEMBER 16-OCTOBER 8, 1973)

By September 16, 1973, the process had reached equilibrium after the precipitous flow reduction from 1.53 m^3/sec (35 mgd) to 0.53 m^3/sec (12 mgd) and then to 0.44 m^3/sec (10 mgd) and Phase 8 was begun.

Since the data collected during the first summer of operation could not be used because of inaccurate instrumentation, this phase was an attempt to backtrack to collect data to fill the void at low-flow loadings. At an average flow of 0.44 m^3/sec (10.1 mgd), with diurnal variations from 0.31 to 0.53 m^3/sec (7 to 12 mgd), the aerator detention time, including return, averaged 2.4 hr; the volumetric organic loading was 1.44 kg BOD/day/m^3 (90 lb/day/1000 ft^3); and the F/M loading was 0.39 kg BOD/day/kg MLVSS. The final tank detention time was 4.7 hr. The final tank overflow rate and solids loading were only 19 m^3/day/m^2 (460 gpd/ft^2) and 112 kg/day/m^2 (23 lb/day/ft^2), respectively. At these low loadings and at the high sewage temperature of 72 F, removals were 89 percent of total BOD, 87 percent of SS, 92 percent of filtrate BOD, 82 percent of COD, and 77 percent of TOC.

An out-of-line slude-collector shaft threatened to cause serious damage to the equipment. Repairs were begun on October 9. The process suffered somewhat during the 24 hr required for the repairs, and the flow had to be reduced. It was not until October 14 that the flow was up to 0.66 m^3/sec (15 mgd) and the next phase could begin.

PHASE 9 (OCTOBER 14-25, 1973)

Biological frothing developed in the aerator before the phase was well established and required its early termination. The data, while representing only 12 days of operation, nevertheless are presented as a phase because they represent the last period of operation at low flow and loadings.

Some of the data obtained during this period must be viewed with extreme caution because of the inordinately high MLSS concentrations observed (average 9040 mg/l). The samples undoubtedly were contaminated by the aerator froth. The aerator detention time (sewage flow plus recycle sludge flow) was 1.6 hr and the volumetric organic loading 1.75 kg BOD/day/m^3 (109 lb/day/1000 ft^3). The final tank detention time was 3.2 hr, and the overflow rate was 27 m^3/day/m^2 (660 gpd/ft^2). Removals averaged

91 percent of total and filtrate BOD, 87 percent of SS, 82 percent of COD, and 81 percent of TOC.

SHUTDOWN (OCTOBER 26, 1973-JANUARY 1, 1974)

By October 26, 1973, the foam had become so pronounced that, in order to protect the stage blowers, the oxygen feed to the system was halted and air feed via the stage compressors was instituted. However, beginning on October 27, frequent stage compressor shutdowns indicated that they had indeed been affected. It was then necessary to dismantle and clean all the compressors and their related oxygen piping. While this was being done, the influent flow was reduced to 0.44 m^3/sec (10 mgd) and the air feed was continued in an effort to sustain the process until the cleaning operation was completed.

The foam which plagued the operation was light brown and frothy, similar to the "head" on a chocolate milkshake. Its appearance was markedly different from the white foam which results from aeration of a wastewater containing detergents, a common sight at many treatment plants. Bench-scale dosage of the foam with a commercial defoaming agent was not effective. A similar foaming condition at the Jamaica step aeration plant a year earlier resulted from an infestation of Nocardia, and an EPA specialist (6) confirmed the presence of these organisms in the UNOX mixed liquor. The foam appeared only in the oxygen bay and never was evident in the parallel air modules. A means of removing the foam was not provided in this installation, but some mechanism for removal appears desirable.

By November 12, the foam had subsided, and so, with the compressors and their piping cleaned, oxygen feed was resumed. The flow was increased gradually from 0.44 m^3/sec (10 mgd) until it reached 0.88 m^3/sec (20 mgd) on November 25. Throughout the episode, filamentous organisms were present, although not as predominant forms.

Early in December, further problems with the return sludge pump bearings became apparent and on the 11th the pump was taken out of service again. To prevent a repetition of the consequences of the first shutdown, the tanks were drained and the settling tank cleaned. Repairs to the pump included replacing the upper and lower pump bearings, building up the impeller wearing ring to reduce excessive clearance, and replacing the worn shaft packing sleeve. Some preventive maintenance also was performed on the sludge collection mechanism, and a piping modification was made to the sludge wasting system. An inspection of the tank interior revealed no grit buildup, no rag accumulation around the mixers, and no apparent concrete deterioration.

RESTART (JANUARY 2-FEBRUARY 5, 1974)

On January 2, 1974, after all repairs were completed, operation was resumed. By the 17th, the fungus had reappeared. Nevertheless, the flow was very gradually increased and by February 6 the process had stablized at 0.88-m^3/sec (20 mgd) diurnal flow.

PHASE 10 (FEBRUARY 6-APRIL 30, 1974)

The intention was to operate during what was left of the 1973-1974 winter at 0.88 m^3/sec (20 mgd) and to combat the fungus by any means except reducing the flow. From the beginning, the phase was characterized by severe fungal proliferation; in fact, the dominant microorganism in the mixed liquor was the fungus, often to the complete exclusion of the microbial forms. The fungus, with its long-branching mycelia, interfered with the settling and compaction of the sludge. Consequently, as during the previous winter, the sludge blanket extended the entire length of the clarifier and the wasting rate frequently had to be increased to control it. The poor compaction resulted in an average return sludge concentration of only 5220 mg/l for the phase and a low for 1 wk of less than 4000 mg/l.

These were in contrast to averages of more than 16,000 mg/l for summer operation and were less than half of those obtained during the previous winter. The weak return sludge concentrations depressed the MLSS concentration, which averaged only 2400 mg/l for the phase and experienced a weekly low of less than 1700 mg/l. From mid-February to mid-April, the sludge age averaged only 1.0 day, considerably less than the 1.3-2.0-day range experienced the previous winter. The SDI slipped to a low of 0.4 g/100 ml during the week of February 10 and 0.6 during the next 2 wk compared to a weekly low of 1.0 during the previous winter and averages of over 2.0 during summer operations and well over 1.0 the previous winter. Although it appeared desirable to increase the sludge age to the level of the previous winter, the low MLSS concentration dictated by the filaments and the self-imposed constraint of maintaining the influent rate made that impossible.

The fungus was not unique to the UNOX system. During this phase and also in Phase 3, the organisms were present in the air plant, too; however, visual observation indicated that their numbers were fewer and their effects far less severe. The average SDI of 1.4 g/100 ml for the air plant during this period was only slightly less than the average of 1.7 for the preceding summer. At a sludge age of 1.3 days, the air plant MLSS concentration averaged 1700 mg/l and the return sludge concentration 8800 mg/l (Tables 11 and 12).

Microscopic examination of the plant influent revealed that the fungus was entering in the raw sewage. It may have originated in the discharge of some connected industry, or conditions in the interceptor system may have promoted its development. Once in the plant, if conditions were favorable, retention and concentration could have caused it to proliferate. It was obvious that further work would have to be done.

PHASE 11 (MAY 1-AUGUST 5, 1974)

Although the EPA grant-funded program ended on April 30, 1974, operations and data collection were continued. Phases 11 and 12, therefore, although not parts of the grant program, are included in this report to present the most recent findings.

This phase was a continuation of Phase 10 into warm weather at 0.88-m^3/sec (20 mgd) diurnal flow. Although the fungi disappeared as the wastewater temperature rose to 60 F and above, a healthy biomass did not reappear as in the previous summer and removal efficiencies averaged only 84 percent for total BOD and 82 percent for SS.

The PSA was taken out of service on June 17 for replacement of a failed compressor motor bearing, and the biological process was entirely dependent on the liquid oxygen backup system until August 1.

FLOW REDUCTION (AUGUST 6-AUGUST 25, 1974)

Flow was gradually reduced preparatory to the approaching shutdown.

SHUTDOWN (AUGUST 26-OCTOBER 31, 1974)

This 9-wk shutdown was a planned operation, primarily to upgrade the performance of the PSA. Due to a malfunction of certain of the PSA switching valves early in the test, two of the four adsorption beds became contaminated by moisture, reducing the output of the unit to 9.1 metric tons of oxygen/day (10 tons/day). Union Carbide could have rehabilitated the beds at any time, but instead elected to supply liquid oxygen at its own cost up to the PSA design rate of 13.6 metric tons oxygen/day (15 tons/day).

The upgrading consisted of replacing the adsorbent material in the two beds and portions of the material in the other two, replacing all valves and rebuilding all valve activators, and increasing the capacity of the PSA compressor and some piping. The result of the refurbishing was that although an output of 13.6 metric tons oxygen/day (15 tons/day) was guaranteed, the unit in fact thereafter delivered 15.2 metric tons oxygen/day (16.7 tons/day) with virtually no downtime.

In addition to the work on the PSA, inspection and preventive maintenance were provided for all other oxygen system equipment during this shutdown period.

RESTART (NOVEMBER 1-DECEMBER 12, 1974)

Because of the unanswered questions relating to the fungal proliferation during winter operations, the City and Union Carbide embarked upon an extensive investigation which lasted throughout the 1974-1975 winter. The aims of the program were to identify the fungus, determine whether it was peculiar to Newtown Creek or was ubiquitous in New York City wastewater, and find some means of eliminating it. To accomplish these objectives, Union Carbide provided a 1.89 l/sec (30-gpm) oxygen pilot plant on which to test the effects of possible fungicides before they were applied to the 0.88-m^3/sec (20-mgd) system and a consultant was engaged to identify the fungus and recommend steps for its control. A second Union Carbide oxygen pilot plant was stationed at the Wards Island step aeration air plant to compare air and oxygen performances in cold weather at that location.

The Newtown Creek oxygen module was restarted at 0.22-m^3/sec (5-mgd) constant flow. Influent flow increased to 0.88-m^3/sec (20-mgd) diurnal by December 12, 1974.

PHASE 12 (DECEMBER 13, 1974-MARCH 11, 1975)

The fungi persisted throughout this period, but their effect on the process was insignificant. Nevertheless, the fungus control program was begun. It was soon found that, although several species of fungi were present in the mixed liquor of both the air and oxygen systems, the predominant form was the arthrospore producer "Geotrichum" (10).

Sampling of the influents at three other New York City plants and one drainage area not yet served by a plant revealed the presence of the same organism in concentrations generally similar to those at Newtown Creek. At Newtown Creek, the fungus concentration increased moderately in the air plant mixed liquor but significantly in the mixed liquors of both the full-scale and pilot oxygen systems. At the three other plants sampled, the fungi did not significantly proliferate in the mixed liquor. The growth in the Wards Island oxygen plant was about the same as in the full-scale air plant. Apparently, Newtown Creek's waste is unique in that it is conducive to the growth of these organisms.

The pilot plant employed at Newtown Creek was a Union Carbide four-stage oxygen system equipped with turbine/spargers for oxygen dissolution and an external circular clarifier. The pilot plant treated an average of 1.1 l/sec (17.5 gpm) on a diurnally-varying pattern approximating those of the field oxygen module and full-scale air plant. The first attempt at combatting the fungus was to operate at a high sludge retention time (SRT), but this was not successful. An SRT of 4.3 days maintained for 2 wk did not diminish the fungi but also did not harm the process, whose effluent averaged 11 mg/l of total BOD and 13 mg/l of SS.

Since the phosphorus content of the waste during Phase 10 was only 2.4 mg/l, the lowest up to that time, it was considered possible that nutrient deficiency might have slowed the growth of the normal biomass population and permitted the fungus to become predominant. Therefore, after a short period during which the 4.3-day SRT was reduced to a normal level, 2-3 mg/l of phosphorus was added to the pilot plant influent. However, 2 wk of phosphorus supplementation had no effect. The effluent during this period averaged 17 mg/l of total BOD and 15 mg/l of SS.

Two wk of chlorine addition followed at a dosage of 9 mg/l. Not only did this have no effect on the fungus, but it injured the process, whose effluent deteriorated to 29 mg/l of total BOD and 32 mg/l of SS.

A third additive, hydrogen peroxide, was assessed using jar tests but failed to improve sludge settling even at dosages up to 200 mg/l.

The final attempt at control was adjustment of the pH of the mixed liquor, although it was expected to be very costly on a full-plant scale. More than 2 yr of data indicated that the pH of the influent, which ranged from 6.3 to 6.9, was depressed by about 0.4 unit during passage through the oxygenation aerator. It was considered possible that this drop could have sparked the growth of the fungus. However, 10 days of lime addition at 100 mg/l increased the pH of the mixed liquor to 7.0 but had no effect on the fungi.

The 1974-1975 winter operation in the 0.88-m^3/sec (20-mgd) oxygen system during Phase 12 differed from the past winters in two respects. First, it was not interrupted by a breakdown of the return sludge pump, nor for any other reason. Second, although the fungus was present from beginning to end, its concentration in the mixed liquor appeared to be less than those of the first two winters. Effluent quality averaged 18 mg/l of total BOD and 13 mg/l of SS for removals of 87 percent. The average sludge age was 1.6 days, and the SDI was 1.5 g/100 ml.

The reduced quantity of the fungus in the mixed liquor during this phase may explain the improved overall process performance of the third winter, but the reasons for the lower fungal concentration are purely speculative. One possibility is that after the shutdowns and restarts of the first two winters, the rapid growth of the fungus aborted the development of a proper activated sludge culture, but Phase 12 with no shutdown and cold-weather restart began with a population that was able to contain the fungi.

TABLE 2. OXYGEN SYSTEM PROCESS PERFORMANCE

Phase Dates	1 09/17- 11/25/72	2 12/10/72- 02/01/73	3 02/25- 04/05/73	4 04/06- 05/31/73	5 06/01- 06/30/73	6 07/08- 08/11/73	7 08/12- 09/01/73	8 09/16- 10/08/73	9 10/14- 10/25/73	10 02/06- 04/30/74	11 05/01- 08/05/74	12 12/13/74- 03/11/75
Flow												
Sewage, m^3/day	78,700	67,000	57,200	76,800	96,900	113,600	134,000	38,200	55,300	74,600	72,300	75,700
(mgd)	(20.8)	(17.7)	(15.1)	(20.3)	(25.6)	(30.0)	(35.4)	(10.1)	(14.6)	(19.7)	(19.1)	(20.0)
Return Sludge*, m^3/day	23,800	26,900	28,800	35,200	41,600	38,600	34,100	9,500	14,400	43,100	28,400	21,600
(mgd)	(6.3)	(7.1)	(7.6)	(9.3)	(11.0)	(10.2)	(9.0)	(2.5)	(3.8)	(11.4)	(7.5)	(5.7)
% Sludge Return	30	40	50	46	43	34	25	25	26	58	39	29
BOD												
Influent (mg/l)	156	157	151	168	240	215	198	178	149	136	146	140
Effluent (mg/l)	9	21	17	17	24	22	21	19	13	26	24	18
% Removal	94	87	89	90	90	90	89	89	91	81	84	87
Filtrate BOD												
Influent (mg/l)	84	78	88	96	130	98	82	96	70	77	80	87
Effluent (mg/l)	4	13	12	11	14	12	14	8	6	16	13	10
% Removal	95	83	86	89	89	88	83	92	91	79	84	89
COD												
Influent (mg/l)	356	365	364	365	320	290	308	363	314	307	-	299
Effluent (mg/l)	61	88	75	77	73	64	62	65	57	87	-	70
% Removal	83	76	79	79	77	78	80	82	82	72	-	77
Suspended Solids												
Influent (mg/l)	149	146	145	159	149	119	131	136	135	126	142	101
% Volatile	79	77	74	76	75	75	83	84	80	72	79	81
Effluent (mg/l)	12	22	18	18	26	17	17	18	17	27	26	13
% Volatile	76	87	89	83	77	71	82	83	76	70	-	82
% Removal	92	85	88	89	83	86	87	87	87	79	82	87
TOC												
Influent (mg/l)	90	99	99	109	104	96	106	103	110	104	-	-
Effluent (mg/l)	21	35	30	54	33	28	26	24	21	42	-	-
% Removal	77	65	70	50	68	71	75	77	81	60	-	-

* Data for Phases 1-11 may be in error because of air entrapment in return sludge magnetic flow meter.

