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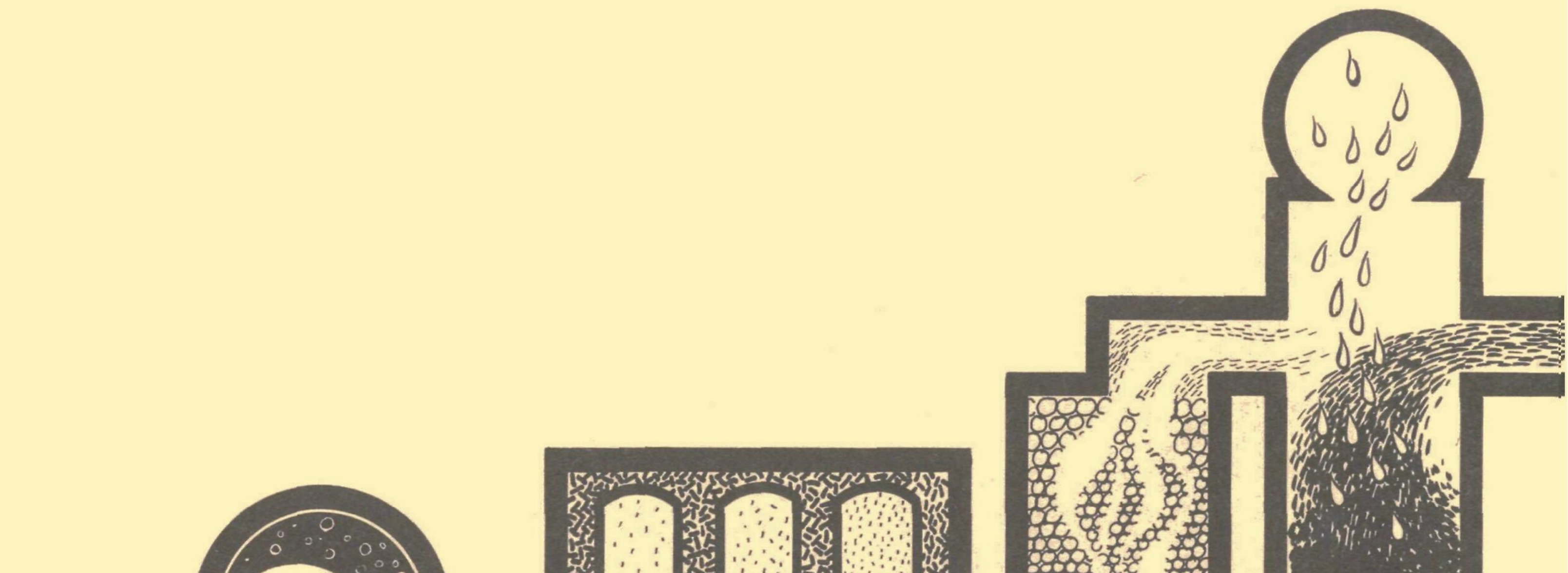
APPLICATION OF ROTATING DISC PROCESS TO MUNICIPAL WASTEWATER TREATMENT



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APPLICATION OF ROTATING DISC PROCESS

TO

MUNICIPAL WASTEWATER TREATMENT

by

Autotrol Corporation
Bio-Systems Division
5855 North Glen Park Road
Milwaukee, Wisconsin 53209

for the

OFFICE OF RESEARCH AND MONITORING

ENVIRONMENTAL PROTECTION AGENCY

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ABSTRACT

A prototype package plant incorporating the rotating disc wastewater treatment process was tested on municipal wastewater at the Village of Pewaukee, Wisconsin, to evaluate its treatment capabilities and establish guidelines for operation and testing of a full-scale rotating disc demonstration plant soon to be put into operation at Pewaukee. The package plant included a rotating bucket feed mechanism, ninety-one 1.75-meter diameter discs divided into two stages, and a secondary clarifier with a sludge-removal mechanism. Variables tested included hydraulic loading, rotational disc speed, sludge recycle, and wastewater temperature as it varied with climatic conditions.

At a hydraulic loading of 1.5 gpd/ft^2 of disc surface, the package plant achieved 87% removal of BOD and 80% removal of suspended solids to yield an effluent of 20 mg/l BOD and suspended solids when treating effluent from the existing primary clarifier. At the same hydraulic loading, 85% removal of ammonia nitrogen was obtained to yield an effluent of 3.5 mg/l.

Low maintenance requirements and low power consumption were demonstrated by the rotating disc process during the test program.

This report was submitted in fulfillment of Project 17050 DAM, Contract 14-12-810, under the sponsorship of the Environmental Protection Agency.

CONTENTS

FIGURES

FIGURES (cont'd)

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SECTION I

CONCLUSIONS

1. The rotating disc method of wastewater treatment provides a compact, highly efficient means of obtaining BOD, suspended solids, and ammonia nitrogen removal from domestic wastewater.

2. The simplicity of the process and its mechanical equipment result in a very low requirement for maintenance.

3. Low maintenance requirements and low power consumption make the rotating disc process well suited to package plant applications and for fulfilling wastewater treatment needs in remote areas.

4. The rotating disc method of wastewater treatment can achieve in excess of 90% BOD and suspended solids removal and produce effluents of less than 15 mg/l BOD and suspended solids when operated at the proper hydraulic loading.

5. Carbonaceous BOD removal by the rotating disc system is first order with respect to BOD concentration up to approximately 90% reduction.

6. At treatment levels above 80% BOD removal and effluents below 35 mg/l BOD, approximately 50% of the remaining BOD is carbonaceous and 50% nitrogenous.

7. Ammonia nitrogen removal by the disc system is first order with respect to ammonia nitrogen concentration. Removals in excess of 95% are achieved, and effluents of less than 0.5 mg/l ammonia nitrogen are produced at the proper hydraulic loading.

8. Because carbonaceous BOD removal and ammonia oxidation are first order, the primary design criterion for rotating disc systems is hydraulic loading as gpd/ft^2 of surface covered with biomass. Peripheral velocity of the rotating discs, and the number of stages of discs are also important design criteria.

9. The optimum rotational disc speed for BOD, suspended solids, and ammonia nitrogen removal is approximately 58 ft/min peripheral velocity (3.2 RPM on the test unit).

10. BOD and suspended solids removal are unaffected by wastewater temperatures above $50^{o}F$. Ammonia nitrogen removal is unaffected by wastewater temperatures above $54^{o}F$. Below these temperatures, lower hydraulic loadings are required for a given degree of treatment.

11. Power consumption at the optimum disc speed is 0.2 Hp-Hr/lb. BOD removed when providing 87% BOD removal and an effluent of 20 mg/l BOD.

12. BOD removal by the rotating disc system during this investigation compares well to that obtained during a previous investigation and demonstrates first order behavior over the range of 147 to 426 mg/l BOD domestic wastewater.

13. BOD removal during this investigation does not compare well to European experience. The reason for this is thought to be the wider disc spacing used on European disc systems, which yields a longer retention time at a given hydraulic loading and therefore a higher degree of treatment.

14. Disc units which are operated in tanks closely contoured to the shape of the discs should have disc spacing greater than 0.5 inch, surface to surface, to obtain full utilization of the surface area.

SECTION II

RECOMMENDATIONS

This investigation has allowed the evaluation of the rotating disc method of wastewater treatment. During the course of the testing, several aspects of rotating disc process operation were revealed which warrant further investigation. Most of these were beyond the scope of the present investigation or could not be tested with the available test equipment. This testing was conducted on a two-stage disc unit. European experience indicates that three and four-stage operation allows significantly higher hydraulic loading for equal treatment. Additional testing on a four-stage disc system at various hydraulic loadings should be conducted to verify the improved performance.

The disc spacing of the test unit in this investigation yielded a liquid holding capacity less than that of European disc systems. The lower retention time occurring at a given hydraulic loading resulted in a lower degree of treatment than in European systems. Additional testing at various disc spacings will be required to determine the optimum disc spacing which will maximize the effectiveness of the disc surface area.

All testing in this investigation was under constant flow conditions. Diurnal flow variations and flow patterns encountered in other domestic wastewater applications should be tested to determine their effect on treatment efficiency by the disc process.

Because both stages of discs in this investigation were mounted on the same shaft and driven by a single drive mechanism, the optimum rotational velocity determined applies only when all discs in the system are rotated at the same velocity. In a multi-stage disc plant, there is probably an optimum rotational velocity for each successive stage of discs as the wastewater undergoes a progressively increasing degree of treatment. Additional studies to optimize the rotational speed of each stage in a multi-stage disc system would improve the already low power consumption of the disc process.

Sludge production measurements from this investigation were erratic. Additional sludge production measurements should be made on a multi-stage disc system to more accurately determine its sludge production at various degrees of treatment.

Sludge recycle rates tested in this investigation were too low to affect any operating or performance parameters of the system. Additional studies at higher recycle rates should be conducted to determine the effect of this process variable.

Biological solids generated by the rotating disc appear to have characteristics which would make them conducive to mechanical separation, such as sand filtration or microscreening. Tests should be conducted on both secondary clarifier effluent and rotating disc mixed liquor to establish the technical feasibility of mechanically clarifying rotating disc process effluents.

It has been demonstrated in this investigation that any desired degree of ammonia nitrogen oxidation can be achieved in the disc system by operating at the proper hydraulic loading without adjustment of normal municipal wastewater pH. It would be of value to determine whether ammonia nitrogen oxidation rates could be increased in the disc system by chemically adjusting the pH of the mixed liquor of disc stages where nitrification was occurring.

Many of the above recommendations on further testing of rotating disc systems can be incorporated into the testing and evaluation program for the rotating disc demonstration plant at Pewaukee, Wisconsin. This will be done to the extent possible within the scope of the evaluation.

SECTION III

INTRODUCTION

The rotating disc process is a secondary biological wastewater treatment system. It has been used for wastewater treatment in Europe for 12 years. At present, there are over 600 commercial installations, primarily in West Germany, France, and Switzerland, ranging in size from 12 people to 100,000 population equivalent and treating a variety of domestic and industrial wastes. Research and development work has been conducted on this process in the United States since 1965, and several commercial installations are now in operation and under construction in this country.

The object of this investigation was to test a rotating disc unit under field conditions with municipal wastewater and evaluate treatment levels at various rates of hydraulic loading.

The results of the tests were to be compared to previous testing and used to establish guidelines for the testing and evaluation of a 400,000-GPD rotating disc treatment plant constructed with Environmental Protection Agency demonstration grant funds at the Village of Pewaukee, Wisconsin.

SECTION IV

PROCESS DESCRIPTION

The system consists of a number of large-diameter, lightweight plastic discs, which are mounted on a horizontal shaft and placed in a semi-circular shaped tank. The discs are rotated while approximately one-half of their surface area is submerged in the wastewater. Immediately after startup, organisms present naturally in the wastewater begin to adhere to the rotating surfaces and multiply until, in about one week, the entire surface area of the discs is covered with an approximately 1/16 to 1/8 inch thick layer of biomass.

In rotation, the discs carry a film of wastewater into the air where it trickles down the surface of the discs and absorbs oxygen. Organisms in the biomass then remove both dissolved oxygen and organic materials from this film of wastewater. As the discs continue rotation through the bulk of the wastewater in the tank, further absorption of dissolved oxygen and organic materials is performed by the biomass. Operating in this manner, the rotating discs serve several functions: provide a medium for the development of a fixed biological growth, contact of the growth with the wastewater, and aeration of the wastewater. Shearing forces exerted on the biomass as it is passed through the wastewater cause excess biomass to slough from the discs into the mixed liquor. This prevents clogging of the disc media and maintains a constant microorganism population on the discs. The mixing action of the rotating discs keeps the sloughed solids in suspension until the treated wastewater carries them out of the disc sections for separation and disposal.

SECTION V

DESCRIPTION OF TEST UNIT

Figure 1 shows the prototype rotating disc package plant used for the investigation. It consists of a wet well and rotating bucket feed system, a two-stage rotating disc treatment system, and a secondary clarifier with a rotating sludge scoop, all incorporated into a single, semi-circular shaped tank. This package system is intended to operate in conjunction with primary treatment and sludge disposal facilities.

In operation, primary treated wastewater flows into the wet well, where a series of buckets, attached to the same shaft that rotates the discs, deposit it via a trough into the first stage of discs (see Figure 2). An overflow connection maintains a constant level in the wet well and, therefore, a constant feed rate. At a given disc speed the feed rate is varied by changing the number of feed buckets.

The disc section contains ninety-one 1.75-meter diameter discs, which are divided into two approximately equal-size stages. The stages are divided by a bulkhead and connected by a trough, so that they operate in series. The discs, which are molded from expanded polystyrene beads, are 0.5 inch thick and spaced on 1.0-inch centers. Figure 3 shows construction features of the type of discs used in the package plant. There are eleven intrinsically molded bosses on the surface of each disc, which act as spacers. Eight of the bosses are located near the perimeter of each disc, two are near the center, and one forms the hub of the disc. Rods pass through holes in the bosses and are attached to spider-like arms located at each end of a stage of discs. The arms are attached to the main shaft, which passes through all the discs in the package plant. The system of main shaft, spider-arms, connecting rods, and bosses uniformly distributes the driving torque applied to the discs and provides support to the discs as they are rotated through the wastewater. The type of disc and support structure described here has been used in Europe for 12 years without any reported mechanical failure of the discs.

Power is supplied to the discs by a 1/6-hp motor, which is mounted on a structure between the disc section and the secondary clarifier. Power is transmitted to the main shaft by the friction of a chain passing over a circular metal strip, the same diameter as the discs and mounted on the last set of spider arms. See Figure 4.

Mixed liquor passes from the last stage of discs into the clarifier through an opening in the bulkhead separating them. To minimize the effects of turbulence, the opening is located in the corner of the clarifier; and a pipe directs the flow against the bulkhead beneath the water level.

Figure 1
Prototype Rotating Disc Package Plant

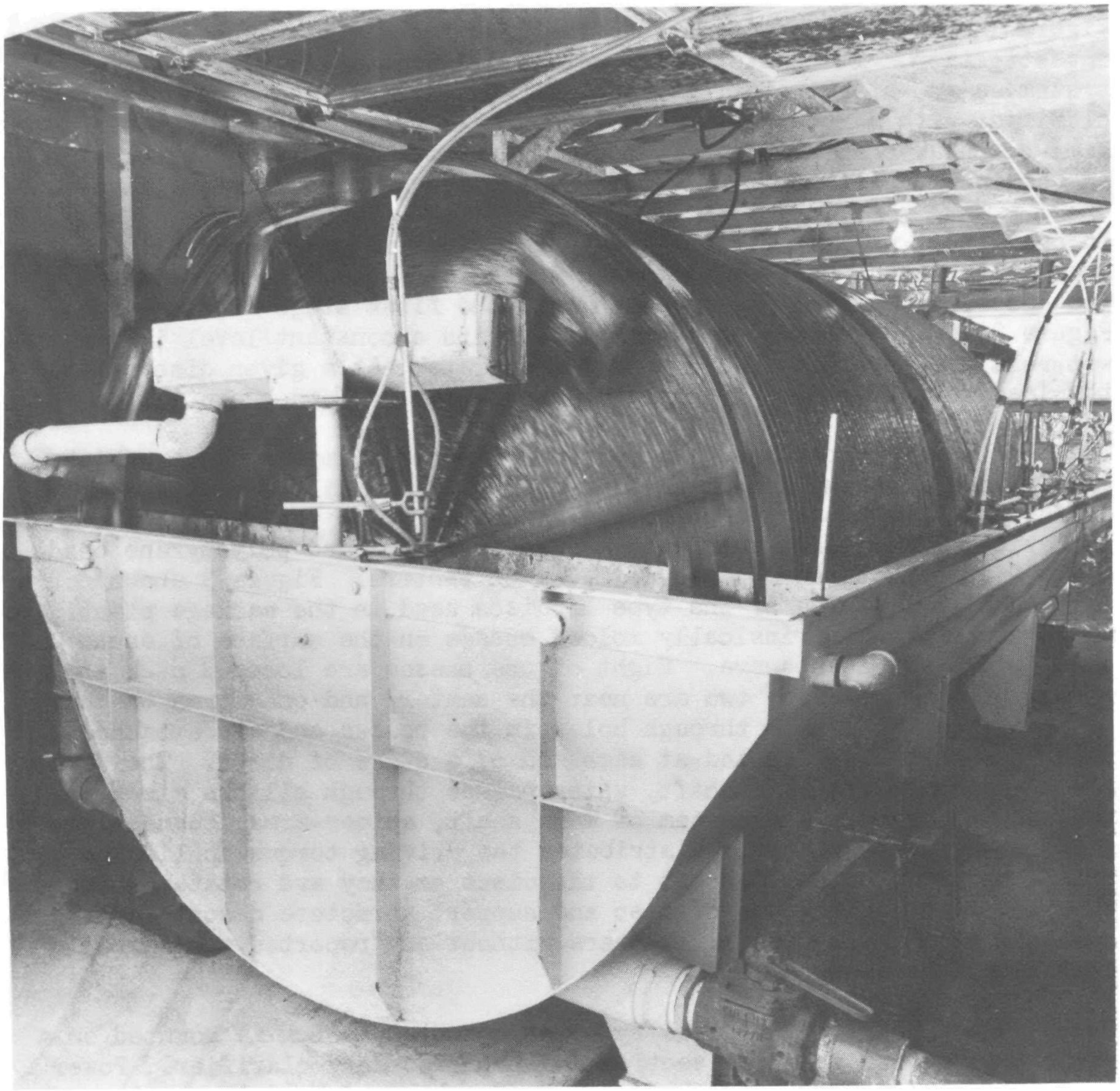
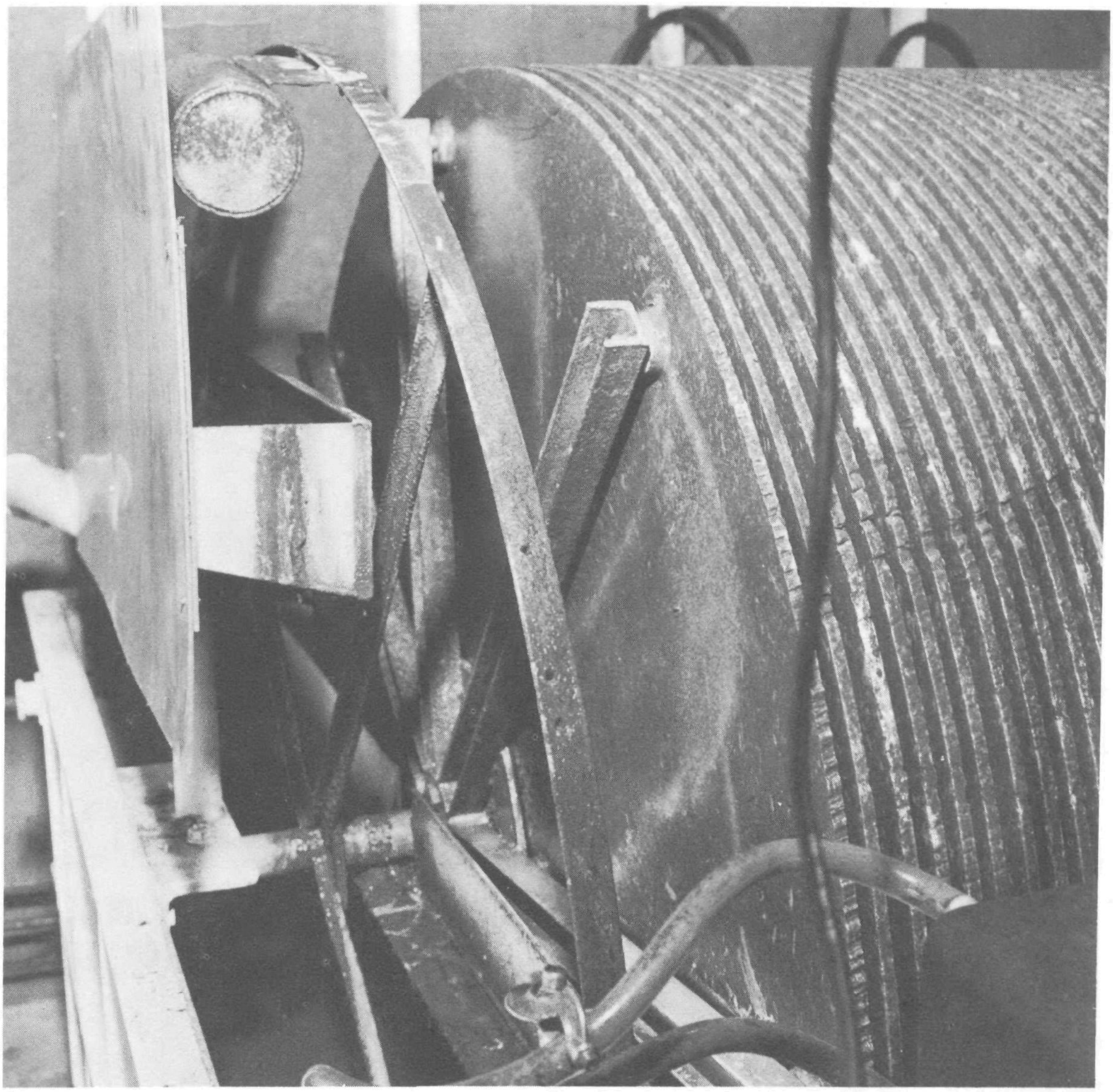
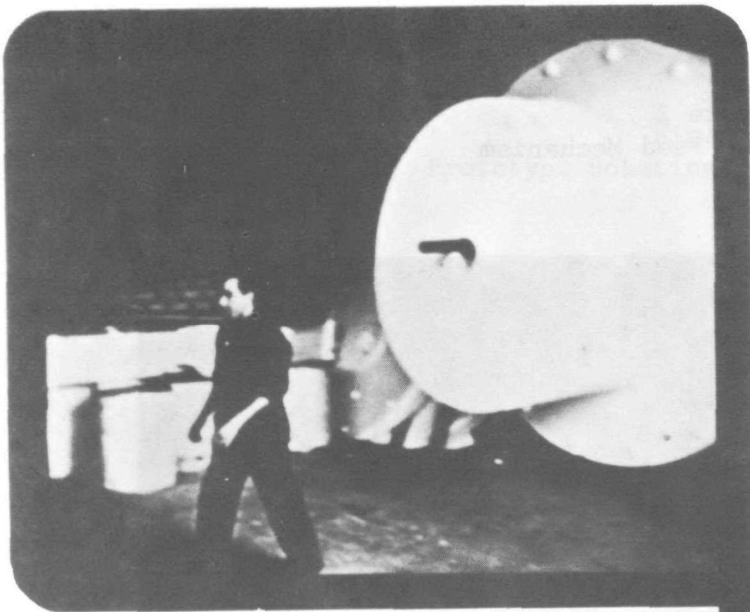


Figure 2
Rotating Bucket Feed Mechanism





SIZES AVAILABLE
6 FT. AND 10 FT. DIA.

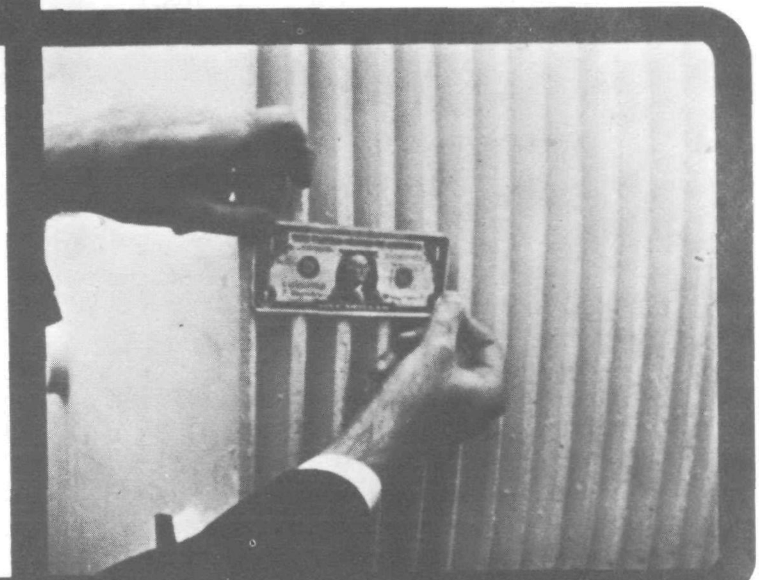
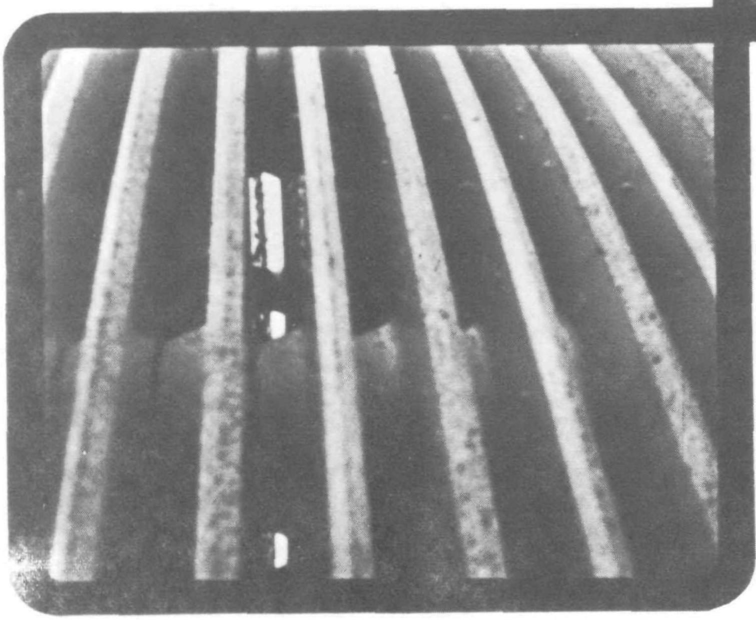


Figure 3

Molded Polystyrene Discs

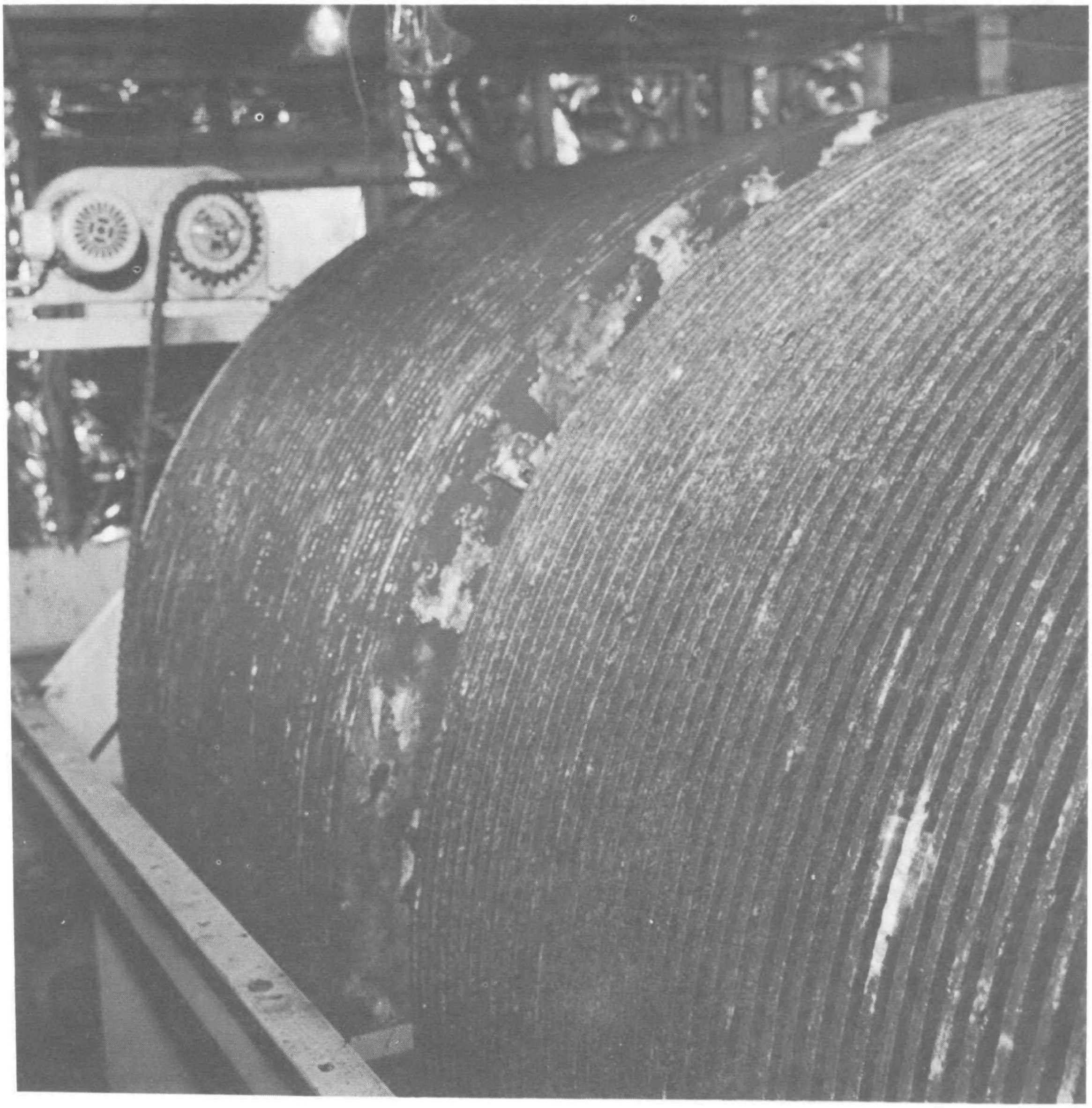
MOLDED POLYSTYRENE DISCS

DISC-NOMINAL
THICKNESS OF 1/2 IN.



