

TREATABILITY OF FIREFIGHTING SCHOOL WASTEWATERS:  
U.S. NAVY COMPLIANCE WITH POTW PRETREATMENT  
REQUIREMENTS

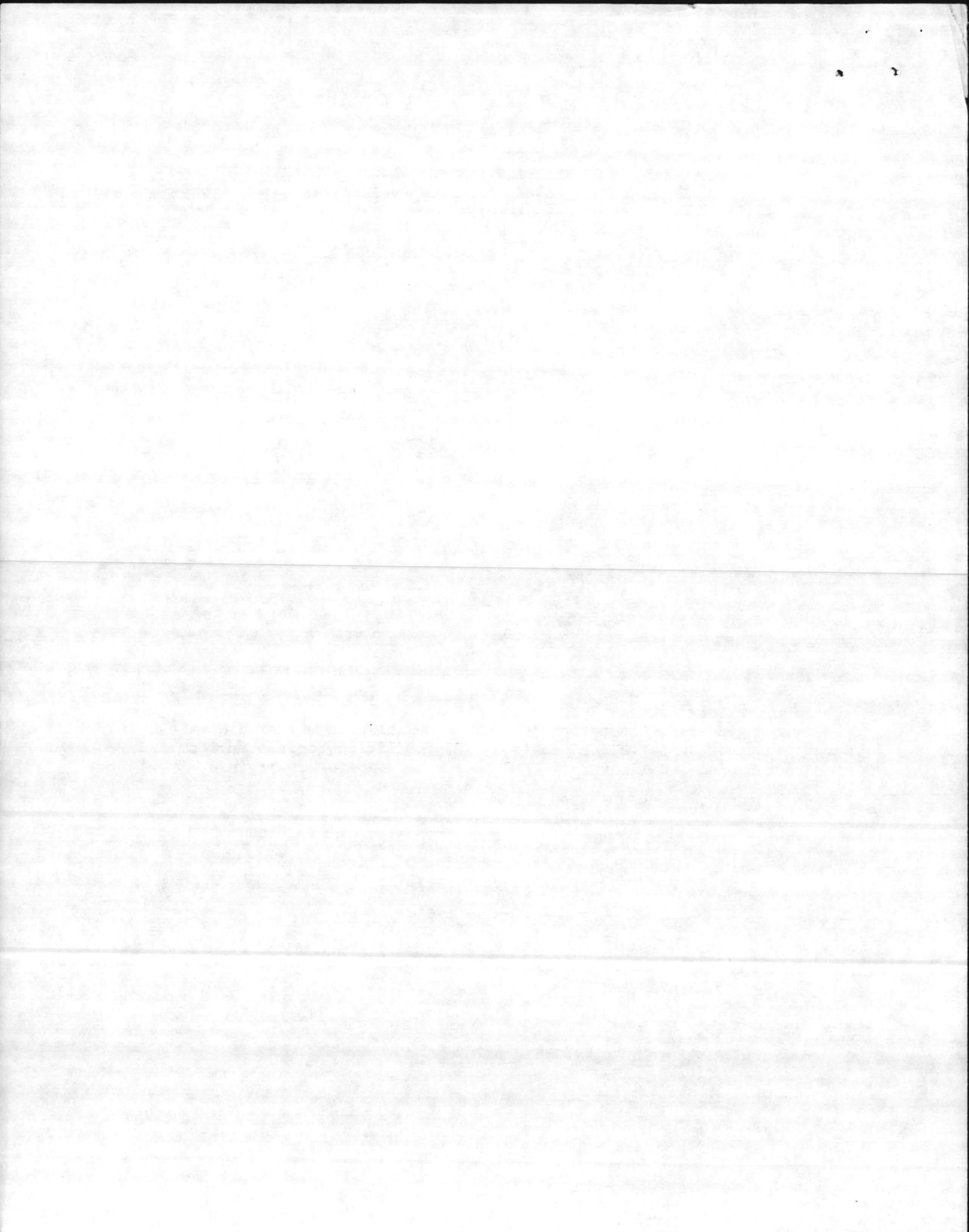
Presented at the 34th Annual Purdue Industrial Waste Conference

By

Richard D. Saam  
Sanitary Engineer  
Civil Engineering Laboratory  
Naval Construction Battalion Center  
Port Hueneme, California

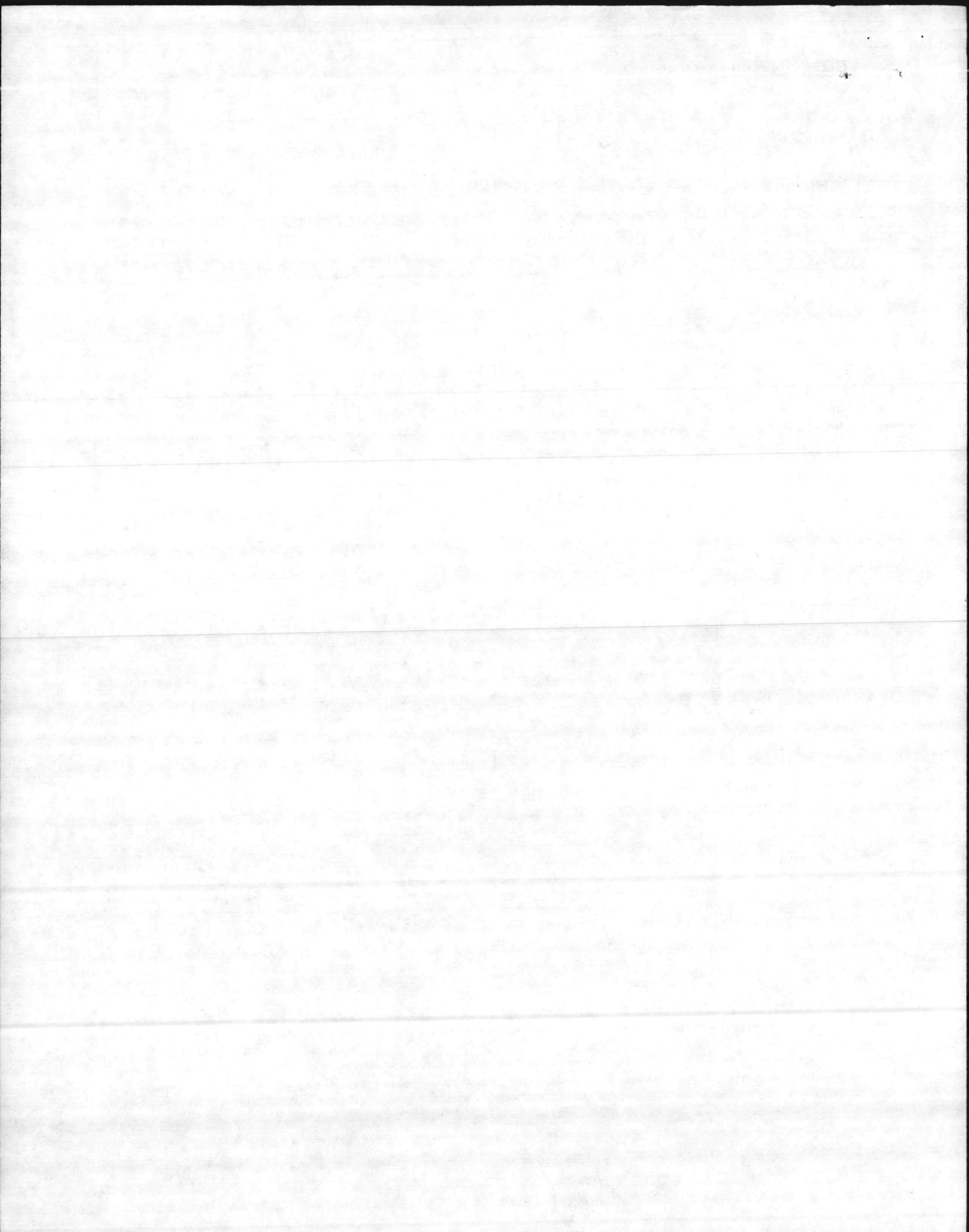
Paul A. Rakowski  
Sanitary Engineer  
Atlantic Division Naval  
Facilities Engineering Command  
Norfolk, Virginia

Guy M. Aydlett  
Chief, Industrial Waste Division  
Hampton Roads Sanitation District  
Virginia Beach, Virginia



N O T I C E

This subject report is not intended for promotional or advertising purposes and should in no way be construed as an endorsement of any product. The views expressed herein are those of the authors and do not necessarily reflect the views of the United States Navy or the Department of Defense.