TABLE 3. OXYGEN SYSTEM AERATION TANK PERFORMANCE

Phase Dates	1 09/17- 11/25/72	2 12/10/72- 02/01/73	3 02/25- 04/05/73	4 04/06- 05/31/73	5 06/01- 06/30/73	6 07/08- 08/11/73	7 08/12- 09/01/73	8 09/16- 10/08/73	9 10/14- 10/25/73	10 02/06- 04/30/74	11 05/01- 08/05/74	12 12/13/74- 03/11/75
MLSS (mg/l) % Volatile	4860 85	4980 82	4010 80	3950 79	4530 79	4150 82	3130 81	4760 79	(9040)+ 80	2400 78	3870 -	2630 84
Sludge Age* (days)	1.9	2.4	2.3	1.5	1.5	1.4	0.8	4.3	-	1.2	1.8	1.6
Sludge Retention Time** (days)	-	-	2.0	1.4	1.3	1.2	0.8	5.5	-	0.9	-	1.2
Detention Time (hr) (Q+R)*** Q	1.1 1.4	1.3 1.7	1.3 2.0	1.0 1.5	0.8 1.2	0.7 1.0	0.7 0.8	2.4 3.0	1.6 2.0	1.0 1.5	1.1 1.6	1.2 1.5
BOD Loading, kg/day/m^3 (lb/day/1000 ft^3)	2.61 (163)	2.24 (140)	1.84 (115)	2.74 (171)	4.95 (309)	5.19 (324)	5.64 (352)	1.44 (90)	1.75 (109)	2.16 (135)	2.24 (140)	2.26 (141)
COD Loading, kg/day/m^3 (lb/day/1000 ft^3)	5.96 (372)	5.21 (325)	4.42 (276)	5.96 (372)	6.60 (412)	7.00 (437)	8.78 (548)	2.95 (184)	3.68 (230)	4.87 (304)	- -	4.79 (299)
F/M Loading (kg BOD/day/kg MLVSS)	0.63	0.55	0.57	0.88	1.38	1.53	2.22	0.39	-	1.15	-	1.02
F/M Loading (kg COD/day/kg MLVSS)	1.45	1.28	1.38	1.92	1.84	2.07	3.45	0.79	-	2.61	-	2.18

+ Samples probably contaminated by foam.
* Defined as kg MLSS in reactor/kg SS in reactor influent/day.
** Defined as kg MLVSS in reactor/kg VSS in waste sludge and final effluent/day.
*** Data for Phases 1-11 may be in error because of air entrapment in the return sludge magnetic flow meter.

TABLE 4. OXYGEN SYSTEM FINAL TANK PERFORMANCE AND SLUDGE SETTLING CHARACTERISTICS

Phase / Dates	1 09/17- 11/25/72	2 12/10/72- 02/01/73	3 02/25- 04/05/73	4 04/06- 05/31/73	5 06/01- 06/30/73	6 07/08- 08/11/73	7 08/12- 09/01/73	8 09/16- 10/08/73	9 10/14- 10/25/73	10 02/06- 04/30/74	11 05/01- 08/05/74	12 12/13/74- 03/11/75
FINAL TANK PERFORMANCE												
Return Sludge SS (mg/l)	16,200	13,000	11,500	13,200	16,300	16,200	13,000	17,300	18,600	5,200	12,700	9,400
% Volatile	83	81	80	80	79	80	81	79	80	78	77	81
Return Sludge COD (mg/l)	20,000	17,900	15,400	17,000	18,800	22,500	16,200	21,400	22,500	6,700	-	13,200
Detention Time, Q (hr)	2.3	2.7	3.1	2.3	1.9	1.6	1.3	4.7	3.2	2.4	2.5	2.4
Overflow Rate, $m^3/day/m^2$	39	33	28	37	47	55	66	19	27	37	35	37
(gpd/ft^2)	(950)	(810)	(690)	(920)	(1160)	(1360)	(1610)	(460)	(660)	(900)	(870)	(910)
Solids Loading, $kg/day/m^2$	244	230	171	220	308	313	259	112	-	137	190	127
($lb/day/ft^2$)	(50)	(47)	(35)	(45)	(63)	(64)	(53)	(23)	-	(28)	(39)	(26)
Weir Loading, $m^3/day/m$	1,615	1,374	1,172	1,576	1,987	2,329	2,749	784	1,135	1,529	1,483	1,553
(gpd/lineal ft)	(130,000)	(110,600)	(94,400)	(126,900)	(160,000)	(187,500)	(221,300)	(63,100)	(91,400)	(123,100)	(119,400)	(125,000)
SLUDGE SETTLING CHARACTERISTICS												
Sludge Density Index												
Unstirred (g/100 ml)	2.2	1.8	1.2	1.9	2.3	2.3	2.1	2.7	2.0	1.2	1.9	1.5
Stirred at 1 rpm (g/100 ml)	-	-	2.2	2.7	2.9	2.8	2.5	3.0	2.8	1.6	-	-
Initial Settling Rate (ISR)												
Unstirred (m/hr)	3.2	2.6	1.6	3.8	4.3	4.4	5.5	5.0	2.0	3.4	-	-
Stirred at 1 rpm (m/hr)	3.4	2.7	3.0	4.1	4.3	4.6	5.5	5.0	2.1	4.0	-	-
Wastewater Temperature (C)	19	14	14	67	21	24	24	22	21	12	21	13
Ambient Temperature (C)	14	3	9	17	25	28	28	22	18	8	-	-

TABLE 5. OXYGEN SUPPLIED TO OXYGEN SYSTEM

Phase Dates	1 09/17- 11/25/72	2 12/10/72- 02/01/73	3 02/25- 04/05/73	4 04/06- 05/31/73	5 06/01- 06/30/73	6 07/08- 08/11/73	7 08/12- 09/01/73	8 09/16- 10/08/73	9 10/14- 10/25/73	10 02/06- 04/30/74	11 05/01- 08/05/74	12 12/13/74- 03/11/75
kg/m^3 sewage	0.16	0.16	0.19	0.16	0.17	0.16	0.15	0.24	0.23	0.13	0.16	0.17
(tons/mil gal sewage)	(0.67)	(0.67)	(0.79)	(0.66)	(0.70)	(0.68)	(0.62)	(1.02)	(0.93)	(0.53)	(0.65)	(0.72)
kg/kg BOD removed	1.1	1.2	1.4	1.0	0.8	0.8	0.8	1.5	1.6	1.2	1.3	1.4
kg/kg COD removed	0.6	0.6	0.7	0.6	0.7	0.7	0.6	0.8	0.9	0.6	-	0.8
kg/kg COD destroyed	-	-	1.9	2.0	2.1	3.5	1.7	1.3	2.0	3.3	-	3.1

TABLE 6. POWER FOR OXYGEN GENERATION AND DISSOLUTION

Phase Dates	1 09/17- 11/25/72	2 12/10/72- 02/01/73	3 02/25- 04/05/73	4 04/06- 05/31/73	5 06/01- 06/30/73	6 07/08- 08/11/73	7 08/12- 09/01/73	8 09/16- 10/08/73	9 10/14- 10/25/73	10 02/06- 04/30/74	11 05/01- 08/05/74**	12 12/13/74- 03/11/75
kWh/m^3 sewage	0.22	0.27	0.33	0.24	0.20*	0.17*	0.15*	0.48	0.33	0.26	-	0.24
(hp-hr/mil gal sewage)	(1117)	(1371)	(1676)	(1218)	(1015)*	(863)*	(761)*	(2436)	(1676)	(1320)	-	(1218)
kWh/kg BOD removed	1.54	1.96	2.49	1.59	1.01*	0.95*	0.90*	2.95	2.42	2.38	-	1.94
(hp-hr/lb BOD removed)	(0.94)	(1.19)	(1.52)	(0.97)	(0.62)*	(0.58)*	(0.55)*	(1.80)	(1.48)	(1.45)	-	(1.18)
kWh/kg O_2 supplied	1.37	1.63	1.74	1.54	1.28*	1.17*	1.10*	1.89	1.48	1.89	-	1.39
(hp-hr/lb O_2 supplied)	(0.83)	(0.99)	(1.06)	(0.94)	(0.78)*	(0.71)*	(0.67)*	(1.15)	(0.90)	(1.15)	-	(0.84)

* Includes 0.37 kWh/kg (451 hp-hr/ton) additional power to generate purchased cryogenic oxygen above 13,600 kg/day (15 tons/day) PSA design capacity.
** 335-kW (450-hp) PSA air compressor motor out of service for bearing repair from June 17 to August 1, 1974.

TABLE 7. OXYGEN SYSTEM SLUDGE PRODUCTION

Phase / Dates	1 09/17-11/25/72	2 12/10/72-02/01/73	3 02/25-04/05/73	4 04/06-05/31/73	5 06/01-06/30/73	6 7/08-08/11/73	7 08/12-09/01/73	8 09/16-10/08/73	9 10/14-10/25/73	10 02/06-04/30/74	11 05/01-08/05/74	12 12/13/74-03/11/75
Wasted, m^3/day	-	-	710	900	860	890	1,300	190	350	2,000	790	980
(gal/day)	-	-	(187,000)	(239,000)	(228,000)	(234,000)	(343,000)	(51,000)	(93,000)	(529,000)	(209,000)	(260,000)
Total SS, dry kg (dry lb)												
Wasted/day*	-	-	8,100	11,900	14,100	14,300	16,900	3,400	6,500	10,400	10,000	9,300
	-	-	(17,900)	(26,300)	(31,100)	(31,600)	(37,300)	(7,400)	(14,400)	(23,000)	(22,100)	(20,400)
In effluent/day	-	-	1,000	1,400	2,500	2,000	2,300	700	1,000	2,000	1,900	1,000
	-	-	(2,300)	(3,000)	(5,600)	(4,300)	(5,000)	(1,500)	(2,100)	(4,400)	(4,100)	(2,200)
Total produced/day	-	-	9,100	13,300	16,600	16,300	19,200	4,100	7,500	12,400	11,900	10,300
	-	-	(20,200)	(29,300)	(36,700)	(35,900)	(42,300)	(8,900)	(16,500)	(27,400)	(26,200)	(22,600)
Wasted, kg/kg BOD removed	-	-	1.06	1.03	0.67	0.65	0.71	0.55	0.87	1.27	1.14	1.00
Wasted, kg/m^3 sewage	-	-	0.143	0.156	0.145	0.126	0.126	0.088	0.119	0.144	0.139	0.122
(lb/mil gal sewage)	-	-	(1,190)	(1,300)	(1,210)	(1,050)	(1,050)	(730)	(990)	(1,200)	(1,160)	(1,020)
Produced, kg/kg BOD removed	-	-	1.20	1.14	0.80	0.74	0.81	0.66	0.99	1.51	1.35	1.11
Produced, kg/m^3 sewage	-	-	0.161	0.173	0.172	0.144	0.143	0.106	0.136	0.167	0.164	0.136
(lb/mil gal sewage)	-	-	(1,340)	(1,440)	(1,430)	(1,200)	(1,190)	(880)	(1,130)	(1,390)	(1,370)	(1,130)
Volatile SS, dry kg (dry lb)												
Wasted/day*	-	-	6,500	9,500	11,100	11,500	13,700	2,600	5,200	8,200	7,700	7,500
	-	-	(14,300)	(21,000)	(24,500)	(25,300)	(30,200)	(5,800)	(11,500)	(18,000)	(17,000)	(16,600)
In effluent/day	-	-	900	1,100	2,000	1,400	1,900	600	700	1,400	-	800
	-	-	(2,000)	(2,500)	(4,300)	(3,000)	(4,100)	(1,300)	(1,600)	(3,100)	-	(1,800)
Total produced/day	-	-	7,400	10,600	13,100	12,900	15,600	3,200	5,900	9,600	-	8,300
	-	-	(16,300)	(23,500)	(28,800)	(28,300)	(34,300)	(7,100)	(13,100)	(21,100)	-	(18,400)
Wasted, kg/kg BOD removed	-	-	0.85	0.82	0.53	0.52	0.58	0.43	0.69	0.99	0.87	0.82
Wasted, kg/m^3 sewage	-	-	0.114	0.124	0.115	0.101	0.102	0.068	0.095	0.109	0.107	0.100
(lb/mil gal sewage)	-	-	(950)	(1,030)	(960)	(840)	(850)	(570)	(790)	(910)	(890)	(830)
Produced, kg/kg BOD removed	-	-	0.96	0.92	0.62	0.59	0.66	0.53	0.79	1.17	-	0.90
Produced, kg/m^3 sewage	-	-	0.130	0.139	0.136	0.113	0.116	0.084	0.108	0.128	-	0.110
(lb/mil gal sewage)	-	-	(1,080)	(1,160)	(1,130)	(940)	(970)	(700)	(900)	(1,070)	-	(920)

* Computed from return sludge concentrations.

