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ADVANCED TRICKLING FILTER FOR WASTEWATER TREATMENT

E. W. Leschber

Cary Aircraft Corporation

Prepared for:

Air Force Civil Engineering Center

August 1975

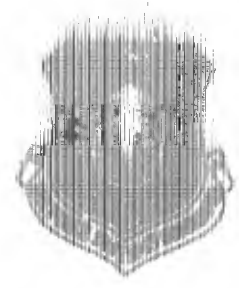
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ADVANCED TRICKLING FILTER FOR WASTEWATER TREATMENT

GARY AIRCRAFT CORPORATION

AUGUST 1975

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FINAL REPORT: JUNE 1974 - DECEMBER 1974

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFCEC-TR-75-6	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) ADVANCED TRICKLING FILTER FOR WASTEWATER TREATMENT		5. TYPE OF REPORT & PERIOD COVERED Final Report June 1974 - December 1974
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) E. W. Leschber		8. CONTRACT OR GRANT NUMBER(s) F08638-74-C-0007
9. PERFORMING ORGANIZATION NAME AND ADDRESS Gary Aircraft Corporation Box 3486 San Antonio, Texas 78211		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Program Element 64708F, Project 2054.
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Civil Engineering Center (EV) Tyndall Air Force Base, Florida 32401		12. REPORT DATE August 1975
		13. NUMBER OF PAGES 41
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Available in DDC.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Civil Engineering Center Environics Water Pollution Advanced Treatment		Trickling Filter Biological Treatment
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A prototype advanced trickling filter unit using a foamed silica medium (GaryGlas®) was designed, constructed, installed, and evaluated. The reduction in biochemical oxygen demand (BOD) and total suspended solids (TSS) were the parameters of most interest. The design hydraulic load of the unit was 700,000 gallons per day. The design organic load (BOD) was 80 pounds per 1000 cubic feet per day. The design solids load was 60 pounds per 1000 cubic feet per day. The assumed organic and solids concentrations were 40 mg/l and 40 mg/l, respectively. Laboratory data shows that the effluent BOD was reduced		

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from 29 mg/l to 18 mg/l. The TSS reduction was from 64 mg/l to 32 mg/l. This indicates a reduction that will allow the upgrading of existing treatment plants to a level consistent with newer effluent limitations. The installation and operation of GaryGlas® advanced trickling filters were economical. These filters demonstrated their effectiveness and efficiency as a wastewater treatment system.

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PREFACE

This report was prepared by Gary Aircraft Corporation, San Antonio, Texas, under Contract F08638-74-C-0007. The research was performed under Program Element 64708F, Project 2054.

Inclusive dates of the research were June 1974 through December 1974. The report was submitted 8 August 1975 by the Air Force Civil Engineering Center (EV). The project officer was Captain Dean D. Nelson.

This report has been reviewed by the information officer and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

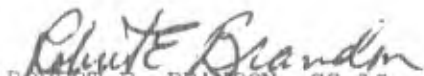
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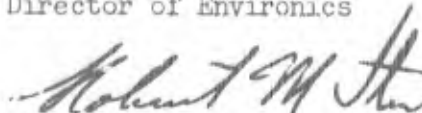
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SECTION I

SECONDARY TREATMENT

Present-day wastewater treatment must be able to deliver an effluent quality that meets increasingly stringent standards. Inadequate water treatment in the past now presents a real challenge in the reduction of water pollution and the upgrading of our environment.

Years ago the sanitary engineer recognized the need to provide more treatment to domestic sewage. Thus, there was begun what is now referred to as secondary treatment.

Secondary treatment involves biological oxidation of the organic matter in sewage to stable forms. Usually this oxidation is followed by final sedimentation and disinfection (Reference 1). Secondary treatment is a process to reduce the amount of dissolved organic matter and suspended solids in wastewater. The effluent from the primary treatment process is given this additional treatment with processes such as activated sludge or trickling filter (Reference 2). The organic matter, commonly expressed as biochemical oxygen demand (BOD), of waste is an indirect measure of the amount of contamination or pollution in that waste. Secondary treatment reduces the organic matter or lowers the BOD. The removal of BOD from wastewaters is most effective when bacteria thrive because optimum environmental conditions exist. The major conditions affecting most bacteria are temperature, pH, available oxygen, food source and concentration (dissolved organic matter), and surface area available for reaction.

The reduction in nonfilterable or total suspended solids (TSS) depends upon a food chain concept. Bacteria act upon the dissolved organic matter and, in turn, are the food source for algae, fungi, and protozoans which are consumed by nematodes and rotifiers. Suspended solids are absorbed on the filter media and become an integral part of the nutrients available for food. The byproducts of each reduction in this process are carbon dioxide, water, and nitrogen compounds and biological mass.

Wastewater that has been treated by a secondary process, while much lower in BOD and TSS, does not always meet the exacting standards of today. Today's water quality standards can require additional treatment to meet lower discharge limits. This treatment is generally known as advanced or tertiary. BOD and TSS must be removed in this advanced process; however,

References

1. W. A. Hardenbergh and Edward B. Rodie, Water Supply and Waste Disposal (Scranton, Pennsylvania: International Textbook Company).
2. Industrial Pollution Control Handbook, ed. Herbert F. Lund (New York: McGraw-Hill, 1971), G-38.

the concentration of available food for the bacterial process is lower. For this reason, the environmental conditions required in advanced treatment must be enhanced for significant removals. Also included in advanced or tertiary treatment in some cases is nutrient removal. The nutrients that are most often removed are phosphate and ammonia. This study did not include nutrient removal.

SECTION II

GARYGLAS®

GaryGlas® is a surface media used to enhance low level BOD and TSS removal. GaryGlas® is a rigid, porous foamed silica that is chemically and biologically inert and nontoxic to biological organisms. GaryGlas® has over 1,000,000 square feet of surface area for each cubic foot of media, as determined by the National Research Council of Canada. GaryGlas® is wettable by water and has a density of 4 to 7 pounds per cubic foot with pore sizes of 200 to 300 microns.

GaryGlas® is a proprietary product manufactured by the Gary Aircraft Corporation in San Antonio, Texas, under a license from Fiberglas of Canada. The initial idea of wastewater treatment with a foamed silica was in response to an internal water treatment problem. The success of this experiment led to an investigation of GaryGlas® to determine its potential future in wastewater treatment.

Development began in August 1972 and since that time the design parameters have been refined from a number of demonstration plants. These tests were accomplished at the Rilling Road Wastewater Plant, San Antonio, Texas.

Two units were tested at the Rilling Road Plant, and the results were so encouraging that an increased flow test was ordered. The Babcock North Subdivision in San Antonio was chosen as the site for testing with a total flow of 40,000 gallons per day. The secondary treatment preceding the GaryGlas® unit in all of these test systems was activated sludge. The GaryGlas® advanced water treatment unit performed most remarkably during a six-month test in 1973. The average BOD and TSS load to the Babcock North GaryGlas® unit was 33.1 mg/l and 68 mg/l, respectively. The average effluent was 5.8 mg/l and 7.7 mg/l which corresponds to a 82.5 percent reduction in BOD and 88.7 percent reduction in TSS. This test was terminated only because main sewer lines were completed to the subdivision.

The City of San Antonio in late 1973 ordered a much larger unit for installation at its Heimer Road Treatment Plant. The Heimer Road Plant is an oxidation ditch followed by a clarifier which feeds the GaryGlas® unit. The test results covering a ten-month period show a very good quality effluent water. The BOD influent averaged 10.9 mg/l and the effluent averaged 7.3 mg/l per ten-month period. The TSS inlet loading was 7.4 mg/l, and the effluent was 4.5 mg/l for the same time period. This quarter-million-gallon-per-day unit went on stream in January 1974 and is still operating.

It is hypothesized that dissolved organics are adsorbed on external surfaces of GaryGlas® where the optimum environmental conditions of temperature, moisture, pH, oxygen and surface area are present. The

capillary size of the pores in GaryGlas® protects the bacteria and allows efficient biological action to take place.

GaryGlas® is hydrophilic and can apparently supply dissolved oxygen from the wastewater to the bacteria so that aerobic conditions normally exist in the filter. This natural oxygenation is supported by forced aeration to insure that sufficient oxygen is available at all times and to increase the biological oxidation rate.

The structural configuration of GaryGlas® produces a capillary attraction that maintains a hydrostatic head of approximately two inches of water. This head promotes uniform distribution of influent water to all parts of the substrate.

The natural and forced biooxidation process takes place in the dissolved organic material. The continuing oxidation breaks down nonfilterable solids to particle sizes that can be consumed by the bacterial action. The completeness of this oxidation process is evidenced by the fact that pluggage or ponding is not a problem in a GaryGlas® advanced trickling filter system.

SECTION III

DESIGN CRITERIA

The following design criteria were provided by the Air Force: average influent five-day BOD, 40 mg/l; average influent nonfilterable solids, 40 mg/l; average hydraulic loading, 700,000 gallons per day; organic loading, 80 pounds BOD per 1000 cubic feet per day; solids loading, 60 pounds TSS per 1000 cubic feet per day; filter depth, 8 feet.

Using this design information with the solids loading being the governing criteria, it was determined that 3885 cubic feet of GaryGlas® were required. With an 8-foot filter depth, this resulted in a required filter surface area of 487 square feet or a 25-foot-diameter tank.