RIGIDITY MAINTAINED
BY MOLDED SPACERS

Figure 4
Two-Stage Disc Assembly with Drive Motor



Settled sludge is removed by the rotating scoop and reservoir system shown in Figure 5. The scoop system is driven independently at 2 to 6 rph to allow adjustment for sludge removal requirements. As the empty reservoir passes into the water, it draws sludge up through the scoop and hollow connecting arms until it is full. Then, as the reservoir leaves the water, it empties the sludge through hollow support arms into the hollow drive shaft. From there it flows out of the system for treatment and disposal. Clarifier overflow passes over a weir to an outlet located in the opposite corner from the inlet.

The clarifier has an operating volume of 455 gallons and an overflow area of 32 square feet. The overall size of the package unit is approximately 15 feet long, 6.5 feet wide, and 6.5 feet high. It has a design capacity of 8,000 gpd.

Additional details on the test unit are listed in Table I and shown in Figure 6.

Figure 5
Secondary Clarifier and Sludge Scoop

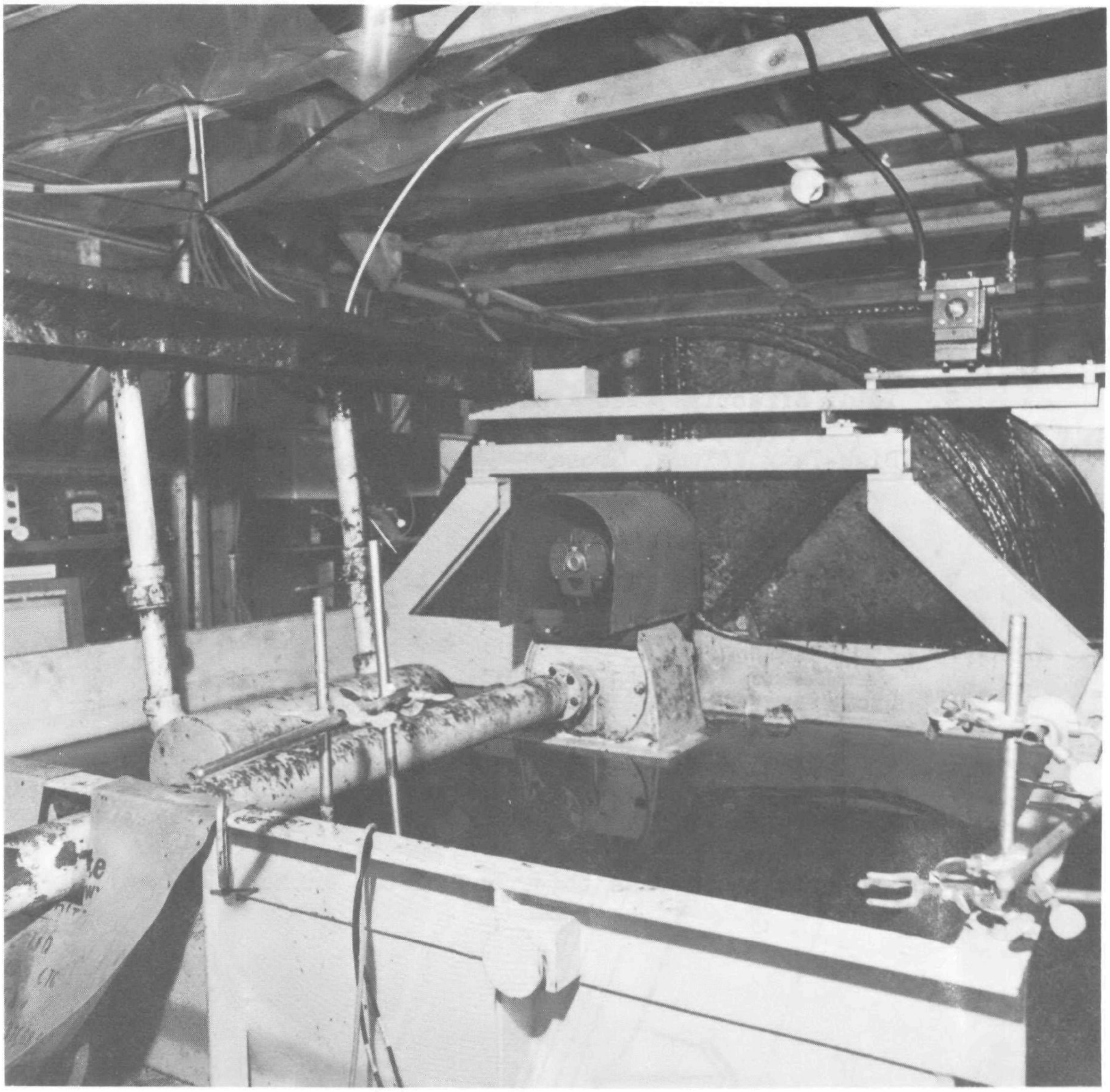


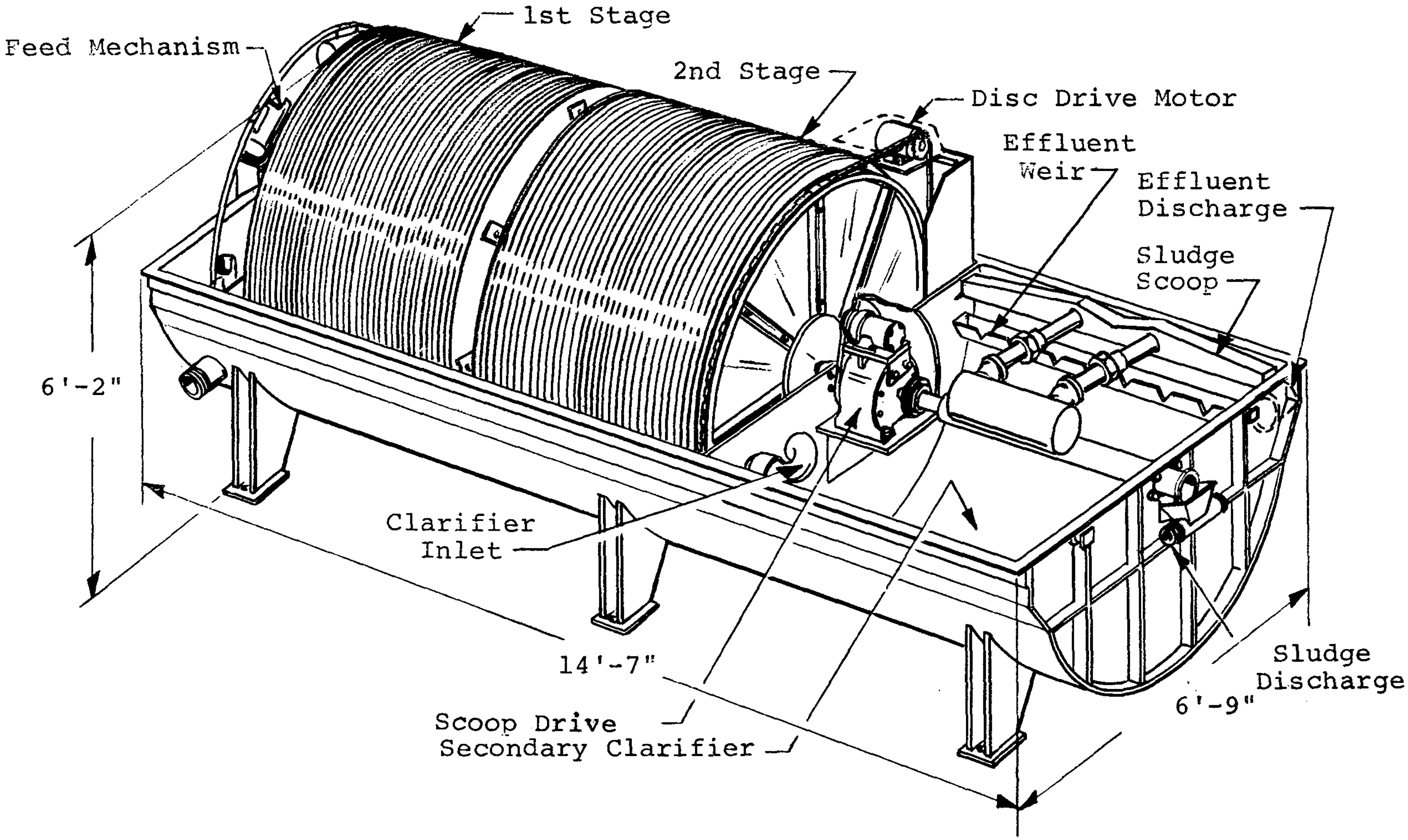
TABLE 1

Rotating Disc Unit Specifications

1.	Disc Velocity	2 - 5 RPM
2.	Disc Diameter	5.74 ft. (1.75 m)
3.	Number of Stages	2
4.	Number of Discs - Stage 1, 45	
	- Stage 2, 46	
	Total:	91
5.	Total Effective Disc Area	4,600 ft^2 (428 m^2)
6.	Disc-Tank Volume, Gross	700 gal. (2.65 m^3)
	Net	280 gal. (1.06 m^3)
7.	Submerged Volume of Discs	420 gal. (1.59 m^3)
8.	Clarifier, Surface Area	32 ft^2 (2.98 m^2)
9.	Clarifier, Volume	455 gal. (1.73 m^3)
10.	Clarifier, Weir Length	5 ft. (1.52m)

* Based upon a bio-mass thickness of 0.1 inches (2.5 mm)

Figure 6
Rotating Disc Package Plant Details



SECTION VI

TEST PROGRAM

The package plant was installed in a garage-like structure to protect it from wind, heavy precipitation, and freezing temperatures and was located within the grounds of the treatment plant of the Village of Pewaukee, Wisconsin. Figure 7 shows the location of the test unit within the treatment plant grounds.

The present Pewaukee treatment plant is rated at 0.3 MGD and includes an uncovered trickling filter, primary and secondary clarifiers, an anaerobic digester, and sludge drying beds. Secondary sludge is drained into the wet well, usually during night hours when low flows are experienced. Sludge from the primary clarifier is normally pumped to the digester twice daily. Digester supernatant is returned to the wet well during these pumping periods. The primary clarifier effluent employed in this investigation, therefore, contained unknown amounts of anaerobic digester supernatant and trickling filter sludge.

Tests were begun in November, 1969, and conducted for 6 months under the contract. At its own expense, Autotrol Corporation extended the test period to October, 1970, to provide a full year of operating data and allow a more complete study of the process. During the year of operation, the primary effluent had the characteristics shown in Table 2.

TABLE 2

Average Wastewater Characteristics

	mg/l
BOD	147
Suspended Solids	128
COD	323
Ammonia Nitrogen	18.2
Kjeldahl Nitrogen	28.9
Phosphorus	11.7
Temperature, °F	55

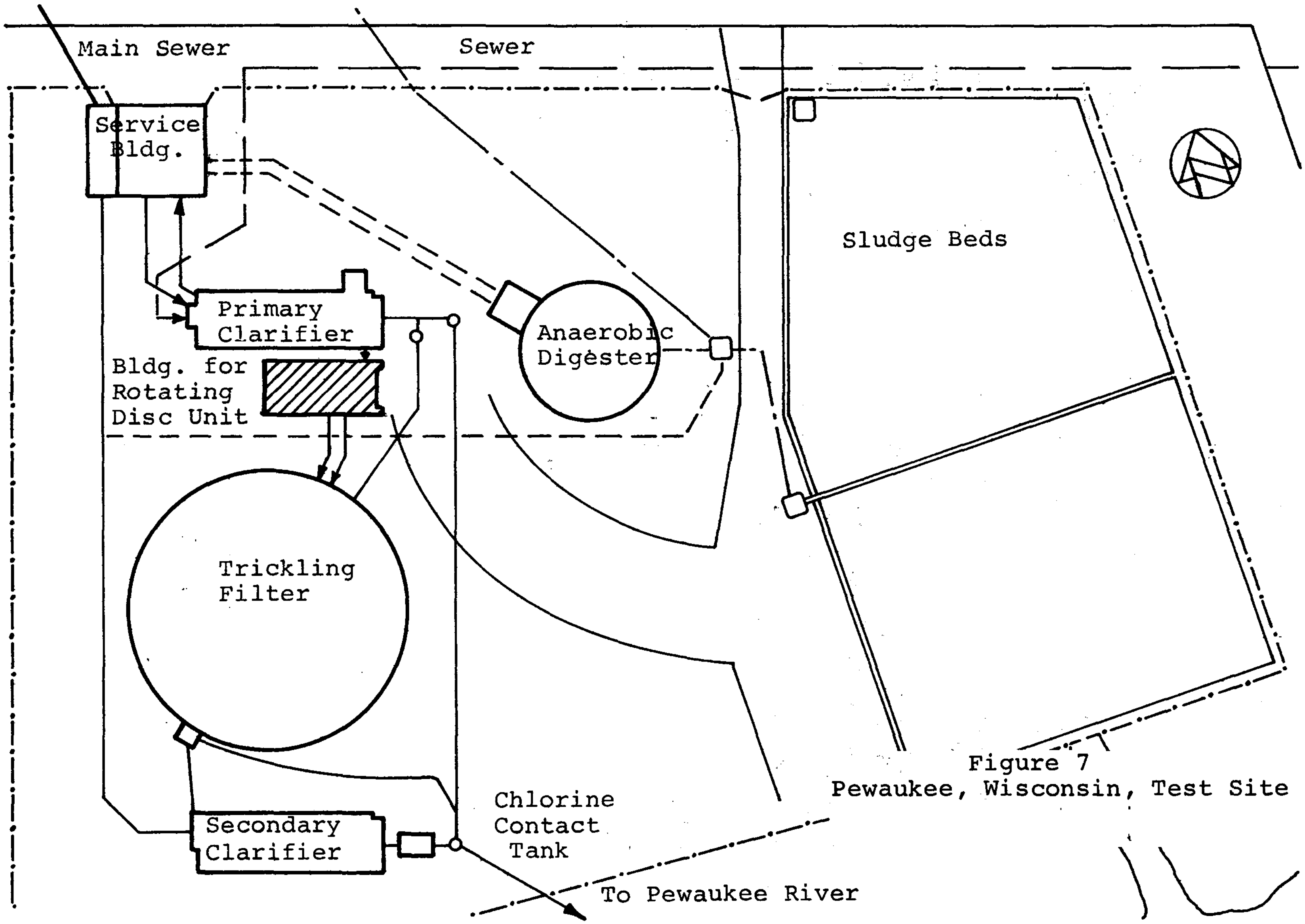


Figure 7
Pewaukee, Wisconsin, Test Site

The test unit was connected to the overflow of the existing primary clarifier. An overflow piping arrangement was used in the wet well of the test unit to obtain a constant depth of wastewater which maintained constant feed rates. Variables investigated included hydraulic loading of 50 to 920 gph, rotational disc speed of 2 to 5 rpm, sludge recycle of 1 and 2% of wastewater flow, and wastewater temperature as it changed with the climate.

A relatively wide range of mixed liquor temperatures was encountered in this investigation. Lower temperatures are believed to be related to the amount of infiltration in the Pewaukee sewerage system during spring periods of thawing and rainfall.

Since the experimental flow rates were relatively low compared with the total Pewaukee plant flow, all discharge lines from the test facility were directed to the existing trickling filter. These included wet well overflow, effluent, and secondary clarifier sludge. Sludge was discharged by gravity from the clarifier into a 50-gallon drum. A sump pump transferred the sludge to the effluent discharge line connecting the test unit with the trickling filter.

When tested, recycling of sludge was accomplished by a peristaltic pump connected to the base of the 50-gallon sludge drum. This pump was actuated about 10 minutes per hour by an automatic timer and delivered the recycled waste sludge to the inlet of the first stage of discs.

Four (4) NAPPE-PORTA-POSITER samplers were installed to take twenty-four hour composite samples at the following four sampling points: the wet well, the first stage mixed liquor, the second stage mixed liquor, and the effluent from the secondary clarifier. When it was not possible to obtain a twenty-four hour composite sample, a grab sample was taken for analysis. In June, 1970, of the test period, these samplers were replaced with samplers which were equipped with refrigeration.

Samples were taken, and laboratory analyses were performed as indicated in Table 3. Procedures employed in these analyses were in accordance with the "Standard Methods for The Examination of Water and Wastewater," Twelfth Edition, 1965, APHA.AWWA. WPCF.

TABLE 3

Sampling and Analysis Program

Analysis	Sampling Points *
Temperature	B
pH	A, D
Dissolved Oxygen	A, B, C, D
Chemical Oxygen Demand	A, D
Sludge Solids	D
Settleable Solids	A, B, C, D
Total Suspended Solids	A, B, C, D
Volatile Suspended Solids	A, B, C, D
Biochemical Oxygen Demand	A, D
Total Phosphorus	A, B, C, D
Dissolved Phosphorus	A, D
Ortho-Phosphorus	A, B, C, D
Kjeldahl Nitrogen	A, B, C, D
Ammonia Nitrogen	A, B, C, D
Nitrate Nitrogen	A, B, C, D
Nitrite Nitrogen	A, B, C, D

* A = Wet Well, B = First Stage Mixed Liquor, C = Second Stage Mixed Liquor, D = Effluent from Secondary Clarifier.

SECTION VII

TEST RESULTS

The test unit was operated for a period of several weeks under each set of operating conditions. Data collected each day is presented in the Appendix. Arithmetic averages of the data collected under each set of operating conditions are also presented in the Appendix. The averages were used for all data correlations. The majority of the following correlations are presented as a function of hydraulic loading, which has been found to be the primary design criterion for the rotating disc process. Hydraulic loading is measured as the amount of wastewater flow per unit of time per unit of surface area covered by biological growth.

BOD Removal

Figures 8 and 9 show percent removal and effluent concentrations for BOD as a function of hydraulic loading. Retention time in the disc sections is also shown for purposes of reference.

Separate loading curves are drawn for the disc speed range of 3.2 to 5 RPM and for 2 RPM for wastewater above 50°F, and 5 RPM for wastewater below 50°F. The data points at 3.2 RPM and 4.3 to 5 RPM appear to follow the same correlation, so a single curve was drawn to include this entire range of disc speed. This was done for all data correlations at wastewater temperatures above 50°F.

At a hydraulic loading of 1.0 GPD per ft^2, 90% BOD removal was obtained with this two-stage system. An effluent BOD concentration of 20 mg/l was obtained at a loading of 1.5 GPD/ft^2, which represents 90% overall removal when including primary treatment on an average municipal wastewater. When treatment requirements call for just roughing treatment, the disc system can obtain 70% removal at a loading of 4.8 gpd/ft^2.

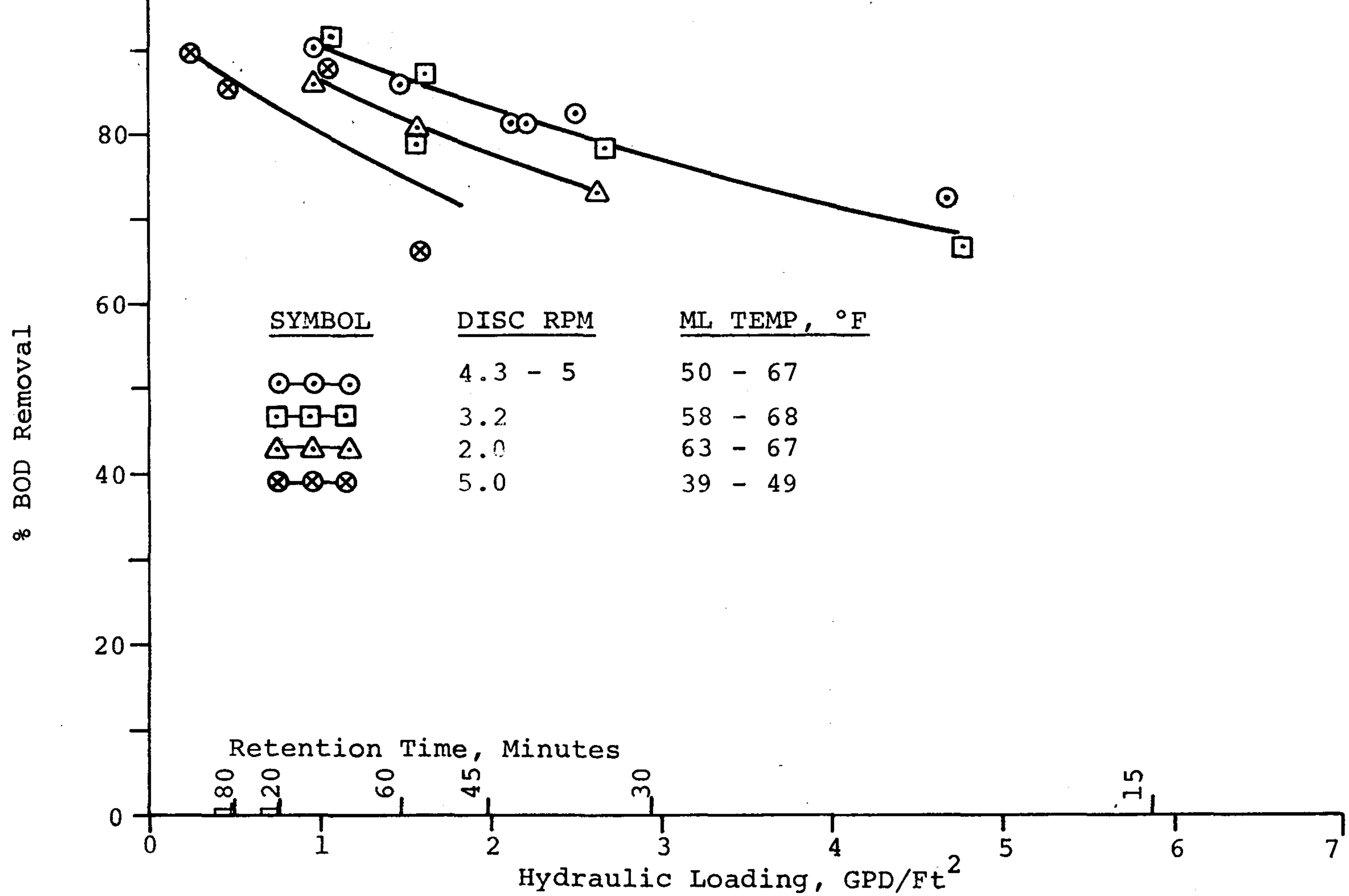
Rotational disc speed had a significant effect on treatment efficiency. While 3.2 and 4.3-5 RPM gave very similar performance, 2.0 RPM gave significantly lower perfornace over the entire range of hydraulic loads tested. The reasons for this are the increased efficiency of mixing within a stage, more effective contact between the biomass and the wastewater, and increased aeration rate at the higher speeds.

Wastewater temperature does not appear to affect BOD removal above 50°F. Below 50°F, BOD removal rates decrease significantly; however, equal treatment can be obtained at reduced hydraulic loading.

Figure 10 reveals some aspects of the kinetics of BOD removal in the disc system. Five-day BOD removal (solid line) is close to first order up to 70 to 80% reduction. At higher degrees of treatment, the reaction rate decreases considerably. This can be explained by the data in Table 4.

Figure 8

BOD Removal vs. Hydraulic Loading



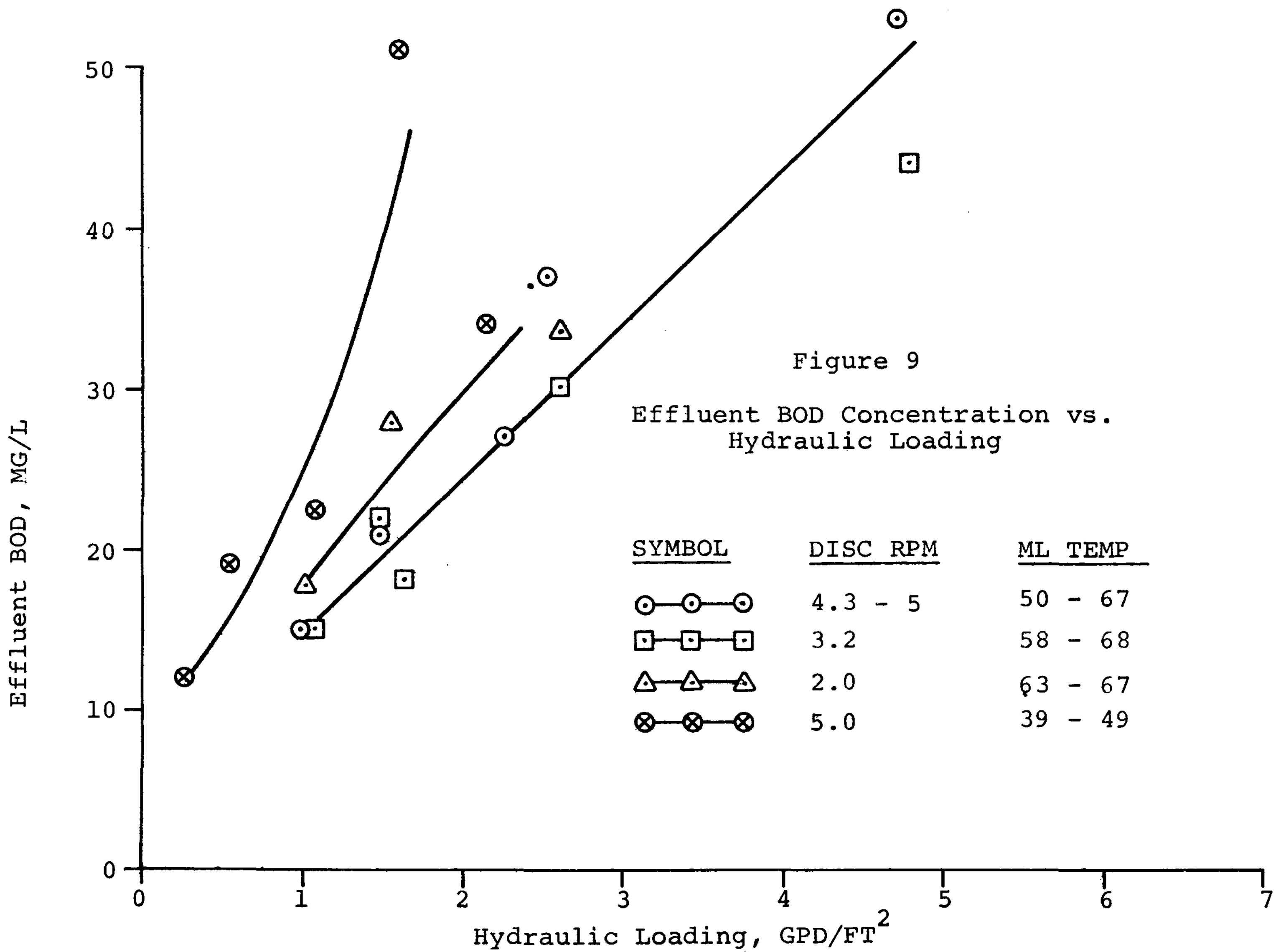


Figure 9

Effluent BOD Concentration vs. Hydraulic Loading

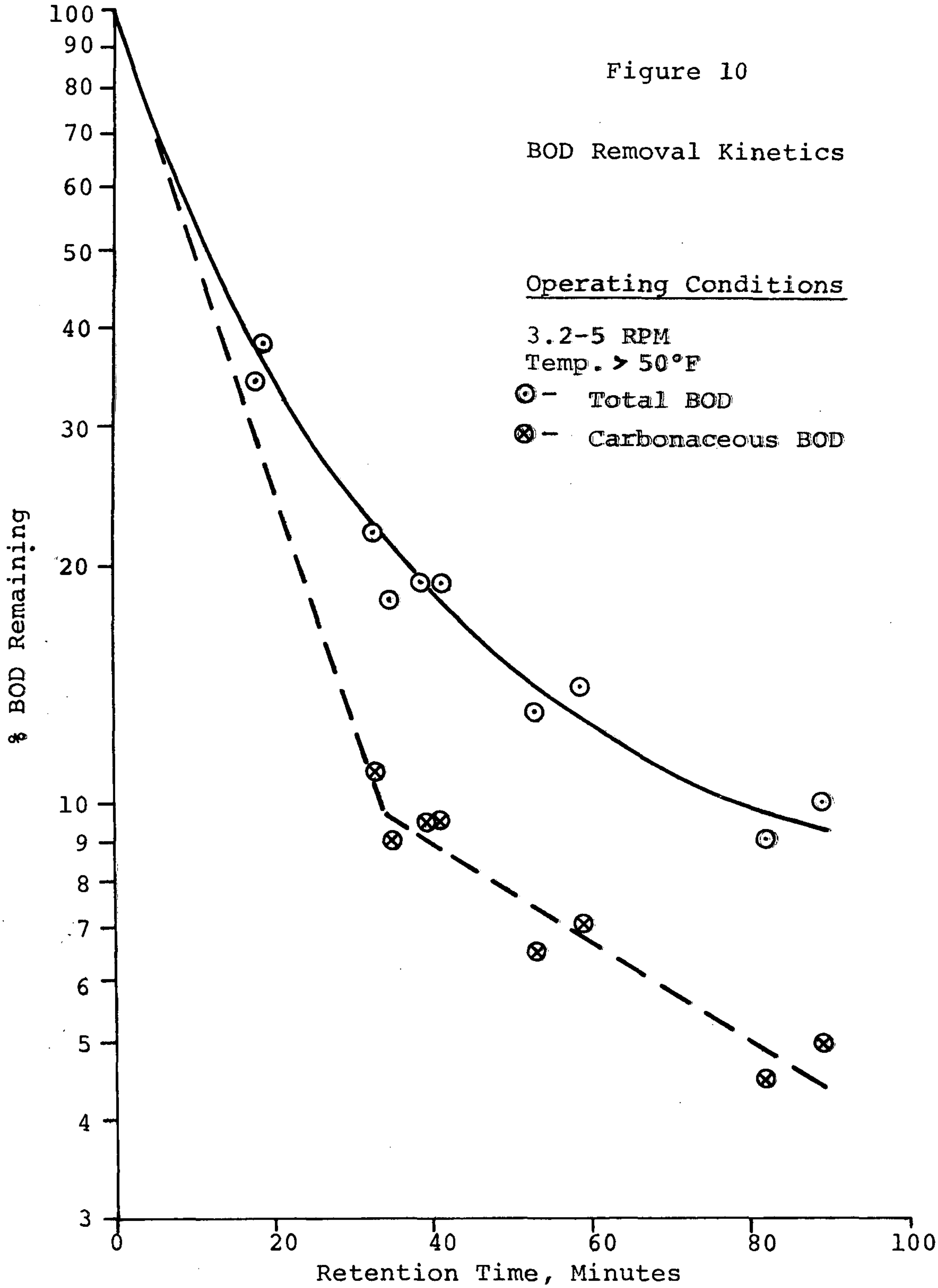


Figure 10
BOD Removal Kinetics
Operating Conditions
3.2-5 RPM
Temp. > 50°F
⊙ – Total BOD
⊗ – Carbonaceous BOD
% BOD Remaining
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
0
20
40
60
80
100
Retention Time, Minutes