TABLE 8. OXYGEN SYSTEM NUTRIENT REMOVALS

Phase Dates	1 09/17- 11/25/72	2 12/10/72- 02/01/73	3 02/25- 04/05/73	4 04/06- 05/31/73	5 06/01- 06/30/73	6 07/08- 08/11/73	7 08/12- 09/01/73	8 09/16- 10/08/73	9 10/14- 10/25/73	10 02/06- 04/30/74	11 05/01- 08/05/74	12 12/13/74- 03/11/75
Total Phosphate (mg/l as P)												
Influent	4.3	3.9	3.6	3.8	2.8	2.7	2.6	3.3	4.1	2.4	-	2.1
Effluent	2.6	2.6	1.5	2.3	1.2	0.9	1.1	1.5	2.3	0.7	-	0.6
% Removal	40	33	58	39	57	67	58	55	44	71	-	71
Soluble Orthophosphate (mg/l as P)												
Influent	2.5	2.2	1.7	2.2	1.3	1.3	1.6	1.6	3.0	1.6	-	1.4
Effluent	1.7	1.4	1.1	1.5	0.6	0.3	0.5	0.9	1.8	0.3	-	0.3
% Removal	32	36	35	32	54	77	69	44	40	81	-	79
Ammonia Nitrogen (mg/l as N)												
Influent	9.3	9.0	9.4	8.8	9.5	7.5	7.6	12.0	11.3	10.6	-	10.1
Effluent	8.0	9.0	9.7	8.0	7.3	6.8	4.6	11.3	8.8	8.5	-	9.0
TKN (mg/l as N)												
Influent	22.0	22.4	22.0	22.3	20.1	18.0	18.0	23.5	21.1	20.7	-	18.4
Effluent	14.4	14.4	14.9	13.6	12.1	10.2	7.9	15.0	12.0	13.1	-	12.6
Nitrite Nitrogen (mg/l as N)											-	-
Influent	0.21	0.18	0.19	0.08	0.20	0.22	0.19	0.21	0.17	0.11	-	-
Effluent	0.21	0.24	0.19	0.05	0.20	0.04	0.19	0.05	0.11	0.11	-	-
Nitrate Nitrogen (mg/l as N)												
Influent	1.87	2.79	3.28	1.85	0.75	0.89	0.75	2.34	1.74	1.97	-	-
Effluent	1.43	1.43	1.07	2.14	0.46	0.80	0.77	1.41	1.67	1.61	-	-

TABLE 9. OTHER OXYGEN SYSTEM SEWAGE CHARACTERISTICS

Phase Dates	1 09/17- 11/25/72	2 12/10/72- 02/01/73	3 02/25- 04/05/73	4 04/06- 05/31/73	5 06/01- 06/30/73	6 07/08- 08/11/73	7 08/12- 09/01/73	8 09/16- 10/08/73	9 10/14- 10/25/73	10 02/06- 04/30/74	11 05/01- 08/05/74	12 12/13/74- 03/11/75
Alkalinity (mg/l as $CaCO_3$)												
Influent	84	71	76	80	77	71	76	68	80	76	-	-
Effluent	95	83	94	85	78	79	73	74	74	78	-	-
Dissolved Solids (mg/l)												
Influent	1156	1003	1038	992	1544	-	-	-	-	-	-	-
Effluent	1087	847	991	976	1263	-	-	-	-	-	-	-
Turbidity (JTU)												
Influent	40	40	38	47	38	-	-	-	-	-	-	-
Effluent	6	9	8	9	8	-	-	-	-	-	-	-
pH												
Influent	6.9	6.8	6.7	6.7	6.6	6.4	6.5	6.6	6.3	6.6	6.6	6.8
Stage 4	-	-	6.2	6.3	6.2	5.9	6.1	5.9	6.0	6.2	6.2	6.4
Effluent	-	6.6	6.6	6.6	6.6	6.4	6.6	6.5	6.3	6.5	6.6	6.8

TABLE 10. NEWTOWN CREEK AIR PLANT PROCESS PERFORMANCE

Phase Dates	1 09/17- 11/25/72	2 12/10/72- 02/01/73	3 02/25- 04/05/73	4 04/06- 05/31/73	5 06/01- 06/30/73	6 07/08- 08/11/73	7 08/12- 09/01/73	8 09/16- 10/08/73	9 10/14- 10/25/73	10 02/06- 04/30/74	11 05/01- 08/05/74	12 12/13/74- 03/11/75
Flow (Per Day)												
Sewage (mgd)*	10.6	10.4	11.1	10.4	12.0	12.0	12.1	12.4	12.0	9.7	11.4	11.5
Return Sludge (mgd)*	2.0	2.1	2.2	2.4	2.4	2.4	2.4	2.4	2.3	2.2	2.1	1.9
% Sludge Return	19	20	20	20	20	19	20	19	19	22	18	17
BOD												
Influent (mg/l)	156	157	151	168	240	215	198	178	149	136	146	140
Effluent (mg/l)	24	33	41	37	46	35	41	30	24	23	32	29
% Removal	85	79	73	78	81	84	79	83	84	83	78	79
Filtrate BOD												
Influent (mg/l)	84	78	88	96	130	98	82	96	70	77	80	87
Effluent (mg/l)	10	27	27	23	29	18	26	15	15	18	21	17
% Removal	88	65	69	76	78	82	68	84	79	77	74	80
Suspended Solids												
Influent (mg/l)	149	146	145	159	149	119	131	136	135	126	142	101
% Volatile	79	77	74	76	75	75	83	84	86	72	79	81
Effluent (mg/l)	40	47	40	45	50	45	41	49	46	35	38	42
% Removal	73	68	72	72	66	62	69	64	66	72	73	58

* 1 mgd = 0.044 m^3/sec = 3785 m^3/day

TABLE 11. NEWTOWN CREEK AIR PLANT AERATION TANK PERFORMANCE

Phase Dates	1 09/17- 11/25/72	2 12/10/72- 02/01/73	3 02/25- 04/05/73	4 04/06- 05/31/73	5 06/01- 06/30/73	6 07/08- 08/11/73	7 08/12- 09/01/73	8 09/16- 10/08/73	9 10/14- 10/25/73	10 02/06- 04/30/74	11 05/01- 08/05/74	12 12/13/74- 03/11/75
MLSS (mg/l)	2000	1900	1800	1800	1800	1700	1900	1900	1800	1700	1700	1600
Sludge Age* (days)	1.5	1.5	1.3	1.3	1.2	1.4	1.4	1.3	1.3	1.6	1.2	1.6
..tention Time (hr) Q + R	2.27	2.30	2.17	2.30	2.00	2.03	1.98	1.94	2.00	2.41	2.13	2.15
Q	2.71	2.76	2.60	2.77	2.40	2.43	2.37	2.32	2.38	2.96	2.53	2.50
BOD Loading (lb/day/1000 ft^3)**	88	87	90	93	154	138	128	118	96	71	89	86

* Defined as kg MLSS in reactor/kg SS in reactor influent/day.

** 1 lb/day/1000 ft^3 = 0.016 kg/day/m^3.

TABLE 12. NEWTOWN CREEK AIR PLANT FINAL TANK PERFORMANCE AND SLUDGE SETTLING CHARACTERISTICS

Phase Dates	1 09/17- 11/25/72	2 12/10/72- 02/01/73	3 02/25- 04/05/73	4 04/06- 05/31/73	5 06/01- 06/30/73	6 07/08- 08/11/73	7 08/12- 09/01/73	8 09/16- 10/08/73	9 10/14- 10/25/73	10 02/06- 04/30/74	11 05/01- 08/05/74	12 12/13/74- 03/11/75
Return Sludge SS (mg/l)	11,500	10,500	10,300	10,000	10,300	10,600	11,000	11,400	10,200	8,800	10,200	9,300
% Volatile	80	82	80	80	78	79	80	79	83	79	78	79
Detention Time, Q (hr)	4.40	4.50	4.22	4.50	3.91	3.93	3.86	3.77	3.88	4.82	4.11	4.07
Overflow Rate (gpd/ft^2)+	490	480	510	480	550	550	560	570	560	450	520	530
Solids Loading, (lb/day/ft^2)*	9.6	9.0	9.1	8.5	9.8	9.3	10.4	10.7	9.8	7.7	8.7	8.1
Weir Loading (gpd/lineal ft)**	66,300	65,000	69,400	65,000	75,000	75,000	75,600	77,600	75,000	60,600	71,300	71,900
Sludge Density Index Unstirred (g/100 ml)	1.5	1.4	1.4	1.4	1.6	1.8	1.7	1.5	1.3	1.4	1.4	1.6

+ 1 gpd/ft^2 = 0.041/m^3/day/m^2

* 1 lb/day/ft^2 = 4.88 kg/day/m^2

** 1 gpd/lineal ft = 0.012 m^3/day/m

TABLE 13. POWER CONSUMPTION FOR AERATION AT NEWTOWN CREEK AIR PLANT

Phase Dates	1 09/17- 11/25/72	2 12/10/72- 02/01/73	3 02/25- 04/05/73	4 04/06- 05/31/73	5 06/01- 06/30/73	6 07/08- 08/11/73	7 08/12- 09/01/73	8 09/16- 10/08/73	9 10/14- 10/25/73	10 02/06- 04/30/74	11 05/01- 08/05/74	12 12/13/74- 03/11/75
hp-hr/mil gal sewage*	898	831	831	898	805	805	831	805	872	898	791	644
hp-hr/lb BOD removed**	0.83	0.83	0.94	0.83	0.48	0.55	0.64	0.67	0.83	0.97	0.85	0.71

* 1 hp-hr/mil gal = 0.197 kWh/1000 m^3

** 1 hp-hr/lb = 1.64 kWh/kg

TABLE 14. NEWTOWN CREEK AIR PLANT SLUDGE PRODUCTION

Phase Dates	1 09/17- 11/25/72	2 12/10/72- 02/01/73	3 02/25- 04/05/73	4 04/06- 05/31/73	5 06/01- 06/30/73	6 07/08- 08/11/73	7 08/12- 09/01/73	8 09/16- 10/08/73	9 10/14- 10/25/73	10 02/06- 04/30/74	11 05/01- 08/05/74	12 12/13/74- 03/11/75
Total SS (dry lb)*												
Wasted/day/bay	-	-	16,500	15,400	14,400	12,600	12,100	13,300	12,300	12,900	14,200	11,200
In effluent/day/bay	-	-	3,700	3,900	5,000	4,500	4,100	5,100	4,600	2,800	3,600	4,000
Total produced/day/bay			20,200	19,300	19,400	17,100	16,200	18,400	16,900	15,700	17,800	15,200
Wasted/lb BOD removed	-	-	1.62	1.35	0.74	0.70	0.76	0.87	0.99	1.41	1.31	1.05
Wasted/mil gal sewage**	-	-	1,490	1,480	1,200	1,050	1,000	1,070	1,030	1,330	1,240	970
Produced/lb BOD removed	-	-	1.98	1.70	1.00	0.95	1.03	1.20	1.35	1.72	1.64	1.43
Produced/mil gal sewage**	-	-	1,820	1,850	1,620	1,430	1,340	1,480	1,410	1,620	1,560	1,520

* 1 lb = 0.45 kg

** 1 lb/mil gal = 0.12 kg/1000 m^3

TABLE 15. POWER CONSUMPTION FOR AERATION AT JAMAICA STEP AERATION AIR PLANT

Month	03/72	04/72	05/72	06/72	07/72	08/72	09/72	10/72	11/72	12/72	01/73	02/73
Flow (mgd)+	95	95	93	97	89	91	92	92	99	94	92	88
BOD Removed in Secondary System (mg/l)	82	83	79	70	61	72	98	66	80	92	99	97
hp-hr/mil gal sewage*	619	577	619	577	619	577	619	644	619	550	619	619
hp-hr/lb BOD removed**	0.90	0.83	0.90	0.97	1.19	0.97	0.74	1.19	0.94	0.74	0.74	0.74

+ 1 mgd = 0.044 m^3/sec = 3785 m^3/day

* 1 hp-hr/mil gal = 0.197 kWh/1000 m^3

** 1 hp-hr/lb = 1.64 kWh/kg

TABLE 16. POWER CONSUMPTION FOR AERATION AT 26th WARD STEP AERATION AIR PLANT

Month	06/75	07/75	08/75	09/75	10/75	11/75	12/75	01/76	02/76	03/76	04/76	05/76	06/76	07/76	08/76	09/76	10/76
Flow (mgd)+	79	88	90	89	82	82	78	85	81	80	81	87	84	85	87	81	83
BOD Removed in Secondary System (mg/l)	86	75	43	52	54	66	58	48	54	53	61	47	48	47	40	56	47
hp-hr/mil gal sewage*	349	295	215	201	215	241	255	228	228	201	241	255	215	228	201	201	201
hp-hr/lb BOD removed**	0.48	0.47	0.60	0.47	0.47	0.43	0.54	0.56	0.51	0.47	0.47	0.64	0.52	0.56	0.59	0.43	0.51

+ 1 mgd = 0.044 m^3/sec = 3785 m^3/day

* 1 hp-hr/mil gal = 0.197 kWh/1000 m^3

** 1 hp-hr/lb = 1.64 kWh/kg

TABLE 17. SLUDGE PRODUCTION AT JAMAICA STEP AERATION AIR PLANT

Month	03/72	04/72	05/72	06/72	07/72	08/72	09/72	10/72	11/72	12/72	01/73	02/73
Flow (mgd)*	95	95	93	97	89	91	92	92	99	94	92	88
BOD Removed (mg/l) (Pri. + Sec.)	124	122	120	115	103	115	109	112	102	121	125	138
Effluent SS (mg/l)	16	17	15	19	22	22	29	26	26	34	22	25
MLSS (mg/l)	2900	2600	2250	1800	1750	3000	2100	1700	2000	2400	1800	1600
Sludge Age** (days)	4.8	4.9	3.9	3.1	4.7	5.9	2.2	3.8	3.3	3.7	3.2	2.3
Total SS (dry lb)+												
Wasted/day (x 1000)	118.6	103.5	104.4	98.8	81.4	74.9	69.1	65.0	85.0	78.6	91.7	77.7
In effluent/day (x 1000)	12.7	13.5	11.6	15.4	16.3	16.7	22.3	20.0	21.5	26.7	16.9	18.4
Total produced/day (x 1000)	131.3	117.0	116.0	114.2	97.8	91.6	91.4	85.0	106.5	105.3	108.6	96.0
Wasted/lb BOD removed	1.21	1.07	1.12	1.06	1.07	0.86	0.83	0.76	1.01	0.83	0.96	0.77
Wasted/mil gal sewage++	1250	1100	1120	1020	920	820	750	710	860	830	1000	880
Produced/lb BOD removed	1.34	1.21	1.25	1.23	1.28	1.05	1.09	0.99	1.26	1.11	1.13	0.95
Produced/mil gal sewage++	1380	1230	1250	1180	1100	1010	990	920	1020	1120	1180	1090

* 1 mgd = 0.044 m^3/sec = 3785 m^3/day

** Defined as kg MLSS in reactor/kg SS in reactor influent/day.

+ 1 lb = 0.454 kg

++ 1 lb/mil gal = 0.12 kg/1000 m^3

TABLE 18. SLUDGE PRODUCTION AT 26th WARD STEP AERATION AIR PLANT

Month	06/75	07/75	08/75	09/75	10/75	11/75	12/75	01/76	02/76	03/76	04/76	05/76	06/76	07/76	08/76	09/76	10/76
Flow (mgd)*	79	88	90	89	82	82	78	85	81	80	81	87	84	85	87	81	83
BOD Removed (mg/l) (Pri. + Sec.)	92	63	59	56	62	84	75	65	73	61	69	58	58	67	65	78	64
Effluent SS (mg/l)	21	16	20	21	16	18	16	22	18	17	14	21	13	17	12	15	20
MLSS (mg/l)	2700	2100	2200	2300	2300	1800	1900	2500	2300	2400	2000	1900	1900	1700	1900	1700	2300
Sludge Age** (days)	3.4	3.2	3.1	2.9	3.8	4.0	3.9	5.3	5.1	5.0	3.7	3.8	3.6	3.5	4.6	3.8	4.7
<u>Total SS (dry/lb)</u>[+]																	
Wasted/day (x 1000)	55.5	55.6	60.8	51.7	53.5	42.1	38.9	39.6	53.9	53.5	59.9	55.1	58.9	52.2	50.2	52.1	54.3
In effluent/day (x 1000)	13.8	11.7	15.0	14.8	10.9	12.3	10.4	15.6	12.2	11.3	9.5	15.2	9.1	12.1	8.7	10.1	13.8
Total produced/day (x 1000)	69.3	67.3	75.8	66.5	64.4	54.4	49.3	55.2	66.1	64.8	69.4	70.3	68.0	64.3	58.9	62.2	68.1
Wasted/lb BOD removed	0.92	1.20	1.37	1.24	1.26	0.73	0.80	0.86	1.09	1.31	1.29	1.31	1.45	1.10	1.06	0.99	1.23
Wasted/mil gal sewage[++]	0.70	0.63	0.68	0.58	0.65	0.51	0.50	0.47	0.67	0.67	0.74	0.63	0.70	0.61	0.58	0.64	0.65
Produced/lb BOD removed	1.14	1.46	1.71	1.60	1.52	0.95	1.01	1.20	1.34	1.59	1.49	1.67	1.67	1.35	1.25	1.18	1.54
Produced/mil gal sewage[++]	0.88	0.76	0.84	0.75	0.79	0.66	0.63	0.65	0.82	0.81	0.86	0.81	0.81	0.76	0.68	0.77	0.82

* 1 mgd = 0.044 m^3/sec = 3785 m^3/day

** Defined as kg MLSS in reactor/kg SS in reactor influent/day.

[+] 1 lb = 0.454 kg

[++] 1 lb/mil gal = 0.12 kg/1000 m^3

SECTION 6

EQUIPMENT AND INSTRUMENTATION OPERATING EXPERIENCES

A multitude of equipment failures and inadequacies were experienced during the course of the test. Unless specifically noted in the operational narrative, Section 5, these difficulties did not significantly affect the overall performance of the process. However, the great number of problems did require a large amount of attention by the technical and operating staffs. This information is provided, not as a criticism of the original design and selection of particular products, but as a matter of record.