A check of surface flow indicates a design flow rate of just under one gallon per minute per square foot of medium. This compared favorably with prior studies that indicated that surface flow should not exceed 1.25 gallons per minute per square foot.

The original concept for this prototype evaluation envisioned the installation of the advanced trickling filter (ATF) and a new final clarifier in series with the existing plant. Economic consideration resulted in the ATF being placed in series between the standard trickling filters and the existing clarifiers, as shown in Figure 1. This change resulted in the design criteria for average BOD and TSS being estimates as no data was available from historical records to indicate their actual concentration.

Because of these unknowns in the design criteria, it was decided to construct the ATF tank 26 feet in diameter. With the 8-foot depth there is approximately 4250 cubic feet of GaryGlas® in the ATF. This resulted in a design organic loading of 55 pounds of BOD and TSS per 1000 cubic feet per day.

It should be noted that the Columbus Air Force Base sewage flow was known to be quite variable on any given day and to have a severe diurnal nature associated with its hydraulic load. There was no attempt with this project to stabilize the hydraulic loading to any significant degree. The only recirculation at Columbus Air Force Base is sludge removal from the secondary clarifiers and its return to the primary clarifiers.

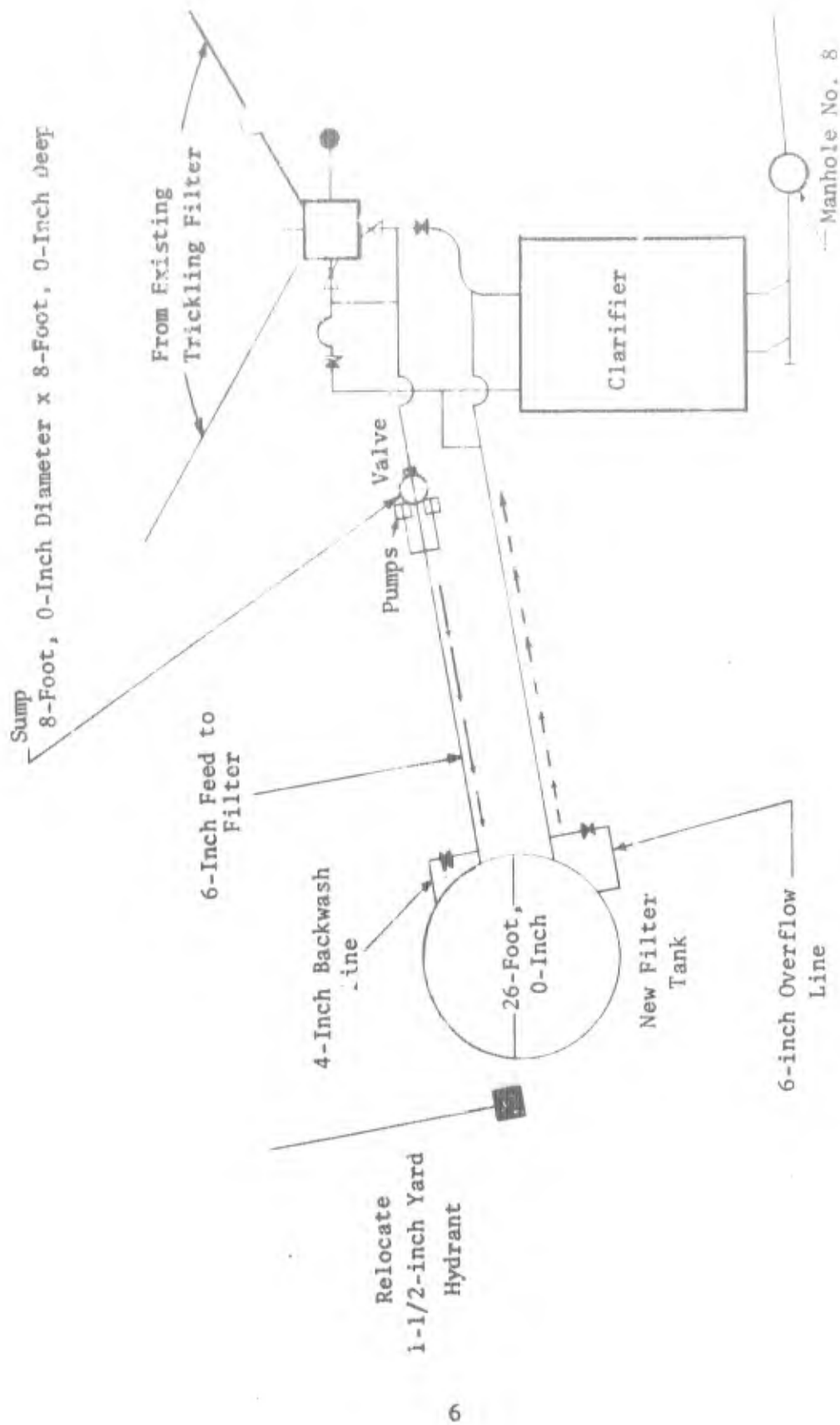


Figure 1. Flow Schematic of the Advanced Trickling Filter

SECTION IV

DRAWINGS

Drawings for the as-built installation are included in this report. Each drawing is referenced as ATF-708- which is a Gary Aircraft Corporation number assigned to this project.

Drawing number ATF-708-2 (Figure 2) details the GaryGlas® filter tank. All valves, piping to the tank, weir, and weir support are shown on this print.

Drawing number ATF-708-3 (Figure 3) is a piping and instrument drawing. Connection to the existing treatment plant and all piping and valves furnished under this contract are on this print.

Drawing number ATF-708-4 (Figure 4) is a topography of the site and details the filter pad construction. Due to the topography, the area had to be filled so that flow would be by gravity from the GaryGlas® unit to the existing clarifier.

Drawing number ATF-708-5 (Figure 5) is a detail of the suction well and pump pad. Wastewater flows by gravity into the suction well and is then pumped to the GaryGlas® tank where it reverses flow and trickles through the media and then flows to the final clarifiers by gravity.

Drawing number ATF-708-6 (Figure 6) is an electrical schematic of the power supply. The pumps are wired for automatic, alternate pumping controlled by a float switch. The blowers are operated by a manual push button switch and operate continuously. Also provided are two 110-volt, 15-ampere waterproof receptacles.