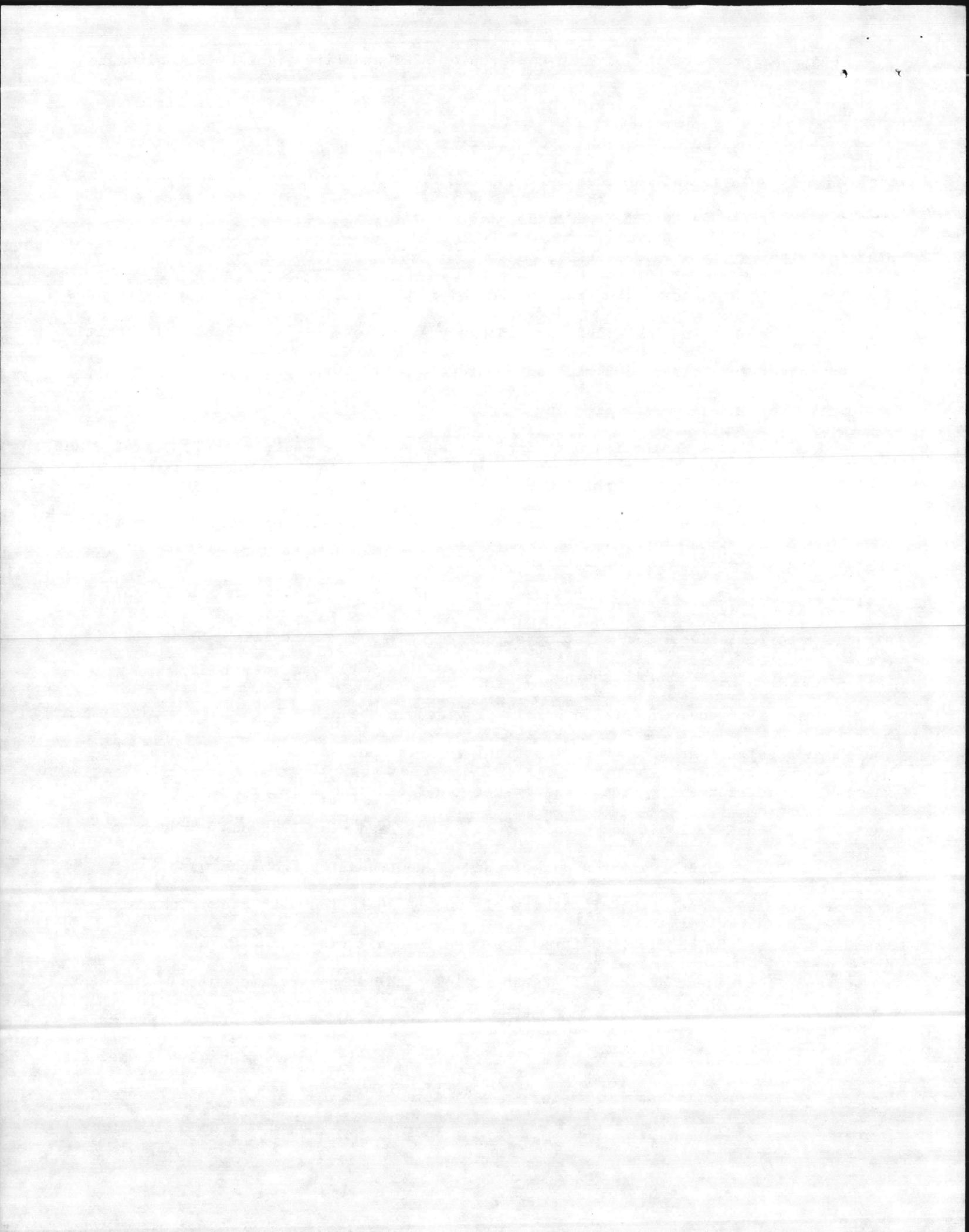


## I. INTRODUCTION

The fire fighting training program for U.S. Navy personnel includes field exercises involving the extinguishing of oil fires burned on the surface of water pools. A 6% solution of the chemical compound known as "Aqueous Film Forming Foam" (AFFF), frequently referred to as "light water", is used alone or in a combination with Purple K Powder (PKP), potassium bicarbonate, to extinguish the fire. The Fleet Training Center Fire Fighting School in Norfolk, Virginia, conducts various shipboard fire training exercises for U.S. Navy Atlantic Fleet personnel. In addition to open tank fires, other simulated shipboard type structures are utilized for fire training. The existing Fire Fighting School Facilities (FFS) are located adjacent to the Hampton Roads Sanitation District's (HRSD) Army Base Wastewater Treatment Plant, a publicly owned treatment works (POTW).

Construction of a \$2.8 million fire fighting school has been completed on a site adjacent to the existing school. (Figure 1). New shipboard and similar open pool training structures have been provided along with environmental controls to reduce air and water emissions. An existing structure, No. 9 Aircraft Flight Deck, has been retained and interfaced with the new facilities. (Figures 2 and 3).

The specific environmental controls provided in the new FFS include a water spray smoke suppression system to reduce particulate emissions and a physical/chemical wastewater pretreatment system. Wastewater generated from fire fighting exercises contains residual fuel oil and gasoline, AFFF, PKP, and miscellaneous combustion products. Based upon previous studies, the effluent quality from the wastewater treatment system, consisting of gravity oil/water separation with mechanical oil removal followed by chemical addition and dissolved air flotation (Figure 4) would not be suitable for direct discharge. Further biological or physical/chemical treatment would be necessary to reduce the organic content of the waste. Prior work indicated additional treatment could effectively be accomplished in conjunction with either sanitary or organic industrial wastes in a biological wastewater treatment system.<sup>1</sup>