TABLE 4

Determination of Carbonaceous and Nitrogenous BOD

Date	Flow GPH	RPM	Inlet BOD APHA*	Inlet BOD ATU**	Outlet BOD APHA	Outlet BOD ATU
9-1	300	2	168	157	32	16
9-8	300	2	169	165	28	16
9-9	300	2	164	173	33	16
9-9 (6-day)	300	2	182	176	43	17
10-1	503	2	137	---	34	26

*American Public Health Association Method ("Standard Methods")

**As above with 0.5 mg/l allylthiourea in dilution water to suppress nitrification. Reference (1).

Several tests were conducted to determine the proportions of carbonaceous and nitrogenous BOD in the disc system effluent. Addition of allylthiourea to the BOD dilution water to suppress nitrification had no significant effect on the BOD of primary effluent. However, use of allylthiourea in BOD tests of disc system effluent indicates that effluents of less than 35 mg/l BOD consist of about 50% nitrogenous BOD. Carbonaceous BOD removals then corresponding to 80 and 90% "Standard Methods" BOD removal would be 90% and 95%, respectively. A reason for the extent of nitrification occurring in the 5-day BOD test is the presence of nitrifying organisms in the effluent from the final stage of discs.

If all effluents of 80% or better BOD removal are assumed to be 50% nitrogenous (this has been verified in subsequent tests up to 95% BOD removal), the kinetics of carbonaceous BOD removal can also be shown in Figure 10 (dotted line). Carbonaceous BOD removal appears to be first order up to 90% reduction. Above this degree of treatment, carbonaceous BOD removal remains first order, but at a reduced rate because of the predominance of a nitrifying culture on the discs.

Figure 10 is based on test data for wastewater above 50°F. A similar relationship can be developed for wastewater below 50°F, however, only limited data is available.

Suspended Solids Removal

Figures 11 and 12 show suspended solids removal and effluent concentrations as functions of hydraulic loading on the disc sections and clarifier. For a disc section loading of 1.5 to 2.5 gpd/ft^2 and a clarifier overflow rate of 200 to 380 gpd/ft^2, 80% suspended solids reduction was obtained. This yielded an effluent concentration of about 20 mg/l.

A 380-gpd/ft^2 overflow rate in the secondary clarifier corresponds to a retention time of about 70 minutes. This relatively low retention time for a 380 gpd/ft^2 overflow rate is due to the semi-circular shape and 29-inch maximum sidewater depth of the clarifier. A suspended solids removal of 90% and an effluent of 11 mg/l were produced at a disc surface loading of 1.0 gpd/ft^2.

Disc speed did not have as significant an effect on suspended solids removal. While higher percentage removals were obtained at 3.2 and 4.7 RPM than at 2 RPM, lower effluent solids concentrations were produced at 2 RPM. The reason for this is that lower influent solids concentrations existed during the 2 RPM tests.

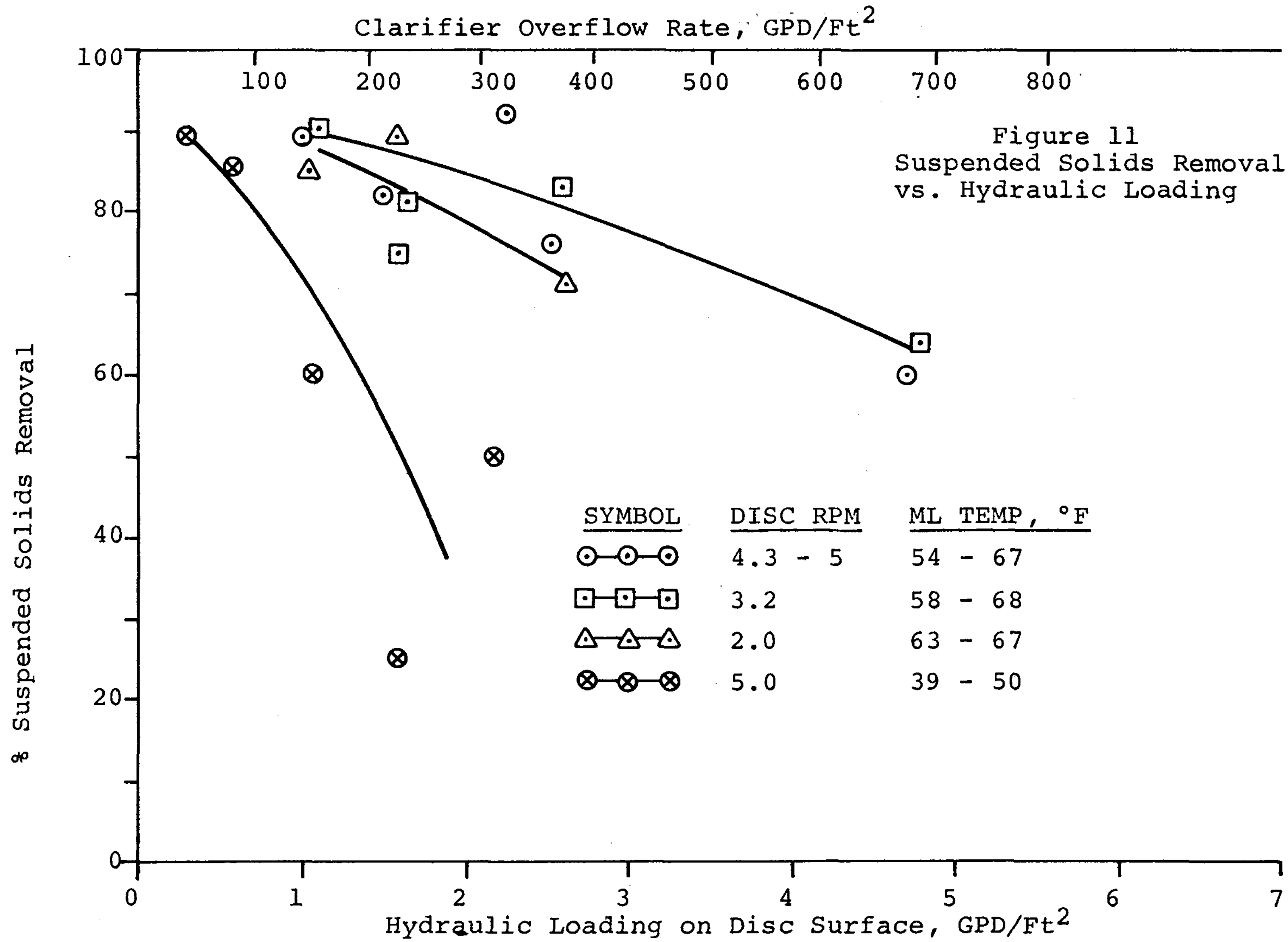


Figure 11
Suspended Solids Removal
vs. Hydraulic Loading

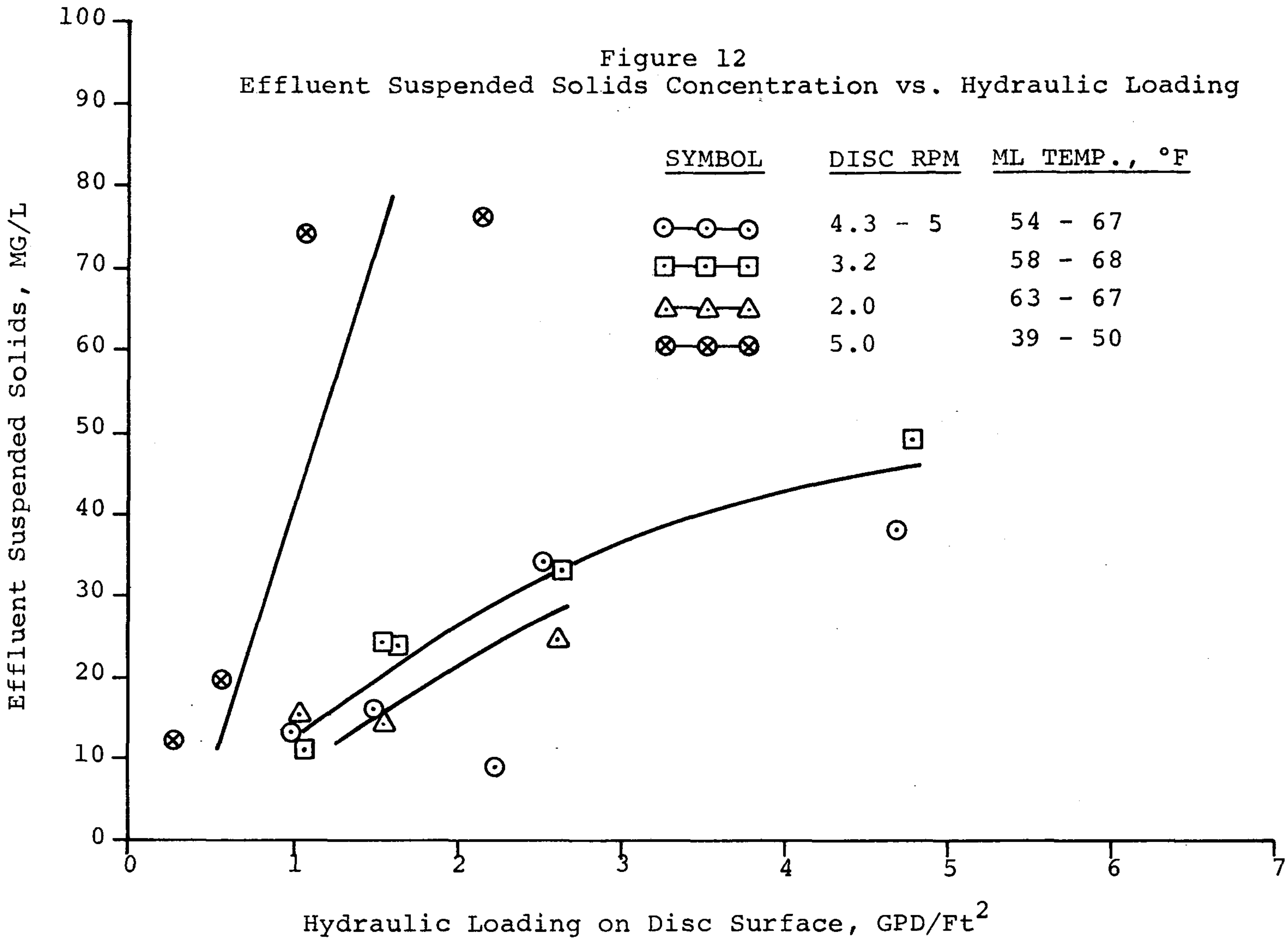


Figure 12
Effluent Suspended Solids Concentration vs. Hydraulic Loading

Wastewater temperature affects suspended solids removal in the same manner as BOD removal; i.e., below 50°F, lower hydraulic loadings are necessary to attain the same removal. The mixing action of the discs appears to flocculate suspended solids very well at all speeds tested and indicates potential for simultaneous biological treatment and flocculation of nutrients with chemical precipitants. The suspended matter remaining in the clarifier effluent is filamentous and flocculent and would appear to filter well in either a sand filter or a microscreen.

COD Removal

COD reduction in Figures 13 and 14 shows relationships of hydraulic loading and disc speed similar to those for BOD and suspended solids removal. One difference is that at wastewater temperatures below 50°F some chemically oxidizable materials are extremely resistant to biochemical oxidation. COD reduction at 2 gpd/ft^2 was not significantly different from that at 0.25 gpd/ft^2.

Ammonia Nitrogen Removal

Figures 15 and 16 show ammonia nitrogen reduction and effluent concentration as a function of hydraulic loading. Separate loading curves are again shown for the different disc speeds and wastewater temperatures. At a hydraulic loading of 1.5 gpd/ft^2, where a 20 mg/l effluent BOD was produced, about 85% removal of ammonia nitrogen was also achieved. An effluent concentration of less than 1.5 mg/l was produced at a loading of 1.0 gpd/ft^2. At still lower loadings during tests on wastewater below 50°F, effluents of less than 0.5 mg/l ammonia nitrogen were produced. Ammonia nitrogen analyses during the low temperature tests were reported to the nearest mg/l; therefore, the reported values of 0.0 mg/l actually represent the range 0.0 to 0.5 mg/l.

The rotating disc method of wastewater treatment is capable of achieving high degrees of ammonia removal in short retention times for two reasons. One is that the system operates as a fixed film biological reactor in which a "captive" population of microorganisms is able to acclimate itself to the particular wastewater it is treating. The other is that by arranging discs in a series of stages, the fixed cultures in successive stages each adapt to the wastewater as it undergoes a progressively increasing degree of treatment. In the case of the two-stage unit tested in this investigation, the first stage developed a culture adapted to metabolizing carbonaceous BOD. With the majority of the carbonaceous matter removed from the wastewater, the second stage then developed a nitrifying culture which metabolized the nitrogenous matter.

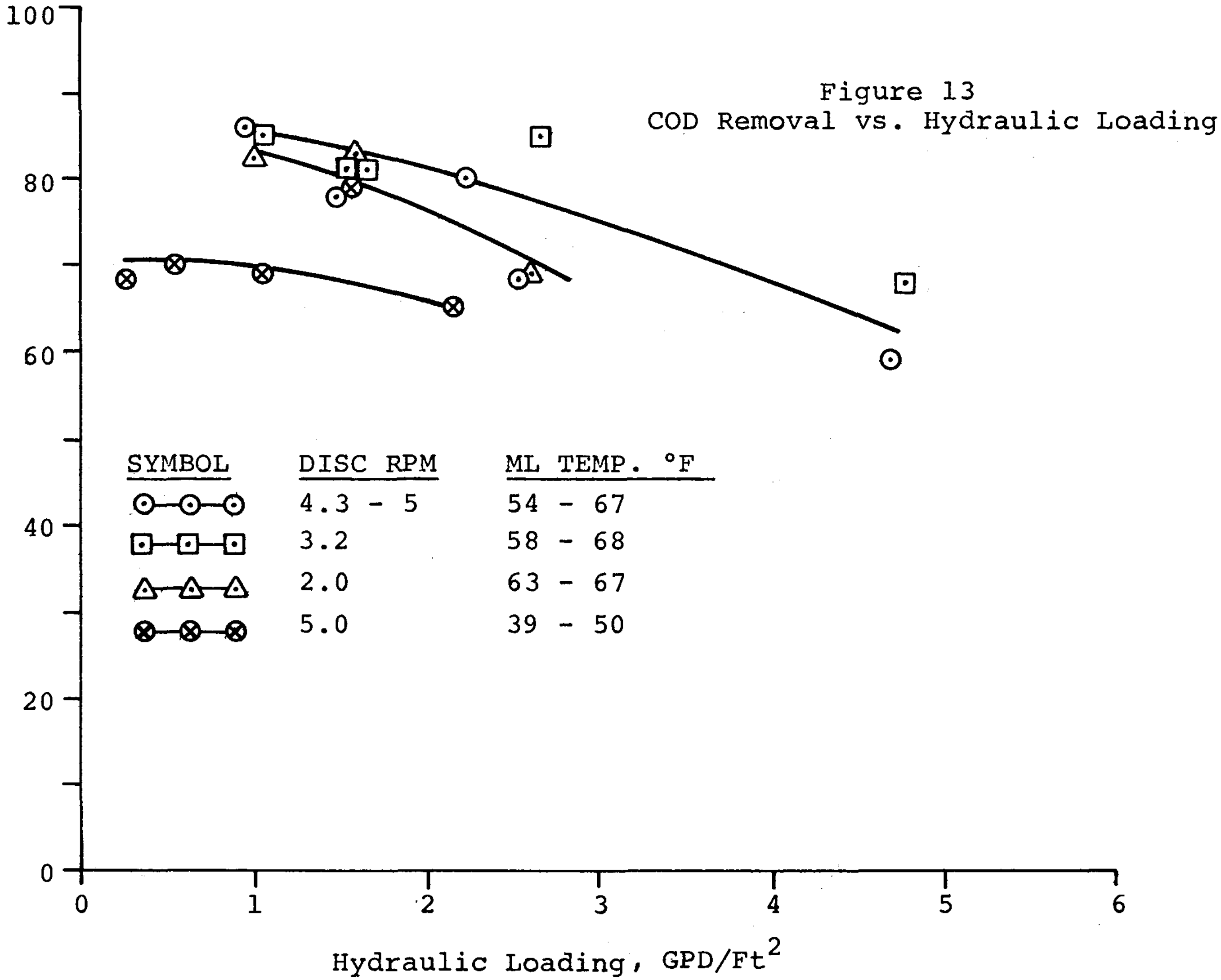


Figure 13
COD Removal vs. Hydraulic Loading

Figure 14
Effluent COD Concentration vs. Hydraulic Loading

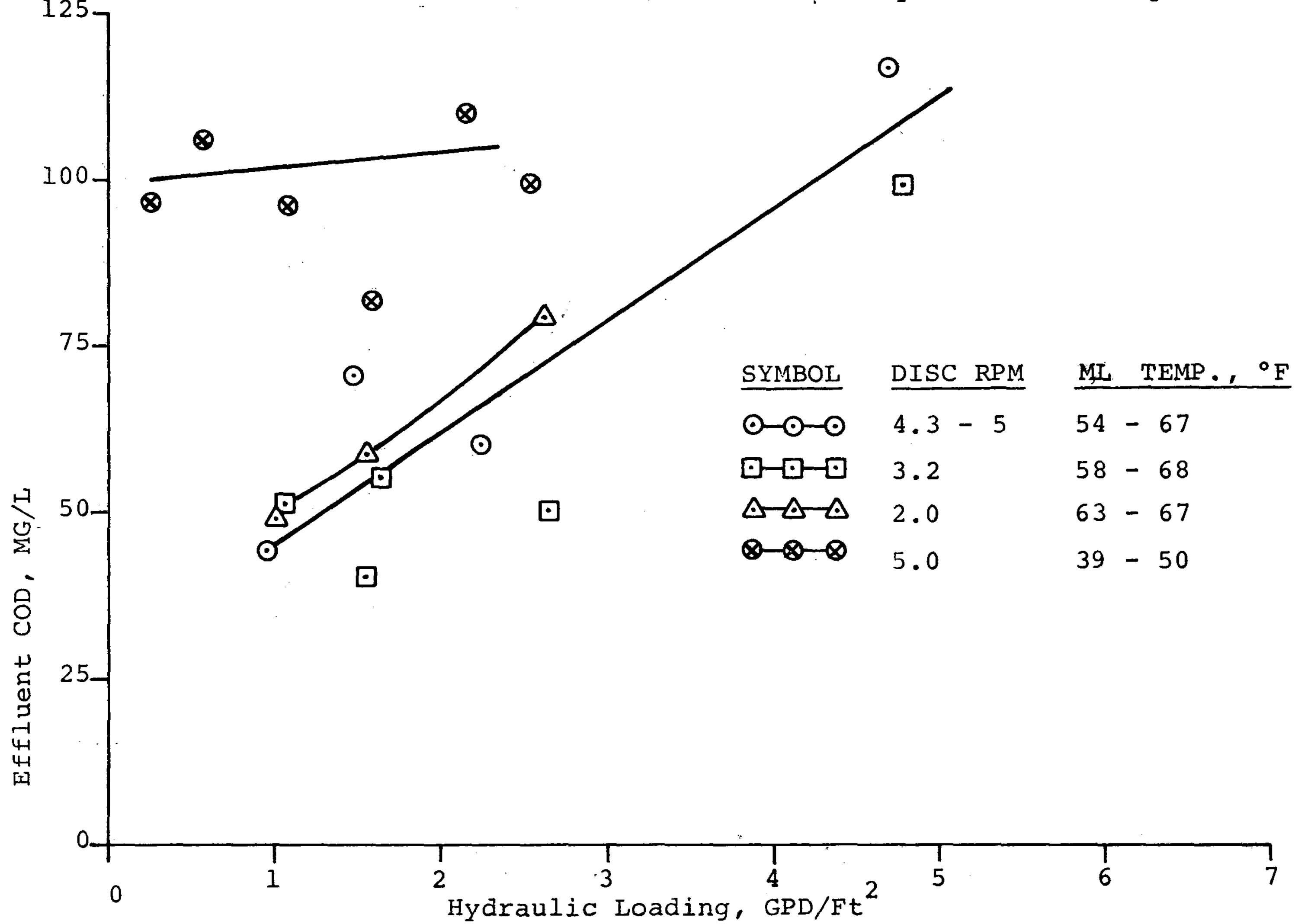


Figure 15
Ammonia Nitrogen Removal vs. Hydraulic Loading

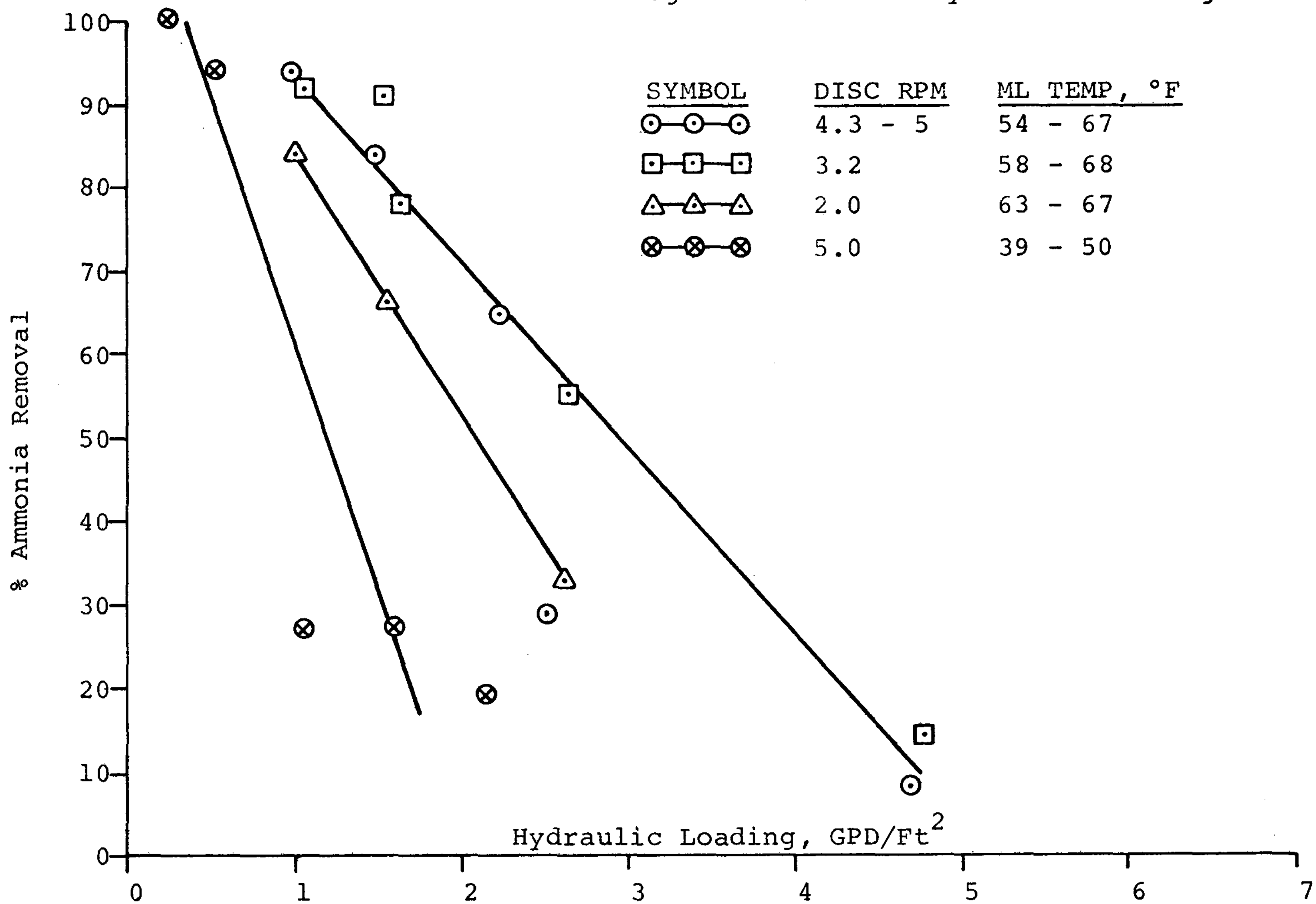
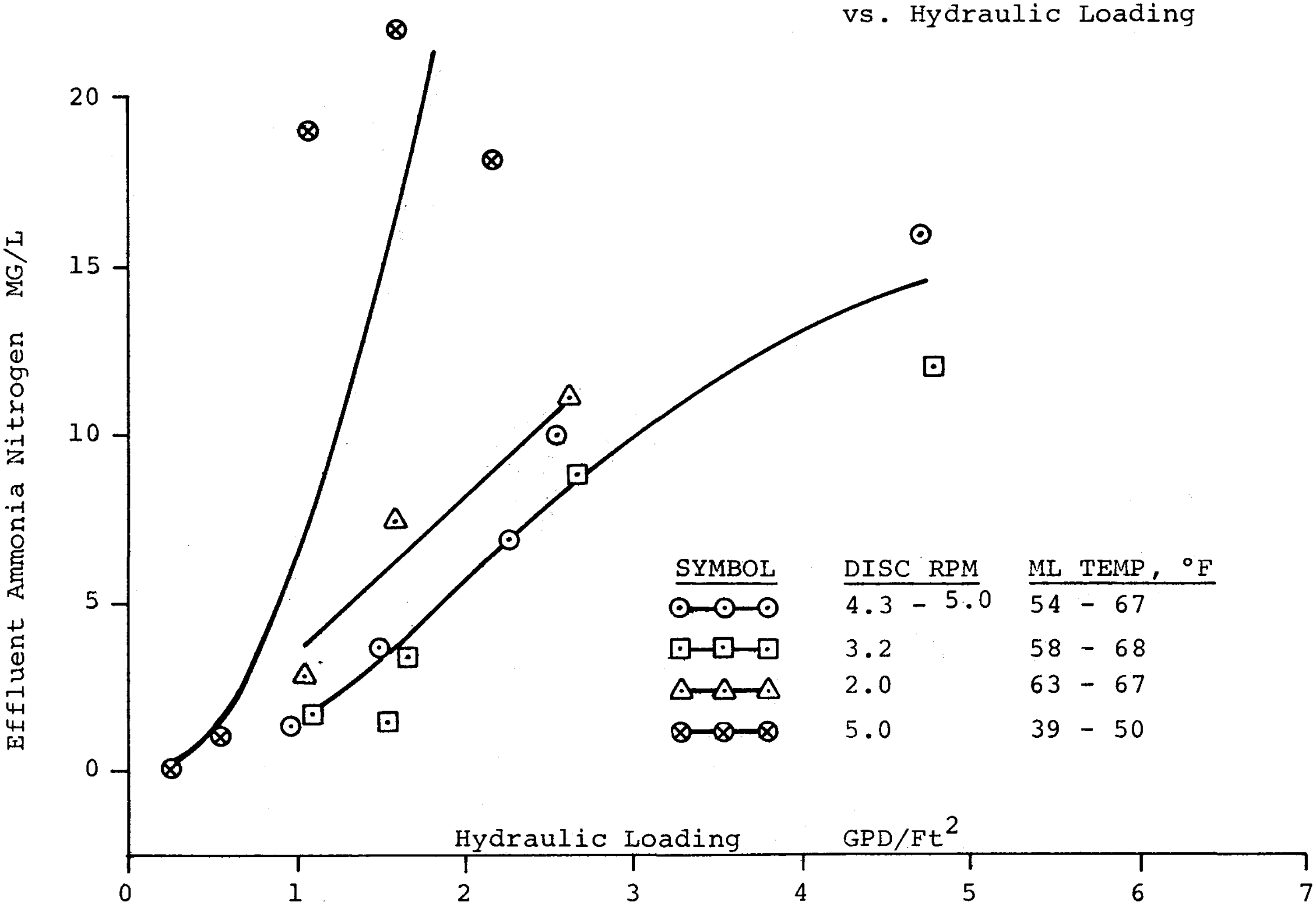


Figure 16
Effluent Ammonia Nitrogen Concentration
vs. Hydraulic Loading



This is shown graphically in Figure 17. Ammonia nitrogen removal did not begin in this two-stage system until the BOD concentration had been reduced to about 60 mg/l. At this point, ammonia removal began and increased rapidly until, at a remaining BOD concentration of about 12 mg/l, ammonia nitrogen removal was virtually complete. This relationship was true for all disc speeds and wastewater temperatures.