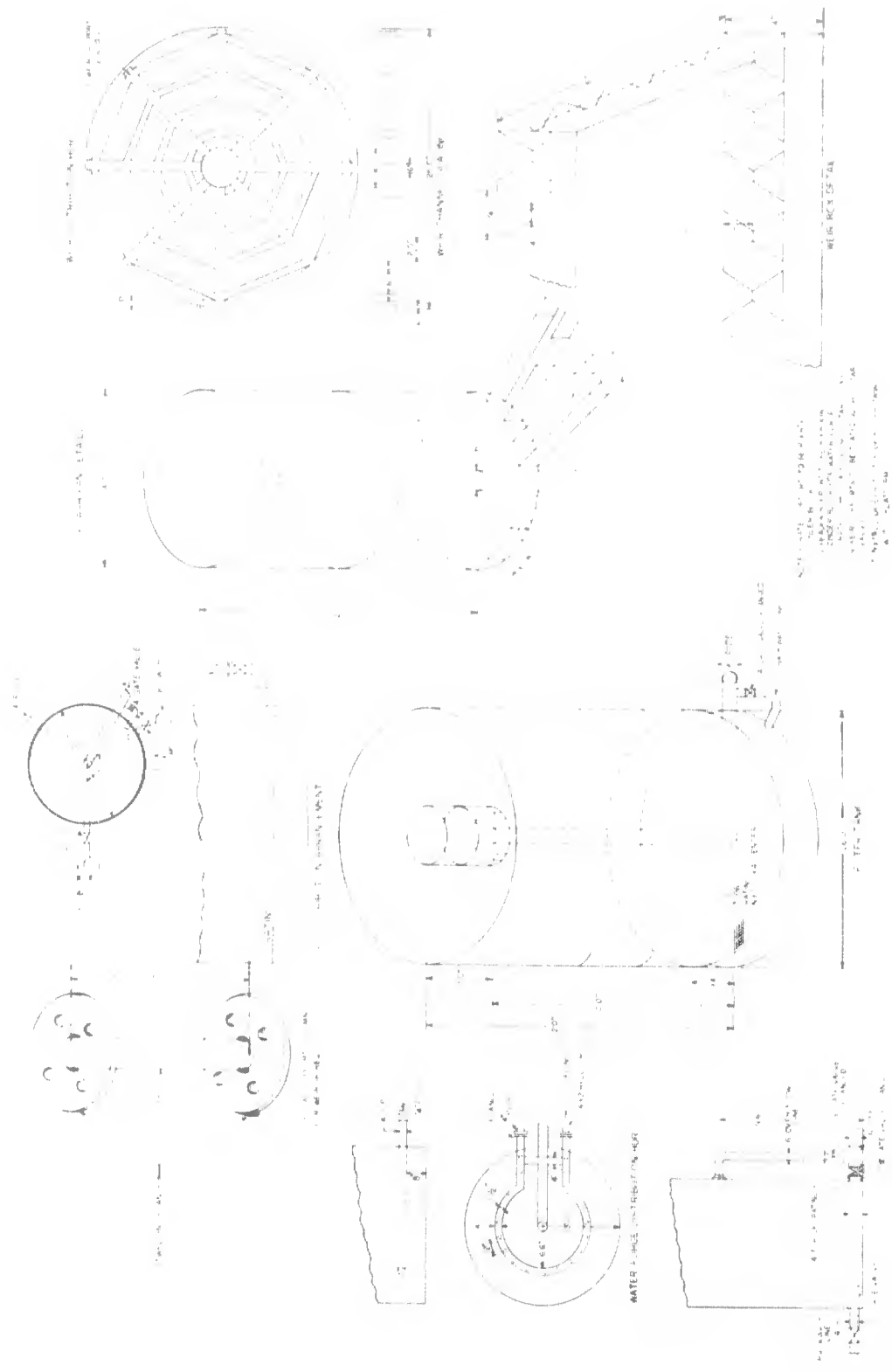
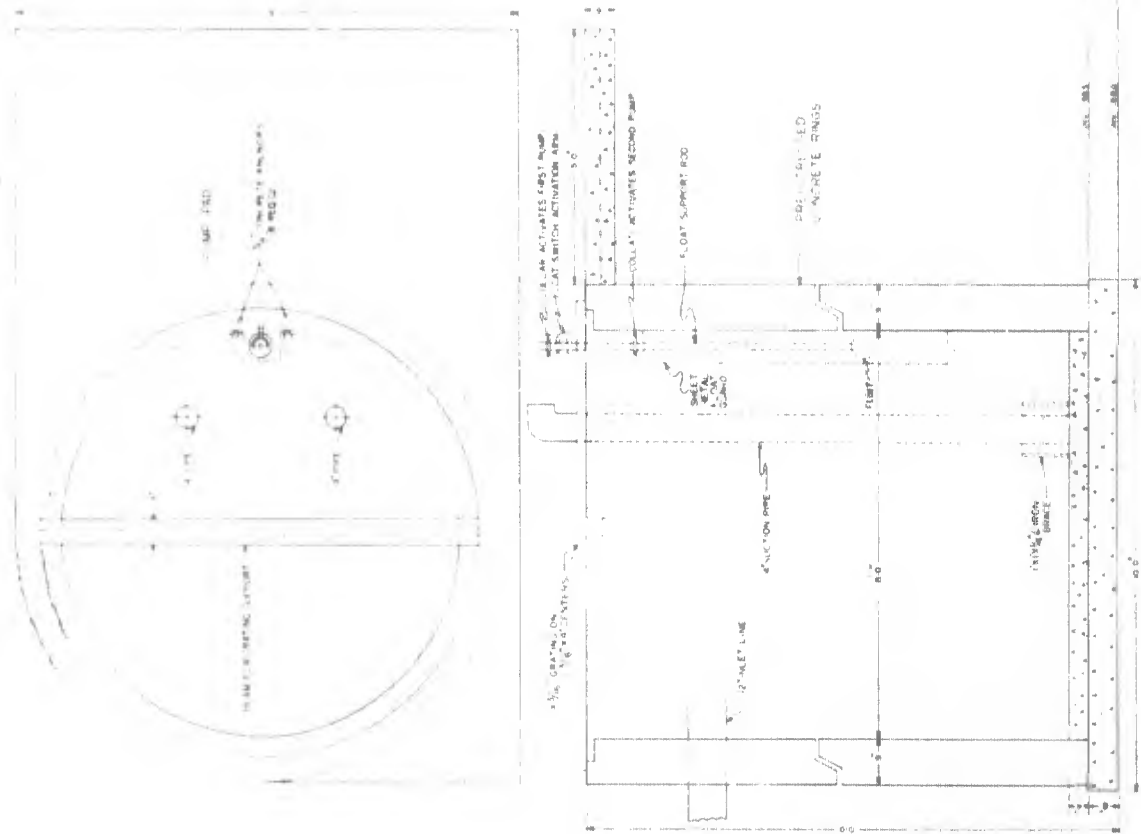


Figure 2. Drawing ATF-708-2, Filter Tank



REINFORCING CURVED BY SHIN FAR
 EPOXY
 2" X 4" REINFORCING W/ SHEET PILE
 EPOXY
 3" ALL CONCRETE JOINTS, PUMP PAD
 TO BE ROUTED

Figure 5. Drawing ATF-708-5, Suction Well and Pump Pad

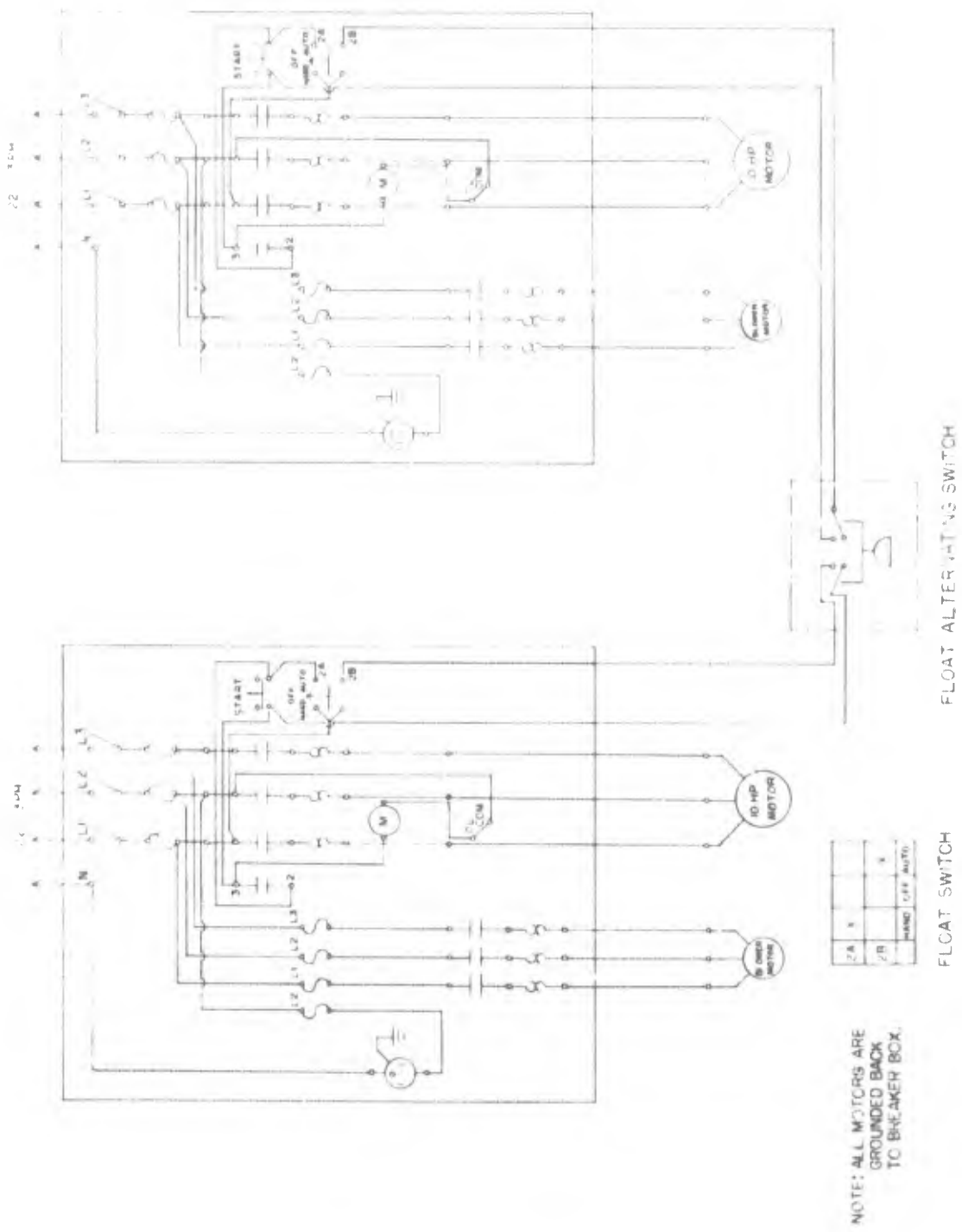


Figure 6. Drawing ATF-708-6, Electrical Schematic of Power Supply

SECTION V

DISCUSSION OF RESULTS

The ATF was started on 27 September 1974. The unit has operated continuously since that date with minor interruptions for flooding to control *Psychoda* flies and one shutdown to modify the forced air blowers. The blower modification was made on 4 and 5 October 1974.

The samplers were put into operation on Monday, 7 October 1974. The samplers were placed before and after the ATF. The influent sampler is located at the suction well and has remained in this position since the ATF was started. The second sampler is located at the effluent of the north clarifier. Sigmamotor refrigerated model WM-5-24-R samplers were used. These locations indicate removal across the ATF and the final clarifiers; any further reference to removal across the ATF includes the final clarifiers in this report. One sample per hour was collected by each sampler. Columbus Air Force Base laboratory personnel collect the individual samples each morning and prepare a composite sample of influent and effluent for analysis. The parameters of nonfilterable solids (TSS), biochemical oxygen demand (BOD), and chemical oxygen demand (COD) are measured daily.