PSA OXYGEN GENERATOR

This unit was rehabilitated in late summer 1974 after 27 mo of rather unreliable service. It operated practically flawlessly after the overhaul, in contrast to its first 2 yr.

Most of the problems were associated with malfunctioning valves beginning early in the program, which resulted in moisture contamination of two of the four adsorption beds. From that time forward, the maximum output of the unit was 10.4 metric tons/day (11.5 tons/day) of 90 percent pure oxygen, instead of the design rate of 15.2 metric tons/day (16.7 tons/day). To protect the adsorption beds from further moisture contamination from stuck valves, an oxygen purity analyzer was later installed to continually monitor the PSA product purity. The analyzer sounded an alarm when the purity fell to 85 percent and shut down the PSA unit at 80 percent.

Continued valve problems required the replacement during the course of the test of all valves, valve actuators, and solenoids, and some pressure switches. The replacements, of a different design, performed considerably better than the originals, but they too failed to function properly from time-to-time.

During checkout before the initial process startup, a defective bearing was discovered in the PSA compressor motor, requiring its removal and repair by the manufacturer.

In September 1973, the PSA oxygen generator was again shut down for 10 days awaiting the return of the compressor motor, which had been removed for repairs to the same bearing, and the repair of a scored shaft.

After 2 mo of operation, the PSA cooling tower fan motor burned out, requiring its replacement; 2 mo later, the replacement motor was removed for repair of a defective bearing.

In the 27 mo prior to its overhaul, the PSA generator was out of service for 3054 hr of a possible 18,504 hr, or 16.5 percent of the time. In the 7 mo following its rehabilitation, there were only 57 hr of interrupted service, or 1 percent downtime.

It must be noted that this PSA unit was the first of its size ever manufactured, and so some bugs were inevitable.

LIQUID OXYGEN FEED VALVE

In September 1973, with the PSA generator shut down for the second compressor bearing repair, the process was dependent entirely on the liquid oxygen supply. At this most inopportune time, the motor operating the liquid oxygen feed valve burned out and had to be shipped to the manufacturer in California for repair. Without the automatic valve, the oxygen feed rate could no longer be controlled by the gas space pressure and only manual control through the valve bypass was possible. This crude manual control could not be adjusted for variations in organic loading and resulted in less effective oxygen utilization. Although the PSA unit was returned to service a week after the valve motor failure, once again permitting PSA oxygen feed control, liquid oxygen feed control was not possible during the 1 mo required for the motor repair.

STAGE COMPRESSORS

During the first days of the test, bearing failures attributed to improperly manufactured ball retainers required the replacement of both sets of shaft bearings on all five gas recirculating stage compressors and the substitution of a conventional petroleum lubricant for the synthetic-based lubricant originally supplied. Even after the replacements were installed, additional bearing failures were experienced. It was then discovered that rain was entering the bearing housings through the shafts, contaminating the lubricant and causing the failures. In October 1972, weather-proof shields were installed around the shafts and some bearings were replaced for the second time. Still another bearing failure occurred in August 1973.

In addition to the compressor shutdowns resulting from bearing failures, there were nuisance shutdowns caused by excessive vibration and low seal air pressure during the first 5 mo. Occasional failures of the couplings between the seal air compressors and their motors, as well as failures of the seal air systems themselves, developed after a year of operation. Some of these difficulties were repaired by plant personnel, while others required the services of the manufacturer.

PROPELLER MIXERS

Oil leaks plagued the operation of the propeller mixers until, after 2 mo of operation, gaskets were fabricated for the speed reducers. Improperly sealed rotating unions resulting in considerable oxygen leakage required replacement; some rotating unions were still leaking at the end of the test program. On one of the two first-stage mixers, the drive motor burned out, some gears and bearings required replacement, and the motor bearings failed. After 6 mo of operation, the mixer high-oil temperature and vibration shutdown systems, which were causing nuisance shutdowns, were deemed extraneous and were removed.

RETURN SLUDGE PUMP

The return sludge pump was the single most troublesome piece of equipment. With no spare unit provided, bearing failures in November 1972 and again in November 1973 required complete process shutdowns to accomplish the repairs.

In addition to the bearing failures, another problem was evidenced by the pump going out on overload at less than half its capacity. The overload resulted from debris accumulating between the shaft sleeve and the packing and between the wearing rings, and also because of a restricted suction.

When the pump was taken out of service for the first bearing replacement, the factory-supplied grease seal system was replaced with a water-seal system. The higher pressure water-seal system prevented the further accumulation of foreign material between the shaft sleeve and packing and also halted the excessive leakage that had been experienced through the packing. The first plant shutdown provided the opportunity to modify the pump suction line; remove the accumulation of grit, rags and other foreign material from the sump, which had been responsible in part for the reduced pump capacity; and install a water jet to prevent future accumulations. With the improved seal system and the suction modification, the pump output increased significantly and overload shutdowns became less frequent. During the second shutdown, it was discovered that the clearance between the wearing rings was excessive, allowing debris to accumulate and restrict the rotation of the impeller. The clearance was reduced by building up the impeller wearing ring in the factory because a new set of wearing rings was not readily available.

WASTE SLUDGE PUMP

The major difficulty with the waste sludge system was an improperly-designed pump suction. Originally, the suction line consisted of a 7.6-cm (3-in.) pipe teed from the 51-cm (20-in.) return sludge pump suction line and operation was frequently interrupted when a vacuum formed in the line and halted the waste sludge flow. Wasting was then attempted by manipulation of valves and the use of an alternate pipeline, but a constant flow could not be maintained. During one of the shutdowns, a piping modification was made to allow the waste sludge pump to take suction from the discharge of the return sludge pump. This also proved unsuccessful: with the waste sludge pump in series with the much larger return pump, the waste flow was dictated by the return pump and operation of the waste sludge pump variable-speed controller had very little effect on controlling the flow rate. Finally, during the third plant shutdown, a new 7.6-cm (3-in.) suction line from the pump directly to the sump was installed. From then on, operation of the waste sludge pump completely independent of the return system was possible.

The only problem with the waste sludge pump itself was a cracked casing, probably caused by water freezing in the casing. During the second summer of operation, the plant force installed a water seal system for the pump to replace the factory-supplied grease seal system.

MAGNETIC DRIVES FOR VARIABLE-SPEED PUMP CONTROL

Before the initial process startup, the influent pump variable-speed magnetic drive had to be removed and returned to the manufacturer for the replacement of a defective bearing. During the second summer of operation, the magnetic pick-up, which is the mechanism that initiated the automatic control of the return sludge pump, became inoperative, requiring manual control of the pump for a short time until the pick-up was replaced by the manufacturer. Two mo later, a faulty signal converter was discovered in the return sludge pump variable-speed drive. Following a flooding of the pump pit, the waste sludge pump lost its speed control and the pump could not be used for the weeks until the manufacturer replaced the tachometer generator and the defective drive bearings.

WASTE SLUDGE MAGNETIC FLOW METER

In January 1973, after 8 mo of operation, a volumetric test of the waste sludge magnetic meter showed that the meter was reading low by almost 40 percent. The manufacturer's explanation was that the indicated calibration voltage may have been incorrect. This error, coupled with additional problems encountered with the power supply boards, required a non-linear correction to the acquired data. Consequently, the first 8 mo of waste sludge data were inaccurate and had to be discarded. The defective meter was replaced in February 1973 by one borrowed from another manufacturer, and in late March, the second meter was replaced by a third meter from a third manufacturer. The second meter was satisfactory, but it was only a loan and had to be returned. By this time, the staff had become wary of magnetic flow meters and weekly volumetric tests of the waste sludge meter were begun. Therefore, the waste sludge data acquired from March 1973 until the end of the test are reliable. Although the permanent replacement meter proved adequate, volumetric checks showed that on two occasions it too required service.

RETURN SLUDGE MAGNETIC FLOW METER

In September 1972, the first routine service check of this meter revealed an improper electrical connection and an incorrect calibration voltage. The return sludge flow data for the first 4 mo of the project, before the meter was recalibrated, were therefore dismissed. Because of the large volume of return sludge, a volumetric check could not be performed in place, as was possible with the much smaller waste sludge meter. The meter was, therefore, removed for a factory bench flow test after almost a year-and-a-half of operation. Accuracy within 1 percent was ascertained. Malfunctions of the electrical circuitry were experienced on two occasions after September 1972 and were corrected by the manufacturer.

In November 1974, after the conclusion of 11 phases of the test program, it was discovered that the return sludge piping had been installed in a manner which permitted the entrainment of air in the meter. Since proper operation of a magnetic flow meter requires full liquid flow, all return sludge data for the first 11 phases before the condition was rectified must be viewed with caution. If anything, recorded return sludge flow data during this period were higher than actual.

INFLUENT MAGNETIC FLOW METER

The first routine service check in September 1972 also revealed an incorrect calibration voltage in the influent magnetic flow meter. The resulting incorrect flow data collected from May through September 1972 were, therefore, abandoned. After recalibration, a volumetric check of the meter indicated acceptable accuracy. No electrical problems due to circuitry were experienced with the meter.

OXYGEN FEED FLOW METER

Difficulties were experienced with the flow totalizer counter, the integrator, the square foot extractor, and the multiplier-divider, all of which required service by the vendor. Although the design combined oxygen supply capacity of the PSA generator and liquid supply system was 30 metric tons/day (33 tons/day), the upper limit of the oxygen feed flow meter was only

23 metric tons/day (25 tons/day). In the summer of 1973, when system influent flow was increased to 1.31 m^3/sec (30 mgd), the resulting increased oxygen flow exceeded the capacity of the meter. During this period, oxygen feed was measured by adding to the PSA generator output the amount of liquid oxygen trucked in. In September 1973, the capacity of the meter was increased to 36 metric tons/day (40 tons/day); however, incorrect calibration data were used to increase the range of the meter, and an incorrect procedure was used during subsequent routine calibrations. The extent of the resulting error was finally determined, and all oxygen feed data acquired from September 1973 to April 1974 were corrected.

HYDROCARBON ANALYZERS

For the first 8 mo of the project, frequent failures of the diffusion heads, as well as large span errors and drifts from zero, were responsible for unreliable analyzer readings. According to the manufacturer, the poor performance resulted from accelerated oxidation of the heads in the moisture-laden, oxygen-rich environment. Performance improved after the heads were replaced with others of a design more compatible with an oxygen environment, but for the remainder of the program, the zero and span required weekly adjustments and the diffusion heads required replacements, although infrequently.

OXYGEN PURITY ANALYZER

Although this unit performed satisfactorily, slight drifts from zero and span errors required weekly calibrations.

DISSOLVED OXYGEN METERS

After 5 mo of troublesome operation, automatic DO measurement was abandoned. It was impossible to keep the meters calibrated. Not only were the high DO levels accelerating the wear of the probes, but with the probes located in the sparger bubble stream, they were continually battered by turbulence, even after deflectors were installed. The end of automatic DO measurement also halted automatic control of the first-stage DO level. Thereafter, the DO was determined manually with a portable analyzer at infrequent intervals since that measurement was not considered to be necessary for successful operation.

SAMPLE COMPOSITORS

The effluent automatic sampler operated successfully throughout the project, but the influent unit was not as fortunate. The sampling line clogged so frequently that after a little more than a year of operation, it was retired and grab sample compositing was substituted.

SERVICE CONTRACT

In order to ensure data accuracy, as well as to attend to the frequent instrumentation problems, a service contract was entered into between the City and an instrumentation company. This contract called for the services of a technician 1 full day each week, in addition to emergency calls.

SECTION 7

DISCUSSION OF RESULTS

EPA's purpose in sponsoring the test was to obtain, evaluate, and disseminate operating and performance data for use in the design or upgrading of plants throughout the country. Equally important to EPA were sludge production, power and oxygen requirements, and equipment performance. In the view of the City of New York, the prime requisite for success and acceptance of the process was 90 percent removal of BOD and SS at 0.83 m^3/sec (20 mgd). A large body of data was obtained even after sizable portions had to be discarded because of defective flow meters. However, although effluent quality can be readily assessed, only qualified conclusions can be offered regarding sludge production, power requirements, and oxygen consumption.

OXYGEN SYSTEM PROCESS PERFORMANCE

Effluent quality during the 12 phases averaged 19 mg/l each of BOD and SS and ranged from 9 to 26 mg/l of BOD and 12 to 27 mg/l of SS. The averages for the eight non-filamentous phases were the same--19 mg/l for BOD and SS--and for the four filamentous periods, 21 and 20 mg/l, respectively. Thus, although the fungi were responsible for some operating difficulties and for increased sludge volumes, they had no significant effect on process efficiency.

No supportable relationship between sewage flow and effluent quality could be discerned. During Phases 5, 6, and 7, when influent flow rates were 120 to 177 percent of the design flow and the BOD loading rates were 123 to 140 percent of the design loading, the effluent quality was only slightly below those at lower flows, and, indeed, improved as the rate was increased.

Removals during Phase 1 (at constant flow, not diurnal) were higher than during any other period--94 percent of BOD and 92 percent of SS. Removals during Phases 8 and 9, at flows only 49 and 70 percent of Phase 1's 0.91 m^3/sec (20.8 mgd), and during the same season of the year, were 3-5 percent less. The reason is not known.

Also unknown is the reason for the failure of the activated sludge culture to return to its normal diversity in Phase 11 following the severely filamentous Phase 10. Effluent BOD and

SS averaged 24 and 26 mg/l, respectively, just about the same as they were during Phase 10.

There was a sharp drop in the COD/BOD ratio during Phases 5 and 6 (June and July 1973) and a gradual return to normal in later periods. Compared to the four earlier phases, influent COD strength was 16 percent lower during Phases 5 and 6 but the BOD was 38 percent greater.

Average influent TOC ranged from 90 to 110 mg/l and effluent TOC from 21 to 54 mg/l. The 54 mg/l occurred in Phase 4 and was far greater than the usual average effluent range of 21 to 35 mg/l. Except for Phase 4, the fungus periods were highest in effluent TOC.

There is strong but circumstantial evidence that restarts of the Newtown Creek oxygen system during the first two winters were responsible for the greater growth of the fungus experienced in those winters as contrasted to the third winter. However, complete shutdowns would not occur in a permanent plant system equipped with the usual assortment of backup equipment.

CONSULTANT OBSERVATIONS AND PILOT PLANT STUDIES

The following conclusions are based on the fungus consultant's observations (10) and the 1974-1975 winter oxygen pilot plant studies at Newtown Creek and Wards Island:

1. The same fungus present in Newtown Creek wastewater was also present in the four other wastewaters sampled, and, thus, it is highly likely that it exists at all other City plants.

2. The fungus organisms did not significantly concentrate in the mixed liquor of the three other plants examined nor in the Wards Island oxygen pilot plant.

3. Newtown Creek's wastewater is conducive to the growth and proliferation of the fungus in activated sludge mixed liquor during cold weather (wastewater temperatures below approximately 60 F), more so under oxygen.