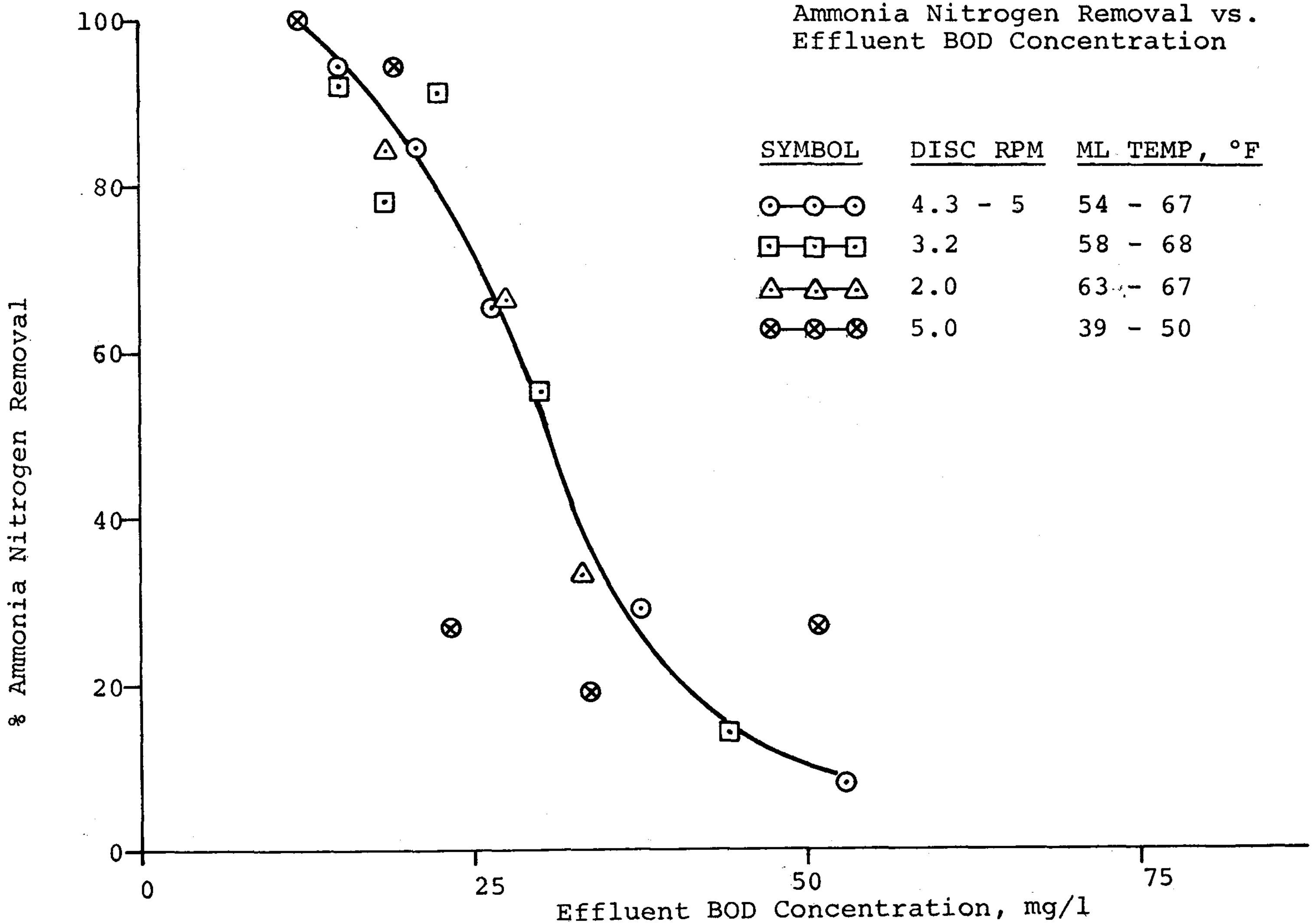
The data on ammonia removal at the higher disc speeds and temperature range is plotted as a function of retention time in Figure 18. The straight-line relationship shows that ammonia removal in the disc system is first order with respect to ammonia concentration at least up to 94% removal and down to 1.3 mg/l effluent ammonia nitrogen. The same type of relationship can be shown for low wastewater temperature, however, only limited data is available.

Because both carbonaceous BOD and ammonia nitrogen removal are approximately first order with respect to carbonaceous BOD and ammonia nitrogen concentration, hydraulic loading is the primary design criterion for the rotating disc process.

Most of the ammonia nitrogen removal consists of oxidation to nitrate and nitrite nitrogen. Figure 19 shows the ration of nitrate and nitrite nitrogen produced per unit ammonia nitrogen removed for the various disc speeds and wastewater temperatures tested. At the higher hydraulic loadings, a greater proportion of the ammonia removal is attributable to cell synthesis. At the lower loadings, where nitrifying organisms predominate, a greater proportion of ammonia removal is conversion to nitrate and nitrite. This data is generalized for all disc speeds and temperatures in Figure 20 as a function of degree of ammonia removal. It shows that a maximum of about 80% conversion to nitrate and nitrite is obtained at the point of virtually complete nitrification. The other 20% is accounted for by cell synthesis, ammonia stripping by the discs, and possibly some denitrification.

All tests in this investigation were conducted at normal municipal wastewater pH. The pH of wastewater is reported to have a significant effect on the rate of biological nitrification.[2] It would be a worthwhile investigation to attempt to accelerate nitrification rate by chemical addition for pH adjustment in later stages of a multi-stage disc system. This would be especially important for reducing surface area requirements when wastewater temperatures were below 50°F.

Figure 17
Ammonia Nitrogen Removal vs.
Effluent BOD Concentration



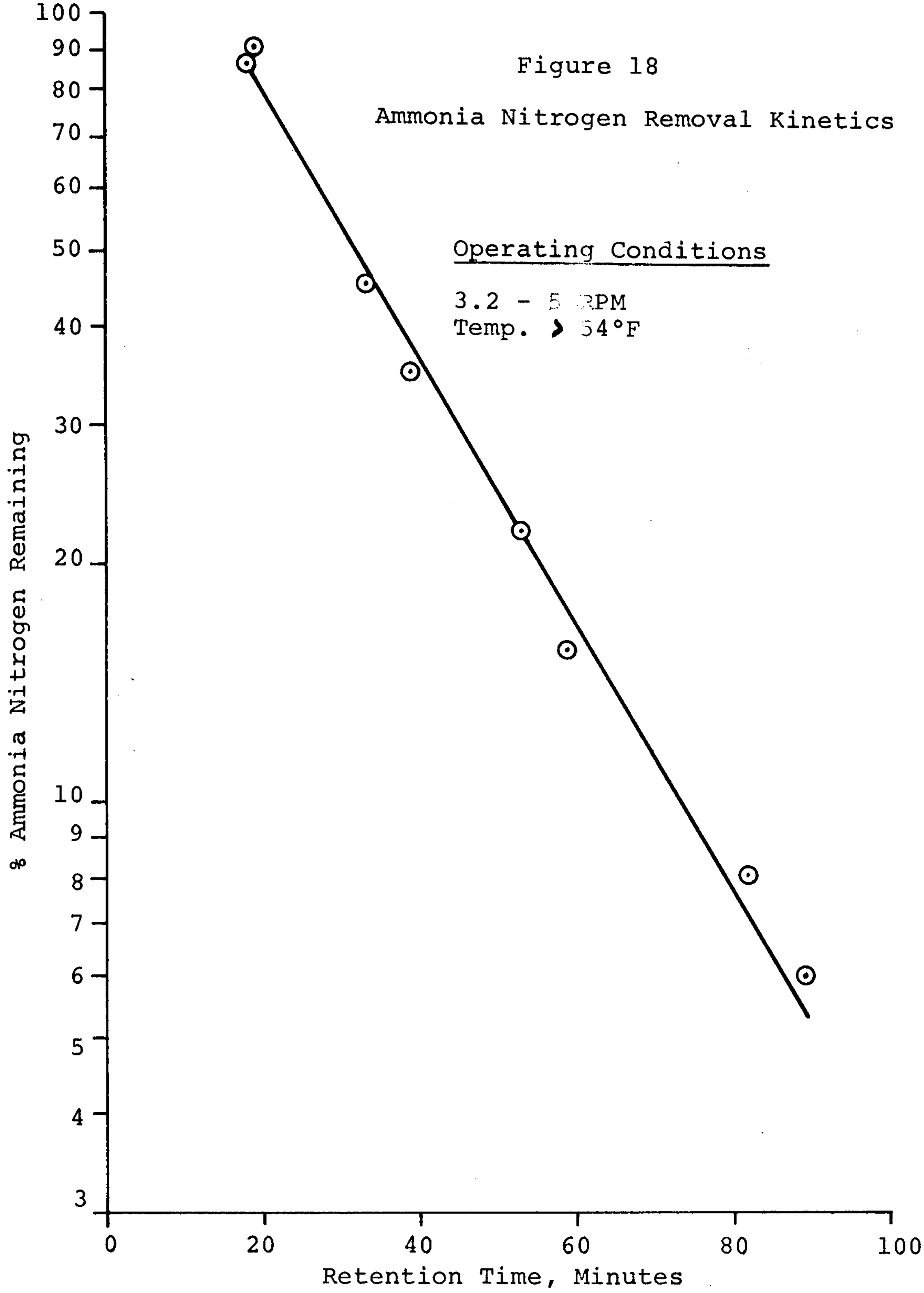
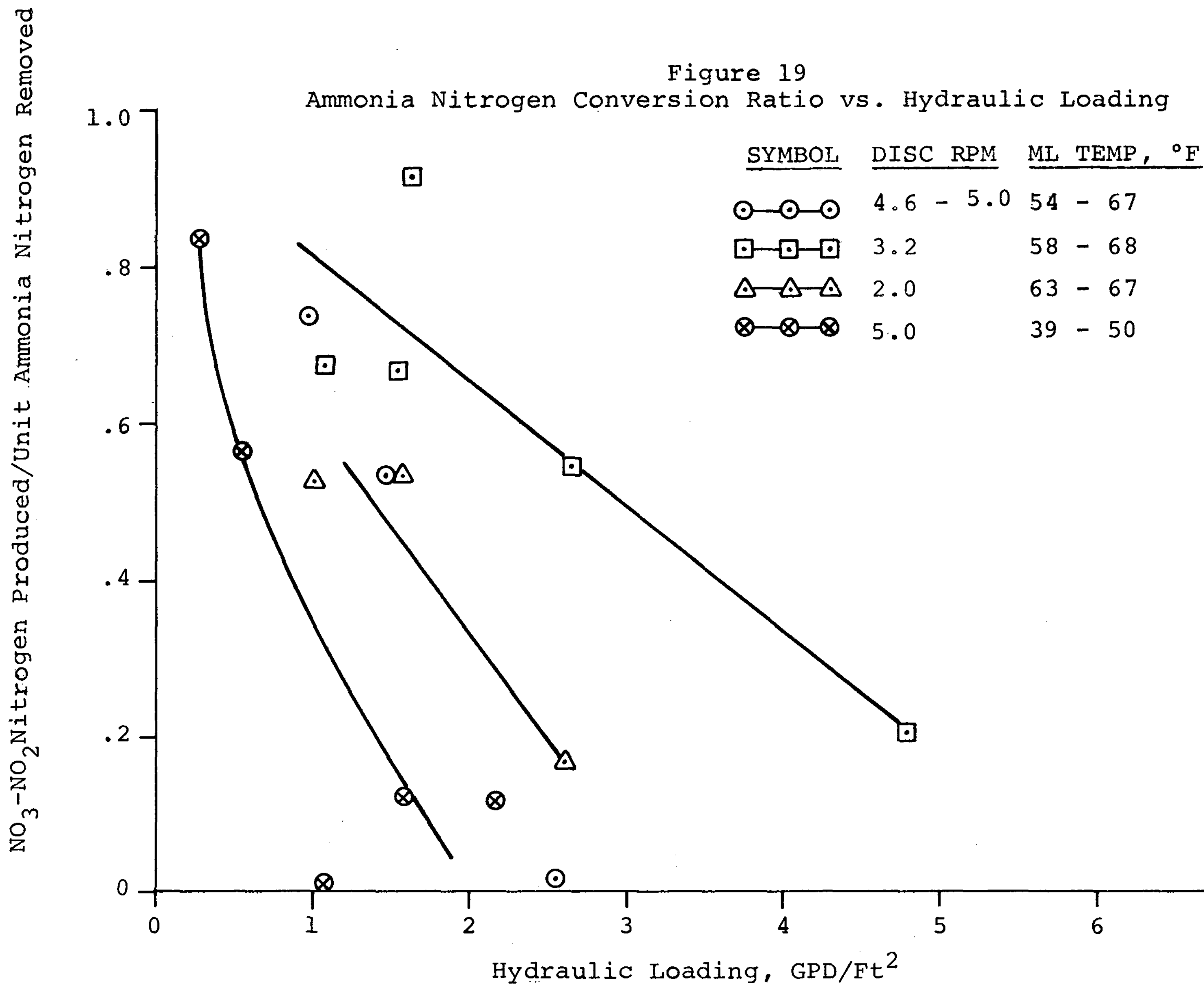


Figure 18

Ammonia Nitrogen Removal Kinetics

Figure 19
Ammonia Nitrogen Conversion Ratio vs. Hydraulic Loading



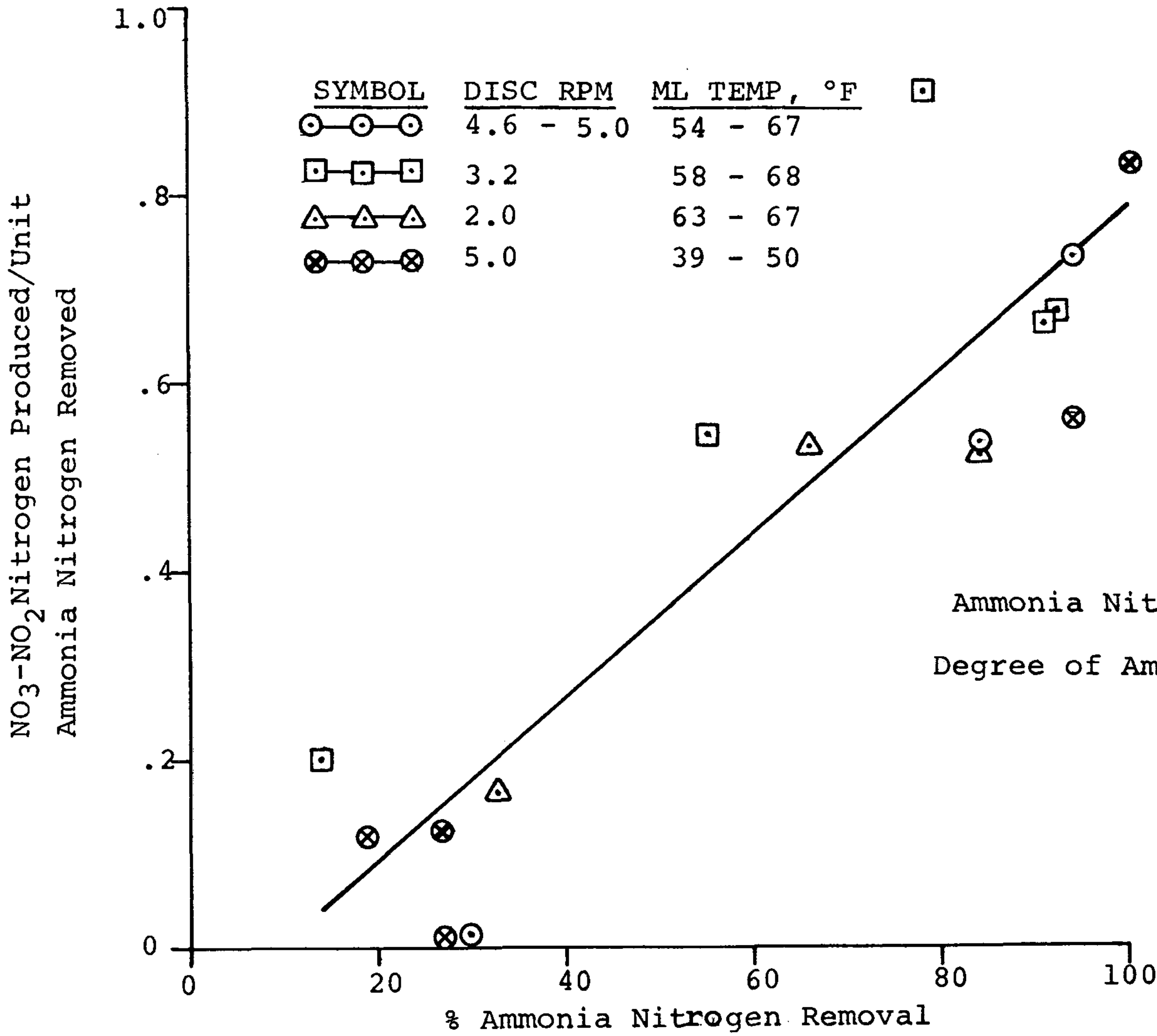


Figure 20
Ammonia Nitrogen Conversion Ratio
vs.
Degree of Ammonia Nitrogen Removal

Kjeldahl Nitrogen Removal

Kjeldahl nitrogen removal and effluent concentrations shown in Figures 21 and 22 follow patterns very similar to ammonia nitrogen removal. At a given hydraulic loading, removal percentages are somewhat lower and effluent concentrations somewhat higher than for ammonia nitrogen. The difference is attributable to residual soluble and colloidal organic nitrogen and organic nitrogen in the suspended matter remaining in the clarifier effluent.

Total Nitrogen Removal

Total nitrogen removal did not exceed 60%, and effluent concentrations did not go below 10 mg/l under any of the test conditions.

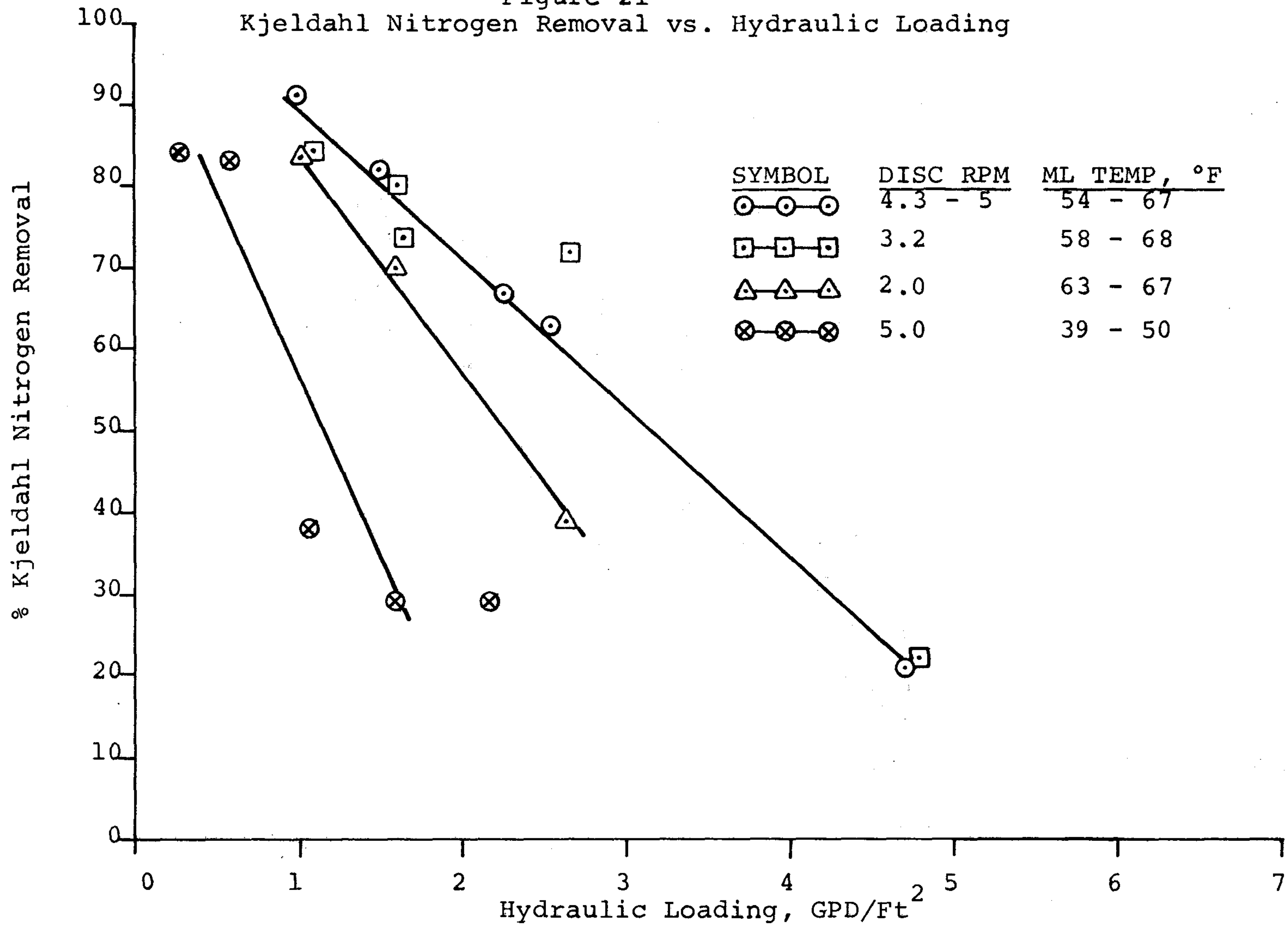
Total nitrogen removal was accomplished primarily through cell synthesis and settling, although ammonia stripping and possibly some denitrification are likely to have occurred. The removal limits of 60% and 10 mg/l in the effluent are imposed by formation of nitrate and nitrite nitrogen from ammonia by nitrifying organisms.

Some correlation exists among hydraulic loading, disc speed, and wastewater temperature as they affect nitrogen removal and effluent nitrogen concentrations in Figures 23 and 24. The greater removal of nitrogen at the higher disc speeds and wastewater temperatures reflects greater biological activity and incorporation of nitrogen into cell synthesis under these conditions. Ammonia stripping would also be more significant at the higher temperatures and disc speeds.

Phosphorus Removal

Total phosphorus removals in the data summary in the Appendix vary generally from 10 to 30% with an overall average of about 20%. No apparent correlation could be found between phosphorus removal and any of the primary operating parameters of the system. On the average, 0.02 units of phosphorus were removed per unit BOD removal. This is higher than the normal phosphorus requirement in biological wastewater treatment of 0.01 unit per unit of BOD present. The difference is likely due to flocculation and settling of organically bound phosphorus, because orthophosphorus concentration generally increased rather than decreased through the disc unit.