Total flow to the ATF is determined by automatic flow recorder. The ability of the ATF to remove TSS, BOD, and COD is discussed in detail in this report. It was discovered early in the testing that the diurnal nature of the flow had an impact on the results. The flow is so low some nights that the clarifier starts to become anaerobic. In an attempt to stabilize flow, the sludge draw-off line on the final clarifiers was opened to recirculate back to the primary clarifier. The amount of recirculation was varied several times to determine the preferred method of operation. The recirculation or sludge draw-off valve is now opened one-third in the late afternoon and closed completely every morning. No determination was made of the actual flow rate, but the gravity returned through the 6-inch line was not substantial in any case.

The relocation of the forced air blowers in early October 1974 eliminated the air distribution header in the bottom of the ATF tank. A use for this header was adopted in mid-November 1974. A fresh water supply was tied into the header, and a flushing program was adopted. The ATF tank bottom is flat which could allow a slight build-up of solids. To prevent any solid build-up, fresh water is sprayed into the tank through the header. This is incorporated as a daily operation and eliminates any possible solids build-up in the tank bottom. Solids build-up and its eventual sloughing only represents a significant problem when it occurs simultaneously with an automatic sample and thereby biases the results.

During the data gathering period the laboratory procedures used to analyze the wastewater were monitored, reviewed, and in some cases, modified. The basic procedure for testing was that set forth in Standard Methods for the Examination of Water and Wastewater (Reference 3). The laboratory at Columbus Air Force Base Sewage Treatment Facility was responsible for the analytical testing. By means of telephone conversations and actual site visits, it was determined that some of the test procedures were not being followed correctly. The determination of BOD was most suspect. Inasmuch as dilute waste, with a low organic loading BOD, was being analyzed, the first step to improve laboratory technique was to increase the aliquot size. Aliquot size of the influent to the ATF was increased from 10 milliliters to 50 milliliters. The same increase in aliquot size was followed on the effluent ATF with one additional step, an increase to 100 milliliters. These sample dilutions, while bringing the final dissolved oxygen content to the desired range, did not appear to solve all questions concerning the data being obtained.

The next step was to visit the site and observe the analytical procedure from start to finish. It was determined that the reference dissolved oxygen was not being properly determined. The laboratory personnel were instructed in the correct analytical techniques. This correction made a significant change in BOD results. The first results following the changes were obtained on 14 December 1974. The impact of this procedural correction will be evident in the evaluation of the test data.

The mechanical and electrical equipment has operated flawlessly since start-up. The weir which distributes the wastewater was adjusted several times very early, but it was never possible to achieve a desirable distribution of wastewater with the weir. This will be discussed later in Section VII, Recommendations.

The ATF was installed to confirm that GaryGlas® was effective in removing BOD and TSS, after secondary treatment by a trickling filter, down to values acceptable by Environmental Protection Agency limits. The basis of the test program was to be a 30-day continuous run. The raw data for this period was supplied by Columbus Air Force Base, Mississippi. The period from 1 December 1974 to 31 December 1974 has been supplied as representative of the complete run to date. Table 1 contains the raw data. Each of the parameters and the flow rate will be evaluated.

1. The BOD removal was, in general, what was anticipated. It should be remembered, however, when working with very small numbers, percentage removal can be a misleading mathematical parameter, due to the large change in percentage value with small change in raw data. The absolute value of the effluent is a more meaningful parameter.

Reference

3. Standard Methods for the Examination of Water and Wastewater, 13th Edition (New York: American Public Health Association, Inc., 1971).

TABLE 1. GARYGLAS® FILTER TEST RAW DATA

DATE DEC. (1974)	FLOW, GAL. X1000	INFLUENT TO FILTER			EFFLUENT FROM FILTER		
		TSS mg/l	COD mg/l	BOD mg/l	TSS mg/l	COD mg/l	BOD mg/l
1	340	84	78	12	19	57	10
2	541	74	52	33	10	82	27
3	427	35	27	30	10	60	25
4	407	71	81	38	21	47	22
5	439	76	171	33	50	50	29
6	526	40	86	30	15	115	25
7	551	40	310	35	25	206	21
8	456	20	144	39	10	74	22
9	410	100	111	48	20	65	20
10	373	70	170	30	30	159	25
11	421	190	219	49	120	127	20
12	369	-	41	35	-	13	26
13	366	86	22	18	72	17	18
14	361	38	145	24	22	98	15
15	382	49	80	30	33	155	6
16	376	34	117	25	27	83	16
17	364	49	106	39	30	59	13
18	365	58	144	26	34	74	23
19	383	60	153	43	20	99	18
20	329	97	114	35	122	132	19
21	-	43	55	46	16	92	16
22	-	49	247	20	21	81	9
23	508	80	159	35	20	49	13
24	516	74	86	22	25	64	27
25	434	92	41	16	35	16	19
26	405	87	81	16	30	81	23
27	508	50	92	33	20	17	5
28	426	7	15	18	6	45	16
29	649	65	12	10	43	33	5
30	683	56	39	6	35	51	9
31	595	45	21	36	30	25	3

The average BOD of the effluent for the period was 18 mg/l. This value has several results included in it that reflect the error of incorrect BOD analysis. The average value for BOD effluent after the BOD testing corrections is less than 15 mg/l. The average effluent BOD has continued to run below this in subsequent testing. The average influent BOD loading during the test period was 29 mg/l.

Figure 7 depicts the influent and effluent values and shows the mg/l of BOD removed. As can be readily seen, there were four days that show inverted results. Without any compensation for these results, the final effluent is acceptable for discharge after disinfection.

The average BOD loading of the ATF in December 1974 was 107 (plus) pounds per day. The total load for the month was 3388 pounds. The ATF removed 40 (plus) pounds of BOD per day and 1366 pounds during the month. This removal corresponds to a 40 percent reduction in BOD. The removal efficiency of the ATF is very good considering the loading and final effluent quality of less than 15 mg/l.

2. The nonfilterable solids feed to the ATF has been quite variable and approximately 60 percent higher than anticipated. Figure 8 shows the highly varied loading, from a low of 7 mg/l to a high of 190 mg/l. With the exception of two results, the effluent of the ATF has been quite steady. The average monthly load on the ATF was 64 mg/l, and the final effluent was 32 mg/l. The high loading to the ATF is most likely attributed to sluffing of biological material from the existing secondary treatment. The ability of the ATF to withstand this variable loading is very important. The ATF effluent did not vary a large amount and produced a steady TSS loading to the clarifiers.

The TSS loading to the ATF was 7122 pounds for the month of December 1974. The daily TSS loading was 238 pounds. The ATF removed 3604 pounds of TSS in December 1974. This corresponds to a 50 percent removal efficiency across the ATF and clarifiers.

3. The COD was monitored since results can be obtained much more rapidly than with BOD. A relationship between COD and BOD can usually be established if the waste stream is more or less constant in chemical and biological loading. The amount of testing to date has not been sufficient to establish a firm relationship; however, it appears the COD/BOD ratio for influent was approximately 3.5:1 and the ratio for effluent was 4:1.

COD is a chemical oxidation analytical technique. A substantial portion of the COD is most probably tied up with the TSS, which is primarily biomass and while biologically degradable, it does not impose a heavy five-day load. Figure 9, the graph of COD influent and effluent versus time, shows the variable COD loading to the ATF.