4. No fungicide or operating strategy was found which could satisfactorily control growth of the undesirable organisms during winter operation at Newtown Creek.

COMPARISON OF OXYGEN SYSTEM AND AIR PLANT PROCESS PERFORMANCE

It was expected that the UNOX process would provide removal efficiencies greater than those of the Newtown Creek air plant, for the air plant was being operated as a high-rate conventional regime and the UNOX process was considered a substitute for step aeration. Excepting the severe fungal Phase 10, the UNOX effluent averaged 15 mg/l of BOD and 25 mg/l of SS lower than the air plant's, which operated at a flow of only 11.3 mgd. In Phase 10, the air plant effluent BOD was 3 mg/l higher but the effluent SS was 1 mg/l lower. However, during Phase 12 (the third winter), the UNOX effluent was better than the air plant's by 15 mg/l of BOD and 28 mg/l of SS.

In terms of percent removal, the oxygen system averaged 88 percent for BOD and 86 percent for SS: for the air plant, the averages were 81 and 68 percent, respectively. Oxygen system flow ranged from 0.44 to 1.55 m^3/sec (10.1 to 35.4 mgd) with an average of 0.91 m^3/sec (20.7 mgd), while the air plant single module average was 0.50 m^3/sec (11.3 mgd) with a range of 0.42 to 0.54 m^3/sec (9.7 to 12.4 mgd). Thus, the oxygen system performed considerably better than the air plant on nearly twice the flow. In terms of filtrate BOD removal, the oxygen system averaged 87 percent compared to 77 percent for the air plant. Flow and process performance (both concentration and percent removal) data were presented previously in Tables 2 and 10 for, respectively, the Newtown Creek oxygen demonstration and full-scale air systems. BOD and SS removals for the two systems are compared graphically in Figures 6 and 7, respectively.

The two systems reacted differently during the three winters. Oxygen system effluent quality was mildly affected during Phase 3 (the first winter), but BOD removal by the air plant fell to 73 percent, the lowest of all 12 phases. During Phase 10 (the second winter), it was oxygen process performance that deteriorated; the air plant was not affected. During Phase 12 (the third winter), however, the air plant was greatly affected and the oxygen system only slightly.

Separate influent samples were collected and analyzed for the air plant and the UNOX system, but the UNOX influent data have been used for the air plant also because they are considered more reliable. The air plant samples were composites taken at the entrances to the aerated grit chambers of two of the 14 tanks; the UNOX samples were taken at the end of the non-aerated grit chamber where, despite some settling of SS, the BOD was only slightly reduced. There was a more serious hazard at the air plant sampling location, where a tendency existed for drawing a stream of return sludge into the aerated grit chambers and contaminating the samples.

AERATION TANK PERFORMANCE

The oxygen diffusion equipment at first was designed for a BOD loading of 15,150 kg/day (33,400 lb/day), but was enlarged before construction to 18,915 kg/day (41,700 lb/day) because the latest analytical data at the time showed the BOD influent strength to be about 250 mg/l. Thus, the design volumetric organic loading for the 4656-m^3 (1.23-mil gal) aeration tank was

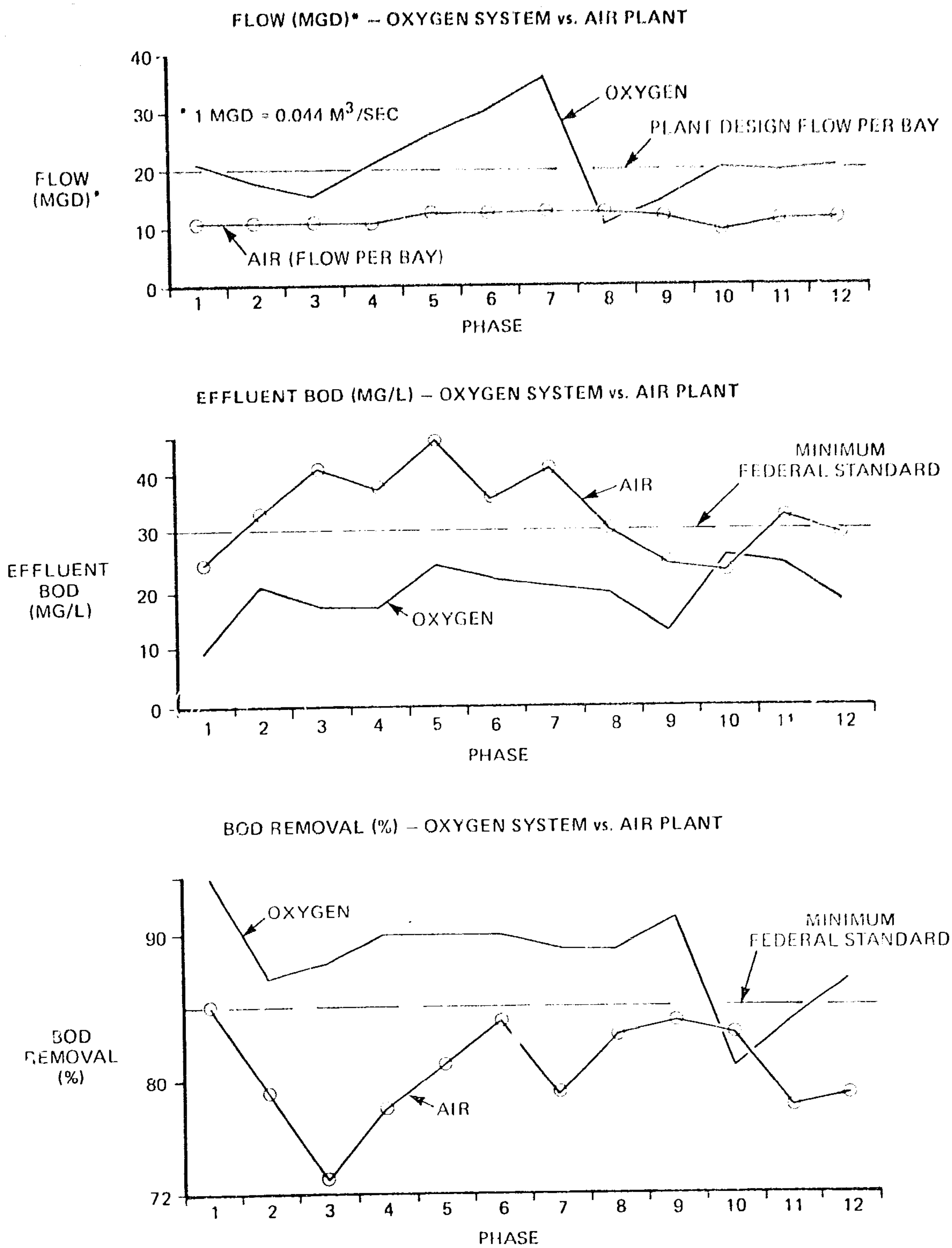

Figure 6. Comparison of Newtown Creek oxygen system and air plant BOD removal performance.

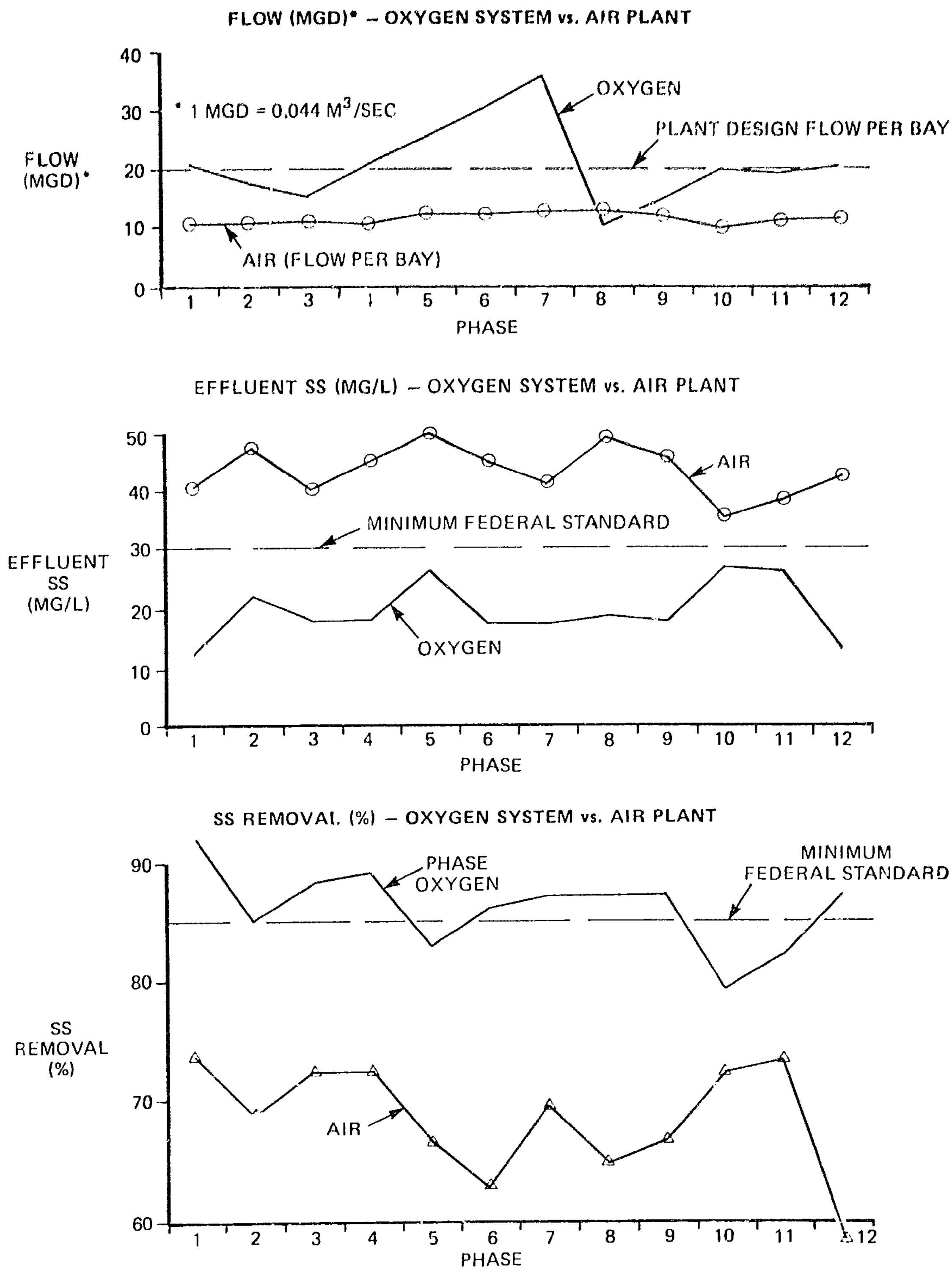

Figure 7. Comparison of Newtown Creek oxygen system and air plant suspended solids removal performance.

4.05 kg BOD/day/m^3 (253 lb/day/1000 ft^3). The volumetric organic loadings encountered during most of the test were considerably lower than the design loading, but during the high-flow, high-BOD Phases 5, 6, and 7, they averaged 4.95 to 5.64 kg BOD/day/m^3 (309 to 352 lb/day/1000 ft^3), 123 to 140 percent of design. This was during the periods of 1.10-to 1.53-m^3/sec (25-to 35-mgd) flows and BOD removal efficiencies of 90 percent. It can be said, then, that the process performed exceptionally well during 3 mo of flow and BOD overloading at high sewage temperatures and in the absence of filamentous organisms.

The oxygenation tank detention time, which was 1.1 hr at 0.88-m^3/sec (20-mgd) influent flow and 25-percent return sludge flow, decreased to 48, 44, and 40 min, respectively, during Phases 5, 6, and 7. These and other aeration tank data for the oxygen system and air plant were shown previously in Tables 3 and 11, respectively.

FINAL TANK PERFORMANCE

Oxygenated return sludge was expected to average 3 percent solids, but the highest phase average actually obtained was only 18,600 mg/l in Phase 9. Excluding Phase 10, the average throughout the test was 14,300 mg/l compared to 10,500 mg/l for the air plant. The reduced compaction of the sludge in the settling tank, chiefly during Phase 10, required the use of high return sludge rates to maintain MLSS (which averaged 3930 mg/l for the entire test program) at desired levels.

The oxygen system final tank overflow rate ranged from 19 m^3/day/m^2 (460 gpd/ft^2) at a flow of 0.44 m^3/sec (10.1 mgd) to 66 m^3/day/m^2 (1610 gpd/ft^2) at 1.55 m^3/sec (35.4 mgd). The data do not show any impairment of effluent quality due to increasing overflow rate. The adjacent Tank No. 10, which was kept empty as a standby if more settling area was needed, was not required.

The solids loading on the oxygen settling tank ranged from 137 to 313 kg/day/m^2 (28 to 64 lb/day/ft^2), from two to seven times the loading on the air plant settling tanks. Weir loadings reached a high of 2749 m^3/day/m (221,300 gpd/ft), compared to the maximum of 963 m^3/day/m (77,500 gpd/ft) for the air plant. The "Ten State Standards" (7) recommend a maximum overflow rate of 33 m^3/day/m^2 (800 gpd/ft^2) and a maximum weir loading of 186 m^3/day/m (15,000 gpd/ft). For solids loadings, the normal practice is 59-88 kg/day/m^2 (12-18 lb/day/ft^2), with a maximum of 146 kg/day/m^2 (30 lb/day/ft^2) (8).

Final tank performance data for the two Newtown Creek processes were previously summarized in Tables 4 (oxygen) and 12 (air).

SLUDGE SETTLING CHARACTERISTICS

During non-fungus periods, the unstirred UNOX SDI averaged 2.2 g/100 ml, and seldom fell below 2.0. During Phases 3 and 10, and less so in Phases 2 and 12, the Index slid severely to averages of 1.2, 1.8, and 1.5 g/100 ml. In addition, there were extended periods during Phase 10 when the SDI bottomed as low as 0.4 g/100 ml. A full plant-scale test under such circumstances would have been afflicted with a formidable sludge disposal problem. In contrast, the Newtown Creek air plant Index was not measurably affected by the fungus, averaging 1.5 g/100 ml throughout the project and on a monthly average basis varying only from 1.3-1.8 g/100 ml. Sludge settling data for the oxygen and air systems are included in Tables 4 and 12, respectively.

OXYGEN SYSTEM OXYGEN REQUIREMENTS

Throughout the test program, an unknown volume of oxygen leaked through the oxygenation tank cover and through the mixer unions. The vent gas was metered, but since the quantity lost through the leaks could not be measured, the amount of oxygen actually used could not be calculated. It is for this reason that only oxygen supplied was listed in Table 5.

In order to minimize the leaks, the gas pressure under the cover was reduced to 2.5-5.1 mm (0.1-0.2-in.) of water. This was far less than the design pressure of 25-76 mm (1 to 3-in.), but it did not affect the process.

The amount of oxygen supplied averaged 173 g/m^3 (1440 lb/mil gal) and was somewhat proportional to the MLVSS and the sludge age. Based on BOD removal, the oxygen requirements varied from 0.8 to 1.6 kg supplied/kg BOD removed. At or above the design flow, the amount of oxygen supplied averaged 1.1 kg/kg BOD removed; at flows below design, it ranged from 1.2 to 1.6 kg/kg. During the 1973 summer high-loading phases (Phases 5, 6 and 7), the requirement was only 0.8 kg supplied/kg BOD removed.