Figure 21
Kjeldahl Nitrogen Removal vs. Hydraulic Loading



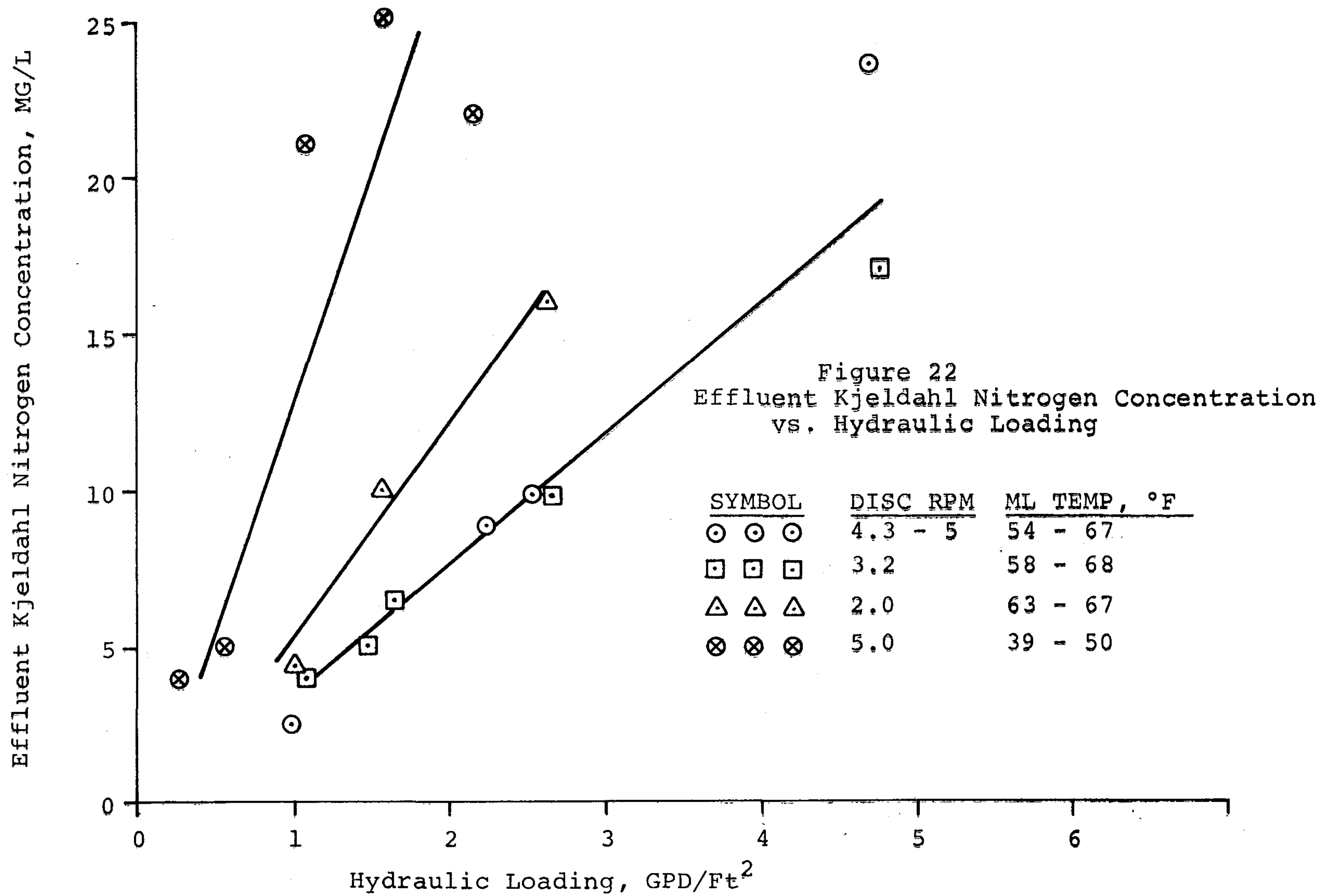


Figure 22
Effluent Kjeldahl Nitrogen Concentration vs. Hydraulic Loading

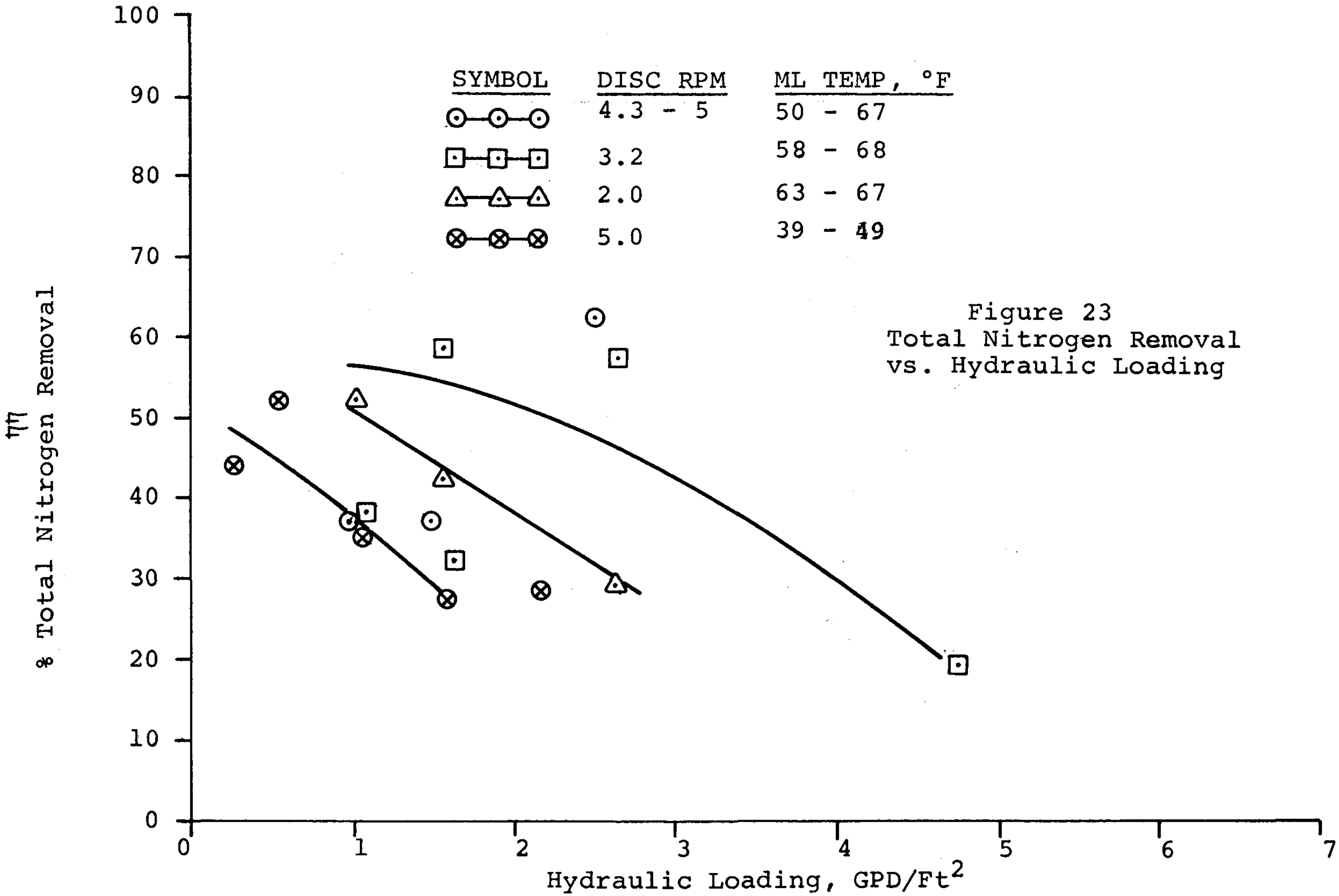
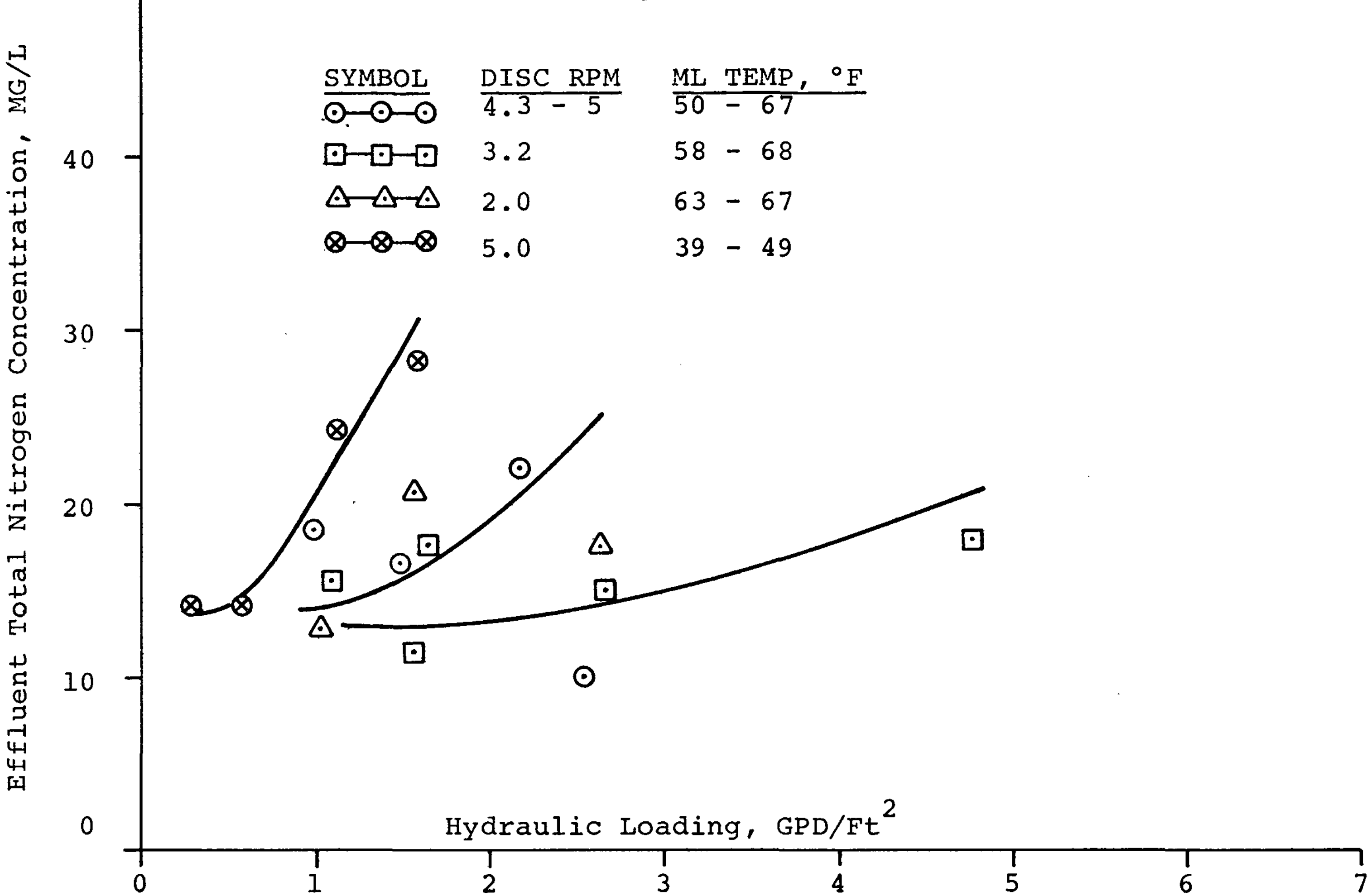


Figure 23
Total Nitrogen Removal
vs. Hydraulic Loading

Figure 24
Effluent Total Nitrogen Concentration vs. Hydraulic Loading



Power Consumption

The expanded polystyrene used for disc fabrication is very buoyant. In operation, the buoyancy of the discs offsets the weight of the biomass and the disc support structure, so that power to overcome friction between the biomass and the wastewater is the only power required for rotation. Figure 25 shows power measurements made on the package plant as a function of disc speed.

Power requirements were determined by mounting a hydraulic motor in a cradle and measuring reaction torque at various speeds. (See Figure 5.) Very little power is required to operate the package plant; however, power requirements do increase rapidly with disc speed. Previous correlations have shown package plant performance at 3.2 and 4.3-5 rpm to be superior to that at 2.0 rpm. In spite of this, Figure 26 shows that a speed of 2.0 rpm makes more efficient use of power for all the treatment levels obtained. However, considering that much less surface area is required for a given degree of treatment, the increased power consumption at higher disc speeds seems justified.

At the disc speed of 3.2 rpm, 5.2 lb. BOD are removed per hp—hr for 87% BOD reduction through the discs and an effluent of 18 mg/l BOD. This power consumption converts to 8 HP per MGD plant capacity or 0.2 hp-hr per 1,000 gal. of wastewater treated. This power requirement applies to consumption by the discs and bearings only and does not include motor or drive inefficiencies.

Power consumption by the rotating disc process would be optimized further than what was accomplished during this investigation. In determining the optimum disc velocity, it was necessary by nature of the construction of the test unit to operate both stages of discs at the same rotational velocity. In a multi-stage disc system, it seems likely that each successive stage of discs would have an optimum velocity which would decrease as the degree of treatment increased.

Sludge Production

Sludge production by the test unit was calculated by subtracting the suspended solids concentration in the clarifier effluent from the suspended solids concentration in the second stage of discs. This difference represents the amount of sludge solids which settled in the clarifier. Dividing this by the decrease in BOD concentration through the test unit yields sludge production as sludge produced per unit BOD removed.

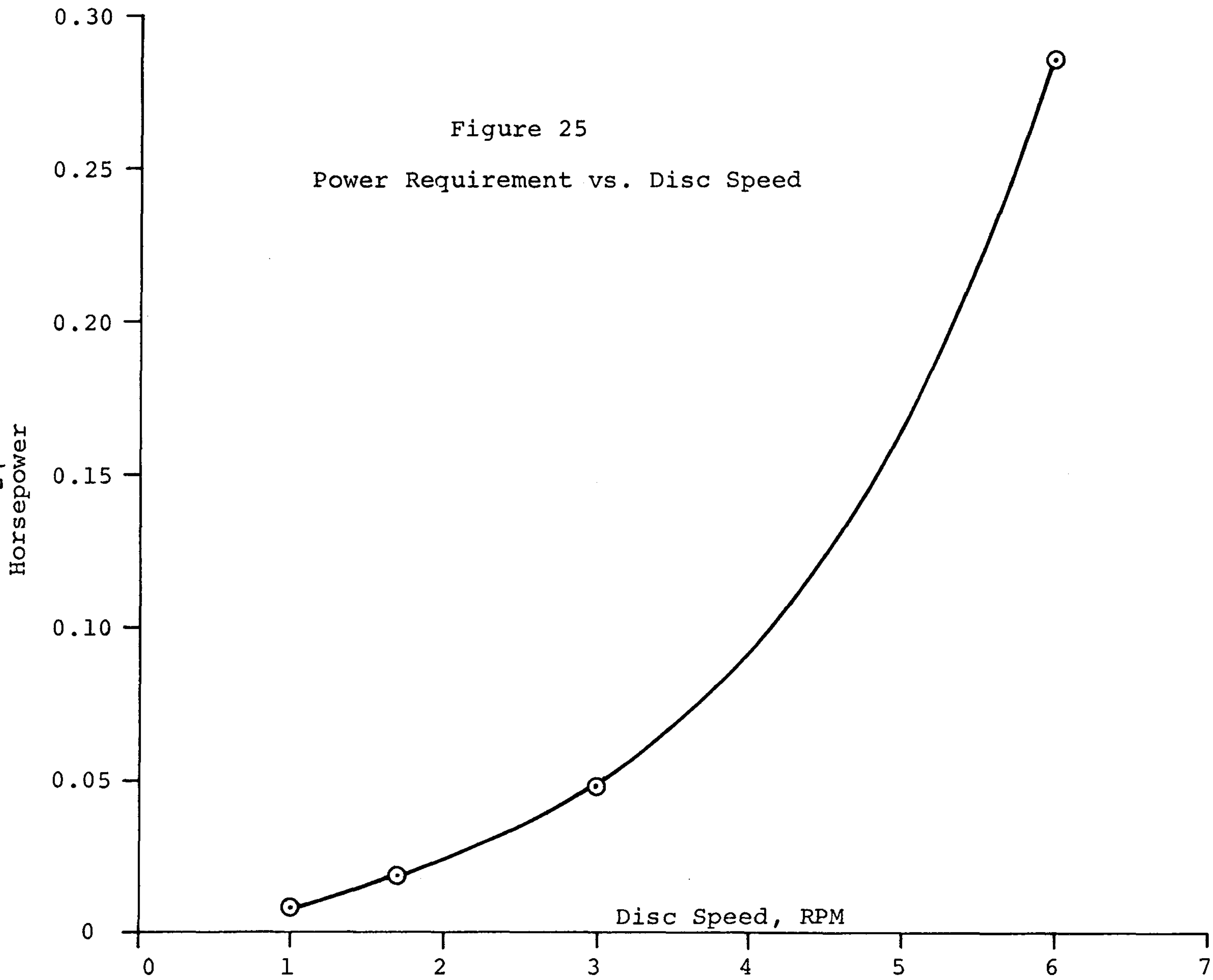
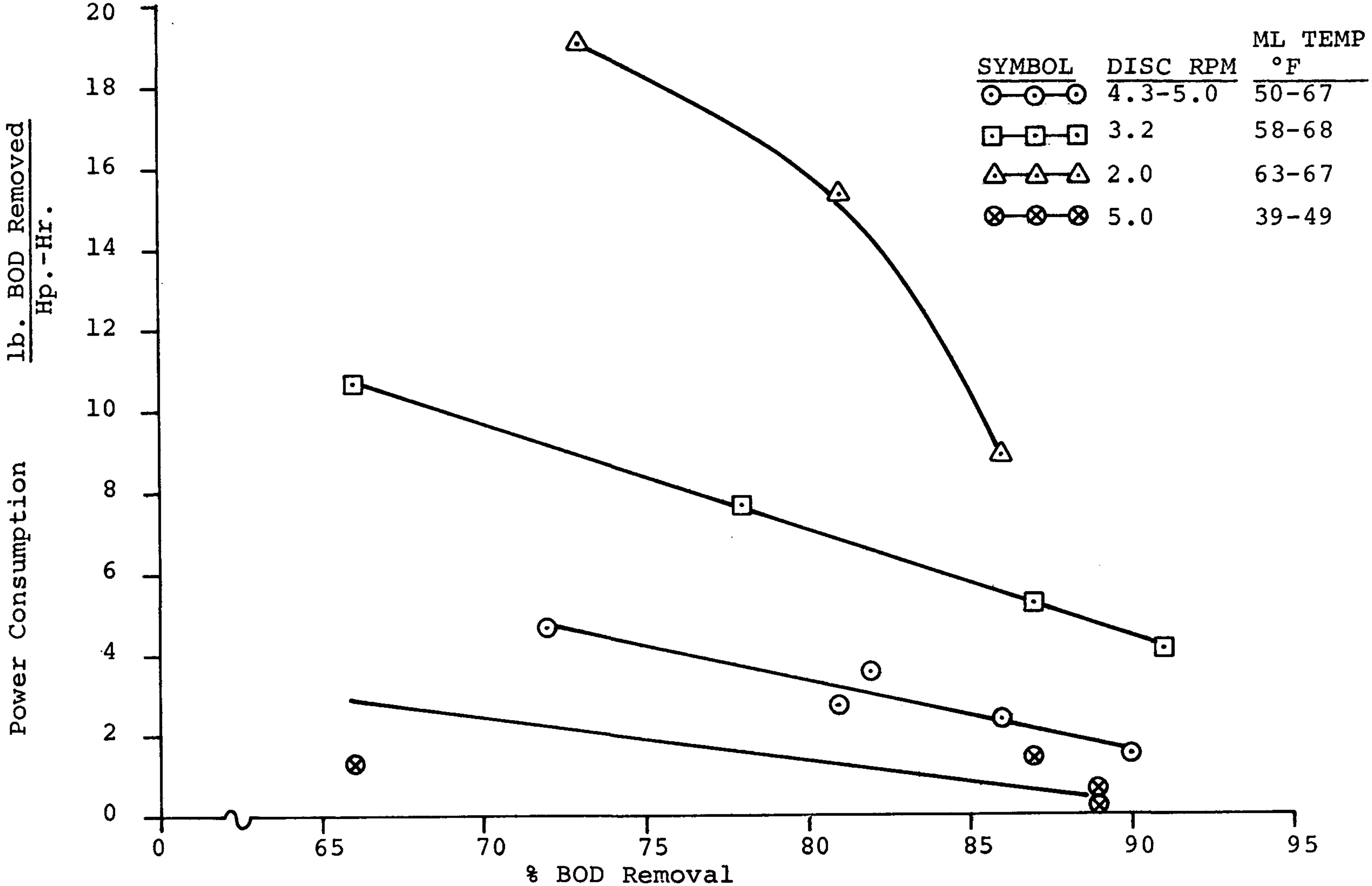


Figure 25

Power Requirement vs. Disc Speed

Figure 26
Power Consumption vs. Degree of Treatment



Sludge production as a function of degree of treatment is presented in Figure 27. The data is scattered, which may indicate difficulty in obtaining accurate mixed liquor samples. Sludge production appears to be much higher when treating wastewater below 50°F. No consistent effect of disc speed can be noted. Sludge production does appear to decrease as the degree of treatment increases as would be expected. At a BOD removal of 86%, which would correspond to an effluent of 20 mg/l BOD, 0.5 to 0.6 lb. sludge were produced per lb. BOD removed. Sludge solids were 80% volatile under all test conditions.

Sludge production will be examined more closely during testing of the demonstration plant at Pewaukee.

Mixed Liquor Characteristics

The parameters of pH, dissolved oxygen concentration, and suspended solids for the mixed liquor of the two stages of discs are summarized in Table 5.

For wastewater above 50°F, suspended matter decreased from Stage 1 to Stage 2 to a concentration generally under 100 mg/l. Mixed liquor solids are filamentous and very dense and appear to settle and thicken well. They also would appear to be readily removed by mechanical means, such as sand filtration or microscreening. In treatment applications where an alternative to a settling tank for secondary clarification is desirable, mechanical separation may be possible when using the rotating disc system for secondary treatment. This is an area which warrants investigation.

For wastewater temperatures below 50°F, suspended matter generally increased from Stage 1 to Stage 2 to concentrations ranging from 130 to 250 mg/l. This accounts for the higher calculated sludge production rate at lower wastewater temperatures.

Effluent pH varied from 7.2 to 8.0 at wastewater temperatures above 50°F. Below 50°F, pH varied from 7.6 to 8.5 Higher pH values at the colder temperatures may have contributed to the high degrees of nitrification obtained in spite of the low temperatures. A pH of 8.5 is near the optimum reported for biological nitrification. (2)

Disc speed may also have had an effect on pH. At 2 RPM, pH ranged from 7.2 to 7.6. At 3.2 to 4.7 RPM, pH ranged from 7.6 to 8.0. More effective stripping of dissolved CO_2 may be the reason for the higher pH values. The higher pH values could have contributed to better nitrification at the higher disc speeds.

Figure 27
Sludge Production vs. Degree of Treatment

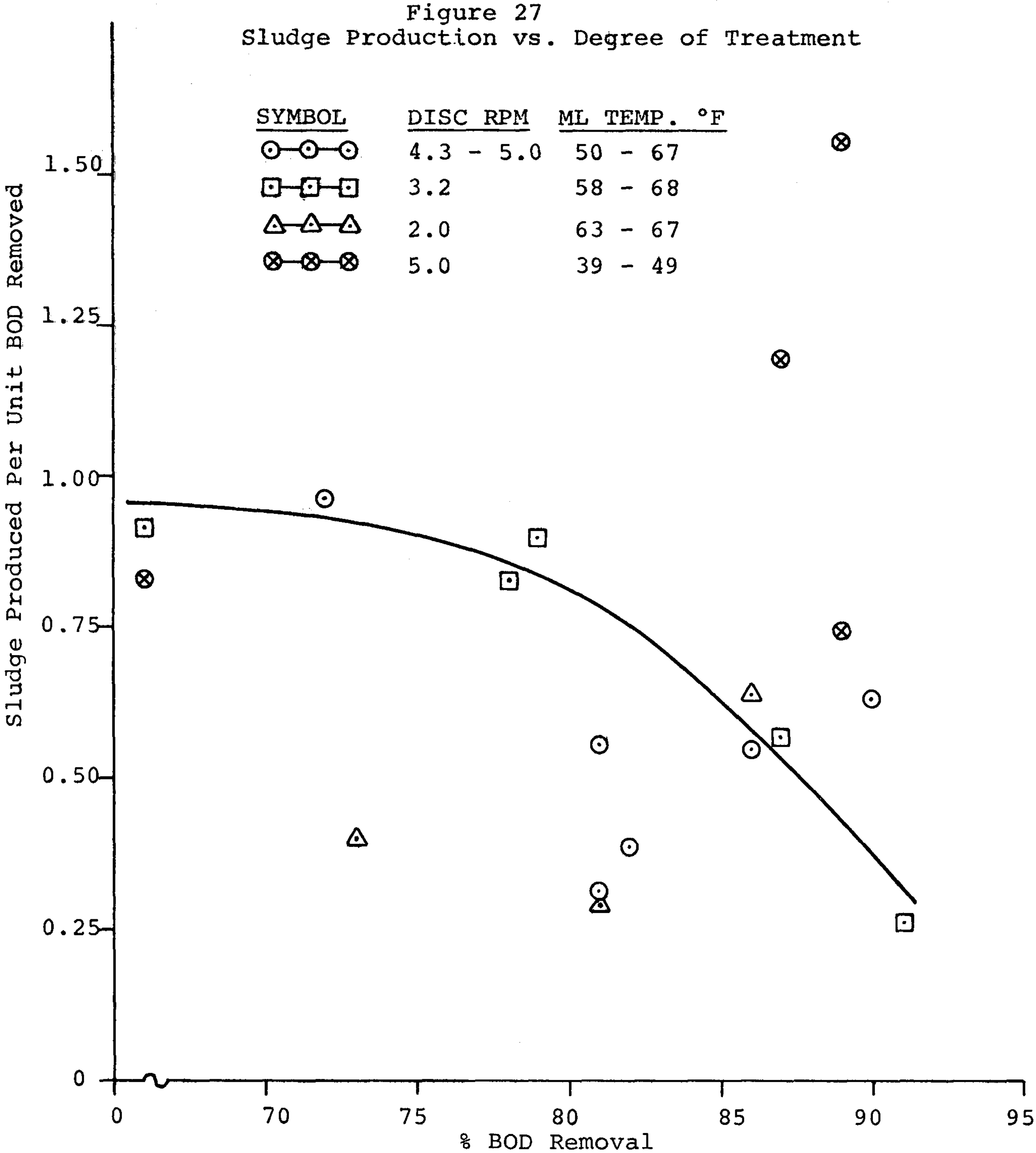


TABLE 5

MIXED LIQUOR CHARACTERISTICS

TEST PERIOD AVERAGES

Test Period Dates	Disc Stage	Susp. Solids (mg/l)	RPM	D.O.	Temp. °F	pH
11/13-12/19	1	275	5		54	-
	2	99	5		-	7.3
12/23-1/19	1	228	5		50	-
	2	122	5		-	7.6
1/20-2/9	1	146	5		49	-
	2	200	5		-	8.0
2/10-2/13	1	202	5		42	-
	2	256	5		-	7.6
2/25-3/2	1	250	5		39	-
	2	131	5		-	8.5
3/3-3/9	1	154	5		45	-
	2	167	5		-	8.5
4/1-5/15	1	138	3.2		-	-
	2	97	3.2		-	-
5/20-6/5	1	268	3.2		58	-
	2	123	3.2		-	8.2
6/10-6/19	1	238	3.2		61	-
	2	126	3.2		-	8.0
6/22-7/17	1	132	3.2		66	-
	2	91	3.2		-	7.8
7/22-8/7	1	171	3.2		68	-
	2	49	3.2		-	7.9
8/12-8/17	1	128	4.3	1.7	67	-
	2	72	4.3	3.6	-	8.0
8/18-8/21	1	196	4.6	3.3	66	-
	2	89	4.6	3.7	-	7.7
8/24-8/29	1	167	4.7	3.8	67	-
	2	96	4.7	5.1	-	7.6
8/31-9/11	1	170	2.0	1.0	66	-
	2	50	2.0	2.6	-	7.6
9/14-9/25	1	139	2.0	2.0	64	-
	2	84	2.0	3.8	-	7.2
9/28-10/3	1	104	2.0	2.6	63	-
	2	60	2.0	4.0	-	-
10/7-10/23	1	88	4.7	3.1	63	-
	2	121	4.7	4.0	-	-

Samples of mixed liquor taken for laboratory analyses were 24-hour composites. Because the mixed liquor solids and supernatant were of necessity kept in the same container for the 24-hour sampling period, the laboratory analyses for solids, nitrogen, and phosphorus may not be truly indicative of conditions which existed in the mixed liquors.

Dissolved oxygen concentration in Stage 1 varied from 1.0 to 3.8 mg/l, depending upon hydraulic loading and disc speed. Stage 2 dissolved oxygen concentrations were 1 to 2 mg/l higher than Stage 1. Less than 1.0 mg/l of dissolved oxygen was consumed in the secondary clarifier, so that effluent dissolved oxygen concentrations were always several milligrams per liter. At wastewater temperatures below 50°F, dissolved oxygen concentrations in the effluent ranged between 7 and 10 mg/l, which indicates that mixed liquor concentrations were also quite high.

Sludge Recycle

Several brief tests were conducted to determine if recycling settled secondary sludge to the first stage of discs would enhance treatment of the wastewater. Sludge removed from the clarifier by the scoop system was collected in a drum and pumped into the first stage of discs at rates of 1% and 2% of the wastewater flow.

Table 6 is a summary of operating data during sludge recycle and during comparable periods without sludge recycle. The amounts of sludge recycled apparently had little effect on the concentration of mixed liquor solids. As a consequence, there was no distinct effect on treatment efficiency. At the 1% recycle rate, BOD and COD removals were lower than without sludge recycle. Suspended solids removal increased in one case and remained the same in the other. Ammonia nitrogen removal increased in one case and decreased in the other. At the 2% recycle rate, BOD and COD removals increased; however, mixed liquor solids concentrations were actually lower with sludge recycle than without.

The proportion of volatile to fixed solids in the mixed liquor was unchanged by recycling sludge. The sludge recycle rates tested had no apparent effect on any system parameters. To determine the effect of sludge recycle, further tests at much higher recycle rates will be necessary. This is being planned during testing of the demonstration plant at Pewaukee.

TABLE 6

Effect of Sludge Recycle on Treatment Efficiency

Test Period	Hydraulic Loading GPD/ft²	ML Temp. °F	Sludge Recycle Rate % of Total Flow	Stage	Mixed Liquor Susp. Solids (mg/l) Total	Mixed Liquor Susp. Solids (mg/l) Volatile	% Removal BOD	% Removal COD	% Removal SS	% Removal NH_3-N
2/10-2/13	1.06	42	0	1	202	160	87	69	60	27
				2	256	189				
2/16-2/20	1.06	42	1	1	230	192	84	66	81	25
				2	249	200				
2/25-3/2	0.55	39	0	1	250	220	89	70	85	94
				2	131	125				
2/23-2/24	0.47	44	1	1	88	83	85	60	85~100	
				2	140	133				
3/3-3/9	0.26	45	0	1	154	136	89	68	89~100	
				2	167	143				
3/10-3/13	0.26	40	2	1	113	90	93	88	90~100	
				2	75	61				

Maintenance

The rotating disc process is inherently simple. There are just a few simple mechanical parts, and there is no need to recycle sludge or effluent. The only regular maintenance required is to grease bearings and check oil levels in drive system components. As long as disc rotation is maintained, the process will operate satisfactorily. Low maintenance makes the rotating disc process very attractive for package plant installations and especially for wastewater treatment in remote areas.