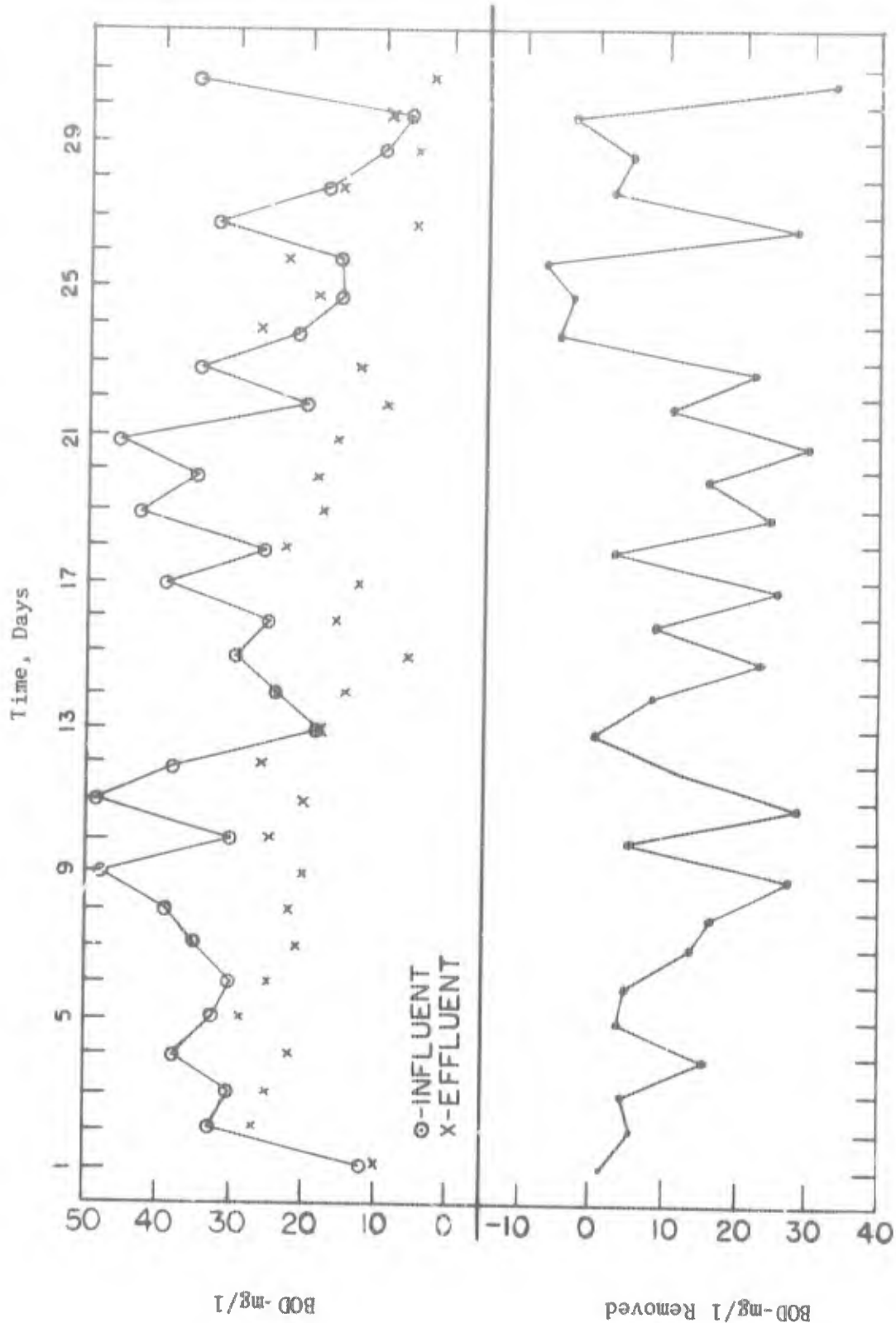


Figure 7. BOD mg/l Influent, Effluent Loading and BOD Removed Versus Time

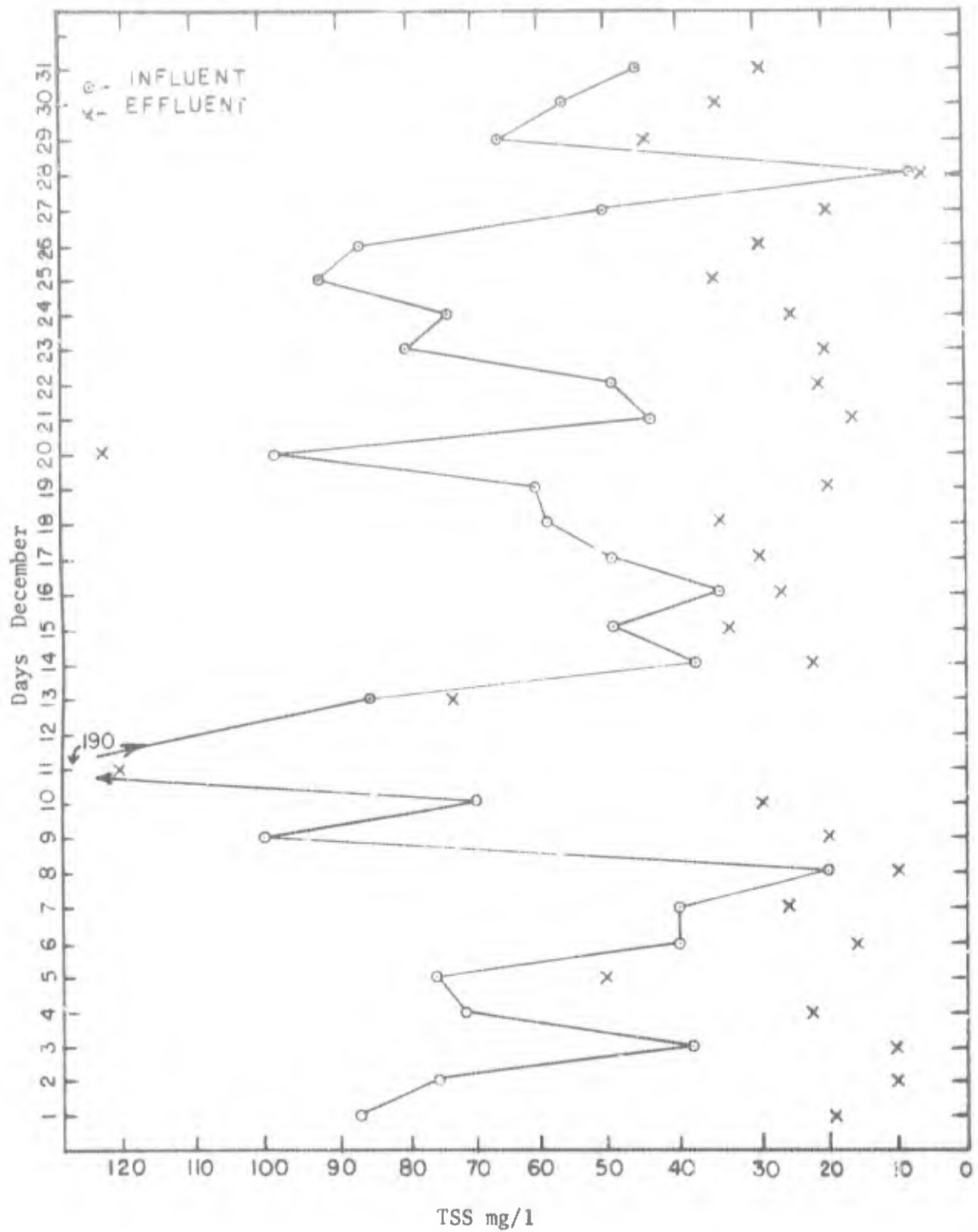


Figure 8. TSS mg/l Influent, Effluent Loading Versus Time

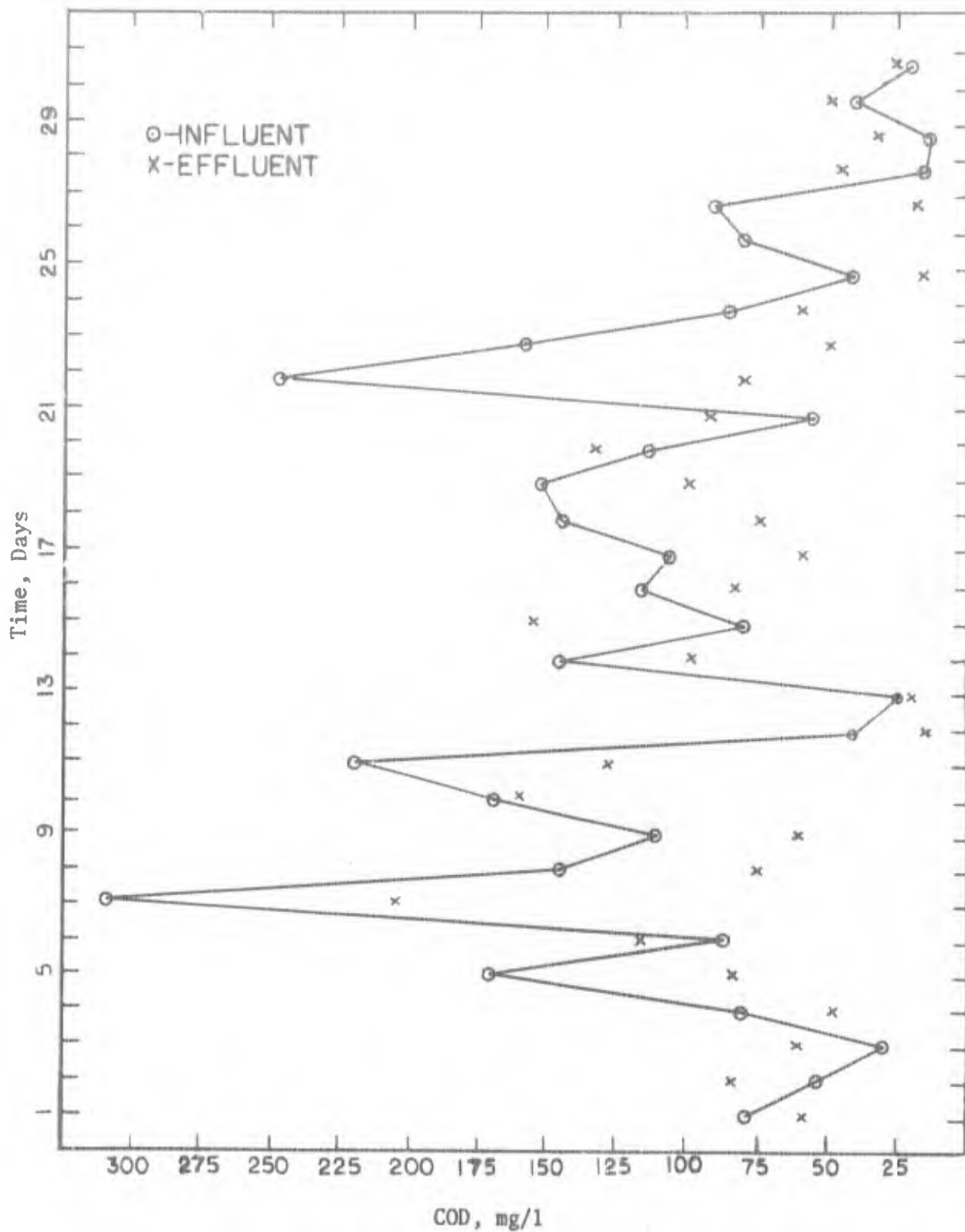


Figure 9. COD mg/l Influent, Effluent Loading Versus Time

The COD loading for the period was 11,947 pounds. This is an average loading of 386 pounds per day. The removal efficiency was 25 percent.