There is much less variation among the phase averages when the oxygen requirement is calculated on a COD removal basis. In the 11 phases in which oxygen supply was monitored, the requirement was either 0.6 or 0.7 kg supplied/kg COD removed in eight phases, and either 0.8 or 0.9 in the other three. In view of the industrial nature of the Newtown Creek wastewater, COD removal probably is the better parameter.

POWER REQUIREMENTS

The oxygen-generating and dissolution equipment, which included the PSA unit and its compressor, the gas recirculating stage compressors, the stage mixer spargers, and the liquid oxygen vaporizer, was sized for a BOD loading of 18,915 kg/day

(41,700 lb/day). Unfortunately, however, it was not equipped with turn-down capability to accommodate lower loadings; about all that could be done was to throttle the suction line of the PSA compressor, which reduced the power only slightly. The result was that essentially the entire 746 kW (1001 hp*) of the equipment was used at all times, regardless of the loading. The power requirements at BOD loading rates below design (during all phases except 5, 6, and 7), therefore, are not fairly representative of the process. It was only during those three 1973 summer phases when the equipment was fully loaded that the power required can be equitably compared with the work performed.

Tables 6, 13, 15, and 16 contain data on the power requirements for the Newtown Creek oxygen system, the Newtown Creek air plant, and the Jamaica and 26th Ward step aeration air plants, respectively. For the three phases when the oxygen system was fully loaded, the power required to provide 90 percent removal of BOD and 85 percent removal of SS averaged 0.95 kWh/kg BOD removed (0.58 hp-hr/lb). During the same period, the Newtown Creek's air plant requirement was 0.92 kWh/kg BOD removed (0.56 hp-hr/lb) but it averaged 1.25 (0.76) for the 12 phases. However, the air plant's power requirement is not a proper basis for comparison; its effluent quality was not equal to the oxygen system's and, consequently, the power used to operate it was lower. Air plant removals during Phases 5, 6, and 7 averaged 81 percent for BOD and 66 percent for SS compared to the UNOX system's 90 and 85 percent, respectively.

An additional comparison can be made with the Jamaica and 26th Ward plants, the only New York City plants which in the past 20 yr have treated their entire flows by step aeration and for which blower power can be identified. The Jamaica data pertains to only a single year. and that for 26th Ward is only for the first 17 mo following its return to service after upgrading. Both plant's wastes are essentially domestic, whereas Newtown Creek's is the most heavily industrial of all City plants.

Jamaica's air diffuser system, which at the time of data collection had been in service for 10 yr, consisted of a single header along one wall with ceramic fine-bubble tubes extending from both sides of the header. The new 26th Ward system has two headers along one wall with ceramic diffusers similar to those at Jamaica extending from both sides of both headers.

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*PSA compressor-450 hp
Liquid oxygen vaporization-96 hp
Stage compressors-160 hp
Mixers-280 hp
Miscellaneous-15 hp

For Jamaica, the power required by the air blowers during the reporting period of March 1972-February 1973 averaged 1.48 kWh/kg BOD removed (0.90 hp-hr/lb) with the lowest rate of 1.21 (0.74) achieved during four of the 12 mo. For 26th Ward, the average from June 1975-October 1976 was 0.84 kWh/kg BOD removed (0.51 hp-hr/lb) with a range of 0.71 to 1.05 (0.43 to 0.64). Caution should be used when considering these power data relative to the Newtown Creek oxygenation system data since the parameter used here (kWh/kg BOD removed) does not account for differences in the rate of oxygen consumption per unit BOD removed or for differences in the plant loading relative to the design point. Therefore, direct comparison of these data to data from the Newtown Creek oxygenation system may not be valid.

SOLIDS PRODUCTION

As a practical operating consideration, more important than the dry weight of sludge produced is its volume, for it is sludge in its liquid form which must be processed. When sludge is digested, as at Newtown Creek, the volume can best be measured when pumped from a thickening tank. Waste oxygen sludge was added to the air plant's return sludge system because piping the waste oxygen sludge and/or oxygenated mixed liquor to one of the plant's eight thickeners would have been too expensive for what was, after all, to have been only a 1-yr test. Thus, no information was obtained on the gravity thickening characteristics of UNOX sludge.

Therefore, the only estimation that can be made of excess sludge production with oxygen at Newtown Creek is on the basis of the dry solids in the waste sludge and the final effluent. Figure 8 compares UNOX sludge production at Newtown Creek with that observed for the air and oxygen trains at Batavia, New York (9), and relates kg volatile solids produced/day/kg MLVSS to kg BOD removed/day/kg MLVSS.

Four Newtown Creek points agree very closely with the Batavia oxygen distribution, while three fungus points and one transition point fall in the neighborhood of the Batavia air distribution. Sludge production data for Phases 1 and 2 could not be used because of the inaccurately calibrated waste sludge meter in use at that time; Phase 9 data were omitted because the mixed liquor samples were contaminated by the froth during that period; and insufficient solids analysis were performed in Phase 11 to plot data from that phase. In comparing sludge production data for Newtown Creek and Batavia, it should be remembered that both plants operate without primary sedimentation.

Newtown Creek oxygen system sludge production during normal and fungus periods can also be compared with sludge production during the same periods for the Newtown Creek air plant. As previously summarized in Table 6, during non-fungus operation, ex-

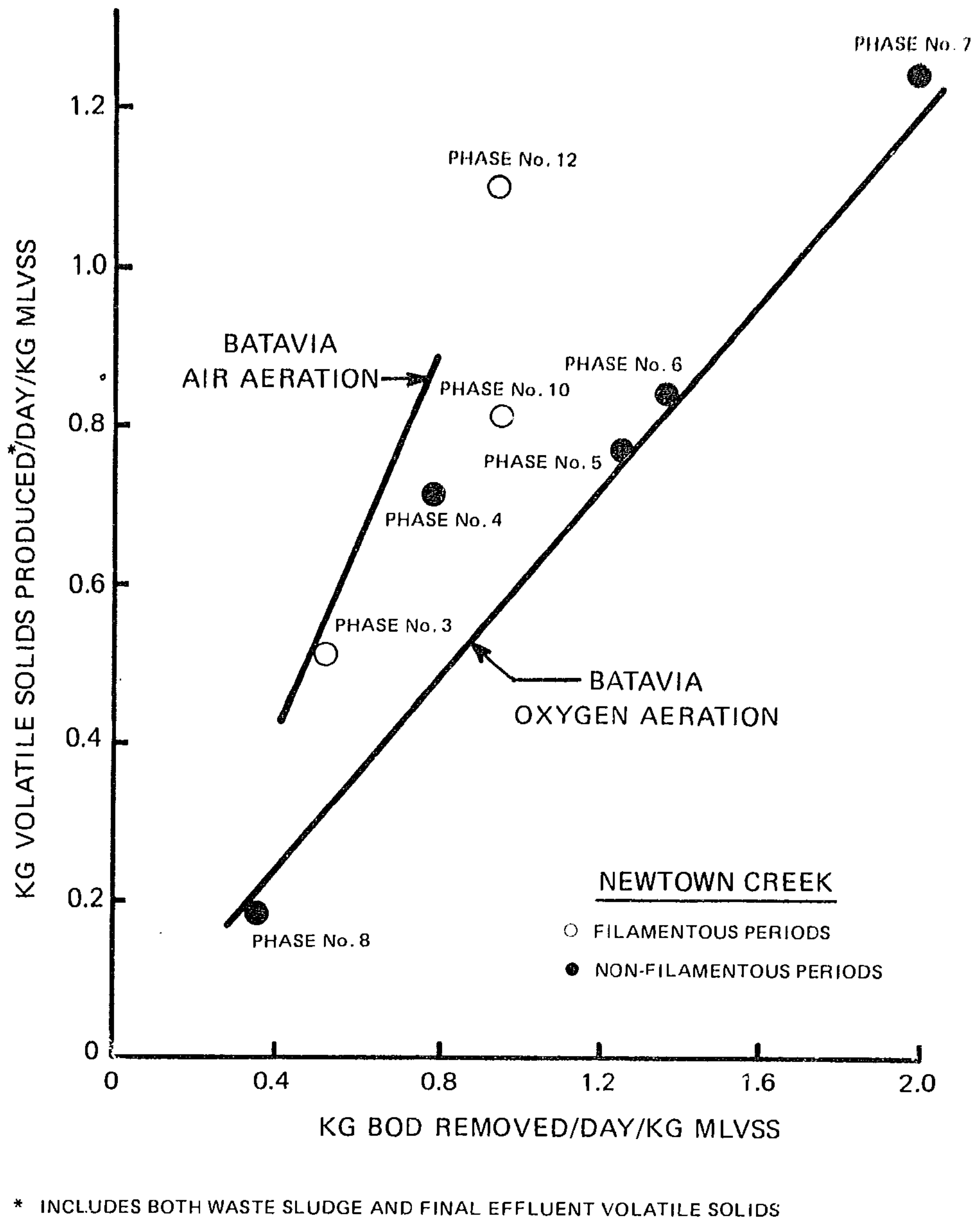

Figure 8. Excess solids produced by Newtown Creek oxygen system superimposed on Batavia, New York sludge production graph.

cess solids generated by the oxygen system averaged 0.93 kg/kg BOD removed but rose to an average of 1.27 kg/kg BOD removed, 37 percent higher, during Phases 3, 10, and 12 (the three fungus phases). For the air plant, the comparable figures were 1.27 and 1.71 kg/kg BOD removed, respectively, as documented previously in Table 14. Oxygen, therefore, produced on a BOD removal basis 27 percent less solids than the air plant during normal periods and 26 percent less during fungus periods.

Data from the Jamaica step aeration air plant, which was not troubled by filamentous organisms, were confined to a narrower range, averaging 1.16 kg/kg BOD removed and varying from 0.95-1.34 during the 12-mo period of March 1972-February 1973 (see Table 17). Using these bases, Newtown Creek oxygen system solids production when unaffected by the fungus was 23 percent less than Jamaica's and during the fungus phases, 6 percent more.

A comparison can also be made with the excess solids produced at New York City's 26th Ward step aeration air plant (also not infected by filamentous growths) during the first 17 mo following its upgrading (Table 18). At an average sludge age of 4.0 days, twice that of the Newtown Creek oxygen system, solids production averaged 1.39 kg/kg BOD removed. Oxygen system production was 9 percent less solids during filamentous periods and 33 percent less during non-filamentous periods.

OXYGEN SYSTEM NUTRIENT REMOVALS

One mo of the program had been set aside for a test of phosphate removal by alum addition. However, in June 1973, a state-wide ban on the use of high-phosphate detergents went into effect, reducing the already low influent phosphorus concentration which had averaged 3.9 mg/l for the previous 8½ mo to 2.8 mg/l for the month of June. Probably the ban had an effect before June because all high-phosphorus products had to be removed from store shelves before that date. During the eight phases following the initiation of the ban, the oxygen system without alum addition achieved 59 percent total phosphorus removal from 2.9 mg/l down to 1.2 mg/l. The alum addition test, therefore, was considered unnecessary.

Table 8 lists by phase the average concentrations of influent and effluent total phosphorus, soluble orthophosphate, and the major nitrogen components. Influent soluble orthophosphate was similarly reduced by the effects of the ban from 2.2 mg/l to 1.7 mg/l (both as P). The average effluent concentration from June 1973 on was only 0.7 mg/l.

Ammonia nitrogen averaged 9.5 mg/l in the influent and 8.2 mg/l in the effluent. Removals were erratic, varying from 0 to 39 percent. The TKN content was relatively steady, averaging 21.0

mg/l in the influent sewage and 12.8 mg/l in the effluent.

OTHER OXYGEN SYSTEM SEWAGE CHARACTERISTICS

Averages for alkalinity, dissolved solids, turbidity, and pH were previously given in Table 9. The principal item of interest here was the drop in the pH of the wastewater in its travel through the covered oxygen aeration tank and its recovery in the settling tank. This decrease in pH may have played some part in the proliferation of the fungi.

Analyses for dissolved solids and turbidity were discontinued after Phase 5 to reduce the workload on the laboratory.

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APPENDIX A

DETAILED DESCRIPTION OF EQUIPMENT

MECHANICAL EQUIPMENT

PSA Oxygen Generation System

Oxygen gas was produced on-site by a Union Carbide pressure swing adsorption (PSA) unit and its associated equipment, which included an air compressor, cooling tower and pump, and instrument air booster and dryer. Air at rates up to 4050 std m^3/hr (143,000 scfh) and pressures up to 28,125 kgf/m^2 (40 psig) was fed to the PSA unit from a Clark Isopac-3 two-stage centrifugal compressor, driven by a Louis Allis Co. 336-kW (450-hp) motor. The PSA unit was designed to produce 473 std m^3/hr (16,700 scfh) equivalent to 15.2 metric tons/day (16.7 tons/day) of 90 percent pure oxygen, or 13.6 metric tons/day (15 tons/day) of 100 percent pure oxygen.

Liquid Oxygen Tank and Vaporizer

These units consisted of a Union Carbide liquid oxygen storage tank with an equivalent gas capacity of 35,853 m^3 (1,266,000 ft^3) and an electrically-heated, water-bath vaporizer with a capacity of 510 std m^3/hr (18,000 scfh) of gas. The tank was a double-walled, vacuum-power-insulated unit with a liquid capacity of 42 m^3 (11,000 gal) and a working pressure of 45,700 kgf/m^2 (65 psig). The vaporizer consisted of a 1.9-m^3 (500-gal) water ballast tank including a vaporizer coil for the product stream, smaller pressure-building coil for pressure maintenance, and an electric immersion heater. The heater, rated at 72 kW, maintained a temperature of 130 F. A sensor in the water bath signaled an alarm if the temperature fell below 90 F, and another sensor in the oxygen piping downstream of the vaporizer sounded an alarm if the temperature of the oxygen fell below 0 F.

Mixers

The characteristics of the eight Philadelphia Gear mixers were slightly different from stage to stage. The Stage 1 mixers were driven by 37-kW (50-hp), 1750-rpm motors, with 183-cm (72-in.) propellers at a 267-cm (105-in.) pitch rotating at 77 rpm.

The mixers in Stages 2, 3, and 4 were driven by 22-kW (30-hp), 1750-rpm motors. The propellers in Stage 2 were 183-cm

(72-in.) diameter, 224-cm (88-in.) pitch, and 70 rpm; in Stage 3, they were 183-cm (72-in.) diameter, 183-cm (72-in.) pitch, and 74 rpm; and in Stage 4, 188-cm (74-in.) diameter, 188-cm (74-in.) pitch, and 71 rpm. Eight-arm oxygen spargers were mounted to the bottom of the hollow, stainless steel mixer shafts 46-cm (18-in.) beneath the propellers. Johnson rotary joints were used at the tops of the shafts as oxygen lead-ins to the rotating shafts.

Motor Control Center

The 460-volt motor control center (by General Electric Co.) was located in the control building and contained motor controls for all major system equipment, including the PSA air compressor, cooling tower pump and fan, instrument air compressor, mixers, oxygen recirculation compressors, influent pumps, return sludge pump, and waste sludge pump.

Main Instrument Panel

The main instrument panel (MIP), located in the control building, contained all the major instruments, controls, and recorders, in addition to the annunciator system for signaling abnormal operating conditions and alarms. The controls and instruments on the MIP are described individually later in this appendix.

Oxygen Recirculation Compressors

Five compressors (Hoffman Division of Clarkson Industries) were provided, two for the first stage, and one each for Stages 2, 3, and 4. The Stage-2 unit was rated at 21 std m^3/min (750 scfm), the other four at 18 std m^3/min (650 scfm). Each was driven by a 30-kW (40-hp), 3550-rpm motor and provided with an integral seal air supply and necessary instrumentation for surge prevention and vibration protection. The suction line leading to each compressor was equipped with a V.D. Anderson Co. "Hi-eF" separator to remove liquid entrained in the recirculated gas.