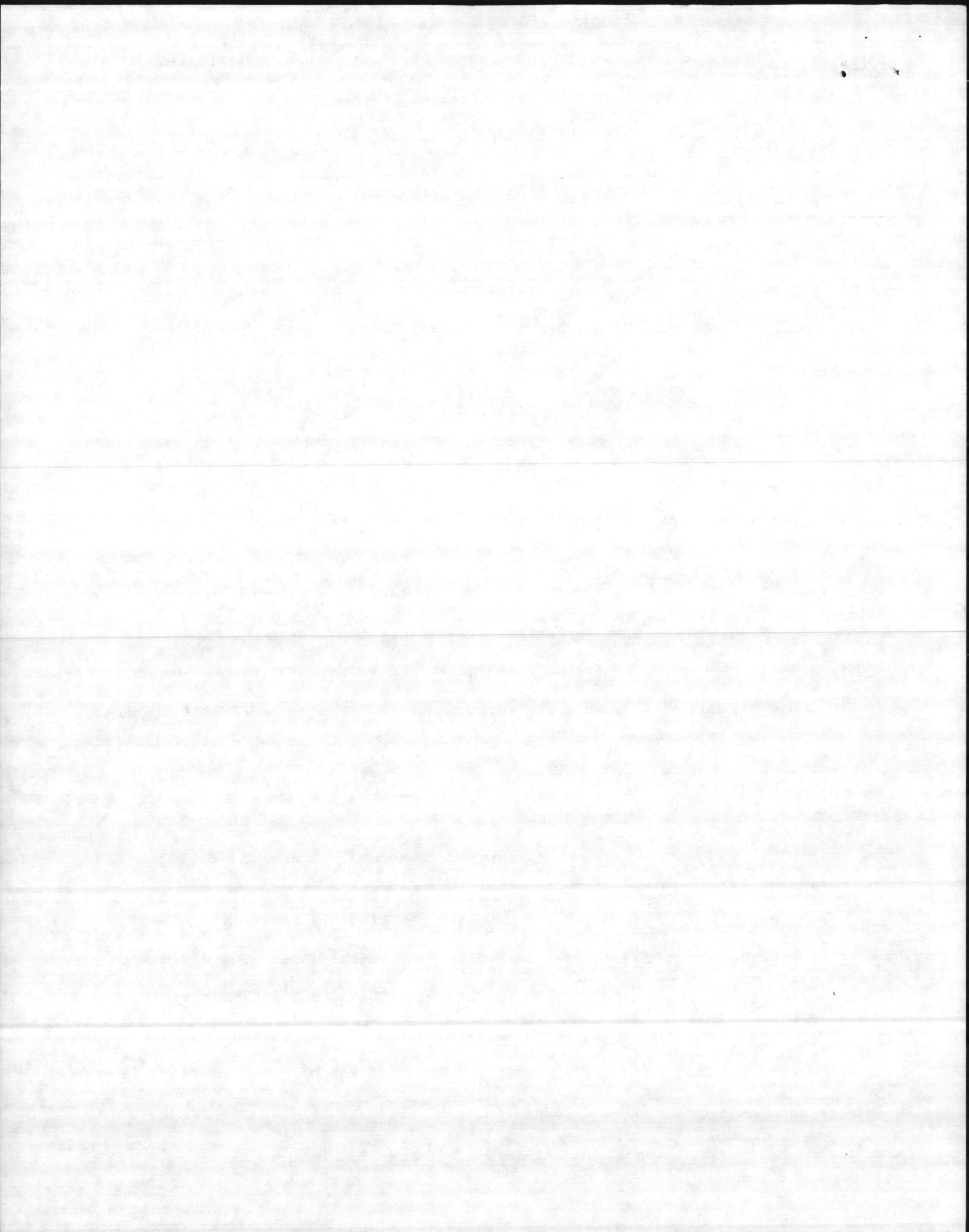
Previous treatability work in the area of AFFF and fire fighting school waste provided considerable information on the treatability and toxicity of pure AFFF, but little was available on the actual fire fighting wastewater that would be generated. The best available information relative to the disposal of wastewater containing AFFF can be summarized as follows:<sup>2-7</sup>

- a. AFFF is toxic to oyster larvae above 100 mg/l and to fish above 1000 mg/l. Limiting concentration for biological treatment systems under conditions of continuous feeding and/or shock loading has been determined.
- b. There is no standard analytical method for measuring AFFF concentrations in mixed wastewaters at concentration levels in the expected range.
- c. There is no discharge standard for AFFF concentrations in treated effluents. There are no human health exposure standards for AFFF. Dilution has been the common practice for disposal of AFFF contaminated wastewaters.
- d. The feasibility of recovery and reuse technology for AFFF has not been investigated.
- e. AFFF contains a high percentage of surfactants and a small percentage of fluorocarbons. A typical analysis of the AFFF used in this study shows a BOD (5-day) of 210,000 mg/l; COD of 500,000 mg/l; Surfactants as MBAS of 41,000 mg/l.
- f. Wastewaters from fire fighting schools contain hydrocarbons (fuel oil) and combustion products that may add significantly to its toxicity.

## II. BACKGROUND

In August, 1976, application was made to the Hampton Roads Sanitation District for acceptance of wastewaters generated by the new Fire Fighting School (FFS).

After reviewing all current available data on the anticipated effluent quality, treatability and toxicity of the waste, HRSD requested that the Navy conduct additional treatability and bioassay studies on the FFS wastewater. The objective of these studies was to further characterize the effluent quality, degradability and toxicity both before and after the FFS wastewater has undergone conventional pure oxygen biological treatment; and to determine if the FFS wastewater



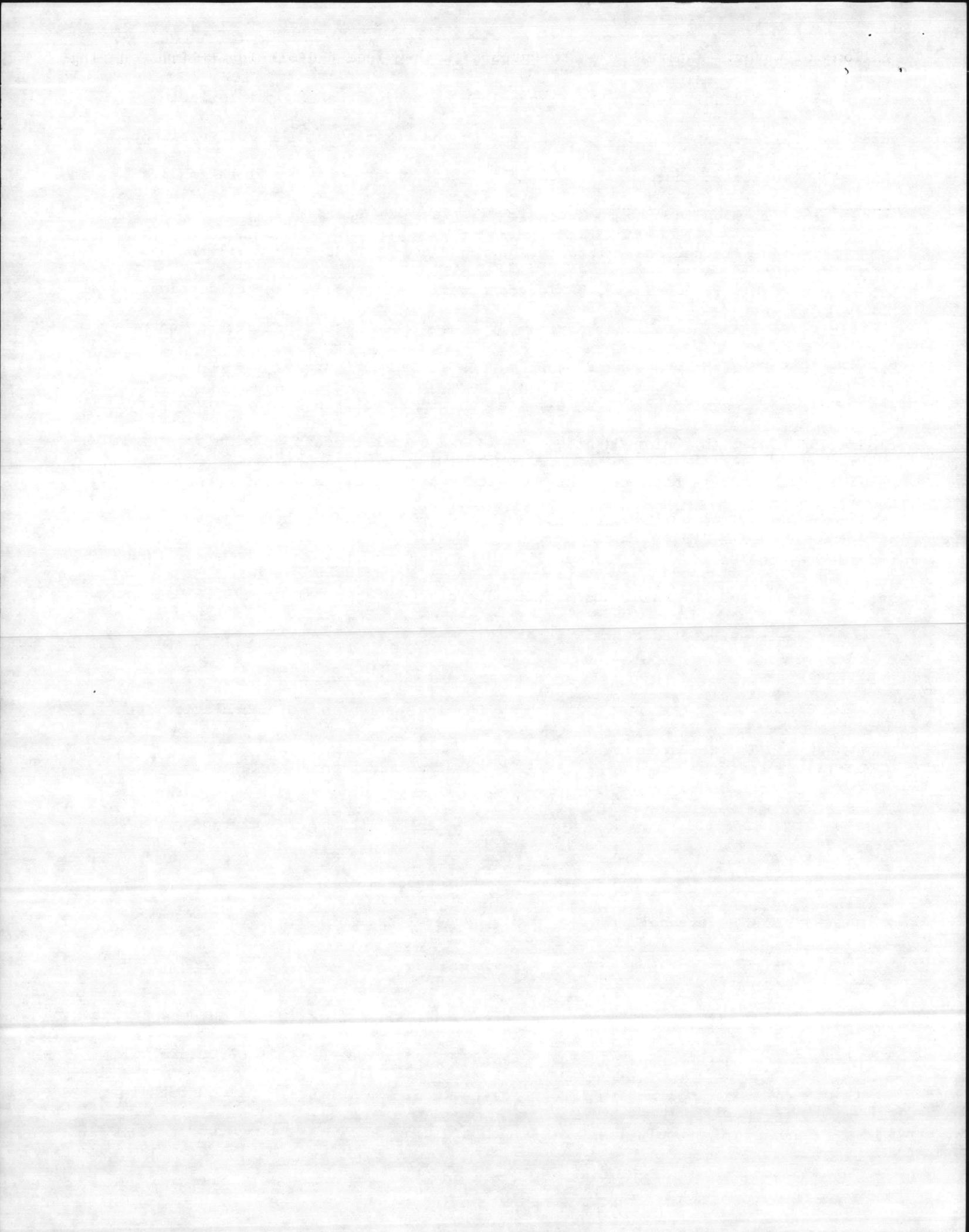
pretreatment scheme would meet the HRSD requirements and pretreatment limits. (Table 1). The requirements were to preclude upsetting the HRSD biological pure oxygen treatment facility and increasing the toxicity of the POTW effluent. This study indicated that chemical coagulation and dissolved air flotation pretreatment will allow the FFS to meet all existing HRSD standards.