4. The hydraulic loading during the test period was considerably less than the design criteria. The solids loading was higher than the design criteria, however. A comparison of design versus actual criteria is given in Table 2.

TABLE 2. DESIGN CRITERIA VERSUS ACTUAL DATA

	<u>Design</u>	<u>Actual</u>
Average Influent BOD	40 mg/l	29 mg/l
Average Influent Nonfilterable Solids	40 mg/l	64 mg/l
Average Hydraulic Loading	0.7 mgD	0.5 mgD
Organic Loading	80 lb BOD <hr/> 1000 ft ³ day	25 lb BOD <hr/> 1000 ft ³ day
Solids Loading	60 lb NFS <hr/> 1000 ft ³ day	56 lb NFS <hr/> 1000 ft ³ day

There is no way to accurately determine the effect of the difference in the two criteria. It is felt that the solids loading was the most critical.

The existing secondary clarifiers are not accomplishing a good job of solids removal during the hours of high flow rates. Visual inspection indicates a high solids content carrying over the weir. This undesirable condition is compounded by the fact that, in connecting into the existing waste lines, a difference in flow resistance was created which causes the north clarifier to receive a heavier hydraulic load than the south clarifier. A solution to this problem is discussed in Section VII, Recommendations.

A 15-day BOD evaluation of filtered influent and effluent samples yielded the following results: average filtered influent 22 mg/l; average filtered effluent 7 mg/l. This short-term test indicates that most BOD being applied to the ATF is dissolved while a substantial portion of the

BOD leaving the filter is associated with the suspended solids. While this data is not conclusive, it indicates the ATF is accomplishing its objective of biologically oxidizing soluble organics.

SECTION VI

POWER REQUIREMENTS

The electrical power for the advanced trickling filter at Columbus Air Force Base was provided through a three-phase, 220-volt, 100-ampere fusible switch box. The power was split and supplied to two pump motor controls, two blower motor controls, and two 110-volt, 15-ampere duplex receptacles.

The feed pumps for the advanced trickling filter were 4 by 4 inches and were capable of delivering 600 gallons per minute at 30 feet of head. The 10-hp motors drew 26.7 amperes of power at full load. Based on the average actual daily flow rate, one pump will handle the total flow working only 51.7 percent of the time. The blowers for the advanced trickling filter were run continuously. The motors were 1/2 hp and drew 2.2 amperes.

The cost of power in Columbus was 1.5 cents per kilowatt-hour. The total cost for power to operate the advanced trickling filter was very low. Power costs were estimated since power to the ATF was not metered. The pumping costs were estimated for one pump running continuously. The reason for one pump running continuously, when only 51.7 percent was required, was to cover the time when both pumps operate due to high instantaneous flow rate. During the morning hours both pumps ran simultaneously, and as the hydraulic load fell, one pump continued to run. There also were times when both pumps stopped due to low flows, especially in the early morning hours. Both blowers ran continuously. The power cost estimate is presented in Table 3. The power factor for the motors in this estimate is 1.0.

TABLE 3. POWER COST TO OPERATE THE ATF

December Flow = 13,846,987 gallons	
Power Cost = 1.5 cents per kilowatt-hour	
100 Percent Pump Operation	
1 Pump	\$2.11 per day
2 Blowers	0.35 per day
Total	<u>\$2.46 per day = \$76.26/month</u>
Power Cost per Gallon-Treated = 0.00053 cent/gallon	

SECTION VII
RECOMMENDATIONS

Based upon the results discussed in Section V and given similar waste discharge limits, recommendations for future units would include, but would not be limited to, the following:

1. Filter tank sizes over 18 feet in diameter would have more even distribution with a rotating arm distributor. Using this water distribution method will require periodic bearing replacement, some routine maintenance, and will eliminate absolute leveling required in the weir distribution concept. Weirs were used on this initial installation to reduce and to eliminate moving parts and therefore mechanical failures.
2. An additional line from the suction well back to the final clarifiers should be a part of future units. This is a safeguard so that, if the power fails, wastewater will flow to the clarifier. This line also provides a safeguard due to run-off water overloading the pumping capacity or overload due to upstream operating errors. A typical case was observed at Columbus when both existing trickling filters had been flooded, and they were released simultaneously. The volume of water was greater than the pumping capacity, and the suction well overflowed for a short period of time.
3. The Columbus facility has two parallel clarifiers as the final treatment before chlorination. The arrangement at Columbus requires that the flow from any upstream treatment must be split before the clarifiers. This presents a minor problem in flow equalization and should be considered for any future installations. Presently the flow to the two existing clarifiers is not balanced because the head loss between the two inlet connections is slightly different. Two additional valves in the advanced treatment plant effluent line would provide flow control for any future installations that have a similar type final treatment.
4. The original plan for Columbus included another secondary clarifier. For purposes of economy, it was felt by the Air Force that valid test results could be obtained without this supplementary clarifier. As shown in Section V, this was a valid choice for the full-scale pilot plant. Future installations should seriously consider including a clarifier before and after the GaryGlas® advanced water treatment unit. A clarifier before the advanced treatment will provide a more stable waste, lower BOD and TSS loading, and partial flow equalization. In turn, the GaryGlas® unit will reduce the BOD and TSS to even lower values.
5. Automatic samplers were installed on the Columbus Air Force Base advanced trickling filter. These samplers were specified in the contract. The purpose of these automatic samplers was to determine the efficiency and effectiveness of the advanced trickling filter; therefore, they were

placed before the GaryGlas® unit and after the final north clarifier. The present Environmental Protection Agency permit requires 24 composite samples from the influent to the plant and the final effluent. Future installations should include provisions for a sampler on the primary influent that is capable of sampling for raw sewage with its high solids content. Presently, there is no composite raw sewage data available at Columbus Air Force Base. The only data available is an occasional grab sample of the primary influent to the treatment plant which does not provide adequate in-depth information.

6. The advanced trickling filter tank, as built for this demonstration, was a flat-bottom tank. There is some evidence that a small amount of solids has collected in the bottom of the tank. Future units should be constructed with a sloping bottom or lowered discharge pipe which will virtually eliminate any solids build-up. The advantage of sloping of bottom discharge is obvious, and the extra capital outlay will be minimal.

SECTION VIII

DISCHARGE STANDARDS

Columbus Air Force Base has been issued an authorization to discharge under the National Pollutant Discharge Elimination System effective 21 October 1974. The order is divided into two parts. The first was effective from date of issue through 30 June 1977, and the second was effective from 1 July 1977 through 31 May 1979.

The first time period does not set any effluent limitations except for chlorine residual. The monitoring requirements are established, and a compliance schedule is required. The first part of this waste control order is being met at this time. The GaryGlas® advanced trickling filter is operating, and the monitoring requirements can be met by installing a sampler capable of sampling raw sewage as discussed previously.

The second time period is the most important in that specific limitations are established for BOD and suspended solids. The order required an 85 percent removal or 30 mg/l of BOD or TSS maximum, or whichever yields the highest water quality. This removal requirement is across the entire treatment system. The limited raw sewage influent data that is available to the plant is given in Table 4. The average loading of BOD was 104 mg/l for the three-month period. During the same period the average loading of TSS was 169 mg/l. The effluent limitations for the plant based on highest water quality would be a BOD of 15 mg/l and a TSS of 25 mg/l. The ATF for the period provided an effluent quality of 18 mg/l BOD overall. The effluent quality of the ATF after BOD test procedures had been corrected was 14 mg/l. This is a quality water that meets the waste control order for the time period beginning 1 July 1977.

The TSS effluent for the test period average 32 mg/l. This value is slightly higher than would be permitted in the waste order for 1977-1979. The waste control order can be met by several different methods. One method of enhancing solids removal would be the addition of a second clarifier between the standard trickling filters and the ATF, as discussed previously. A second method could be improvement of solids settling velocity by chemical addition. This could be accomplished with alum, ferric chloride, polyelectrolyte, or other chemicals commonly used for this purpose. The plant at Columbus would probably be best suited to polyelectrolyte because it is doubtful the digester could handle the increased sludge volume from chemicals such as alum.

The results of this full scale test unit in Columbus indicates that the waste control order requirements can and will be met. Incorporation of recommendations in the preceding section could allow other military bases to upgrade existing treatment plants economically to a level that complies with the Federal Water Pollution Control Act.

TABLE 4. RAW SEWAGE INFLUENT DATA

	<u>BOD</u> <u>(mg/l)</u>	<u>TSS</u> <u>(mg/l)</u>
Oct 1974	90	214
	105	265
	120	239
	135	160
Nov 1974	81	134
	93	142
	114	151
	139	145
Dec 1974	93	140
	63	170
	111	100
	<hr/>	<hr/>
Total	1144	1860
Arithmetic Mean	104	169

SECTION IX

COST FOR FUTURE UNITS

The estimated cost for future units, including the recommended changes, varies with several parameters. Major considerations are geographical area, inflation, size of installation, and topography of the selected site. A price estimate for an advanced trickling filter of comparable size in Columbus, Mississippi, at today's cost would be in the range of \$130,000.00 to \$150,000.00.