Influent Pumps

These units were Worthington 61-cm (24-in.) "Mixflo" horizontal volute pumps. The variable-speed pump was driven by an Electric Machinery Ampli-Speed magnetic drive from a Westinghouse 119-kW (150-hp), 585-rpm motor. A Regutron II control and FIS signal transmitter were used to regulate the magnetic drive. The constant-speed pump was driven directly by a Westinghouse 119-kW (150-hp), 585-rpm motor.

Return Sludge Pump

This variable-speed pump was a Worthington 51-cm (20-in.), 0.66-m^3/sec (15-mgd) "Mixflo" vertical volute pump, driven by an Electric Machinery Ampli-Speed magnetic drive from a Westinghouse 75-kW (100-hp), 705-rpm motor. A Regutron II control and an RIS signal transmitter regulated the drive.

Waste Sludge Pump

The waste sludge pump was a variable-speed, ITT Marlow, vertical "Vane-Flow" solids-handling unit with a 0-1135-l/min (0-300-gpm) range, driven by an Electric Machinery Ampli-Speed magnetic drive from a 5.6 kW (7½-hp), 880-rpm motor. The Ampli-Speed drive was controlled by a Regutron II control, and speed was manually regulated from the control building.

AUTOMATIC VALVES

Liquid Oxygen Feed Valve

The Driox feed valve was a 5-cm (2-in.) Masoneilan electronically-controlled automatic globe valve with cast bronze body, percent-contoured bronze trim, and Teflon seat. It was operated by a General Controls hydromotor actuator in response to a 12- to 20-ma increase-to-open input signal. The valve was set to fail closed upon loss of power.

Oxygen Feed Valve

The PSA oxygen valve was a 5-cm (2-in.) Masoneilan automatic bronze globe valve with a 3.8-cm (1½-in.) percent-contoured trim. It was pneumatically-controlled, diaphragm-operated, 2100-6300 kgf/m^2 (3-9 psig) air-to-open, and equipped with a positioner. An adjustable limit stop permitted presetting the maximum open position of the valve. A solenoid valve in the diaphragm supply normally was energized to allow the valve to respond to its positioner signal. The solenoid valve was de-energized automatically in the event of a lower explosive level (LEL) alarm, or manually by operation of a switch which interrupted the signal, thereby closing the oxygen feed valve.

Stage 1 Mixer Bypass Valve

The bypass valve was a 10-cm (4-in.) Masoneilan electronically-controlled automatic globe valve with cast bronze body, percent-contoured bronze trim, and Teflon seat. It was operated by a General Controls hydromotor actuator in response to a 4-to 20-ma increase-to-open input signal.

Air Bypass Valve

This was a 10-cm (4-in.) Norriseal automatic butterfly valve, with case iron body, neoprene seat, Buna-N seals, and aluminum-bronze disk. The valve was pneumatically-controlled, diaphragm-operated, 2100-10,500 kgf/m^2 (3-15 psig) air-to-open, with its air line interrupted by a solenoid valve. The solenoid was normally energized, keeping the valve closed. The solenoid was deenergized either manually by operating a switch or automatically in the event of an LEL alarm.

Relief Valves

These valves were 30-cm (12-in.) Oceco regulators with Fluorel (Viton) diaphragms designed to provide both pressure and vacuum relief. Those for the first three stages were set to open at 15 cm (6 in.) of water, the fourth-stage valve at 13 cm (5 in.) of water. All were set to open at 10 cm (4 in.) of vacuum.

INSTRUMENTS

Stage 1 Pressure Controller

The Stage 1 pressure controller, located on the MIP, was a Honeywell electronic deviation-indicating controller with a 4-20-ma input signal and a 4-20-ma output signal. The controller was reverse acting, that is, a decreasing input signal caused the output to increase. The controller had both manual and automatic control selection; the output signal was continously displayed.

Stage 1 Pressure Recorder/Oxygen Feed Signal Recorder

A two-pen Honeywell strip chart recorder on the MIP recorded Stage 1 reactor pressure and the oxygen feed signal on a single 0-100 chart.

Oxygen Feed Flow Totalizer

This instrument consisted of a Honeywell linear integrator and a Honeywell totalizing counter with mechanical reset, both located on the MIP. The integrator accepted a 1-5-volt-dc input signal linearly proportional to the oxygen flow and produced 25-volt pulses to drive the totalizing counter.

Oxygen Feed Flow Recorder/Vent Gas Pressure Recorder

A two-pen Honeywell strip chart recorder on the MIP recorded on a single chart the oxygen flow to the aerator and the vent gas pressure at Stage 4.

Oxygen Purity Analyzer

This instrument, a Servomex Controls Ltd. (Adam David Co.) oxygen analyzer, was also mounted on the MIP. It had two scales, 0-25 percent and 0-100 percent, and provided an output signal of 0-10 mv dc proportional to the scale, which was converted to a 4-20-ma signal. The analyzer normally monitored the purity of the vent gas stream from Stage 4, but connections permitted sampling the PSA stream or the oxygen content of any of the other stages.

Oxygen Purity Recorder

An instrument on the MIP recorded the oxygen purity on a single 0 to 100 chart.

Stages 1 and 4 Combustible Gas Detection Systems

Two identical combustible gas detection system were provided to monitor Stage 1 and Stage 4 gas. Each system, by Mine Safety Appliances, consisted of flow control components and the MIP-mounted analyzer unit.

The flow control components consisted of the diffusion head for detecting combustible gas concentrations and a flow meter and necessary filters to protect the devices. A pressurized stream from the recirculation compressor normally was sensed; however, the low-pressure reactor gas space could be sampled by the use of a pump and appropriate valves on the sample rack. The analyzer contained a power supply, readout circuitry, alarm circuits, and operating controls. Dual set points were provided to signal the detection of combustible gas when it reached 25 percent of the LEL, and again when 50 percent of the LEL was detected.

Alarm switches announced alarm levels of combustible gases in the stages and triggered automatic responses in the control circuits.

Stages 1 and 4 LEL Recorders

A two-pen Honeywell strip chart recorder on the MIP recorded LEL levels for Stages 1 and 4 on a single 0-100 linear chart, representing percent of LEL for hexane, the hydrocarbon for which the analyzer was calibrated.

Vent Gas Flow Meter and Totalizer

An Eastech, Inc. 8-cm (3-in.) vortex shedding flow meter was provided with an Eastech signal conditioner and totalizer to measure vent gas flow from Stage 4. The meter body and bluff body were of 316 stainless steel, and the O-rings of Viton.

Influent Flow Meter and Transmitter

This instrument was a Brooks Instruments electromagnetic flow-sensing device with an integral signal converter and located in the influent line leading to the aeration tank. The flow tube was neoprene-lined stainless steel, and the 316 stainless steel electrodes were equipped with automatic mechanical electrode cleaners. The converter produced a linear output signal of 4-20 ma. The meter had a flow measuring capacity of 94.6 m^3/min (25,000 gpm).

Influent Flow Controller

This controller was a Research, Inc. "Data-Trak" programmer which could provide a 24-hr cycle by varying the output signal according to the time of the day. It was equipped with a Research, Inc. Model 607-R1000 "Match-Pack" signal transducer which converted the 0-1000-ohm output to a 4-20-ma output signal.

Influent Flow Totalizer

This influent flow totalizer consisted of a Honeywell linear integrator and a Honeywell totalizing counter with mechanical reset, both located on the MIP. The integrator accepted a 1-5-volt-dc input signal linearly proportional to the influent flow and produced 25-volt output pulses to drive the totalizing counter.

Influent Flow, Return Sludge Flow, and Waste Sludge Flow Recorders

A three-pen Honeywell strip chart recorder on the MIP recorded the flow rates of the three system streams on a single chart.

Return Sludge Flow Meter and Transmitter

A 57-m^3/min (15,000-gpm) Brooks Instruments electromagnetic meter with integral signal converter was provided to monitor return sludge flow. The tube was neoprene-lined 304 stainless steel and the electrodes 316 stainless steel equipped with automatic mechanical electrode cleaners.

Return Sludge Flow Controller

This unit was a Honeywell electronic deviation-indicating cascade controller which accepted both a 1-5-volt-dc signal input proportional to the return sludge flow and a 1-5-volt-dc, remote, set-point input from a ratio controller for cascade operation. The controller could be operated in manual, automatic, or cascade modes.

Return Sludge Flow Ratio Controller

A Honeywell electronic ratio/bias device receiving a 1-5-volt-dc input signal and producing a 4-20-ma output signal was included with the return sludge flow control package.

Waste Sludge Flow Meter and Transmitter

The waste sludge flow meter was a 1.1-m^3/min (300-gpm) Honeywell electromagnetic flowhead with integral signal converter and a neoprene-lined 304 stainless steel tube and 316 stainless steel electrodes equipped with ultrasonic cleaners.

Waste Sludge Flow Totalizer

The waste sludge flow totalizer consisted of a Honeywell linear integrator and a Honeywell totalizing counter with mechanical reset, both located on the MIP. The integrator accepted 1-5-volt-dc input signal linearly proportional to the waste sludge flow and produced 25-volt output pulses to drive the totalizing counter.

Sample Compositor System

Two Union Carbide flow-proportional samplers, one for the influent from the grit chamber and the other for the settling tank effluent, were used for collecting system influent and effluent samples. During each sampling action, a 3-ml portion was taken from the respective stream and deposited into a refrigerated jug. The device varied the rate at which the portions were taken in accordance with an internal rate control adjustment and an external flow ratio control signal. The external signal required was 5-20 ma with the 5-ma signal producing high sampling rates (6 ml/min maximum).

Sample Compositor Flow Ratio Controller

This segment of the sample compositor system was composed of a Honeywell electronic ratio-bias station that received a 1-5-volt-dc input signal and produced a 4-20-ma output signal. The ratio of the output signal to the input signal was set by the vertical thumbwheel and could be varied from 0.3 to 3.0.

APPENDIX B

ESTIMATED CAPITAL COST FOR CONVERSION OF THE NEWTOWN CREEK PLANT TO OXYGEN ACTIVATED SLUDGE

The EPA Project Officer requested that an estimate be added to this report of the capital cost that would be required if the entire Newtown Creek plant were converted to oxygen activated sludge. Design and estimated cost data are based on the UNOX system and were provided by Union Carbide Corporation.

DESIGN BASIS

Since the termination of data collection on the UNOX system demonstration module, the Manhattan pumping sta_ion has been completed, bringing an approximate 5.3 m^3/sec (120 mgd) of very dilute wastewater to the Newtown Creek plant via a force main under the East River. The net effect of this additional contribution to the plant's influent has been a significant reduction in wastewater strength. Raw wastewater characteristics during the project and after addition of the Manhattan sewage are compared in Table 19.

TABLE 19. COMPARISON OF NEWTOWN CREEK WASTEWATER CHARACTERISTICS BEFORE AND AFTER INTRODUCTION OF MANHATTAN FLOW

	Characteristics During the Project: Brooklyn and Queens Flows Only (range of monthly averages)	Current Characteristics: Brooklyn, Queens, and Manhattan Flows (typical values)
BOD (mg/l)	150 - 240	130
COD (mg/l)	290 - 365	260
Suspended Solids (mg/l)	100 - 160	100

The current flow of 5.3 m^3/sec (120 mgd) from Manhattan is far less than the original estimate of 7.4 m^3/sec (170 mgd). For this design exercise, the average dry-weather hydraulic loading selected for the full-plant conversion to oxygen at Newtown Creek is 13.4 m^3/sec (307 mgd). This allows for a modest increase in the Manhattan flow to about 5.9 m^3/sec (135 mgd). Combined with an average BOD of 130 mg/l, the design average BOD loading is, therefore, 150,980 kg/day (332,850 lb/day).

OXYGEN SYSTEM DESCRIPTION AND DISCUSSION

Since the original design and construction of the UNOX System demonstration plant at Newtown Creek, the technology base for oxygenation system process and equipment design has been greatly expanded through extensive research and development programs, equipment testing and vendor development programs, and design and operating experiences on the more than 100 oxygenation systems currently in operation around the world. In fact, the previously-cited problems experienced with equipment and instrumentation during the Newtown Creek demonstration project initiated many of the programs mentioned above. As a result of these efforts, many improvements have been made in equipment reliability and performance as well as in operating power efficiency of oxygenation systems over the last 6 yr. The oxygenation system described below, which is proposed today for upgrading of the entire Newtown Creek facility, bears little resemblance to the original demonstration system in terms of the specific mass transfer, oxygen generation, and control instrumentation equipment included in the system. However, the functional definition of the oxygenation system and the process parameters used to design the system remain entirely consistent with the system tested and performance results obtained during the Newtown Creek demonstration project.

Based on the organic loading defined above and the process performance data gathered during the testing program, a UNOX system to treat the Newtown Creek wastewater would require conversion of 14 of the 16 existing aeration tanks to oxygen service. Each tank would be modified to contain four equal-volume stages operating in series. Each stage would be 15.2 m long x 16.8 m wide x 4.6 m liquid depth (50 ft x 55 ft x 15 ft) and contain 1168 m^3 (308,590 gal) of mixed liquor. The total oxygenation volume would be 65,410 m^3 (17.28 mil gal). One surface aerator would be provided in each stage for mixing and mass transfer. Each first stage would have an aerator with an installed nameplate rating of 44.7 kW (60 nameplate hp (nhp)). The second stages would be equipped with aerators having nameplate ratings of 29.8 kW (40 nhp). The third and fourth stages would be equipped with aerators having nameplate ratings of 22.4 kW (30 nhp). Thus, each aeration tank would contain four surface aerators with a total nameplate power of 119.3 kW (160 nhp), and the total system installed power for oxygen dissolution would be 1670 kW (2240 nhp) at 480 volts.

The surface aeration mass transfer equipment proposed here for upgrading the Newtown Creek facility is substantially simpler and in much broader use for similar applications than the submerged turbine system originally tested during the Newtown Creek demonstration project. Employing surface aerators would eliminate many of the pieces of equipment which were sources of mechanical problems during the testing program, such as the gas recirculation compressors and the rotary unions connecting the oxygen gas piping to the mixer sparger unit. A substantial amount of oxygen piping would also be eliminated. Furthermore, use of surface aeration equipment would eliminate or minimize the problems caused during the testing program due to foaming since the high level of surface turbulence and mechanical agitation would disperse the foam if it tended to form.

The existing UNOX system demonstration module (Aeration Tank No. 9), which utilized the submerged turbine equipment, would either be dismantled or "mothballed". This tank along with one other aeration tank (not specified for this exercise) would not be incorporated in the upgraded oxygen system design, but their companion final tanks would be used to keep secondary clarifier overflow rates as low as possible. The aerated grit chambers mated with the two aeration tanks to be removed from service would also be retained to maximize grit removal. Figure 1 presented previously in Section 1 illustrates the plant layout and the interrelationship of the various tank complexes.

Modifications to the existing tankage would include: (1) removal of all air diffusers and associated piping from the aeration tanks, (2) installation of three interstage partitions per aeration tank with openings to permit flow of mixed liquor and gas from stage-to-stage, (3) installation of gas-tight covers for the aeration tanks to retain the oxygen rich gas, (4) installation of a new sludge recycle pump station, and (5) improvements to the 16 aerated grit chambers and 16 final settling tanks. The 0.9-m (3-ft) freeboard available in the 5.5-m (18-ft) deep aeration tanks would provide sufficient gas space for the surface aerators employed in UNOX designs.