SECTION VIII

COMPARISON TO PREVIOUS ROTATING DISC PROCESS EXPERIENCE

Previous testing of a rotating disc system on municipal wastewater in the U.S. was conducted at the Jones Island Sewage Treatment Plant of the Milwaukee Metropolitan Sewerage Commission. These tests were conducted under Environmental Protection Agency Contract 14-12-24.[3] Table 7 is a comparison of the Jones Island test unit and operating conditions with those for this investigation. Figure 28 compares the design hydraulic loading curve determined from Figure 8 at higher temperatures and disc speeds with the results of the Jones Island tests. The Jones Island test unit yielded equal or better percentage BOD removals at all hydraulic loadings tested, even though the organic loading was considerably higher. This demonstrates that the rotating disc process is first order with respect to BOD concentration from 147 mg/l at least up to 426/mg/l for municipal wastewater.

A factor contributing to the better performance by the Jones Island test unit was the larger number of stages of discs. Residence time distribution tests on the 10-shaft unit revealed that 4-6 equivalent, completely mixed stages in series were obtained at the wastewater flows tested. A separate stage of treatment for each shaft was not obtained because of the high degree of backmixing between adjacent shafts. Similar tests on the Pewaukee test unit indicated that each stage was thoroughly mixed, and it therefore operated as a two-stage reactor.

TABLE 7

Comparison with Previous Test Unit

		Jones Island	Pewaukee
a.	Disc Diameter, Ft.	1	5.74
b.	Disc Velocity, RPM	15-30	2-5
c.	Disc Shafts or Stages, No.	10	2
d.	Effective Disc Area, Ft^2	500	4,600
e.	Disc Spacing Surface to Surface, In.	0.44	0.5
f.	Net Tank Volume, Gal.	40	280
g.	Ratio $\frac{f}{d}$, $\frac{gal}{ft.^2}$	0.08	0.06
h.	Temperature, ^oF	50-68	39-67
i.	Average Influent BOD Concentration, mg/l	426	147

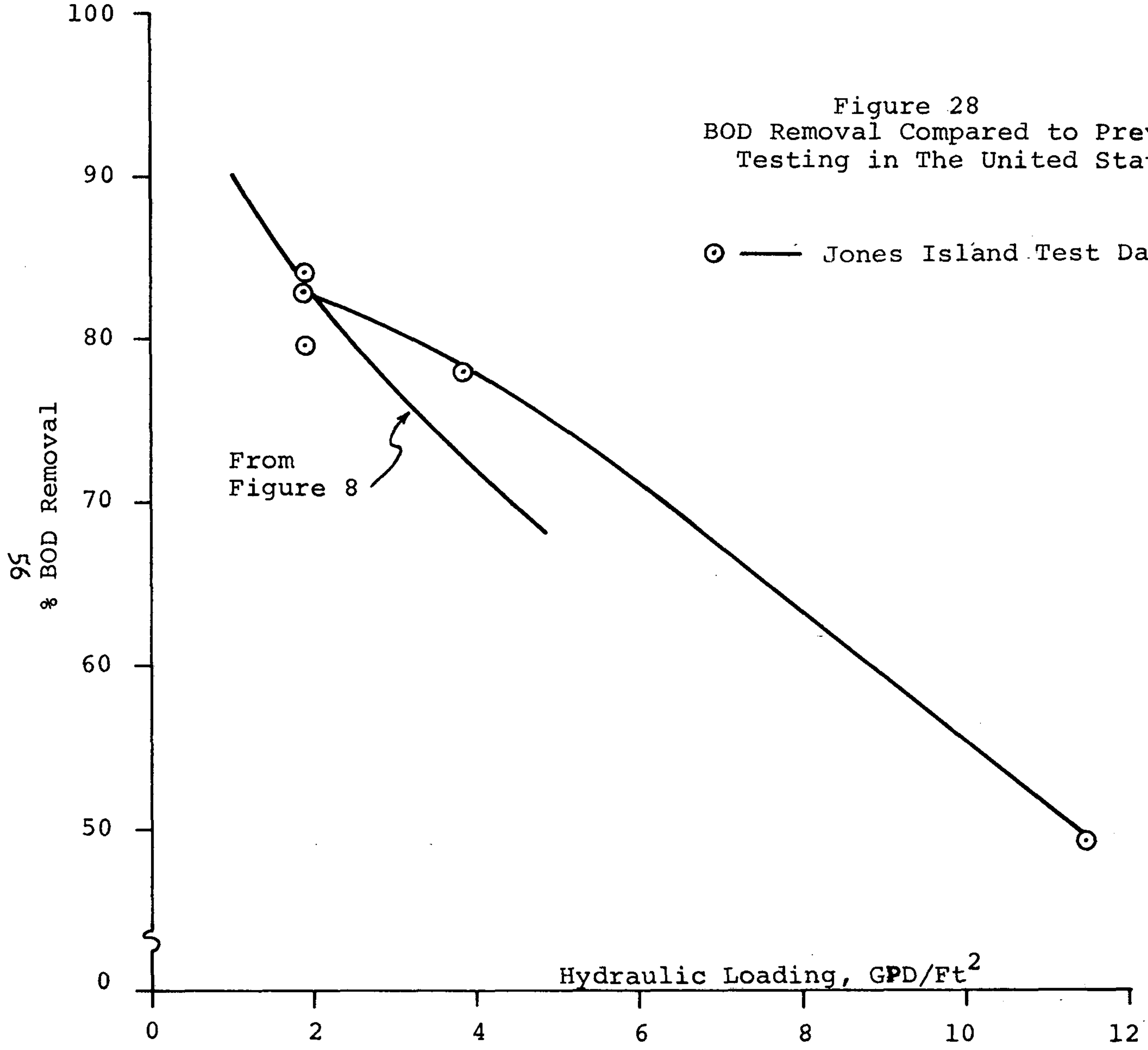


Figure 28
BOD Removal Compared to Previous Testing in The United States

Another factor contributing to better performance by the Jones Island unit is a greater liquid-holding capacity per unit surface area. This means that at a given hydraulic loading in gpd/ft^2, the Jones Island unit had a longer retention time. The importance of liquid holding capacity per unit surface area is shown in Figure 29, where the performance curve from Figure 8 is compared to European experience with the rotating disc process.[4] European disc systems have 0.85 inch spaces, surface to surface, between discs, which, in contoured-bottom tankage, yields a liquid holding capacity of 0.085 gal/ft^2 of disc surface. The European experience on multistage disc systems also indicates that a 4-stage disc plant can be loaded at a 30% greater rate than a 2-stage plant and achieve the same degree of treatment. The reason for this is that the more favorable residence time distribution of a 4-stage system and the approximately first order BOD removal kinetics of the disc process increase the overall BOD removal rate.

The 400,000-gpd demonstration plant at Pewaukee, Wisconsin, is constructed in four stages and with 0.085 gal. liquid capacity per sq. ft. of disc surface, which will verify the treatment capacity experienced in Europe.

The correlation of disc speed with various treatment parameters has been done on the basis of revolutions per minute in this report. To utilize disc speed as a design criterion requires that a measure of disc speed common to all disc diameters be used. The peripheral or circumferential velocity is such a measure and, because it is also directly proportional to the average velocity of the disc surface area, strongly suggests that it be utilized as a design criterion. The Jones Island tests with 1.0-ft. diameter discs at 15-30 RPM, the tests reported here on 5.7 ft. diameter discs at 2-5 RPM and European experience with 10-ft. diameter discs at 1-2 RPM indicate peripheral speed to be a common design criterion. Tests at various disc speeds during the evaluation of the demonstration plant at Pewaukee will help verify peripheral velocity as a basic design criterion.

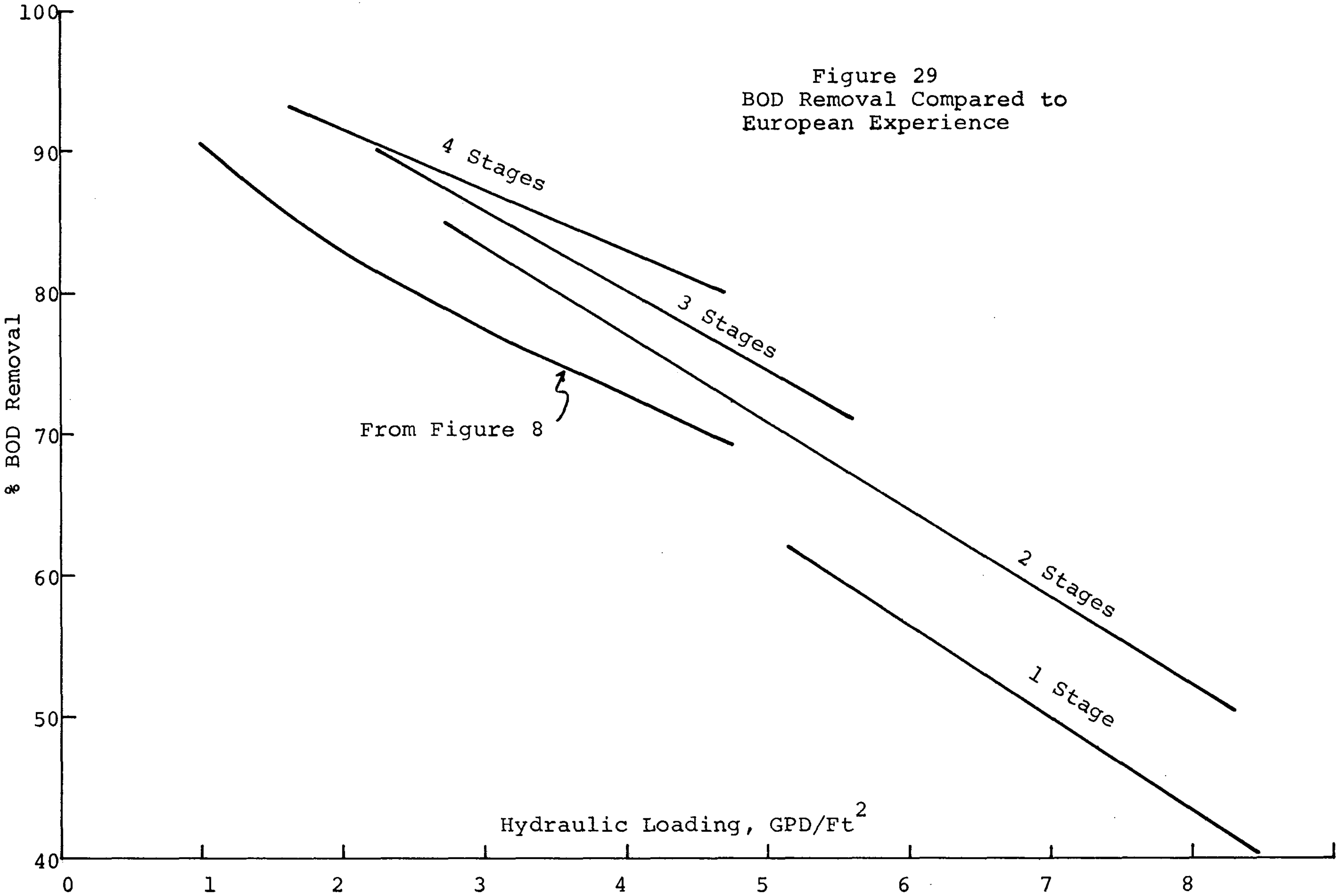


Figure 29
BOD Removal Compared to
European Experience

SECTION IX

COMPARISON TO OTHER PROCESSES

A complete comparison of the rotating disc process to other processes should include capital cost comparisons; but since this is beyond the scope of this investigation, the discussion will be limited to operating characteristics of the processes.

The rotating disc process is similar to the trickling filter process in that they are both fixed film biological reactors. There are some key differences, however, which give the disc process some important benefits. In the disc system, the biomass is passed through the wastewater rather than the wastewater over the biomass. This provides intimate contact of all of the organisms with the wastewater and prevents problems with clogging of the media by excess biomass. Shearing forces created by rotation at peripheral disc velocities of 30 to 60 ft/min continuously and uniformly strip excess biomass from the discs. Continuous wetting of the entire biomass also prevents development of the flies often associated with trickling filter operation.

Aeration with rotating discs is a very positive means of supplying sufficient dissolved oxygen to the attached biomass and prevents development of anaerobic conditions. Both the intensity of contact between the biomass and the wastewater and the aeration rate can be controlled simply by adjusting the rotational speed of the discs. This can be done to suit a particular wastewater and its treatment requirements.

Wastewater retention time can also be controlled by selecting an appropriate disc spacing and tank size. This allows much higher degrees of treatment to be obtained than in the trickling filter process where relatively short retention times are unavoidable. It is unnecessary to recycle effluent to achieve minimum wetting rates or aid in sloughing as in the trickling filter. This allows the disc process to take advantage of the benefits of staged operation, which would otherwise be destroyed by effluent recycle.

The rotating disc process is somewhat similar to the activated sludge process in that it has a suspended culture in its mixed liquor. However, the suspended culture is estimated to represent less than 5% of the total amount of biological solids on the discs and would therefore contribute only marginally to the treatment. Because of this, the disc process is not upset by variations in hydraulic or organic loading (5,6,7) as is the activated sludge process. Like the activated sludge process, the disc process does produce a sparkling clear effluent when operated at appropriate hydraulic loadings.

Two problems encountered in the operation of activated sludge treatment plants are start-up at flows much lower than design flow and operation during periods of very low flow. Operating a rotating disc plant at low initial flows or during periods of very low flow will yield effluents of higher quality than at design flow. During periods of no flow, effluent can be recycled at a nominal rate to maintain biological activity.(5)

Minimal operator attention and low power consumption are attractive features of the rotating disc process when compared to the activated sludge process, especially for package plant applications and for wastewater treatment needs in remote locations. Unlike the activated sludge process, the rotating disc process can be designed for any degree of treatment and the secondary sludge will settle well.

The rotating disc process lends itself well to upgrading existing treatment facilities. Because of its modular construction, low head loss and shallow excavation, it can be installed to follow existing primary treatment plants, including Imhoff tanks and septic tanks.

Many state regulatory agencies are requiring treatment plants to be designed to achieve various degrees of nitrification as well as BOD and suspended solids removal. To achieve this with the activated sludge process requires that the plant be constructed in at least two stages of aeration, settling and sludge recycle. The rotating disc process has demonstrated in this investigation that it can achieve any desired degree of nitrification with one settling tank and no sludge recycle.

A disadvantage to the disc process is the need for covering the discs to protect the biological growth from freezing temperatures and precipitation and protect the discs from wind damage and vandalism. For installations as large as 100,000 population equivalent in Europe, heating and forced ventilation of the enclosure have not been found necessary. European winters are not as severe as in the northern United States; so the demonstration plant at Pewaukee, Wisconsin, should demonstrate any need for heating or forced ventilation.

Although an enclosure is an additional expense for the disc process, aesthetic requirements for wastewater treatment facilities may dictate providing enclosures for all treatment processes in the near future.

In winter, a covered treatment plant will experience fog and condensation from water evaporating from the relatively warm wastewater. This will accelerate corrosion and create slippery footing within the enclosure. To avoid this problem with rotating disc plants, a semicircular shaped, insulated cover has been developed to be supplied, as an integral part of a disc assembly. It covers only the discs and drive components. Fog and condensation are restricted to the atmosphere surrounding the discs, and less treatment plant area needs to be covered.

SECTION X

ACKNOWLEDGMENTS

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SECTION XI

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SECTION XII

GLOSSARY

D.O.	Dissolved Oxygen
Effl.	Effluent
GPD	Gallons per Day
Infl.	Influent
mg/l	Milligrams per Liter
ML	Mixed Liquor
NH_3-N	Ammonia Nitrogen
N_k	Kjeldahl Nitrogen
NO_3-N	Nitrate Nitrogen
NO_2-N	Nitrite Nitrogen
Rem'd	Removed
RPM	Revolutions per Minute
Susp.	Suspended
Vol.	Volatile
SS	Suspended Solids

SECTION XIII

PATENTS AND PUBLICATIONS

No patents have been applied for as a result of work done during this project.

An oral presentation of the results of this project was made at the 43rd Annual Conference of the Water Pollution Control Federation, Boston, Massachusetts, October 4-9, 1970. Limited distribution of copies of the presentation has been made to individuals who specifically requested them.

SECTION XIV

APPENDIX

PEWAUKEE TEST DATA SUMMARY

CONTRACT 14-12-810

MONTH, YEAR		NOVEMBER, 1969									DECEMBER, 1969														AVG 11/13-12/19				JANUARY 1970					AVG 12/23-1/19							
DAY		13	17	18	19	21	24	25	26	27	1	2	3	4	5	8	9	10	11	12	15	16	17	18	19		23	29	30	7	9	15	16	19		20	21	22	23	26	28	29
FLOW, GPH																							484			484	403	414		406			428	407	414		305	305				
GPD/FT.² (DISC)																										2.52									2.16							
RETENT. TIME, MIN.																										35									41							
SLUDGE RECYCLE, % (1)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DISC SPEED, RPM		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
ML TEMP., °F													54					54					55			54	51	51		54				46	50							
D.O. MG/L	INFL.												1.6					1.7					2.3			1.9	3.6	3.1						4.0	3.6							
	STAGE I																																									
	STAGE II																																									
	EFFL.												4.0					4.5					3.6			4.0	5.4	5.8						5.0	5.4							
TURBIDITY, JTU	INFL.												44					45					70			53	30	45		62				—	46							
	EFFL.												6					9					14			10	3	4		26				20	13							
BOD, MG/L	INFL.												220					185					209			205	270	144		~~181~~				136	183							
	EFFL.												38					31					43			37	47	19		~~118~~				36	34							
	% REM'D												83					83					79			82	83	87						74	81							
COD, MG/L	INFL.	287	431	258	473	300	~~198~~	211	297	303	296	516	382	274	306	294	287	282	284	~~257~~	447	333	310	286	259	323	363	328	370	271	305	330	302	276	318	468	323	330	347	486	542	554
	EFFL.	108	167	109	121	87	~~170~~	97	131	103	17	165	109	85	93	107	96	91	75	~~176~~	102	86	82	82	63	99	85	80	84	99	88	215	115	118	110	47	71	76	84	100	119	68
	% REM'D	62	61	58	74	71	~~14~~	54	56	66	94	68	72	69	61	64	67	68	74	~~34~~	77	74	74	71	76	69	77	76	77	64	71	35	62	57	65	90	78	77	76	79	78	88
SUSP. MATTER, MG/L	INFL.												130					126					176			144	82	147		206				174	152							
	STAGE I												162					204					459			275	296	265		172				178	228							
	STAGE II												106					94					98			99	193	94		64				138	122							
	EFFL.												48					48					6			34	42	26		132				106	76							
	% REM'D												63					62					97			76	49	82		34				39	50							
VOLATILE SUSP. MATTER, MG/L	INFL.												125					118					142			128	72	105		148				92	104							
	STAGE I												147					192					409			249	238	214		136				57	161							
	STAGE II												98					88					98			95	138	71		52				90	88							
	EFFL.												32					48					6			29	28	18		115				48	52							
	% REM'D												74					59					96			77	61	83		22				48	50							
NH_3 - N AS MG/L N	INFL.												16.5					10.2					15.5			14.1	22.3	23.5		~~21.0~~				22.0	22.6							
	STAGE I																																									
	STAGE II																																									
	EFFL.												15.0					4.9					10.2			10.0	17.0	17.5		~~23.5~~				20.0	18.2							
	% REM'D												9					52					34			29	24	26						9	19							
N_K - N AS MG/L N	INFL.												25.2					25.7					27.3			26.5	~~26.4~~	32.2		~~30.8~~				29.2	30.7							
	STAGE I																																									
	STAGE II																																									
	EFFL.												-					8.5					11.2			9.8	—	18.6		~~38.4~~				25.2	21.9							
	% REM'D																	67					59			63		42						14	29							
pH	INFL.												6.7					7.0					6.3			6.7	6.6	7.0		7.4				7.6	7.2							
	STAGE I																																									
	STAGE II																																									
	EFFL.												7.4					7.6					7.0			7.3	7.4	7.6		7.6				7.8	7.6							
	% REM'D																																									
NO_3 - N AS MG/L N	INFL.												0.12					0.09					0.15			0.12	0.11	0.06		0.11				0.21	0.12							
	STAGE I																																									
	STAGE II																		(3)													(3)										
	EFFL.												0.12					0.06					0.14			0.11	0.13	0.13		0.15				0.27	0.17							
	% REM'D																																									
TOTAL-N AS MG/L N	INFL.																	25.8					27.4			26.6		32.3		~~30.9~~				29.4	30.8							
	STAGE I																																									
	STAGE II																																									
	EFFL.																	8.6					11.3			10.0		18.7		~~38.5~~				25.8	22.2							
	% REM'D																	67					59			62		42						12	28							
SOLUBLE-P AS MG/L P	INFL.												10.3					11.1					9.6			10.3	9.8	10.0		8.6				11.8	10.0							
	STAGE I																																									
	STAGE II																																									
	EFFL.												9.6					9.6					8.8			9.3	10.3	10.2		9.2				10.6	10.1							
	% REM'D																									10									—							
TOTAL - P AS MG/L P	INFL.												10.7					13.8					10.4			11.6	13.0	12.0		9.2				12.6	11.7							
	STAGE I																																									
	STAGE II																																									
	EFFL.												11.0					12.4					10.2			11.2	12.0	10.6		10.4				10.6	10.9							
	% REM'D																									3									7							
ORTHO - P AS MG/L P	INFL.																																									
	STAGE I																																									
	STAGE II																																									
	EFFL.																																									
SET'BLE MATTER, ML/L	INFL.																	1.3					1.0			1.2	1.5	1.5		1.4				0.6	1.2							
	STAGE I																						8.5			8.5	9	10		6.0				2.5	7							
	STAGE II																	6.0					2.0			4.0	3.2	5		3.0				3.3	4							
	EFFL.																	2.0					0.1			1.0	0.5	0.5		1.9				1.1	1.0							
	SLUDGE																																	45.0	45.0							
SLUDGE RESIDUE, MG/L																		807	(2)							807	2035	885		3131		(2)		1342	1848							
VOL. SL. RESIDUE, MG/L																		647								647	1682	694		2534				1055	1491							

NOTES: (1) % SETTLED SLUDGE BY VOLUME OF INFLUENT (2) SETTLED 15 MINUTES (3) INCLUDES NITRITES

PEWAUKEE TEST DATA SUMMARY

CONTRACT 14-12-810

		AVG [illegible]					AVG 2/10-2/13						AVG 2/16-2/20			AVG 2/23-2/24					AVG 2/25-3/2
MONTH, YEAR								FEBRUARY					1970								
DAY		9		10	11	12	13		16	17	18	19	20		23	24		25	26	27	2
FLOW, GPH		305	305	206	207	197	206	204	202	202	205	202		203	85	96	90	97	109	111	109	106
GPD/FT² (DISC)			1.59					1.06						1.06			0.47					0.55
RETENT. TIME, MIN			55					82						83			187					159
SLUDGE RECYCLE, % (1)		0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0
DISC SPEED, RPM		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
ML TEMP, °F		49	49	46	43	40	40	42	43	43	45	42	37	42	44	44	44	36	38	39	43	39
D.O. MG/L	INFL.																					
	STAGE I																					
	STAGE II																					
	EFFL.			9.1	9.8	7.6	8.8	8.8	9.4	9.0	8.2	9.2	6.6	8.5	7.9	8.6	8.2	9.0	9.0	9.4	7.0	8.6
pH	INFL.																					
	EFFL.	8.0	8.0	7.3	7.1	7.5	8.7	7.6	6.6	9.0	8.4	8.7	9.2	8.3	8.5	8.5	8.5	8.3	8.5	8.3	8.8	8.5
BOD, MG/L	INFL.	148	148			175		175		196		188		192		111	111		194		145	170
	EFFL.	51	51			22		22		33		28		30		17	17		23		15	19
	% REM'D	66	66			87		87		83		85		84		85	85		88		90	89
COD, MG/L	INFL.	290	418	279	361	319	279	310	~~720~~	380	~~404~~	300	360	347	285	340	312	370	390	356	300	354
	EFFL.	90	82	110	104	70	100	96	~~127~~	136	~~200~~	78	131	125	120	130	125	110	116	90	110	106
	% REM'D	69	80	61	71	78	64	69	~~82~~	64	~~36~~	74	64	66	58	62	60	70	70	75	67	70
SUSP. MATTER, MG/L	INFL.	159	159	160	164	320	88	183	~~284~~	84	112	~~104~~	56	84	106	84	95	92	144	132	128	124
	STAGE I	146	146	120	244	280	164	202	160	280	284	180	248	230	116	60	88	200	160	384	256	250
	STAGE II	200	200	200	284	360	180	256	132	256	368	304	184	249	152	128	140	140	156	140	88	131
	EFFL.	120	120	110	116	50	20	74	~~8~~	7	18	~~100~~	23	16	12	15	14	11	17	40	7	19
	% REM'D	25	25	31	29	84	77	60	97	92	84	—	59	81	89	82	85	88	88	70	95	85
VOLATILE SUSP. MATTER, MG/L	INFL.	132	132	146	152	150	72	130	~~164~~	74	104	~~88~~	54	77	102	80	91	88	138	96	104	106
	STAGE I	116	116	100	220	200	121	160	139	270	216	136	200	192	110	56	83	194	154	300	232	220
	STAGE II	168	168	170	255	160	170	189	76	242	280	232	172	200	144	122	133	135	152	128	86	125
	EFFL.	111	111	100	108	10	10	57	~~8~~	7	14	~~84~~	13	11	12	15	14	11	17	40	4	18
	% REM'D	17	17	31	29	93	86	56	~~96~~	91	87	—	76	86	88	81	85	88	88	58	96	83
NH_3-N AS MG/L N	INFL.	30	30	26	23	30	26	26	~~59~~	16	16	17	14	16	12	15	14	15	16	16	15	16
	STAGE I																					
	STAGE II																					
	EFFL.	22	22	22	18	19	18	19	~~11~~	12	13	13	8	12	0	0	0	0	1	1	1	1
	% REM'D	27	27	15	22	37	31	27	~~81~~	25	19	24	43	25	100	100	100	100	94	94	93	94
N_K-N AS MG/L N	INFL.	35	35	33	34	35	35	34	~~76~~	32	34	32	34	33	24	29	26	29	32	30	26	29
	STAGE I																					
	STAGE II																					
	EFFL.	25	25	24	20	20	20	21	~~19~~	20	19	18	16	18	5	5	5	5	6	5	5	5
	% REM'D	29	29	27	41	43	43	38	~~83~~	38	43	44	53	44	79	83	81	83	81	83	81	83
NO_2-N AS MG/L N	INFL.																					
	STAGE I																					
	STAGE II																					
	EFFL.																					
	% REM'D																					
NO_3-N AS MG/L N	INFL.	2	2	2	4	3	2	3	2	7	1	4	2	3	0	0	0	0	0	0	0	0
	STAGE I	←					(2)											(2)				
	STAGE II																					
	EFFL.	3	3	2	4	3	3	3	6	6	5	7	7	6	6	8	7	8	10	10	8	9
	% REM'D																					
TOTAL-N AS MG/L N	INFL.	37	37	35	38	38	37	37	~~78~~	39	35	36	36	37	24	29	26	29	32	30	26	29
	STAGE I																					
	STAGE II																					
	EFFL.	28	28	26	24	23	23	24	~~19~~	26	24	25	23	24	11	13	12	13	16	15	13	14
	% REM'D	27	27	26	37	40	38	35	~~76~~	33	31	31	34	35	54	55	54	55	50	50	50	52
SOLUBLE-P AS MG/L P	INFL.	7	7	7	11	11	13	10	10	6	13	5	8	8	5	9	7	6	8	10	5	7
	STAGE I																					
	STAGE II																					
	EFFL.	8	8	10	10	10	9	10	7	7	12	7	9	8	10	10	10	11	6	7	6	8
	% REM'D	—	—					—						—			—					—
TOTAL-P AS MG/L P	INFL.	12	12	11	12	11	14	12	14	6	16	12	9	11	10	10	10	10	9	10	11	10
	STAGE I																					
	STAGE II																					
	EFFL.	10	10	10	12	12	12	12	8	11	14	8	10	10	11	13	12	11	7	10	11	9
	% REM'D	17	17					—						10			—					10
ORTHO-P AS MG/L P (SOLUBLE)	INFL.																					
	STAGE I																					
	STAGE II																					
	EFFL.																					
SET'BLE MATTER, ML/L	INFL.	1.8	1.8	1.3	2.5	2.2	1.5	1.9	4.0	0.8	1.5	1.5	1.6	1.9	0.6	1.0	0.8	1.4	2.3	2.0	1.4	1.8
	STAGE I	2.5	2.5	5.1	8.0	5.5	5.0	5.9	4.5	10.0	11.0	8.0	10.0	8.7	3.5	3.0	3.2	9.0	3.5	15.5	12.5	10.1
	STAGE II	6.0	6.0	5.3	12	6.5	6.0	7.4	5.0	15.0	19.0	19.0	14.0	14.4	5.0	6.0	5.5	6.0	6.6	6.0	2.5	5.3
	EFFL.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	SLUDGE	180	180	—	—	62	—	62	—	100	—	100	—	100	75	—	75	—	65	—	55	—
SLUDGE RESIDUE, MG/L		5080	5080			1520		1520		4000		2074		3037	1003		1003		836		601	718
VOL. SL. RESIDUE, MG/L		3280	3280			1210		1210		3240		1661		2450	313		813		656		471	564