This breaks down as follows:

Filter tank piping, valves, suction well, pumps, blowers	\$ 45,000.00	\$ 50,000.00
Clarifiers, 2-hour detention	36,500.00	50,000.00
Site preparation, fill, or excavation	5,000.00	7,500.00
GaryGlas®	42,500.00	42,500.00
Total	\$130,000.00	\$150,000.00

These figures are presented as fair engineering estimates; however, each new site will require an in-depth study and cost evaluation. Another site may not require any pumping since flow through the ATF could be by gravity, whereas another site may require more pumping to move the hydraulic load. The above figures do not include any land acquisition that may be required. Land requirement for the estimated installation would be approximately 5000 square feet or slightly less than 1/8 of an acre.

Operating costs on future projects will be minimal as the Columbus installation has required no additional manpower to operate. Operators making their normal inspections are spending approximately 1/2-hour longer per inspection making adjustments. This time estimate is probably inflated due to the experimental nature of the unit. The amount of additional manhours spent testing in the laboratory is great; however, this manpower is partially required by the discharge permit and will eventually have to be done at all installations regardless of any additional water treatment systems. The time spent analyzing above the permit requirements are unique to this test alone. The GaryGlas® advanced water treatment system is designed for virtually automatic operation and low maintenance.

The filter media, GaryGlas®, is presently being marketed at \$10.00 per cubic foot. The data collected show that the ATF is operating

effectively and efficiently. The economy of the unit is of prime importance. The anticipated life of GaryGlas® is a minimum of 10 years with no recharge. It is recommended that the filter be topped off each year, and GaryGlas® is guaranteed to require no more than 10 percent replacement per year. Based on a 10 percent recharge yearly, at a design hydraulic flow of 700,000 gallons per day, the cost to treat 1000 gallons of water will be 3.3 cents for GaryGlas® alone.

Assuming a 25-year life, amortizing the capital investment represents a 1.5 cents per 1000-gallon cost. Estimating maintenance upkeep at 1 percent of the capital investment per year, a cost of 0.5 cent per 1000 gallons is arrived at. The power costs previously mentioned translate to 0.5 cent per 1000 gallons. This total is 5.8 cents per 1000 gallons which is very economical.

Addition of an advanced trickling filter with GaryGlas® is a viable consideration for military installations that will be required to upgrade existing systems to meet new discharge standards. The ATF is a more economical choice than building complete new systems. This is especially true in areas that foresee joining regional disposal systems in the predicted future. The ATF is a system that will fill this interim gap yet provide an effluent meeting today's standards.