A cryogenic oxygen generation plant having a production capacity of 171 metric tons/day (188 tons/day) of 95-99 percent pure oxygen would be the recommended unit to supply oxygen feed gas to the oxygenation system. Two 189-m^3 (50,000-gal) DRIOX storage tanks with 434 metric tons (478 tons) of oxygen capacity would be recommended for back-up liquid oxygen supply, which is sufficient for 2.5 days of operation at design average-load conditions when the cryogenic oxygen generation plant required maintenance or repairs. At the design operating point, the above cryogenic unit would be capable of supplying 1.10 kg oxygen/kg BOD removed at the design oxygen utilization rate of 90 percent and an effluent soluble BOD concentration of 10 mg/l. This value is entirely consistent with the experience during the demonstration project. The back-up liquid oxygen supply would be used to meet diurnal oxygen demand peaks above 171 metric tons/day (188 tons/day).

Although years of testing and design improvements have corrected the mechanical problems and significantly improved the performance efficiency of the Pressure Swing Adsorption (PSA) oxygen generation system relative to the experiences with the early version of this unit tested in the Newtown Creek demonstration, the magnitude of the oxygen requirements for a full-scale upgrading at Newtown Creek make use of today's version of the PSA system economically impractical. It is for this reason that the larger capacity cryogenic oxygen generation system is included in this cost estimating exercise.

The installed power of the oxygen supply system, including that for liquid oxygen vaporization, would be 2610 kW (3500 nhp) at 2300 volts. Adding the above specified connected dissolution power plus 37 kW (50 nhp @ 480 volts) for miscellaneous power needs, the total installed power is estimated at 4317 kW (5790 nhp).

By way of comparison to the Newtown Creek demonstration oxygen system which produced a power efficiency at or above design loadings of 0.95 kWh/kg BOD removed (0.58 nhp/lb BOD), the system described above for the proposed upgrading at Newtown Creek would have an overall power efficiency on the basis of installed power and, assuming an effluent total BOD of 20 mg/l, of 0.81 kWh/kg BOD removed (0.49 nhp/lb BOD). This represents a projected efficiency improvement over the demonstration system of approximately 15 percent at design loadings and is the result of improvements in oxygen dissolution technology over the last 7-8 yr and the use of the more efficient cryogenic oxygen generation system. It should further be noted that the actual line operating power draw at design conditions for this system would be approximately 4 to 5 percent less than the installed nameplate power ratings of the equipment previously discussed.

Based on the past oxygen system demonstration experiences at Newtown Creek, it is anticipated that the return sludge suspended solids concentration for the proposed system would average about 15,000 mg/l. At an assumed return sludge flow equal to 40 percent of the influent flow, and MLSS concentration would approximate 4285 mg/l. During the demonstration project, the volatile fraction of the mixed liquor suspended solids averaged 81 percent. Due to the decreased strength of Newtown Creek's wastewater since addition of the Manhattan sewage, it is possible

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY Public File Copy

DATE: APR 29 1983

SUBJECT: Status Report* 8EHQ-0483-0475

Approved

Revision Needed

FROM: Justine L. Welch, Team Leader
Chemical Selection and Profiles Team/CHIB

TO: Frank D. Kover, Chief
Chemical Hazard Identification Branch/AD

Submission Description

The Eastman Kodak Company submitted a March 2, 1983, interim summary report entitled "Inhalation Teratological Potential of Ethylene Glycol Monobutyl Ether [EGBE; 2-butoxyethanol] in the Rat." Eastman Kodak reported that the study is being conducted under contract for the Chemical Manufactures Association (CMA) and is being sponsored by the Glycol Ether Program (GEP) of which the Tennessee Eastman Company (a division of the Eastman Kodak Company) is a member. In its submission, Eastman Kodak noted that the data contained in the interim report "have not been subjected to Quality Assurance and are incomplete since fetal skeletal examination and statistics have not been finished."

According to the submitted interim report, 4 groups of 30 mated female Fischer 344 rats were exposed via inhalation to EGBE vapor concentrations of 0, 100, 200, or 300 ppm for 6 hours per day on gestation days (GD) 6 through 15. In addition, the interim report presented the following summarized clinical observations and results of examinations performed as of March 2, 1983:

"Gestation Body Weight Changes: Gestational body weight gains of animals exposed to 300 ppm were significantly depressed (compared to controls) from GD 6-21. Significant reductions in body weight gains (compared to controls) were also present in the 200 ppm group from GD 6-15 and in the 100 ppm group from GD 6-12."

Gestational Food Consumption: Food consumption was reduced during the dosing period in all groups exposed to EGBE. Significant reductions in food consumption (compared to controls) were noted in the 300 ppm group from GD 6-15, in the 200 ppm group from GD 6-12, and in the 100 ppm group from GD 6-12. Animals in the 300 and 200 ppm groups had a significant increase in their food consumption (compared to controls) from the end of exposures (GD 15) until sacrifce (GD 21).

*NOTE: This status report is the result of a preliminary staff evaluation of information submitted to EPA. Statements made herein are not to be regarded as expressing final Agency policy or intent with respect to this particular chemical. Any review of the status report should take into consideration the fact that it may be based on incomplete information.

Gestational Water Consumption: Only animals exposed to 300 and 200 ppm had significant reductions in water consumption. Those exposed to 300 ppm consumed less water than controls from GD 6-12. Animals in the 200 ppm group consumed less water than controls in the periods GD 6-9 and GD 12-15. Water consumption prior to the exposure segment of the study and following exposures were similar in all groups.

Maternal Clinical Observations: Exposures to EGBE resulted in a dose-related increase in the frequency of signs indicative of hematuria. These signs included red fluid on cage trays, and urogenital wetness, discharges and encrustations of red and/or black color. In addition, animals exposed to EGBE were hypoactive during the exposure segment of the study when compared with controls.

Maternal Organ Weights: The weight of the uteri of animals exposed to 300 ppm was significantly lower than those of controls. This reduction in uterine weight is associated with the high degree of embryo and fetal lethality present at this exposure level.

Maternal Uterine and Ovarian Examinations: Exposures to EGBE, particularly at the 300 ppm level, resulted in a marked increase in embryo and fetal lethality manifested by resorptions of concepti. Exposures to 200 ppm produced a more moderate increase in resorption when compared to controls.

Fetal Visceral Examinations: Exposures to EGBE resulted in a dose-related increase in fetal atelectasis [the incomplete expansion of the lung(s) at birth]. In addition, fetuses from groups exposed to EGBE had ventricular septal defects, absent innominate arteries, and severely shortened innominate arteries."

In addition to the March 2, 1983, interim report, the Eastman Kodak Company provided the following background information:

"Nelson et al at the National Institute for Occupational Safety and Health (NIOSH) studied the teratogenic potential of three glycol ethers in rats; 2-butoxyethanol (EB), 2-methoxyethanol (EM), and 2-ethoxyethyl acetate (EEA). They found that EM and EEA were teratogenic, while 2-butoxyethanol did not produce significant embryofetotoxicity. The exposure concentrations of 2-butoxyethanol were 150 to 200 ppm and Nelson et al reported that these concentrations were difficult to generate (vapor pressure of EB = 0.6 mm Hg at 20°C). Maternal toxicity was evident at both dose levels and consisted of hematuria only after the first exposure. No other adverse effects were seen in the dams exposed to either level. No major skeletal or soft tissue malformations were seen at 150 or 200 ppm of 2-butoxyethanol and the incidence of common skeletal variants and minor soft tissue anomalies seen in the treated groups were comparable to the controls. Potential

> reproductive effects of 2-butoxyethanol and other glycol ethers were studied in male rats in [the submitter's] laboratory and in male mice by Nagano et al in Japan. Administration was by gavage five times per week. In the former, doses from 222 to 885 mg/kg/day, and in the latter, doses from 250 to 1000 mg/kg/day, did not produce testicular effects."

Finally, Eastman Kodak noted that the following factors should be considered by EPA in assessing the CMA/GEP-sponsored inhalation teratology study of 2-butoxyethanol in rats: "the severe maternal toxicity produced, the lack of a dose-related response and the low incidence of effects seen in the [CMA/GEP] study, as well as the negative results from the NIOSH study, the known toxicity of 2-butoxyethanol in adult male and non-pregnant female rats, and [the chemical's] vapor pressure."

Submission Evaluation

Although the submitted findings indicate that 2-butoxyethanol did produce some degree of maternal toxicity in the CMA/GEP-sponsored teratology study, EPA does not believe that 2-butoxyethanol produced "severe" maternal toxicity in the study. One of the most common major manifestations of severe maternal toxicity in this type of study is a significant weight change (usually seen as a decrease) in exposed versus control dams. The summarized data that are presented in Table 4 (which contains measured maternal organ weights and "corrected" maternal body weights (i.e., the maternal body weight minus the weight of the uterus and its contents)), indicate that there were no significant changes in the corrected body weights of exposed dams when compared to the corrected body weights of control dams. There was, however, a significant decrease found in the uterine weights of dams exposed to 300 ppm 2-butoxyethanol when compared to controls. Stated in another way, the apparent decreases in maternal body weights of dams exposed to 300 ppm 2-butoxyethanol are due primarily to the decrease in the weight of the uterus and its contents.

In order for EPA to more properly evaluate the significance of the embryo/fetotoxic effects (including abnormalities) observed in the CMA/GEP-sponsored inhalation study of 2-butoxyethanol, a complete copy of the final report (including protocol(s), data and the results of performed statistical analyses) should be obtained. It should be noted at the present time, however, that the embryo/fetotoxic effects observed in the CMA/GEP-sponsored study (although in apparent contrast to previous findings), are consistent with the adverse developmental effects found in laboratory animals exposed to two structurally related chemicals: 2-methoxyethanol and 2-ethoxyethanol.

Current Production and Use

A review of the production range (includes importation volumes) statistics for 2-butoxyethanol (CAS No. 111-76-2), which is listed in the initial TSCA Inventory, has shown that between 31 million and 161 million pounds of this chemical were reported as produced/imported in 1977. This production range information does not include any production/importation data claimed as confidential by the person(s) reporting for the TSCA Inventory, nor does it include any information which would compromise Confidential Business Information (CBI). The data submitted for the TSCA Inventory, including production range information, are subject to the limitations contained in the Inventory Reporting Regulations (40 CFR 710).

2-Butoxyethanol is used as a solvent for nitrocellulose resins, spray and quick-drying lacquers, varnish and varnish removers, enamels, and drycleaning compounds. The chemical is also used for preventing spotting during the printing and/or dyeing of textiles and as an ingredient in certain pesticides.

Comments/Recommendations

EPA's Office of Toxic Substances (OTS) has received and evaluated several Section 8(e) and "For Your Information (FYI)" submissions concerning various glycol ethers. The Chemical Hazard Identification Branch (CHIB/AD/OTS) has prepared CHIPs (Chemical Hazard Information Profiles) on 2-methoxyethanol, 2-ethoxyethanol, and their acetates. In addition, Priority Review Level-1 (PRL-1) documents on 2-methoxyethanol and 2-ethoxyethanol have been prepared by the Health and Environmental Review Division (HERD/OTS). At present, the OTS "Existing Chemicals Task Force (ECTF)" is considering various EPA options with regard to chemicals within the class of glycol ethers.

a) The Chemical Hazard Identification Branch will request the Eastman Kodak Company to submit, when available, a complete copy of the final report from the CMA/GEP-sponsored inhalation teratology study of 2-butoxyethanol in rats. The submitter will also be requested to provide a complete copy of the final report (including test protocols and data) from the Eastman Kodak study reportedly conducted to determine potential reproductive system effects of 2-butoxyethanol administered to male rats by gavage five (5) times per week at doses ranging from 222 to 885 mg/kg/day.

b) In view of EPA's general interest in company actions that are taken on a voluntary basis in response to chemical toxicity/exposure information, the Chemical Hazard Identification Branch will request the Eastman Kodak Company to describe the actions it has taken to warn workers and others and to reduce and/or eliminate exposure to 2-butoxyethanol.

c) The Chemical Hazard Identification Branch will transmit a copy of this status report to NIOSH, OSHA, CPSC, FDA, NTP, OANR/EPA, ORD/EPA, OSWER/EPA, OW/EPA, OPP/OPTS/EPA, and the OTS "Existing Chemicals Task Force (ECTF)." A copy of this report will also be provided to EPA's Industry Assistance Office (IAO/OTS) for further distribution.

that the volatile fraction might drop to as low as 75 percent in a full-scale system. The MLVSS concentration for design purposes is, therefore, assigned a value of 3215 mg/l (75 percent of MLSS). Using the above assumptions, expected oxygen system operating conditions are summarized in Table 20 for a design flow of 13.4 m^3/sec (307 mgd) and a design BOD loading of 150,980 kg/day (332,850 lb/day). All other process design parameters except as mentioned above are consistent with process performance experiences during the Newtown Creek demonstration project.

TABLE 20. DESIGN OPERATING CONDITIONS FOR FULL-SCALE NEWTOWN CREEK OXYGEN SYSTEM

Oxygenation Tank Detention Time	
Based on Q (hr)	1.35
Based on Q + R (hr)	0.96
F/M Loading (kg BOD/day/kg MLVSS)	0.72
Volumetric Organic Loading	
(kg BOD/day/m^3)	2.31
(lb BOD/day/1000 ft^3)	144
Secondary Clarifier Overflow Rate	
(m^3/day/m^2)	36
(gpd/ft^2)	872
Sludge Wasted	
Based on Figure 8 (non-filamentous curve) and assumed effluent suspended solids of 20 mg/l	
(kg/day)	94,350
(lb/day)	208,000
Sludge Retention Time	
Based on Figure 8 (days)	2.4
Average Mixed Liquor DO (mg/l)	6
Average O_2 Utilization Efficiency (%)	90
Design Oxygen Supply (metric tons/day)	171
(US tons/day)	188
Effluent BOD (mg/l)	20
Effluent Soluble BOD (mg/l)	10
Effluent Suspended Solids (mg/l)	20

ESTIMATED CONSTRUCTION AND CAPITAL COSTS

The estimated construction cost of converting the Newtown Creek plant to oxygen is $44,000,000. Adding anticipated fees for engineering, legal, fiscal, and administrative services and interest over an assumed construction period of 2 yr, the estimated capital (total project) cost becomes $54,335,000. At a design flow of 13.4 m^3/sec (307 mgd), this capital cost is equivalent to $46.76/daily m^3 ($0.18/daily gal) of upgraded plant capacity. The above estimate, which is applicable to the fourth quarter, 1977, and includes provisions for major site work and improvements to existing plant grit removal, clarification, and sludge recycle facilities in addition to oxygen system equipment, installation, and retrofit costs, is broken down by cost element in Table 21.

TABLE 21. ESTIMATED CAPITAL COST FOR OXYGEN SYSTEM RETROFIT AT NEWTOWN CREEK

Oxygen Dissolution Equipment	$ 4,375,000
Installation	485,000
Oxygen Supply Equipment	3,225,000
Installation	1,025,000
Site Work (including pilings)	3,000,000
Aeration System Retrofit Modifications	16,000,000
Secondary Clarifier Modifications	6,000,000
Grit Chamber Modifications	2,890,000
New Sludge Recycle Pump Station	3,000,000
Subtotal	40,000,000
Contingency @ 10%	4,000,000
ESTIMATED CONSTRUCTION COST	$44,000,000
Engineering, Legal, Fiscal, Administrative @ 16.5%	7,260,000
Subtotal	51,260,000
Interest During Construction @ 6% for 2 yr	3,075,000
ESTIMATED CAPITAL COST	$54,335,000