							AVG 3/3-3/9					AVG 3/10-3/13									
MONTH, YEAR				MARCH					1970						APRIL	1970		MAY		1970	
DAY		3	4	5	6	9		10	11	12	13		20	25	1	29	30	1	6	7	8
FLOW, GPH		50	50	50	50	50	50	50	50	50	50	50		297							
GPD/FT² (DISC)							0.26					0.26		1.55							
RETENT. TIME, MIN							336					336		57							
SLUDGE RECYCLE, % (1)		0	0	0	0	0	0	2	2	2	2	2	0	0	0	0	0	0	0	0	0
DISC SPEED, RPM		5	5	5	5	5	5	5	5	5	5	5	5	5	3.2	3.2	3.2	3.2	3.2	3.2	3.2
ML TEMP, °F		45	46	43	44	46	45	40	40	42	40	40									
D.O. MG/L	INFL.																				
	STAGE I																				
	STAGE II																				
	EFFL.	5.9	7.0	7.2	7.0	7.3	6.9	7.6	6.8	6.4	6.8	6.9									
pH	INFL.																				
	EFFL.	8.5	8.3	8.3	8.8	8.6	8.5	8.5	8.4	8.6	8.6	8.5									
BOD, MG/L	INFL.			117		106	112			134		134	147	107	132	140	108	132	100	89	157
	EFFL.			14		10	12			10		10	34	11	36	29	27	28	25	20	17
	% REM'D			88		91	89			93		93	77	90	73	79	75	79	75	78	89
COD, MG/L	INFL.	400	320	300	280	198	300	375	249	200	252	269	271	260	178	277	213	266	232	181	317
	EFFL.	100	140	100	101	40	96	33	28	29	42	33	75	56	39	62	44	52	44	35	39
	% REM'D	75	56	67	64	80	68	91	89	86	83	88	72	78	78	78	79	80	81	81	88
SUSP. MATTER, MG/L	INFL.	152	112	104	84	84	107	128	112	56	152	112				164	95	121	74	62	132
	STAGE I	132	152	192	176	120	154	148	108	120	76	113				146	187	135	91	108	128
	STAGE II	252	144	168	164	108	167	108	52	72	68	75				158	79	79	78	79	105
	EFFL.	14	15	11	12	10	12	8	10	12	14	11				80	13	37	7	12	16
	% REM'D	91	87	89	86	88	89	94	91	79	91	90				51	86	69	91	81	88
VOLATILE SUSP. MATTER, MG/L	INFL.	112	109	92	84	60	91	116	92	32	112	84				132	77	93	69	60	105
	STAGE I	124	124	176	160	96	136	124	88	80	68	90				136	153	105	88	97	103
	STAGE II	196	124	160	136	100	143	106	52	44	44	61				148	62	55	71	67	85
	EFFL.	14	15	11	12	0	10	8	8	3	14	8				72	13	25	7	12	13
	% REM'D	88	86	88	86	100	89	93	91	91	88	90				45	83	73	90	80	88
NH_3-N AS MG/L N	INFL.	14	12	11	12	12	12	14	14	15	16	15					11.6	14.7	13.8		24.8
	STAGE I																19.9	12.8	11.2		15.0
	STAGE II																6.0	3.2	1.0		2.0
	EFFL.	0	0	0	0	0	0	0	0	0	0	0					2.1	2.5	1.4		2.0
	% REM'D	100	100	100	100	100	100	100	100	100	100	100					82	83	90		92
N_K-N AS MG/L N	INFL.	28	23	24	27	24	25	27	28	32	30	29	26.0	24.4	22	22.3	24.5	25.4	21.9		38.6
	STAGE I												24.0	21.0	2.5	32.4	35.4	25.6	20.2		24.2
	STAGE II												12.5	14.9	3.6	15.5	13.2	9.2	8.2		8.8
	EFFL.	4	3	4	5	4	4	6	4	4	4	4	11.1	12.0	10	8.9	6.9	6.6	3.7		2.6
	% REM'D	86	87	83	81	83	84	78	86	88	87	86	57	51	54	60	72	74	83		93
NO_2-N AS MG/L N	INFL.																	0.0	0.1		0.2
	STAGE I																	0.1	0.2		0.2
	STAGE II																	1.5	0.7		0.6
	EFFL.																	1.2	0.7		0.7
	% REM'D																				
NO_3-N AS MG/L N	INFL.	0	0	0	0	0	0	0	0	0	0	0						0.1	0.0		0.2
	STAGE I								(2)			→						0.0	0.4		0.2
	STAGE II																	2.8	8.9		10.4
	EFFL.	14	10	7	8	10	10	9	9	11	6	9						2.4	7.9		10.7
	% REM'D																				
TOTAL-N AS MG/L N	INFL.	28	23	24	27	24	25	27	28	32	30	29						25.5	22.0		39.0
	STAGE I																	25.7	20.8		24.6
	STAGE II																	13.5	17.8		19.8
	EFFL.	18	13	11	13	14	14	15	13	15	10	13						10.2	12.3		14.0
	% REM'D	36	34	53	52	32	44	44	54	53	67	55						60	44		65
SOLUBLE-P AS MG/L P	INFL.	11	10	5	8	9	9	6	8	12	9	9									
	STAGE I																				
	STAGE II																				
	EFFL.	14	13	10	10	10	11	8	9	8	7	8									
	% REM'D						—					11									
TOTAL-P AS MG/L P	INFL.	15	10	8	8	11	10	10	11	12	9	10	9.8	11.1	9.1	8.8	10.0		9.2	8.8	10.5
	STAGE I												9.7	10.0	10.7	9.0	6.8		8.2	10.1	8.8
	STAGE II												8.2	8.8	10.9	6.8	6.0		9.9	9.3	8.8
	EFFL.	15	15	10	10	10	12	9	9	8	8	8	7.7	9.2	7.1	6.9	7.0		8.5	8.2	7.3
	% REM'D						—					20	21	17	22	22	30		8	7	30
ORTHO-P AS MG/L P (SOLUBLE)	INFL.																	8.4	5.3		4.5
	STAGE I																	7.6	6.8		6.1
	STAGE II																	4.8	7.5		6.6
	EFFL.																	7.2	7.0		6.8
SET'BLE MATTER, ML/L	INFL.	1.2	1.4	0.4	0.1	0.1	0.6	0.8	0.2	0.7	0.8	0.6									
	STAGE I	4.6	5.5	5.5	6.0	3.0	4.9	6.0	4.0	3.5	3.5	4.2									
	STAGE II	11.5	5.5	6.0	6.0	3.0	6.4	4.5	3.0	2.5	2.5	3.1									
	EFFL.	—	—	—	—	—	—	—	—	—	—	—									
	SLUDGE	—	—	3.5	—	~~1.0~~	3.5	—	—	~~1.0~~	—	—									
SLUDGE RESIDUE, MG/L				770		225	498			94		94	2500						8220		
VOL. SL. RESIDUE, MG/L				598		173	386			67		67	1580						1960		

NOTES: (1) % SETTLED SLUDGE BY VOLUME OF INFLUENT (2) INCLUDES NITRITES

PEWAUKEE TEST DATA SUMMARY

CONTRACT 14-12-810

Parameter		13	14	15	AVG 4/1-5/15	20	21	22	27	28	3	4	5	AVG 5/20-6/5	10	11	12	17	17	19	19	AVG 6/10-6/19	AVG 6/10-6/19
MONTH, YEAR					MAY		1970												JUNE			1970	
FLOW, GPH					297	488	515	515	515	505	514	514	514	510	918	918	918	918		918		918	
GPD/FT.² (DISC)					1.55									2.66					(3)		(3)	4.78	(3)
RETENT. TIME, MIN.					37									33								18	
SLUDGE RECYCLE, %		(1)0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0		0	
DISC SPEED, RPM		3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2		3.2		3.2	
ML TEMP. °F						56	68	58	56	57	56	62	59	58	59	58	62	64		60		61	
D.O. MG/L	INFL.																						
	STAGE I																						
	STAGE II																						
	EFFL.																						
pH	INFL.																						
	EFFL.					7.8	8.2	8.1		7.9	8.0	8.0	~~8.1~~	8.2	8.1	8.2	8.1	7.8		7.6		8.0	
BOD, MG/L	INFL.	61	54	68	104	140	94	88	212	357	38	44	~~54~~	139	138	89	169	119		126		128	
	EFFL.	13	12	11	22	18	22	37	63	28	16	24	~~38~~	30	35	39	63		62	41		44	62
	% REM'D	79	78	84	79	87	77	58	70	92	58	45		78	75	56	63	48		69		66	
COD, MG/L	INFL.	124	139	147	207	296	234	202	529	895	87	85	~~135~~	333	296	252	468	252		260	296	306	296
	EFFL.	23	35	31	40	16	28	60	81	87	38	40	~~123~~	50	60	98	122	96	~~169~~	96	92	98	92
	% REM'D	81	75	79	81	95	88	70	85	90	56	53		85	73	61	73	62		63	69	68	69
SUSP. MATTER, MG/L	INFL.	71	65	76	96	126	148	90	266	582	38	79	~~89~~	190	138	130	170	116				138	
	STAGE I	137	121	184	138	204	248	160	420	496	85	261	~~269~~	268	154	314	296	180				238	
	STAGE II	109	102	86	97	19	81	60	72	460	78	92	~~93~~	123	96	160	122		124			126	124
	EFFL.	17	23	8	24	18	22	34	51	48	27	33	~~72~~	33	30	58	82	27				49	
	% REM'D	76	65	69	75	86	85	62	81	92	29	58		83	78	55	52	77				64	
VOLATILE SUSP. MATTER, MG/L	INFL.	57	59	58	79	104	122	82	220	422	30	61	~~75~~	149	108	110	140	92				112	
	STAGE I	108	100	138	114	168	190	140	336	398	61	195	~~209~~	213	122	242	220	156				185	
	STAGE II	81	93	64	81	19	63	60	65	358	78	68	~~81~~	102	78	126	90		104			98	104
	EFFL.	17	21	8	21	18	17	34	47	43	27	33	~~62~~	31	30	56	68	27				45	
	% REM'D	70	64	86	73	83	86	59	79	90	10	44		79	72	49	51	71				60	
NH_3-N AS MG/L N	INFL.	12.2	8.2	11.5	13.8	19.4	17.2	15.0	25.5	40.2	9.9	8.8	~~10.0~~	19.4		13.5		14.5				14.0	
	STAGE I	7.0	5.5	3.7	10.7	14.7	16.3	11.7	11.4	18.0	10.6	8.3	~~12.2~~	13.0		14.7		15.0				14.8	
	STAGE II	1.1	1.2	0.3	2.1	19.0	22.0	19.5	15.0	29.7	13.9	11.4	~~20.5~~	18.6		~~24.0~~			13.2				13.2
	EFFL.	0.2	0.7	0.5	1.3	5.0	7.5	5.8	16.5	12.4	4.3	10.2	~~20.3~~	8.8		12.0		~~23.3~~				12.0	
	% REM'D	98	91	96	91	74	56	61	35	49	57	-16		55		11						14	
N_K-N AS MG/L N	INFL.	20.4	20.0	30.0	25.0	29.1	25.3	19.5	47.1	72.9		14.9	~~14.9~~	34.8		21.6		22.5				22.0	
	STAGE I	16.6	16.5	17.2	23.7	25.1	28.0	20.5	35.3	32.2		21.4	~~15.9~~	27.1		30.2		28.4				29.3	
	STAGE II	8.6	7.4	6.0	12.5	22.0	26.7	21.8	20.5	49.7		15.6	~~28.6~~	26.0					23.6				23.6
	EFFL.	1.6	2.5	1.5	4.9	5.6	8.0	7.5	11.0	14.4		12.0	~~25.5~~	9.8		17.1		~~27.2~~				17.1	
	% REM'D	92	88	95	80	81	68	62	77	80				72		21						22	
NO_2-N AS MG/L N	INFL.				0.1	0.4	0.0	0.0	0.1			0.1	~~0.0~~	0.1									
	STAGE I				0.2	0.2	0.0	0.0	0.0			0.4	~~0.0~~	0.1									
	STAGE II				0.9	0.8			1.5			1.0		1.1									
	EFFL.				0.9	0.7			1.0			1.0		0.9									
	% REM'D																						
NO_3-N AS MG/L N	INFL.	(2)1.6	(2)1.0	(2)1.1	(2)0.7	0.0	(2)0.0	(2)0.0	0.0	(2)0.8		0.0	~~(2)0.0~~	(2)0.2		(2)0.1		(2)0.0	(2)			(2)0.0	
	STAGE I	2.0	3.8	3.8	1.8	0.4	0.0	0.0	0.2	0.2		0.4	~~0.0~~	0.3		0.1		0.1				0.1	(2)
	STAGE II	8.4	13.4	9.3	9.3	4.4	4.2	4.0	3.1	2.1		4.4	~~2.5~~	4.2		0.8			0.1			0.8	0.1
	EFFL.	8.1	8.8	8.7	8.2	5.3	6.0	5.0	2.6	5.4		4.5	~~2.5~~	5.2		0.8		0.1				0.4	
	% REM'D																						
TOTAL-N AS MG/L N	INFL.	22.0	21.0	31.1	26.8	29.5	25.3	19.5	47.2	73.7		15.0	~~14.9~~	35.0		21.7		22.5				22.1	
	STAGE I	18.6	20.3	21.0	21.8	25.7	28.0	20.5	35.5	32.4		22.2	~~15.9~~	27.4		30.3		28.5				29.4	
	STAGE II	17.0	20.6	15.3	17.4	27.2	30.9	25.8	25.1	51.8		21.0	~~30.5~~	30.3					23.7				
	EFFL.	9.7	11.3	10.2	11.3	11.6	14.0	12.5	14.6	19.8		17.5	~~28.0~~	15.0		17.9		~~27.3~~				17.9	
	% REM'D	56	44	67	58	61	45	36	69	73		-17		57		18						19	
SOLUBLE-P AS MG/L P	INFL.																						
	STAGE I																						
	STAGE II																						
	EFFL.																						
	% REM'D																						
TOTAL-P AS MG/L P	INFL.	7.0	6.7	5.7	6.4	13.5	12.7	9.3	9.2	~~25.2~~		8.6	~~3.8~~	10.7		13.6		11.6				12.6	
	STAGE I	8.0	6.3	7.2	6.6	7.8	9.2	7.4	6.3	~~10.2~~		9.0	~~3.5~~	7.9		12.8		11.6				12.2	
	STAGE II	6.7	5.2	6.0	6.0	6.3	7.4	6.8	6.3	—		5.2	~~4.2~~	6.4		12.4			11.6			12.4	11.6
	EFFL.	5.8	4.6	3.8	6.6	6.0	7.3	7.3	9.0	—		3.6	~~4.1~~	6.6		9.0		7.8				8.4	
	% REM'D	17	31	33	21	56	43	22	2			58		38		34		33				33	
ORTHO-P AS MG/L P (SOLUBLE)	INFL.		2.5	3.0	4.7	4.0	5.3	4.4	8.0	10.8		4.3	~~10.4~~	6.1		7.5		5.8				6.6	
	STAGE I		2.7	2.4	5.1	3.3	3.5	3.2	4.8	7.8		3.5	~~12.2~~	4.4		5.4		6.7				5.0	
	STAGE II		2.6	3.4	5.0	3.7	4.8	4.2	4.2	9.7		2.9	~~8.6~~	4.9		4.6			6.5			4.6	
	EFFL.		3.0	3.0	5.4	3.5	4.7	4.8	7.2	7.5		2.7	~~6.6~~	5.1		5.0		5.2				5.1	
SET'BLE MATTER, ML/L	INFL.	0.9	0.7	0.8	0.8	0.7	0.5	0.3	4.0	8.7	0.8	1.5		2.4			2.0					2.0	
	STAGE I	6	9	15	11	8.5	9.0	5.5	20.7	9.0	2.3	10.5	SLUDGE SCOUR DIFFICULTIES	9.4			11					11	
	STAGE II	10	10	10	10	3.0	2.1	1.0	3.0	10.0	3.4	4.0		3.8			2.2					2.2	
	EFFL.	<0.1	0.6	0.1	<0.3	0.2	0.2	0.5	2.7	0.6	<0.1	<0.1		<0.6			0.5					0.5	
	SLUDGE						(4)		(4) → 700														
SLUDGE RESIDUE, MG/L					8220	2045	(1096)		(9395)	5984	7449			6156									
VOL. SL. RESIDUE, MG/L					1960	1148	(632)		(7045)	[illegible]	5210			4722									

Parameter		22	24	24	25	25	26	26	30	30	1	1	2	2	8	8	9	9	10	10
MONTH, YEAR													JULY				1970			
FLOW, GPH		318	318		315		315		315		315		315		315		315		315	
GPD/FT.² (DISC)				(3)		(3)		(3)		(3)		(3)		(3)		(3)		(3)		(3)
RETENT. TIME, MIN.																				
SLUDGE RECYCLE, %		0			0		0		0		0		0		0		0		0	
DISC SPEED, RPM		3.2			3.2		3.2		3.2		3.2		3.2		3.2		3.2		3.2	
ML TEMP. °F			65		60		60		69		70		67		65		64		66	
D.O. MG/L	INFL.																			
	STAGE I																			
	STAGE II																			
	EFFL.																2.5			
pH	INFL.																			
	EFFL.		8.0		7.5		7.8		8.1		7.9		7.9		7.8		7.5			
BOD, MG/L	INFL.		120		128		151				120	101	118	112	148	146		155		
	EFFL.		16	19	22	20		17			14	14	20	11	20	23		18		
	% REM'D		87		83		89				88	86	83	90	86	84		88		
COD, MG/L	INFL.	349	261		295		340		362	225	328	248	344	275	352	304	346	310	394	328
	EFFL.	64	63	53	55	55		57	73	57	53	41	37	53	52	66	40	56	50	70
	% REM'D	69	76		81		83		81	75	84	83	89	81	85	78	88	82	87	79
SUSP. MATTER, MG/L	INFL.		108		122				160	120	204	116								
	STAGE I		154		244															
	STAGE II			100		126														
	EFFL.		16	17		21			44	38	23	17								
	% REM'D		85		83				73	68	89	85								
VOLATILE SUSP. MATTER, MG/L	INFL.		90		92		196		130	96	158	100					144	110		
	STAGE I		142		192		364	246									192	188		
	STAGE II			86		108		200									48	41		
	EFFL.		16	17		14		38	36	36	19	17					26	27		
	% REM'D		82		85		81		72	62	88	83					82	75		
NH_3-N AS MG/L N	INFL.								15.3	13.7	19.5	18.2							14.8	18.0
	STAGE I								14.6	13.7									13.6	14.6
	STAGE II								3.5	4.1									2.4	2.4
	EFFL.								6.0	4.6	5.2	4.8							2.4	3.2
	% REM'D								61	66	73	74							84	82
N_K-N AS MG/L N	INFL.								23.0	19.2	29.4	24.9							31.4	31.2
	STAGE I																		38.5	41.8
	STAGE II																		7.8	7.0
	EFFL.								7.8	8.4	5.8	5.2							6.3	6.9
	% REM'D								65	56	80	79							80	78
NO_2-N AS MG/L N	INFL.																		0.01	0.36
	STAGE I																		0.01	0.18
	STAGE II																		2.5	2.3
	EFFL.																		2.5	2.3
	% REM'D																			
NO_3-N AS MG/L N	INFL.		(2)0.0	(2)					(2)0.3	(2)0.9	(2)0.3	(2)0.2							0.4	0.3
	STAGE I		0.0																0.5	0.7
	STAGE II			7.4															10.9	11.9
	EFFL.		7.4	6.8					9.2	8.0	11.5	10.5							10.9	11.4
	% REM'D																			
TOTAL-N AS MG/L N	INFL.								23.3	20.1	29.7	25.1							31.8	31.9
	STAGE I																		39.0	42.7
	STAGE II																		20.4	21.2
	EFFL.								17.0	16.4	17.3	15.7							19.7	20.6
	% REM'D								27	18	42	37							38	35
SOLUBLE-P AS MG/L P	INFL.																			
	STAGE I																			
	STAGE II																			
	EFFL.																			
	% REM'D																			
TOTAL-P AS MG/L P	INFL.								~~14.6~~	~~11.0~~									14.5	15.0
	STAGE I																		16.3	15.0
	STAGE II																		11.6	11.0
	EFFL.								~~17.2~~	~~12.6~~									10.7	11.0
	% REM'D																		26	27
ORTHO-P AS MG/L P (SOLUBLE)	INFL.								6.1	5.2	6.6	5.0							8.9	7.8
	STAGE I								10.4	9.7									9.8	9.2
	STAGE II								10.6	10.5									9.4	9.4
	EFFL.								13.7	10.8	6.2	7.0							9.1	9.8
SET'BLE MATTER, ML/L	INFL.	2.5	0.2		1.4		3.5						3.5	1.2						
	STAGE I	4.3	2.0		12.0		17	10					18.5	12	20	20				
	STAGE II	3.0		1.7		6.0		0.2					2.2	1.1	0.7	0.1				
	EFFL.	0.3	0.1	<0.1				<0.1							<0.1	<0.1				
	SLUDGE													(4)						
SLUDGE RESIDUE, MG/L					3505								6665	(1935)						
VOL. SL. RESIDUE, MG/L					1325								1535	(1480)						

NOTES: (1) % SETTLED SLUDGE BY VOLUME OF INFLUENT (2) INCLUDES NITRITES (3) REFRIGERATED SAMPLE (4) SUSP. MATTER

PEWAUKEE TEST DATA SUMMARY

CONTRACT 14-12-810

MONTH, YEAR / DAY	15	16	16	17	AVG 6/15-6/17	
FLOW, GPH	315	315		315	315	
GPD/FT.² (DISC)					1.64	
RETENT. TIME, MIN			(3)	(3)	53	(3)
SLUDGE RECYCLE, % (1)	0	0			0	
DISC SPEED, RPM	3.2	3.2		3.2	3.2	
ML TEMP., °F	68	67		68	66	
D.O. MG/L INFL.	0.4				0.4	
D.O. STAGE I						
D.O. STAGE II						
D.O. EFFL.		0.7		0.6	1.3	
pH INFL.	7.7				7.7	
pH EFFL.		7.6		7.5	7.8	
BOD, MG/L INFL.	172	143	133	171	138	136
BOD EFFL.	17	21	23	17	19	18
BOD % REM'D	90	85	83	90	86	87
COD, MG/L INFL.	348	292	259	333	336	285
COD EFFL.	53	43	55	45	53	55
COD % REM'D	85	85	79	86	84	81
SUSP. MATTER, MG/L INFL.		156	136		150	124
SUSP. MATTER STAGE I		228	132		209	132
SUSP. MATTER STAGE II		47	48		47	91
SUSP. MATTER EFFL.		26	25		27	24
SUSP. MATTER % REM'D		83	82		82	81
VOLATILE SUSP. MATTER, MG/L INFL.		140	88		136	98
VOLATILE STAGE I		188	104		216	179
VOLATILE STAGE II		34	38		41	95
VOLATILE EFFL.		20	13		23	23
VOLATILE % REM'D		86	85		83	77
NH_3-N AS MG/L N INFL.			12.2	15.8	16.5	15.6
NH_3-N STAGE I			8.2	11.8	14.2	12.1
NH_3-N STAGE II			0.2	2.6	3.0	2.3
NH_3-N EFFL.			0.8	3.6	4.5	3.4
NH_3-N % REM'D			93	77	73	78
N_K-N AS MG/L N INFL.			22.6	25.4	27.9	24.9
N_K-N STAGE I			25.9	28.1	38.5	31.9
N_K-N STAGE II			5.0	5.9	7.8	6.0
N_K-N EFFL.			4.5	8.6	6.6	6.5
N_K-N % REM'D			80	66	76	74
NO_2-N AS MG/L N INFL.					0.01	0.36
NO_2-N STAGE I					0.01	0.18
NO_2-N STAGE II					2.5	2.3
NO_2-N EFFL.					2.5	2.3
NO_2-N % REM'D						
NO_3-N AS MG/L N (2) INFL.					0.2	0.6
NO_3-N STAGE I					0.3	0.9
NO_3-N STAGE II					13.4	10.8
NO_3-N EFFL.					10.4	9.8
NO_3-N % REM'D						
TOTAL-N AS MG/L N INFL.					28.3	25.7
TOTAL-N STAGE I					39.0	42.7
TOTAL-N STAGE II					20.4	21.2
TOTAL-N EFFL.					18.0	17.6
TOTAL-N % REM'D					36	32
SOLUBLE-P AS MG/L P INFL.						
SOLUBLE-P STAGE I						
SOLUBLE-P STAGE II						
SOLUBLE-P EFFL.						
SOLUBLE-P % REM'D						
TOTAL-P AS MG/L P INFL.		13.0	12.3	15.0	13.8	14.1
TOTAL-P STAGE I		14.4	14.5	15.4	15.4	15.0
TOTAL-P STAGE II		10.8	10.5	11.6	11.2	11.0
TOTAL-P EFFL.		10.5	10.6	12.2	10.6	11.3
TOTAL-P % REM'D					23	20
ORTHO-P AS MG/L P (SOLUBLE) INFL.					7.9	6.0
ORTHO-P STAGE I					10.1	9.4
ORTHO-P STAGE II					10.0	10.0
ORTHO-P EFFL.					9.7	9.2
SET'BLE MATTER, ML/L INFL.					2.2	1.2
SET'BLE MATTER STAGE I					12.4	14
SET'BLE MATTER STAGE II					2.0	1.8
SET'BLE MATTER EFFL.					0.1	<0.1
SET'BLE MATTER SLUDGE						
SLUDGE RESIDUE, MG/L					5085	
VOL. SL. RESIDUE, MG/L					1430	