APPENDIX A
PHOTOGRAPHS
OF
COLUMBUS AIR FORCE BASE INSTALLATIONS

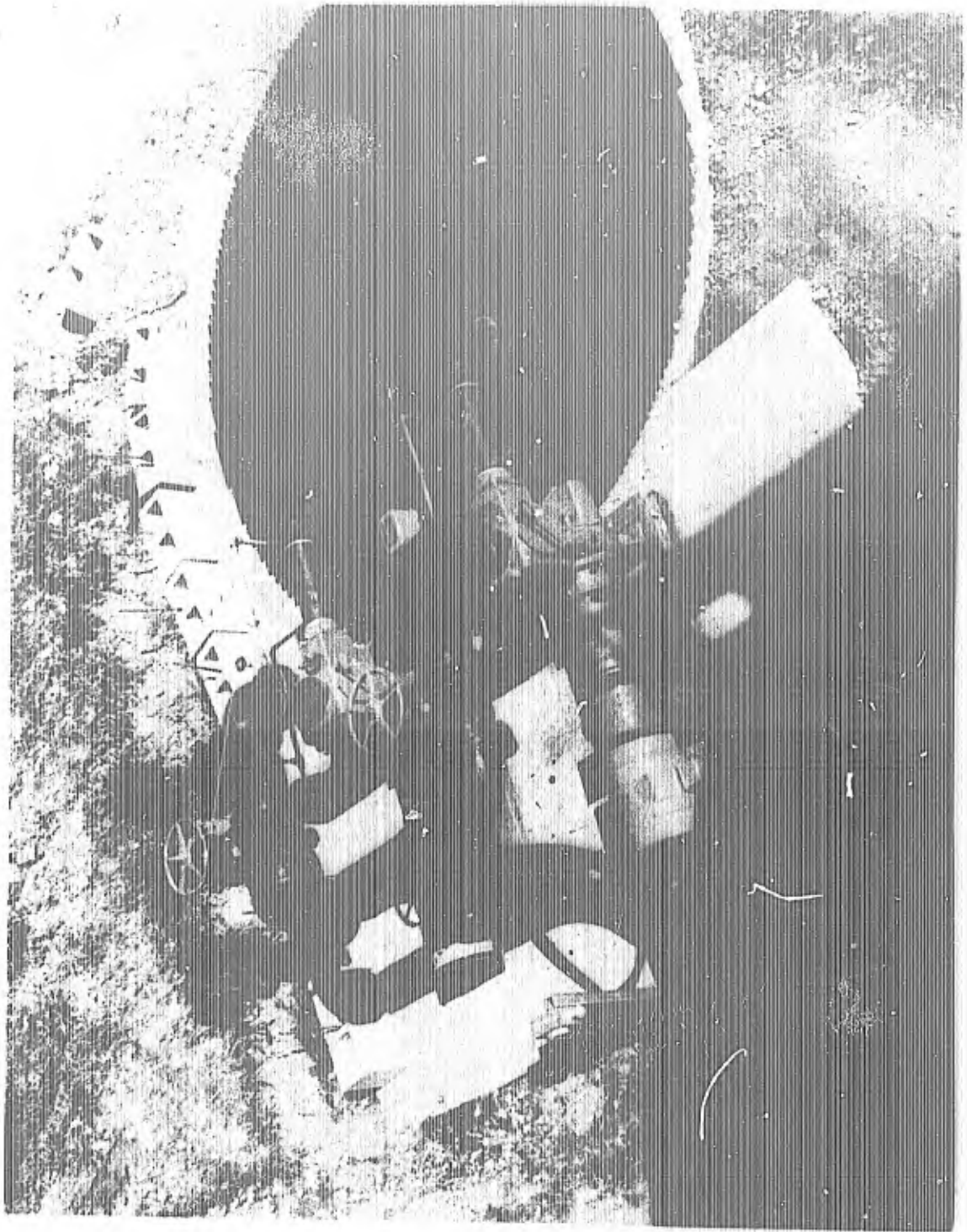


Figure A-1. Sump and Pumps

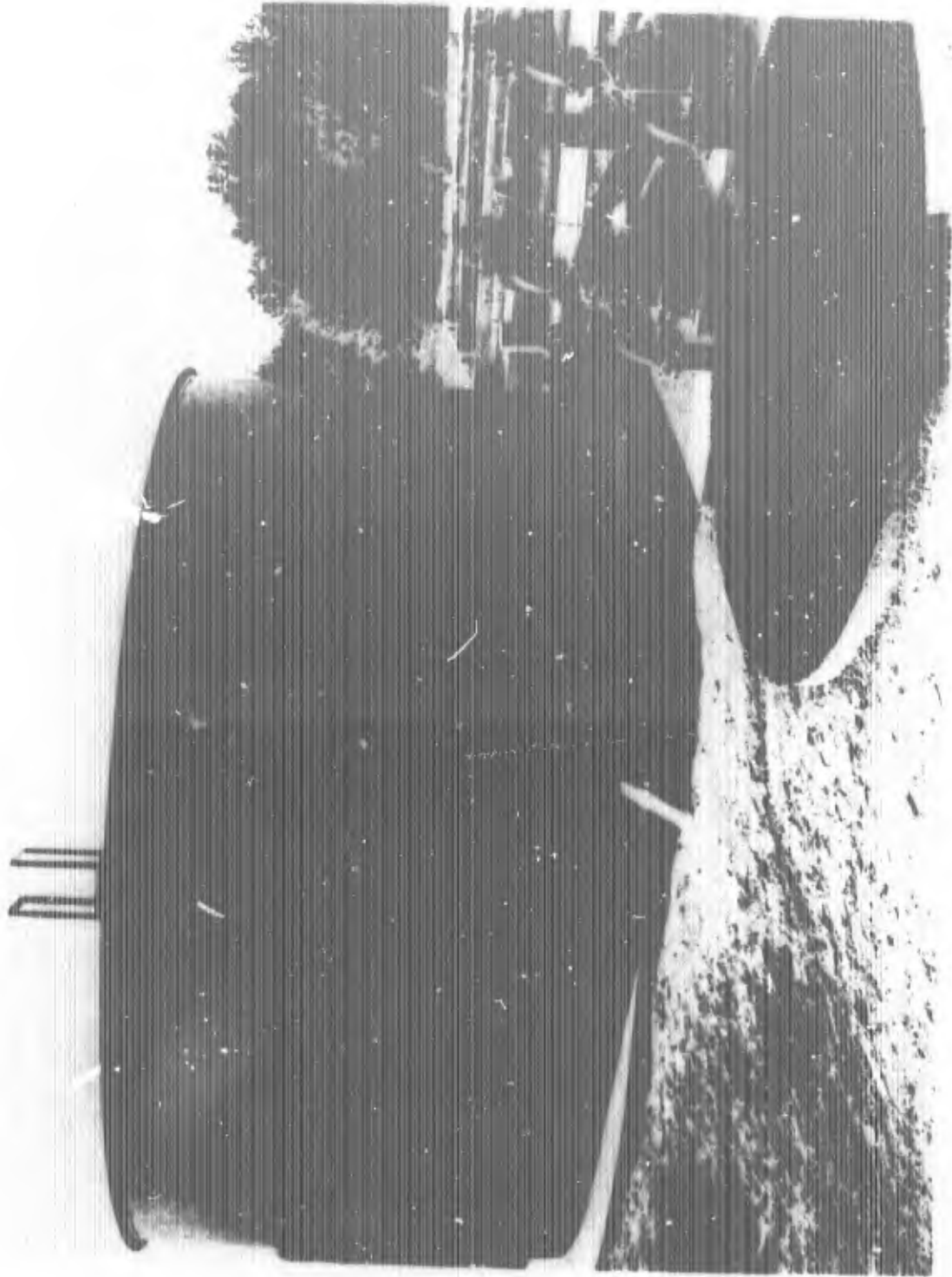


Figure A-2. Overall View of Sump Pumps and Advanced Tricking Filter

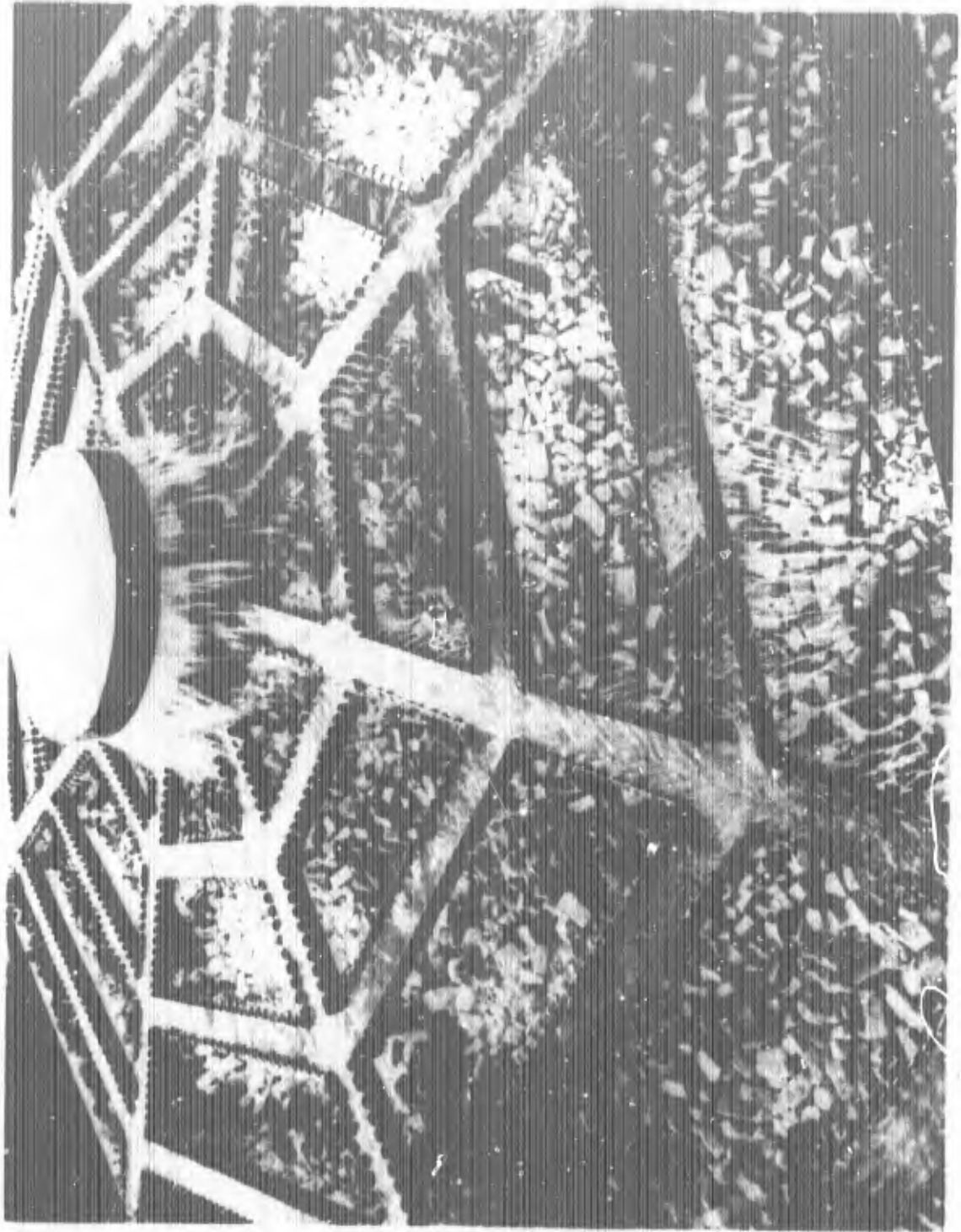


Figure A-3. Weir

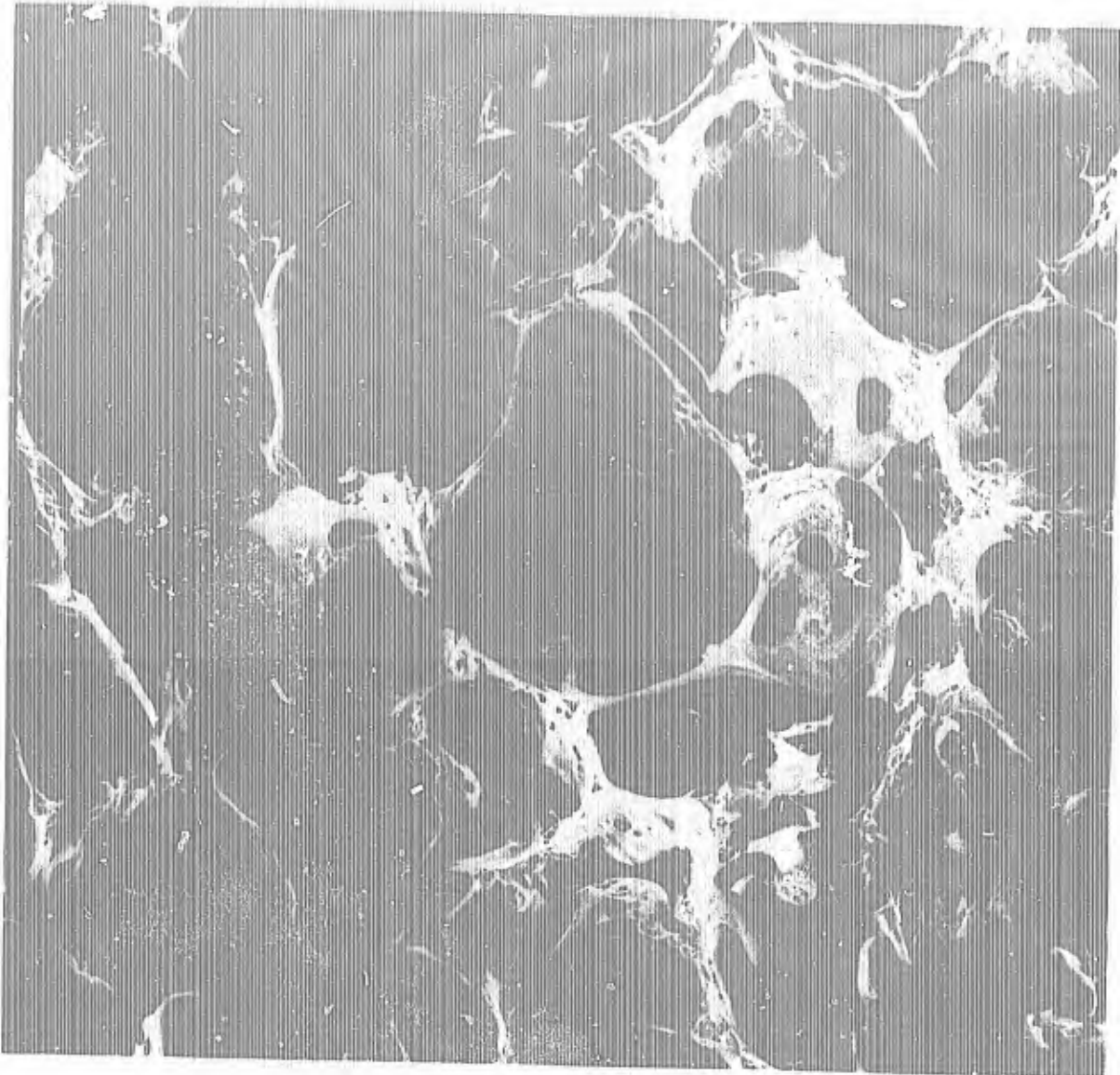


Figure A-4. Microscopic Photograph of GaryGlas® 120X

LIST OF ABBREVIATIONS

ATF	advanced trickling filter
BOD	biochemical oxygen demand
COD	chemical oxygen demand
ft ³	cubic feet
gal	gallon
hp	horsepower
lb	pound
mgD	million gallons per day
mg/l	milligrams per liter
NFS	nonfilterable solids
TSS	total suspended solids (nonfilterable solids)