To provide the necessary information requested by HRSD, the Civil Engineering Laboratory (CEL), Port Hueneme, CA in coordination with the Atlantic Division, Naval Facilities Engineering Command, Norfolk, VA, developed a test and evaluation program for resolution of the wastewater problem. As shown in Figure 5, the study was divided into three main parts, namely, (a) chemical addition and dissolved air floatation (DAF), (b) Union Carbide's UNOX pure oxygen process to simulate the POTW, and (c) oyster larvae bioassay tests. Bench scale jar tests were conducted to define optimum chemical dosages by Puricons, Inc. of Berwyn, PA. In-house support was provided by the David W. Taylor Naval Ship Research and Development Center (NSRDC) Annapolis, MD, and the Naval Research Laboratory (NRL), Washington, DC. Contracted work and their associated tests were as follows:

<u>Contractor</u>	<u>Test</u>
NSRDC & NRL	Chemical addition and coagulation.
Southeast Applied Research (SEAR) New Orleans, LA	Chemical addition coagulation.
The Pielkenroad Separator Co. Houston, TX	Chemical addition, coagulation/and DAF.
Union Carbide Corp., Tonawanda, NY	UNOX process.
Bionomics (EG&G), Pensacola, FL	Oyster larvae bioassay.

### III. DISCUSSION

a. Wastewater generation - Structure No. 9, Aircraft Flight Deck, was selected for evaluation in this study as the worst case condition, as this structure will utilize the largest volume of AFFF in the new FFS. The structure is 50 feet in diameter and approximately 1.5 feet deep containing an average of 20,000 to 25,000



gallons of water. Water is used to support the  $\frac{1}{4}$ - $\frac{1}{2}$  inch pad oil layer burned during the fire exercises. Varying quantities of gasoline are applied to the pad oil before each fire exercise to ignite this oil.

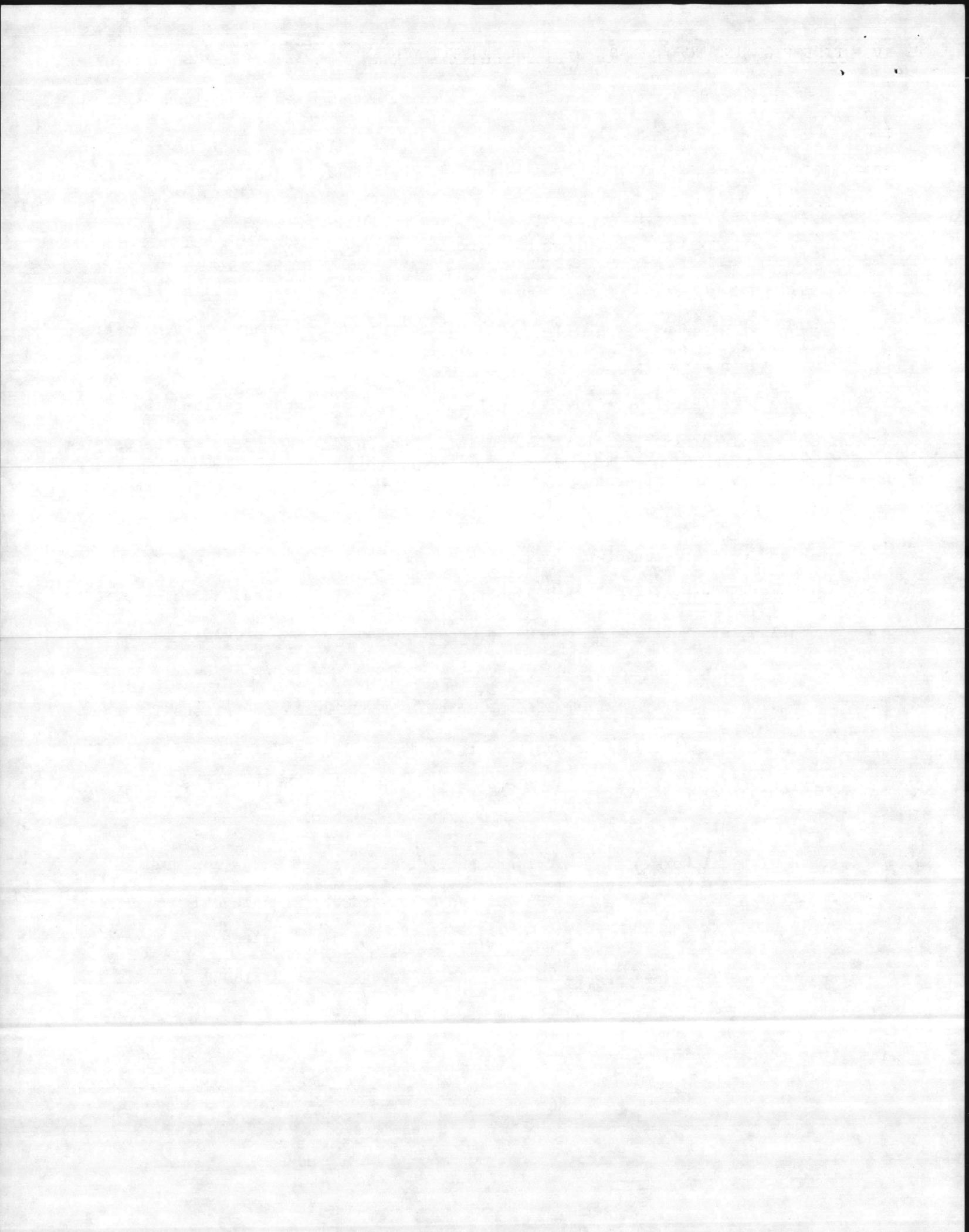
After gasoline ignition, the pad oil burns until 60 to 80% of the pit is ignited (preburn). The fire fighting teams then advance on the structure to extinguish the oil fire. (Figure 6 and 7). Wastewater generated during 3 to 4 such fire cycles comprises a complete training exercise. The existing FFS was operated by Fleet Training Center personnel in a manner to simulate proposed procedures and conditions expected in the new facility.

b. Dissolved Air Flotation (DAF) - The Pielkenroad Company operated the 10 GPM pilot dissolved air flotation (DAF) unit for the study. To optimize the DAF pretreatment portion of the study, bench scale jar tests were performed on FFS wastewater by Puricons, Inc., to obtain optimum chemical dosages for coagulation/flocculation and flotation of the wastewater.

c. Surfloc Process - Southeast Applied Research (SEAR) tested their proprietary flocculant aid Surfloc, in the DAF process. NSRDC and NRL provided technical support in the area of chemical addition.

d. Pure Oxygen Biological Treatment System - Bench scale operations for the future HRSD biological treatment system were conducted at the Union Carbide facility. A single stage pilot scale unit was utilized to conduct biological oxidation treatability studies.

e. Analytical Work <sup>8,9,10</sup> - Primary analytical parameters for monitoring unit process performance were Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), Surfactants as Methylene Blue Active Substances (MBAS), oil and grease (O/G), and pH. Oyster larvae bioassay of various samples utilizing embryos of the eastern oyster (Crassostrea virginica) were performed at the Bionomics Laboratory in Pensacola, Florida.