JULY 1970 / DAY	22	22	23	23	24	24	29	29	30	31	5	5	6	7	AVG 7/22-8/7	
FLOW, GPH	206		206		206		206		206	206	206		206	206	206	
GPD/FT.² (DISC)															1.08	
RETENT. TIME, MIN		(3)		(3)		(3)		(3)	(3)	(3)		(3)	(3)		82	(3)
SLUDGE RECYCLE, % (1)	0		0		0		0		0	0	0		0	0	0	
DISC SPEED, RPM	3.2		3.2		3.2		3.2		3.2	3.2	3.2		3.2	3.2	3.2	
ML TEMP., °F	67		65		66		70		69	70	65		67	69	68	
D.O. MG/L INFL.																
D.O. STAGE I																
D.O. STAGE II																
D.O. EFFL.	1.0		1.9		3.8		3.4		3.0	3.7	3.0		3.0	2.7	2.8	
pH INFL.																
pH EFFL.	7.8		7.5		7.8		8.4		8.4		7.8		7.9	7.6	7.9	
BOD, MG/L INFL.		122		150		160		162	162	170		186	152			158
BOD EFFL.		16		18		12		14	14	16		17	14			15
BOD % REM'D		87		88		92		91	91	91		91	91			91
COD, MG/L INFL.		244	352	292	335	307	317	262	312	387	426	386	468		358	332
COD EFFL.		44		46		48		41	44	44	62	57	87		62	51
COD % REM'D		82		84		84		84	86	89	85	85	81		83	85
SUSP. MATTER, MG/L INFL.		74		99		86		96	112	110		130	148			107
SUSP. MATTER STAGE I		160		156		184		143	162	162		206	198			171
SUSP. MATTER STAGE II	32			42		38		45	41	42		78	58		32	49
SUSP. MATTER EFFL.		14		14		8		10	8	8		16	12			11
SUSP. MATTER % REM'D		81		86		91		90	93	91		88	92			90
VOLATILE SUSP. MATTER, MG/L INFL.		68		77		66		83	90	94		116	134			91
VOLATILE STAGE I		134		138		132		114	138	146		176	174			144
VOLATILE STAGE II	30			36		31		42	33	38		66	48		30	42
VOLATILE EFFL.		12		14		4		10	7	8		14	10			10
VOLATILE % REM'D		82		82		94		88	92	91		88	93			89
NH_3-N AS MG/L N INFL.		16.5		18.6		17.0	16.7	15.7	22.3	20.7		22.5	22.7		16.7	19.5
NH_3-N STAGE I		12.7		16.0		12.2		10.0	12.2	11.2		11.7	14.2			12.5
NH_3-N STAGE II	1.8			0.8	0.0	0.0		1.4	1.4	1.5		1.3	1.8		0.9	1.2
NH_3-N EFFL.		2.0		1.7		0.8		1.9	1.6	1.3		1.5	2.2			1.6
NH_3-N % REM'D		88		91		95		88	93	94		93	90			92
N_K-N AS MG/L N INFL.		21.8		24.7		23.2	24.3	22.3	28.0	26.3			29.7		24.3	25.1
N_K-N STAGE I		25.6		27.0		28.9		19.3	22.8	23.8		25.2	24.6			24.6
N_K-N STAGE II	4.8			4.4	5.2			4.4	4.1	3.5		7.0	6.5		5.0	5.0
N_K-N EFFL.		3.8		3.7		2.8		2.8	2.4	3.0		10.4	3.8			4.1
N_K-N % REM'D		83		85		88		87	91	89			87		79	84
NO_2-N AS MG/L N INFL.										0.2						0.2
NO_2-N STAGE I										1.7						1.5
NO_2-N STAGE II										0.6						0.8
NO_2-N EFFL.										0.9						0.9
NO_2-N % REM'D																
NO_3-N AS MG/L N (2) INFL.		0.4								0.9						0.6
NO_3-N STAGE I		0.8								2.0						1.4
NO_3-N STAGE II	11.8									10.5					11.8	10.5
NO_3-N EFFL.		14.1								10.0						12.0
NO_3-N % REM'D																
TOTAL-N AS MG/L N INFL.		22.2								27.2						24.7
TOTAL-N STAGE I		26.4								25.8						26.1
TOTAL-N STAGE II	16.6									14.0					16.6	14.0
TOTAL-N EFFL.		17.9								13.0						15.4
TOTAL-N % REM'D		19								52						38
SOLUBLE-P AS MG/L P INFL.																
SOLUBLE-P STAGE I																
SOLUBLE-P STAGE II																
SOLUBLE-P EFFL.																
SOLUBLE-P % REM'D																
TOTAL-P AS MG/L P INFL.		13.5		14.3			13.1	14.0	11.6	13.4		13.2	14.1		13.1	13.4
TOTAL-P STAGE I		15.5		16.0				15.4	12.9	15.0		14.2	15.8			15.0
TOTAL-P STAGE II	12.2			12.3				13.8	9.3	10.7		11.6	12.8		12.2	11.8
TOTAL-P EFFL.		11.8		12.2				10.8	9.2	10.2		9.4	17.6			10.7
TOTAL-P % REM'D		13		15				23	21	24		29	28			20
ORTHO-P AS MG/L P (SOLUBLE) INFL.										7.3						7.3
ORTHO-P STAGE I										9.2						9.2
ORTHO-P STAGE II										9.4						9.4
ORTHO-P EFFL.										9.2						9.2
SET'BLE MATTER, ML/L INFL.																
SET'BLE MATTER STAGE I																
SET'BLE MATTER STAGE II																
SET'BLE MATTER EFFL.																
SET'BLE MATTER SLUDGE																
SLUDGE RESIDUE, MG/L																
VOL. SL. RESIDUE, MG/L																

AUGUST 1970 / DAY	12	12	13	14	14	17	AVG 8/12-8/17		18	19	20	21	AVG 8/18-8/21 (3)	24	25	26	27	28	AVG 8/24-8/28 (3)
FLOW, GPH	428		428	428		428	428		286	286	286	286	286	188	188	188	188	188	188
GPD/FT.² (DISC)							2.23						1.49						0.98
RETENT. TIME, MIN		(3)	(3)		(3)		39	(3)	(3)	(3)	(3)	(3)	59	(3)	(3)	(3)	(3)	(3)	89
SLUDGE RECYCLE, % (1)	0		0			0	0		0	0	0	0	0	0	0	0	0	0	0
DISC SPEED, RPM	4.3		4.3			4.3	4.3		4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	5.0	4.7	4.7
ML TEMP., °F	68		66			67	67		69	68	63	65	66	62	67	68	68	68	67
D.O. MG/L INFL.										0.2		0.6	0.4	0.4	0.7	0.6	0.5	0.6	0.6
D.O. STAGE I	1.6		2.1	1.5			1.7		3.8	2.6		3.6	3.3	4.6	4.2	3.3	3.5	3.3	3.8
D.O. STAGE II	2.8		3.3	4.4		3.7	3.6		3.9	3.2		4.0	3.7	6.0	4.7	4.6	5.2	4.9	5.1
D.O. EFFL.										2.5		3.7	3.1	5.7	4.2	3.5	3.9	4.4	4.3
pH INFL.										6.7	7.2	7.5	7.4	7.6	7.5	7.4	7.8	7.5	7.6
pH EFFL.	7.9		8.3	8.3		7.5	8.0		8.0	6.2	7.0	8.1	7.7	7.8	7.4	7.5	7.8	7.6	7.6
BOD, MG/L INFL.		129	144	151	147	186	168	140	135	145	184	157	155	119	149	161	155	150	147
BOD EFFL.		34	24	25	24	50	38	27	24	26	13	21	21	19	14	15	12	13	15
BOD % REM'D		74	83	83	84	73	77	81	82	82	93	87	86	84	91	91	92	91	90
COD, MG/L INFL.	340	284	296	366	320	442	383	300	293	298	410	317	330	300	312	345	331	311	320
COD EFFL.	68	68	60	52	54	108	76	61	65	75	80	64	71	46	39	46	46	42	44
COD % REM'D	80	76	80	86	83	73	80	80	78	75	80	80	78	85	88	87	86	86	86
SUSP. MATTER, MG/L INFL.			104		110			107	102	96	130	36	91	106	110	112	134	108	114
SUSP. MATTER STAGE I			138		118			128	192	186	266	140	196	156	194	156	176	152	167
SUSP. MATTER STAGE II			88		57			72	74	78	144	60	89	102	88	88	106	94	96
SUSP. MATTER EFFL.			17		1			9	17	16	13	16	16	21	9	12	12	13	13
SUSP. MATTER % REM'D			84		99			92	83	83	90	56	82	80	92	89	91	88	89
VOLATILE SUSP. MATTER, MG/L INFL.			86		88			87	86	86	76	24	68	78	96	76	116	96	92
VOLATILE STAGE I			106		106			106	156	162	206	118	160	116	158	116	156	126	134
VOLATILE STAGE II			72		49			60	66	64	100	52	70	88	82	54	98	78	80
VOLATILE EFFL.			14		1			8	15	15	6	12	12	16	4	10	12	10	10
VOLATILE % REM'D			84		99			91	83	83	92	50	82	79	96	87	90	90	89
NH_3-N AS MG/L N INFL.			20.0		19.3			19.6	20.0	23.7	22.3	22.5	22.1			23.0	23.0	23.0	23.0
NH_3-N STAGE I			15.0		16.1			15.6											
NH_3-N STAGE II			5.2		7.2			6.2											
NH_3-N EFFL.			5.3		8.3			6.8	3.4	5.5	3.0	2.4	3.6			1.1	1.5	1.2	1.3
NH_3-N % REM'D			74		57			65	83	77	87	89	84			95	93	95	94
N_K-N AS MG/L N INFL.			26.3		26.3			26.3	25.6	28.5	28.5	26.6	27.3	23.1	26.5	29.6	29.4	30.3	27.8
N_K-N STAGE I			24.9		25.8			24.4											
N_K-N STAGE II			11.2		12.7			12.0											
N_K-N EFFL.			7.7		10.0			8.8	5.8	6.5	4.0	3.8	5.0	2.5	2.4	2.4	2.6	2.6	2.5
N_K-N % REM'D			71		62			67	77	77	86	86	82	89	91	92	91	91	91
NO_2-N AS MG/L N INFL.																			
NO_2-N STAGE I																			
NO_2-N STAGE II																			
NO_2-N EFFL.																			
NO_2-N % REM'D																			
NO_3-N AS MG/L N (2) INFL.									0.9				0.9				0.1		0.1
NO_3-N STAGE I																			
NO_3-N STAGE II																			
NO_3-N EFFL.									10.8				10.8				16.0		16.0
NO_3-N % REM'D																			
TOTAL-N AS MG/L N INFL.									26.5				26.5				29.5		29.5
TOTAL-N STAGE I																			
TOTAL-N STAGE II																			
TOTAL-N EFFL.									16.6				16.6				18.6		18.6
TOTAL-N % REM'D									37				37				37		37
SOLUBLE-P AS MG/L P INFL.																			
SOLUBLE-P STAGE I																			
SOLUBLE-P STAGE II																			
SOLUBLE-P EFFL.																			
SOLUBLE-P % REM'D																			
TOTAL-P AS MG/L P INFL.			13.4		12.5			13.0	15.6	12.2	12.0	14.7	13.6				12.1		12.1
TOTAL-P STAGE I			13.6		12.4			13.0											
TOTAL-P STAGE II			12.9		11.5			12.2											
TOTAL-P EFFL.			11.1		9.6			10.4	14.2	10.2	9.0	11.2	11.2				9.6		9.6
TOTAL-P % REM'D			17		23			20	9	16	25	24	18				21		21
ORTHO-P AS MG/L P (SOLUBLE) INFL.											5.4		5.4						
ORTHO-P STAGE I																			
ORTHO-P STAGE II																			
ORTHO-P EFFL.											8.3		8.3						
SET'BLE MATTER, ML/L INFL.																			
SET'BLE MATTER STAGE I																			
SET'BLE MATTER STAGE II																			
SET'BLE MATTER EFFL.																			
SET'BLE MATTER SLUDGE																			
SLUDGE RESIDUE, MG/L																			
VOL. SL. RESIDUE, MG/L																			

NOTES: (1) % SETTLED SLUDGE BY VOLUME OF INFLUENT (2) INCLUDES NITRITES (3) REFRIGERATED SAMPLE

PEWAUKEE TEST DATA SUMMARY

CONTRACT 14-12-810

Parameter														
MONTH, YEAR	8-70	SEPTEMBER 1970												
DAY	31	1	1	2	3	4	8	8	9	9	10	11	AVG 8/31–9/11	
FLOW, GPH	305	300		295	300	300	300		300		300	300	300	
GPD/FT.² (DISC)													1.57	
RETENT. TIME, MIN.		(3)	(3)	(3)	(3)	(3)			(3)		(3)	(3)	56	(3)
SLUDGE RECYCLE, % (1)	0	0		0	0	0	0		0		0	0	0	
DISC SPEED, RPM	2.0	2.0		2.0	2.0	2.0	2.0		2.0		2.0	2.0	2.0	
ML TEMP., °F	66	65		68	68	67	68		66		62	66	67	66
D.O. MG/L INFL.	0.6			0.8			0.7		0.7		0.9	0.7	0.7	
D.O. MG/L STAGE I	1.0	1.2		0.8	0.9	1.0	0.8		1.0		1.5	1.0	1.0	
D.O. MG/L STAGE II	2.7	2.6		2.7	2.3	2.5	2.4		2.2		3.0	2.6	2.6	
D.O. MG/L EFFL.	2.5	2.2		1.9	1.3	1.7	1.8		1.4		2.3	1.8	1.9	
pH INFL.	7.4			7.4			8.0		7.7		7.3	7.6	7.5	
pH EFFL.	7.6	7.8	(4)	7.4	8.2	7.8	7.7	(4)	7.4	(4)	7.3	7.0	7.6	
BOD, MG/L INFL.	210	168	157	160	150	145	169	165	164	173	135	134	190	151
BOD, MG/L EFFL.	28	32	16	35	27	24	28	16	33	16	24	22	28	28
BOD, MG/L % REM'D	87	81	90	78	82	83	83	90	80	91	82	83	85	81
COD, MG/L INFL.	515	375		321	333	293	486		387		294	308	500	330
COD, MG/L EFFL.	68	70		57	60	58	87		60		55	47	78	58
COD, MG/L % REM'D	87	81		82	82	80	82		84		81	85	84	82
SUSP. MATTER, MG/L INFL.	194	130		122	132	104	264		168		116	146	229	131
SUSP. MATTER, MG/L STAGE I	162	128		316	196	176	180		128		112	134	171	170
SUSP. MATTER, MG/L STAGE II	58	46		51	48	45	142		52		42	65	100	50
SUSP. MATTER, MG/L EFFL.	17	16		15	13	11	42		13		12	15	30	14
SUSP. MATTER, MG/L % REM'D	91	88		88	90	89	84		92		90	90	87	89
VOLATILE SUSP. MATTER, MG/L INFL.	152	98		96	100	92	182		140		86	110	167	103
VOLATILE SUSP. MATTER, MG/L STAGE I	144	104		252	154	146	114		114		90	104	129	138
VOLATILE SUSP. MATTER, MG/L STAGE II	54	36		38	38	36	70		44		32	53	62	40
VOLATILE SUSP. MATTER, MG/L EFFL.	15	14		10	12	10	23		12		8	13	19	11
VOLATILE SUSP. MATTER, MG/L % REM'D	90	86		90	88	89	87		91		91	88	89	89
NH_3-N AS MG/L N INFL.	30.0	24.3		24.5	25.5	21.2	41.2		23.3		16.5	16.7	35.6	21.7
NH_3-N AS MG/L N STAGE I														
NH_3-N AS MG/L N STAGE II														
NH_3-N AS MG/L N EFFL.	15.9	9.6		5.5	10.8	7.2	16.6		8.0		5.5	5.4	16.2	7.4
NH_3-N AS MG/L N % REM'D	47	60		78	58	66	60		66		67	68	54	66
N_K-N AS MG/L N INFL.	43.3	36.7		35.1	33.6	28.9	63.7		37.4		26.8	31.2	53.5	32.8
N_K-N AS MG/L N STAGE I														
N_K-N AS MG/L N STAGE II														
N_K-N AS MG/L N EFFL.	17.6	12.1		12.3	11.4	8.6	19.6		10.4		7.5	7.8	18.6	10.0
N_K-N AS MG/L N % REM'D	59	67		65	66	70	69		72		72	75	65	70
NO_2-N AS MG/L N INFL.				0.3										0.3
NO_2-N AS MG/L N STAGE I														
NO_2-N AS MG/L N STAGE II														
NO_2-N AS MG/L N EFFL.				0.6										0.6
NO_2-N AS MG/L N % REM'D														
NO_3-N AS MG/L N INFL.				0.5							0.2			0.5
NO_3-N AS MG/L N STAGE I											(2)			(2)
NO_3-N AS MG/L N STAGE II														
NO_3-N AS MG/L N EFFL.				7.4							7.6			7.8
NO_3-N AS MG/L N % REM'D														
TOTAL-N AS MG/L N INFL.				34.9										34.9
TOTAL-N AS MG/L N STAGE I														
TOTAL-N AS MG/L N STAGE II														
TOTAL-N AS MG/L N EFFL.				20.3										20.3
TOTAL-N AS MG/L N % REM'D				42										42
SOLUBLE-P AS MG/L P INFL.														
SOLUBLE-P AS MG/L P STAGE I														
SOLUBLE-P AS MG/L P STAGE II														
SOLUBLE-P AS MG/L P EFFL.														
SOLUBLE-P AS MG/L P % REM'D														
TOTAL-P AS MG/L P INFL.				14.0	14.7	10.7	13.5		14.8		11.8	13.4	13.5	13.2
TOTAL-P AS MG/L P STAGE I														
TOTAL-P AS MG/L P STAGE II														
TOTAL-P AS MG/L P EFFL.				11.6	11.8	8.8	11.8		11.7		10.0	10.9	11.8	10.8
TOTAL-P AS MG/L P % REM'D.				17	20	18	13		21		15	19	13	18
ORTHO-P AS MG/L P (SOLUBLE) INFL.				10.3	9.2	6.7					7.8			8.5
ORTHO-P AS MG/L P (SOLUBLE) STAGE I														
ORTHO-P AS MG/L P (SOLUBLE) STAGE II														
ORTHO-P AS MG/L P (SOLUBLE) EFFL.				11.6	11.4	8.5					9.4			10.2
SET'BLE MATTER, ML/L INFL.														
SET'BLE MATTER, ML/L STAGE I														
SET'BLE MATTER, ML/L STAGE II														
SET'BLE MATTER, ML/L EFFL.														
SET'BLE MATTER, ML/L SLUDGE														
SLUDGE RESIDUE, MG/L														
VOL. SL. RESIDUE, MG/L														

Parameter										
MONTH, YEAR	SEPTEMBER 1970									
DAY	14	15	16	17	18	22	23	24	25	(3) AVG 9/14–9/25
FLOW, GPH	200	187	187	187	187	200	200	200	200	194
GPD/FT.² (DISC)										1.01
RETENT. TIME, MIN.	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	87
SLUDGE RECYCLE, % (1)	0	0	0	0	0	0	0	0	0	0
DISC SPEED, RPM	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
ML TEMP., °F	63	63	65	64	65	66	64	65	63	64
D.O. MG/L INFL.	0.8	0.6								0.7
D.O. MG/L STAGE I	2.2	2.0	1.9	2.2	1.5	1.4	2.0		2.5	2.0
D.O. MG/L STAGE II	3.8	3.6	4.0	4.1	4.3	4.2	4.3		5.7	3.8
D.O. MG/L EFFL.	3.6	3.6		3.2	3.4					3.5
pH INFL.	7.3	7.3	7.3	7.4	7.4					7.3
pH EFFL.	7.3	7.4					6.9			7.2
BOD, MG/L INFL.	132	136	100	138	129	139	139	98	129	127
BOD, MG/L EFFL.	18	20	13	18	18	20	21	22	16	18
BOD, MG/L % REM'D	86	85	87	87	86	86	85	78	88	86
COD, MG/L INFL.	272	282	244	274	244	310	279	233	260	266
COD, MG/L EFFL.	47	50	53	53	38	48	48	52	48	49
COD, MG/L % REM'D	83	82	78	81	84	85	83	78	82	82
SUSP. MATTER, MG/L INFL.	100	96			94		108			100
SUSP. MATTER, MG/L STAGE I		152			140		126			139
SUSP. MATTER, MG/L STAGE II	78	86			68		102			84
SUSP. MATTER, MG/L EFFL.	13	19			14		13			15
SUSP. MATTER, MG/L % REM'D	87	80			85		88			85
VOLATILE SUSP. MATTER, MG/L INFL.	86	74			78		92			82
VOLATILE SUSP. MATTER, MG/L STAGE I		118			114		104			112
VOLATILE SUSP. MATTER, MG/L STAGE II	58	70			54		78			65
VOLATILE SUSP. MATTER, MG/L EFFL.	9	15			11		12			12
VOLATILE SUSP. MATTER, MG/L % REM'D	90	80			86		87			85
NH_3-N AS MG/L N INFL.	18.8	16.3			15.5		19.0			17.4
NH_3-N AS MG/L N STAGE I										
NH_3-N AS MG/L N STAGE II										
NH_3-N AS MG/L N EFFL.	2.8	2.4			3.0		2.6			2.7
NH_3-N AS MG/L N % REM'D	85	85			81		86			84
N_K-N AS MG/L N INFL.	28.0	25.5	23.5		24.4		28.9			26.6
N_K-N AS MG/L N STAGE I										
N_K-N AS MG/L N STAGE II										
N_K-N AS MG/L N EFFL.	4.6	4.2	2.9		4.3		5.5			4.3
N_K-N AS MG/L N % REM'D	84	84	88		82		81			84
NO_2-N AS MG/L N INFL.										
NO_2-N AS MG/L N STAGE I										
NO_2-N AS MG/L N STAGE II										
NO_2-N AS MG/L N EFFL.										
NO_2-N AS MG/L N % REM'D										
NO_3-N AS MG/L N INFL.					0.2		0.3			0.2
NO_3-N AS MG/L N STAGE I					(2)		(2)			(2)
NO_3-N AS MG/L N STAGE II										
NO_3-N AS MG/L N EFFL.					7.8		8.0			7.9
NO_3-N AS MG/L N % REM'D										
TOTAL-N AS MG/L N INFL.					24.6		29.2			26.9
TOTAL-N AS MG/L N STAGE I										
TOTAL-N AS MG/L N STAGE II										
TOTAL-N AS MG/L N EFFL.					12.1		13.5			12.8
TOTAL-N AS MG/L N % REM'D					51		54			52
SOLUBLE-P AS MG/L P INFL.										
SOLUBLE-P AS MG/L P STAGE I										
SOLUBLE-P AS MG/L P STAGE II										
SOLUBLE-P AS MG/L P EFFL.										
SOLUBLE-P AS MG/L P % REM'D										
TOTAL-P AS MG/L P INFL.	11.2				7.6		10.8			9.9
TOTAL-P AS MG/L P STAGE I										
TOTAL-P AS MG/L P STAGE II										
TOTAL-P AS MG/L P EFFL.	9.0				6.2		8.2			7.8
TOTAL-P AS MG/L P % REM'D.	20				18		24			21
ORTHO-P AS MG/L P (SOLUBLE) INFL.					4.6		6.6			5.6
ORTHO-P AS MG/L P (SOLUBLE) STAGE I										
ORTHO-P AS MG/L P (SOLUBLE) STAGE II										
ORTHO-P AS MG/L P (SOLUBLE) EFFL.					5.8		7.4			6.6
SET'BLE MATTER, ML/L INFL.										
SET'BLE MATTER, ML/L STAGE I										
SET'BLE MATTER, ML/L STAGE II										
SET'BLE MATTER, ML/L EFFL.										
SET'BLE MATTER, ML/L SLUDGE										
SLUDGE RESIDUE, MG/L										
VOL. SL. RESIDUE, MG/L										

Parameter																
MONTH, YEAR	SEPTEMBER 1970			OCTOBER 1970												
DAY	28	29	30	1		2	(3) AVG 9/28–10/2	7	8	9	19	20	21	22	23	(3) AVG 10/7–10/23
FLOW, GPH	503	503	503	503		503	503	900	900	900	900	900	900	900	900	900
GPD/FT.² (DISC)							2.62									4.70
RETENT. TIME, MIN.		(3)	(3)	(3)		(3)	33	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	19
SLUDGE RECYCLE, % (1)	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0
DISC SPEED, RPM	2.0	2.0	2.0	2.0		2.0	2.0	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
ML TEMP., °F	62	62	64	62		63	63	64	65	65	61	63	62	62	62	63
D.O. MG/L INFL.																
D.O. MG/L STAGE I	2.8	2.2	2.5	2.7		2.8	2.6	4.3	3.6	2.7	2.5	2.8	2.1	3.7	3.2	3.1
D.O. MG/L STAGE II	3.5	4.4	3.7	4.3		4.3	4.0	3.0	4.3	3.0	3.7	4.1	4.3	4.0	5.8	4.0
D.O. MG/L EFFL.																
pH INFL.																
pH EFFL.					(4)											
BOD, MG/L INFL.		149	124	137		89	125	148	117	144				147		139
BOD, MG/L EFFL.		47	30	34	26	24	34	84	48	44				36		53
BOD, MG/L % REM'D		68	76	75		73	73	43	59	71				75		72
COD, MG/L INFL.		300	242	290		202	258	292	239	230	257	353	268	325	312	284
COD, MG/L EFFL.		107	71	75		63	79	159	110	100	118	137	106	101	106	117
COD, MG/L % REM'D		64	71	74		69	69	46	54	57	56	61	60	69	66	59
SUSP. MATTER, MG/L INFL.		98	66	90		74	82		100		90	134			52	94
SUSP. MATTER, MG/L STAGE I		150	84	128		52	104		86		120	82			66	88
SUSP. MATTER, MG/L STAGE II		98	34	66		44	60		80		122	224			58	121
SUSP. MATTER, MG/L EFFL.		36	15	25		20	24		43		37	42			32	38
SUSP. MATTER, MG/L % REM'D		63	77	72		73	71		57		59	69			38	60
VOLATILE SUSP. MATTER, MG/L INFL.		58	56	76		46	60		94		74	108			51	82
VOLATILE SUSP. MATTER, MG/L STAGE I		112	70	94		38	78		84		98	82			59	81
VOLATILE SUSP. MATTER, MG/L STAGE II		80	28	52		30	48		80		96	180			52	102
VOLATILE SUSP. MATTER, MG/L EFFL.		34	9	18		14	19		43		30	38			32	36
VOLATILE SUSP. MATTER, MG/L % REM'D		41	84	76		70	68		54		59	65			37	56
NH_3-N AS MG/L N INFL.		19.0	16.5	15.2		15.8	16.6		15.5		16.5	19.8				17.3
NH_3-N AS MG/L N STAGE I																
NH_3-N AS MG/L N STAGE II																
NH_3-N AS MG/L N EFFL.		11.5	10.2	11.4		11.8	11.2		15.5		15.0	17.1				15.9
NH_3-N AS MG/L N % REM'D		39	38	25		25	33		0		9	14				8
N_K-N AS MG/L N INFL.		29.1	25.3	25.8		23.9	26.0		25.2		26.8	33.8		33.3		29.8
N_K-N AS MG/L N STAGE I																
N_K-N AS MG/L N STAGE II																
N_K-N AS MG/L N EFFL.		17.8	13.6	16.4		15.9	15.9		22.4		21.5	25.7		24.8		23.6
N_K-N AS MG/L N % REM'D		39	46	36		33	39		14		20	24		25		21
NO_2-N AS MG/L N INFL.																
NO_2-N AS MG/L N STAGE I																
NO_2-N AS MG/L N STAGE II																
NO_2-N AS MG/L N EFFL.																
NO_2-N AS MG/L N % REM'D																
NO_3-N AS MG/L N INFL.						0.6	0.6									
NO_3-N AS MG/L N STAGE I						(2)	(2)									
NO_3-N AS MG/L N STAGE II																
NO_3-N AS MG/L N EFFL.						1.5	1.5									
NO_3-N AS MG/L N % REM'D																
TOTAL-N AS MG/L N INFL.						24.5	24.5									
TOTAL-N AS MG/L N STAGE I																
TOTAL-N AS MG/L N STAGE II																
TOTAL-N AS MG/L N EFFL.						17.4	17.4									
TOTAL-N AS MG/L N % REM'D						29	29									
SOLUBLE-P AS MG/L P INFL.																
SOLUBLE-P AS MG/L P STAGE I																
SOLUBLE-P AS MG/L P STAGE II																
SOLUBLE-P AS MG/L P EFFL.																
SOLUBLE-P AS MG/L P % REM'D																
TOTAL-P AS MG/L P INFL.		14.0		12.4			13.2									
TOTAL-P AS MG/L P STAGE I																
TOTAL-P AS MG/L P STAGE II																
TOTAL-P AS MG/L P EFFL.		11.2		10.4			10.8									
TOTAL-P AS MG/L P % REM'D.		20		16			18									
ORTHO-P AS MG/L P (SOLUBLE) INFL.				8.4			8.4									
ORTHO-P AS MG/L P (SOLUBLE) STAGE I																
ORTHO-P AS MG/L P (SOLUBLE) STAGE II																
ORTHO-P AS MG/L P (SOLUBLE) EFFL.				7.4			7.4									
SET'BLE MATTER, ML/L INFL.																
SET'BLE MATTER, ML/L STAGE I																
SET'BLE MATTER, ML/L STAGE II																
SET'BLE MATTER, ML/L EFFL.																
SET'BLE MATTER, ML/L SLUDGE																
SLUDGE RESIDUE, MG/L																
VOL. SL. RESIDUE, MG/L																

NOTES: (1) % SETTLED SLUDGE BY VOLUME OF INFLUENT (2) INCLUDES NITRITES (3) REFRIGERATED SAMPLE (4) ALLYLTHIOUREA ADDED, CONCENTRATION .5 MG/L IN BOD TESTS

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16. Abstract

A prototype package plant incorporating the rotating disc wastewater treatment process was tested on municipal wastewater at the Village of Pewaukee, Wisconsin, to evaluate its treatment capabilities and establish guidelines for operation and testing of a full-scale rotating disc demonstration plant soon to be put into operation at Pewaukee. The package plant included a rotating bucket feed mechanism, ninety-one 1.75-meter diameter discs divided into two stages, and a secondary clarifier with a sludge-removal mechanism. Variables tested included hydraulic loading, rotational disc speed, sludge recycle, and wastewater temperature as it varied with climatic conditions.

At a hydraulic loading of 1.5 gpd/ft^2 of disc surface, the package plant achieved 87% removal of BOD and 80% removal of suspended solids to yield an effluent of 20 mg/l BOD and suspended solids when treating effluent from the existing primary clarifier. At the same loading, 85% removal of ammonia nitrogen was obtained to yield an effluent of 3.5 mg/l.

Low maintenance requirements and low power consumption were demonstrated by the rotating disc process during the test program.

17a. Descriptors

Wastewater Treatment
BOD Removal
Nitrification

17b. Identifiers

BIO-DISC Process, Rotating Disc Process, Rotating Biological Contactor, Tauchtropkorper

17c. COWRR Field & Group

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