#### IV. FIRE FIGHTING SCHOOL WASTEWATER CHARACTERIZATION

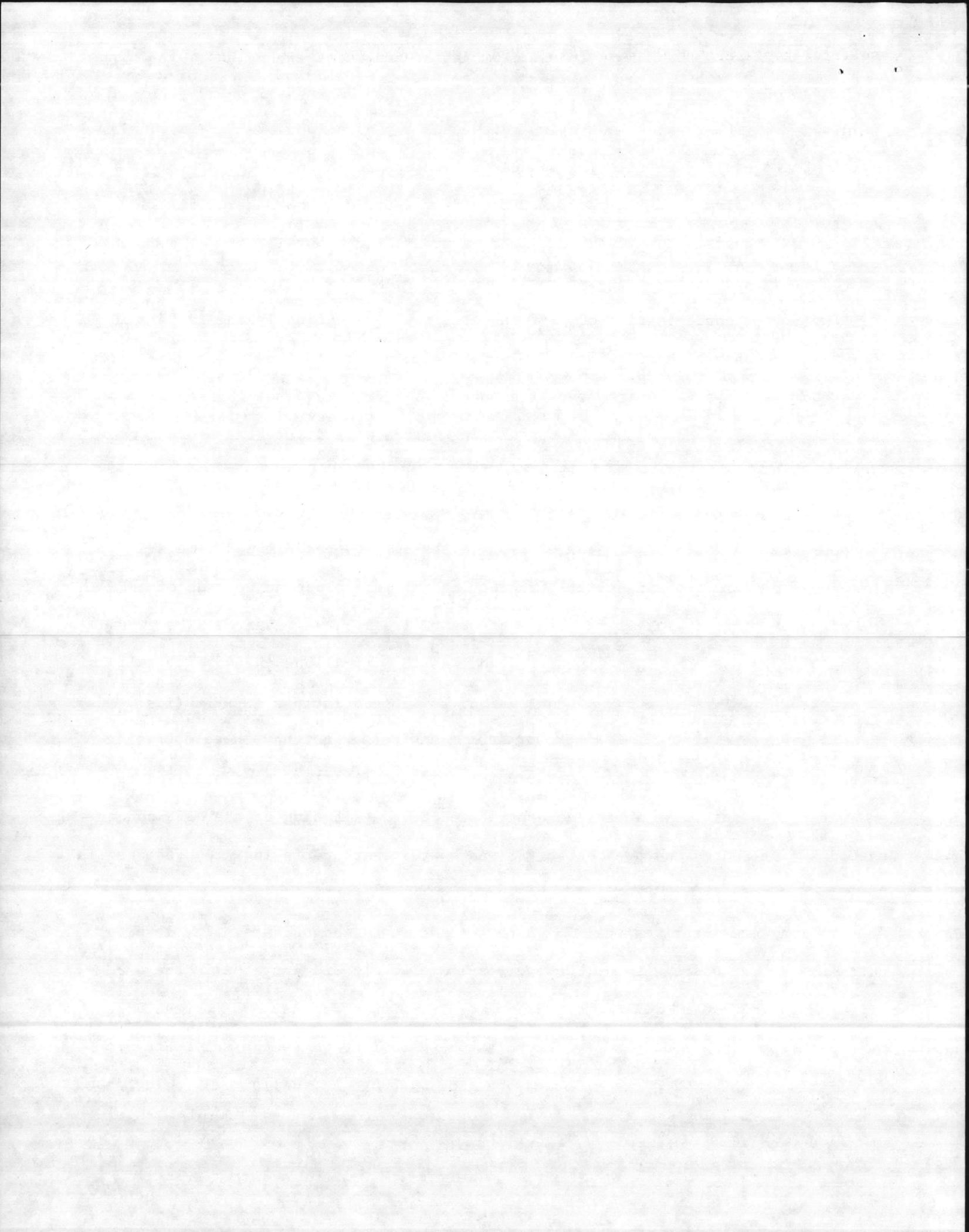
Based on information collected by the Fleet Training Center, Norfolk, VA., projected daily wastewater generation rates and concentrations of AFFF in the anticipated overall fire fighting school wastewater are shown in Table 2.

Predicted flow rates in the new FFS of 25,000 to 50,000 GPD were utilized for design purposes. The 50,000 GPD is an extreme figure but is used as a basis for the study and ultimate design to account for peak flow periods.

The proper concentration of AFFF in water for fire extinguishing is 6%. The projected concentration of 1.8% in Table 2, indicates that dilution from the water smoke abatement system, wastewaters from other fire fighting training structures not utilizing AFFF, and miscellaneous cooling waters will dilute the overall ratio of AFFF to FFS wastewater in the full scale facilities.

Data on the number of fire fighting cycles, water utilized, and AFFF applied are presented in Table 3. No correlation exists between the preburn time and the number of fire fighting events, indicating that the expected buildup of AFFF in the structure did not interfere with subsequent fire fighting events. The average amount of AFFF used per fire fighting event was  $18 \pm 6$  gallons in  $445 \pm 120$  gallons of water or  $4.1 \pm 1.3$  percent concentration. Low concentrations of AFFF (i.e., less than 6%) indicate that the foam proportioning device may not have been operating properly. In addition, cooling water used to protect the lead hose handling team and water used for smoke abatement contributed to the diluting of the AFFF concentrations. Untreated and pretreated FFS wastewater characteristics are presented in detail in Table 4.

Table 5 characterizes the FFS waste for nutrients and sulfate. The level of nutrients in the waste was low; however, sulfate levels did increase in the DAF effluent waste stream. The fluorocarbon solubilizing group is, most often, a sulfonate compound (i.e., sodium fluorocarbon sulfonate) where the sulfonate group is soluble in water with the fluorocarbon group soluble in fuel or oil.<sup>3</sup> Increased

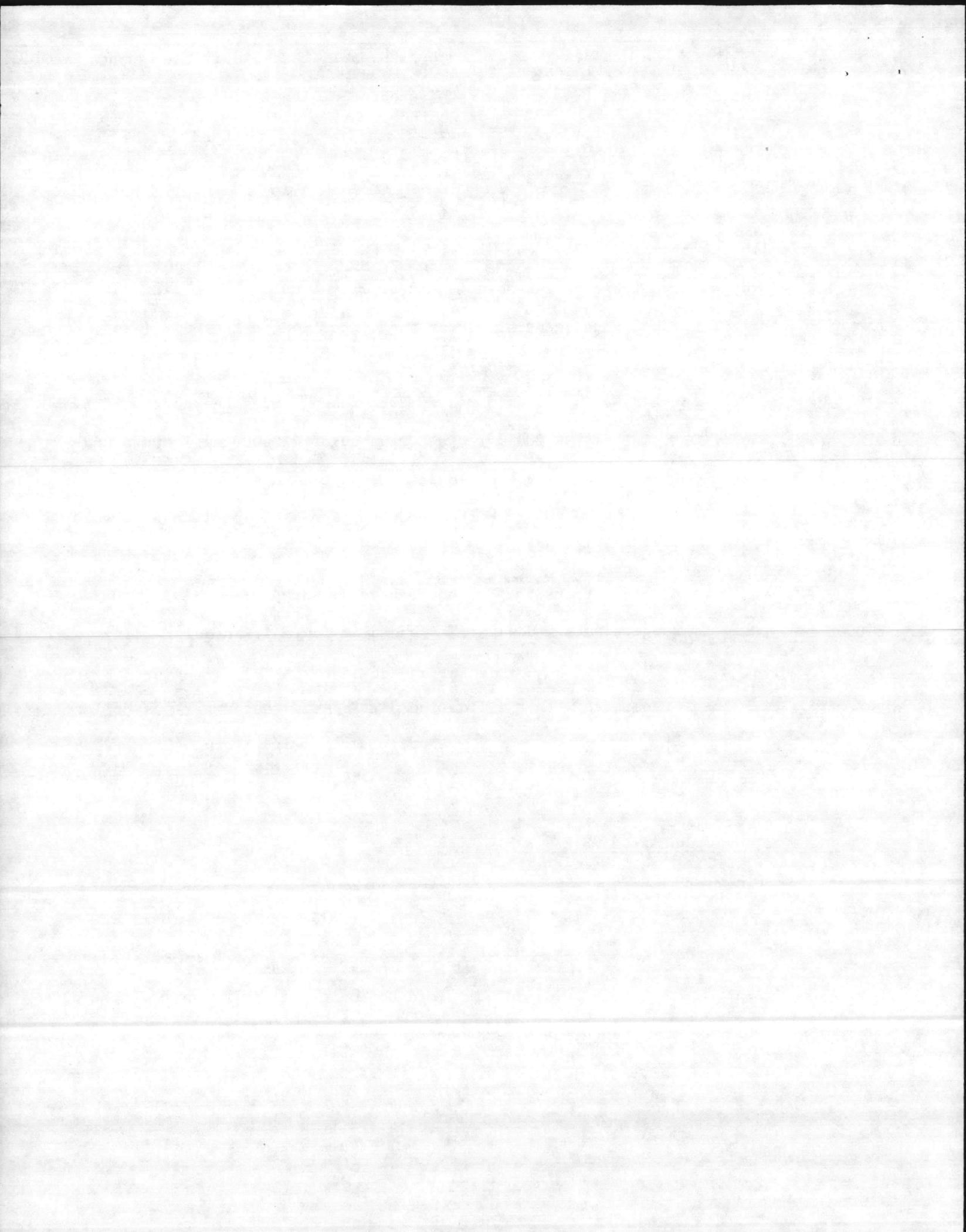


sulfate levels are thought to result from the breakdown of the solubilizing group in the DAF treatment process and from the sulfate associated with influent oil and grease particles. Table 5 presents the average level of heavy metals measured in the wastewater which are insignificant for discharge to a POTW.

The AFFF compound is produced under Military Specification and is characterized by a stable fluorocarbon tail which can either be organic or inorganic, anionic, cationic, nonionic, amphoteric, water soluble and/or oil soluble. In addition to the AFFF contribution, pollutants generated from the combustion of the oil, (i.e., particulates, heavy metals, BOD, COD, etc.) result from this fuel oil and the gasoline used. The pure AFFF compound (3-M's FC-206), used during the course of this study, has a COD value of 590,000 mg/l, a BOD value of 210,000 mg/l and a surfactant value of 41,000 mg/l as MBAS. The logical assumption was that the values of BOD, COD and surfactant would increase in the 25,000 gallon water pool in Structure 9 after each event. On October 3, 1977, after 21 fire fighting events, the values of BOD, COD and surfactant in the burn pit should have been approximately 9,000, 6,000, and 600 mg/l, respectively. However, as shown in Table 4, actual readings were about 3,000, 4,000 and 30 mg/l. A substantial amount of the AFFF, as measured by these parameters, remained associated with the floating oil layer. Wastewater was collected from the surface overflow at the structure and from a center drain after each fire event to simulate the new school operation.

#### V. BENCH SCALE COAGULATION OF FFS WASTEWATER

Standard jar tests were performed by Puricons Inc., Berwyn, PA, to determine which coagulating and flocculating agents that would provide the best removal of pollutants from the FFS waste. Optimum dosages were determined for alum as the prime coagulant and two types of cationic, anionic, and nonionic organic polymers. The alum was selected as a primary coagulant based upon previous work.<sup>1</sup> The program determined the effectiveness of varying dosages of alum, polymers and combinations of alum and polymers.



FFS wastewater contains high levels of surfactants. Organic polymers may also act as a precipitating agent for surface active materials of opposite charge. Hence, higher concentrations of polymers, than are normally used, were included in the study.

Since alum imparted acidity to the FFS waste, addition of alkali in the form of caustic soda (sodium hydroxide) was necessary to maintain the optimum pH range (6 to 7) for flocculation.

The program was originally planned to study air flotation; but, in tests with the first samples of FFS waste, the floc floated spontaneously without air flotation.

The results of the bench scale work are summarized below:

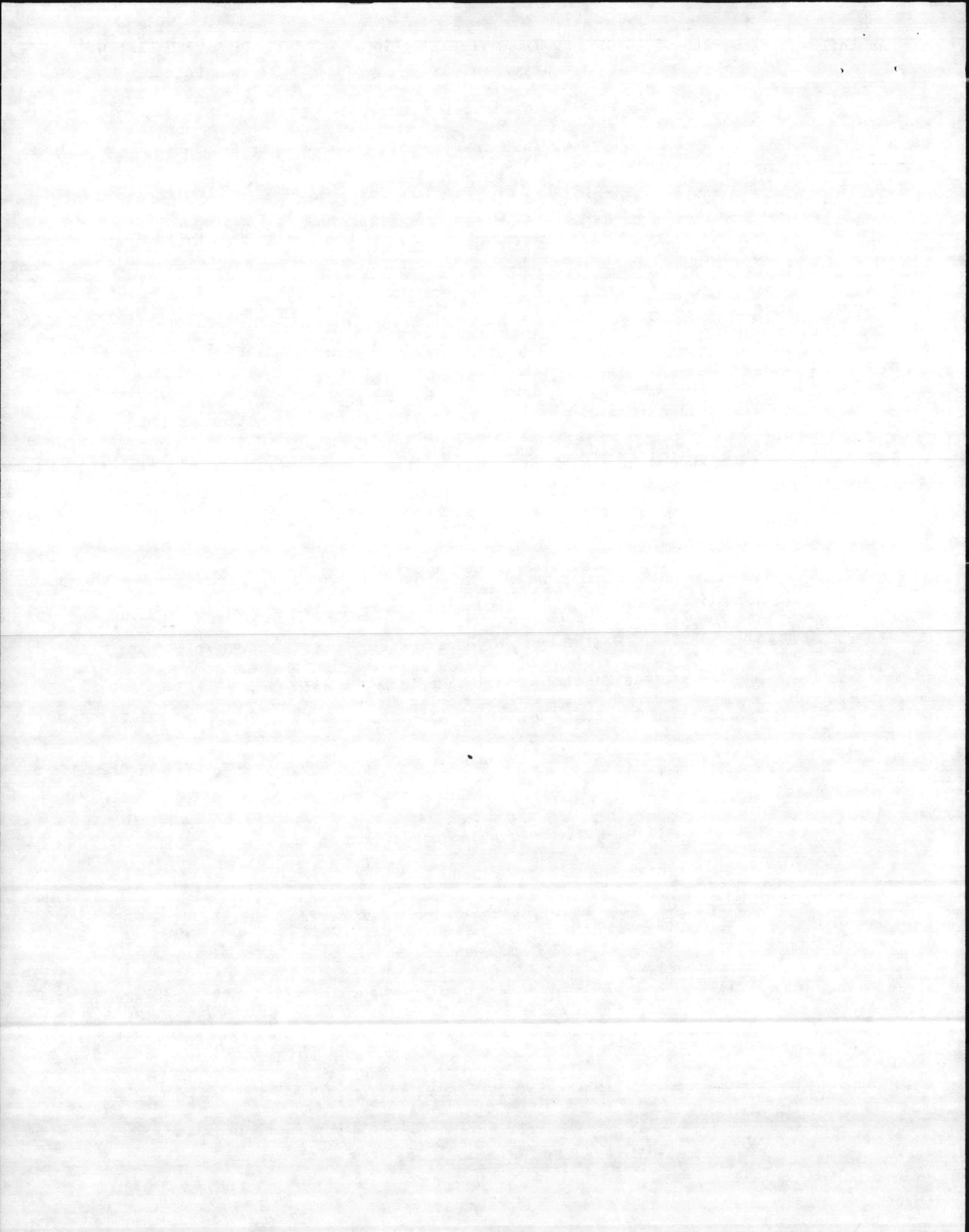
1. Alum (aluminum sulfate) appeared to be an effective coagulant at 120 mg/l for clarification of FFS wastewater and the reduction of the levels of the various contaminants. Due to the low alkalinity in the wastewater, approximately 80 mg/l of sodium hydroxide was added to adjust the pH to the optimum 6 to 7 range.
2. There was no significant difference in the action of cationic, anionic and nonionic polymers in combination with alum, with regard to the removal of oil and grease, COD, BOD and MBAS. Of the six polymers tested, Purifloc N-20 (Dow Chemical Co.) a nonionic polymer, and Mangifloc 835A (American Cyanamid Co.) an anionic polymer excelled in producing a compact floc together with alum.
3. The only significant effects of polymer addition, compared to the use of alum only, are:
  - the formation of a more conglomerated floc
  - higher removal of oil and grease

No advantages were found in the use of polymers as flocculation aids over the use of alum only in the removal of BOD, COD and MBAS.

4. Use of Primafloc C-3 polymer without alum is possible, but at a much higher dosage level. None of the other polymers produced floc when used alone.

## VI. DISSOLVED AIR FLOTATION - PILOT PLANT OPERATION

The pilot DAF unit was sized to hold approximately 750 gallons of water. (Figure 8).



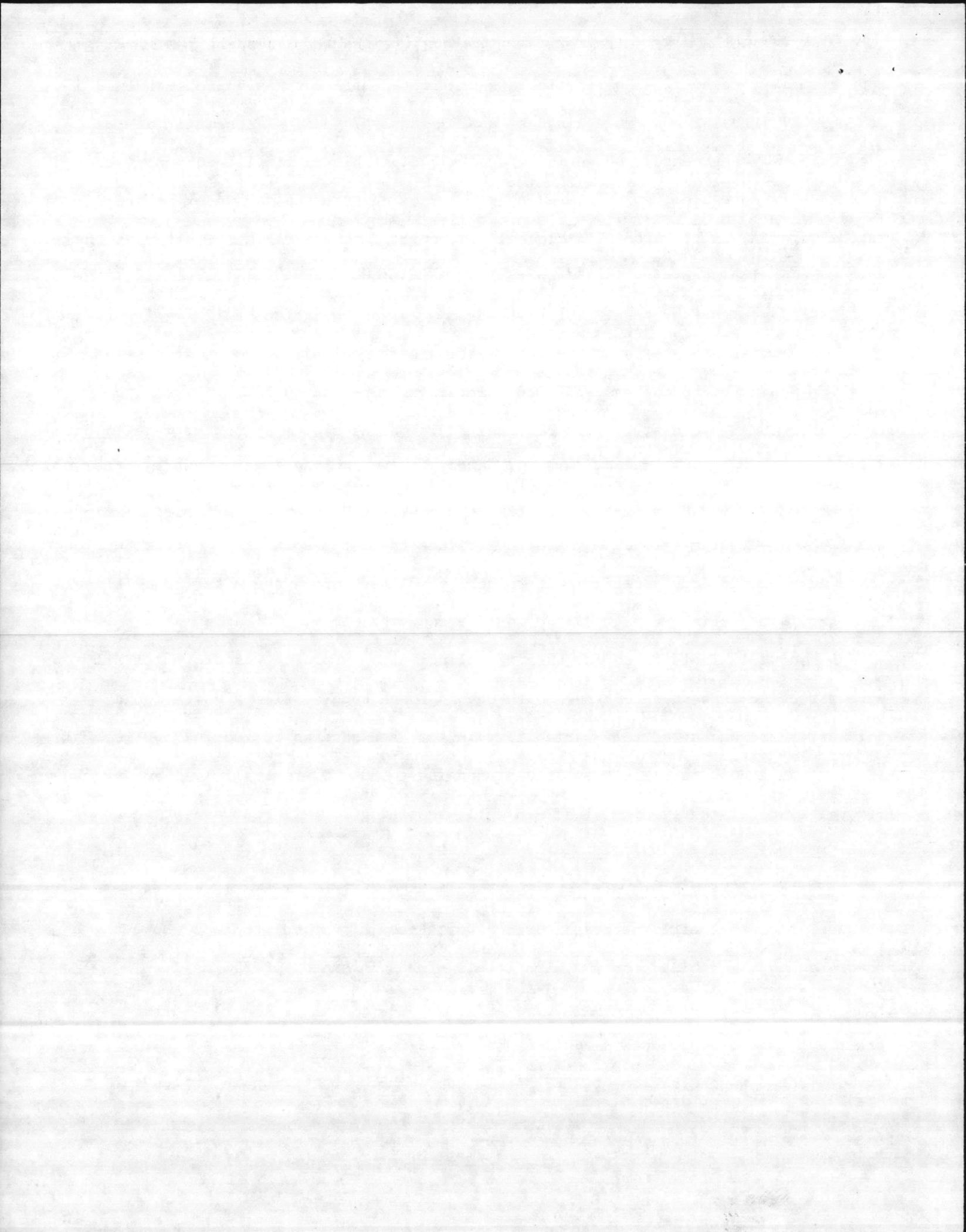
An influent flow rate of 10 GPM was used resulting in an overall detention time of approximately one hour. The recycle rate of treated effluent was approximately 3.5 GPM or 35%. Pressure was maintained at approximately 75 psi. A schematic of the pilot plant arrangement is shown in Figure 8. Adjustable chemical feed pumps were used to introduce alum, polymer, and sodium hydroxide into the raw water before it reached the DAF unit. A baffled flocculator, built into the DAF unit, afforded the quiescent period necessary for adequate floc formation.

Based upon the jar testing program, alum at a concentration of 120 mg/l was added to the raw wastewater followed by either cationic or nonionic polymers at dosages of 3 mg/l. Sodium hydroxide was added to maintain a proper pH (6-7).

In the SEAR process, Surfloc chemical addition and sodium hydroxide were injected into the inlet side of the pump with alum added in the outlet. Sodium hydroxide is used to improve the solubility of the Surfloc and was added to produce a desired inlet water of pH 9. Alum was added to further reduce the water solubility of the Surfloc which must be added as a sodium salt to achieve dispersion in the water. Additionally, alum provides particle charge disruption for coagulation.

As shown in Table 4, no one chemical flocculation approach was proven clearly more effective than another. Even with one approach such as alum plus cationic polymer, there was an extreme variability in the data such as 28% to 74% BOD removal (i.e., 1000 to 360 mg/l) in the effluent and 16% to 60% COD removal. Oil and grease removal is consistently high with 2-18 mg/l, remaining for all runs except when no chemicals were applied.

Comparison of Table 4 with the pretreatment guidelines, Table 1, indicates compliance of the DAF effluent, even for the worst case situation studied. However, a surcharge may be applied for the high levels of BOD in excess of 250 mg/l. With the holding and equalization capacity in the new FFS facilities, AFFF and other wastewater contaminants would be diluted from other wastewater sources. The projected concentration of AFFF should approximate that shown in Table 2.



The ratio (0.5) of this projected concentration (1.8%) in the overall FFS facility to the average concentration of AFFF used at Structure No. 9 during the course of this study (4.1%) was used to predict the attainable effluent quality of the pretreated wastewater. This predicted effluent from the overall FFS facility is shown in Table 7.

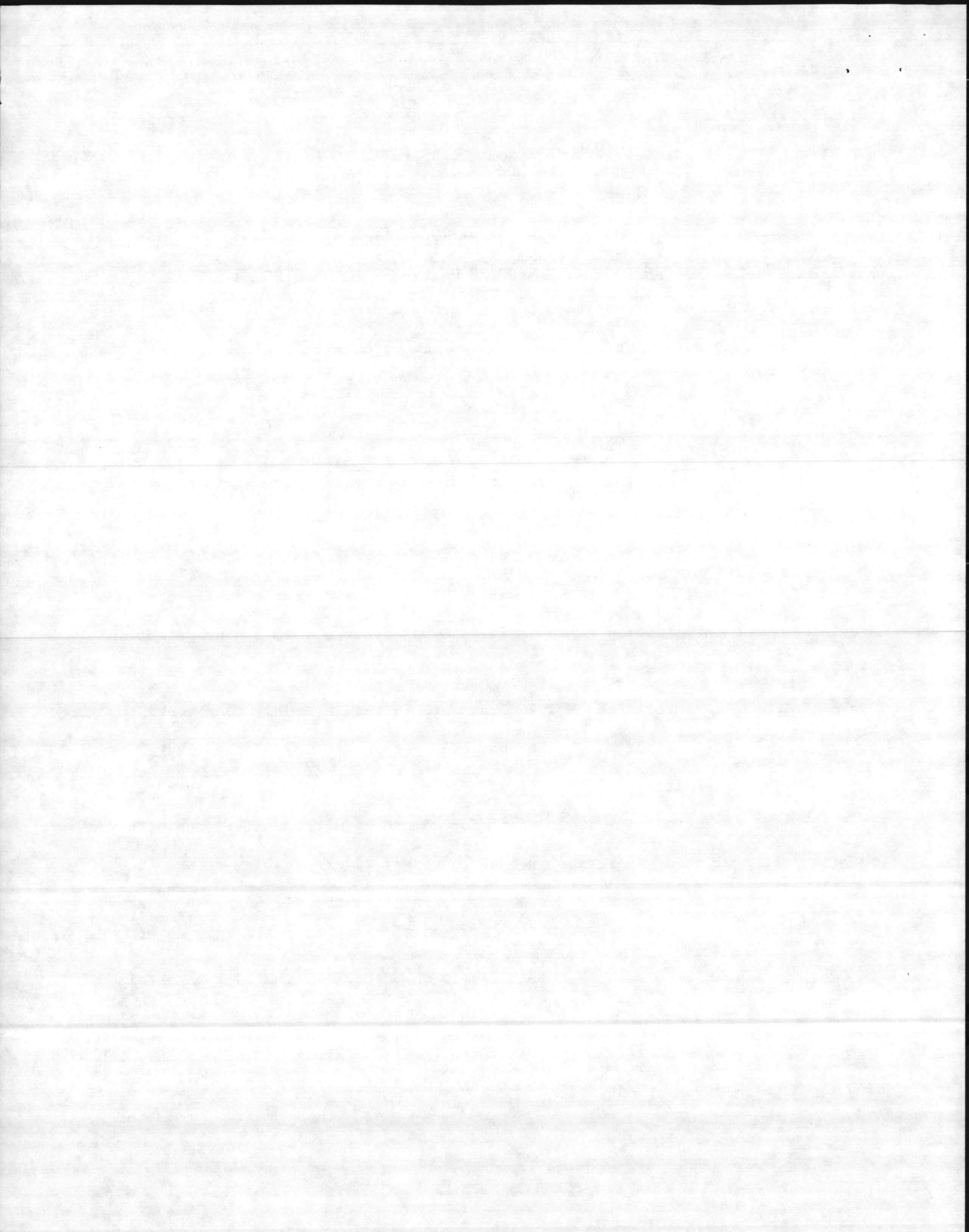
MBAS removal rates were on the order of 10 - 40% with effluent values consistently in the 15-50 mg/l range. One data point for the SEAR process indicates 48 mg/l effluent MBAS which was higher than the influent value of 40 mg/l. This high MBAS level indicates that the Surfloc chemical was not effective in removing surfactants from the waste.

## VII. SLUDGE CHARACTERIZATION

During the course of this study, float/sludge material generated in the DAF treatment was collected and analyzed with the following results:

a. Sludge Quantity - On average, 25 gallons of sludge material was generated per hour from 600 gallons of FFS wastewater. It was noted that this float/sludge material reduced in volume by approximately 40-50% after a 4 to 6 hour detention period.

b. Sludge Characteristics - The float material had a creamy foam consistency, varying in color from light to dark brown. The percent solids of the sludge material (Table 8) after the detention period ranged from 0.6% to 8.2% with an average of 4.4%. Float material detention time is critical for volume reduction. The consistency of the float material upon generation is such that only severe gravity slopes (i.e.,  $>45^{\circ}$ ) were effective in transporting this material from the DAF unit. A sludge thickening (compaction) tank has been provided adjacent to the DAF units in the new FFS facility. Two relatively high MBAS levels on October 19 and 20 were obtained during the operation with Surfloc in the SEAR process. The average heavy metal content of the sludge, presented in Table 8, indicates low concentrations of metals which will not limit sludge disposal options.



c. Sludge Dewatering - The pilot plant study did not include evaluations of alternative sludge treatment methods such as thickening, mechanical dewatering, incineration, land disposal, etc. However, information was collected describing the sludge characteristics (Table 8) to provide a preliminary basis for design of a sludge dewatering system.

Thickening of the float/sludge material is not an accurate description of the volume reduction process that occurred during the pilot study. The volume reduction process (Figure 9) is a foam collapse step rather than typical gravity thickening. The float material, when held for 4 to 6 hours, collapsed from a 80% foam/20% sludge mixture to a mixture containing approximately 10% foam and 90% sludge.

d. Ultimate Sludge Disposal - Feasible sludge disposal techniques under consideration include on-site dewatering by mechanical equipment or sand drying beds, contract disposal via truck hauling, direct discharge to existing sludge handling facilities, and incineration and landfill. The direct discharge and incineration methods are currently proposed for the Norfolk FFS. The POTW has dewatering equipment and facilities within pumping distance of the Norfolk FFS. The direct pumping of sludge to the POTW for final treatment is currently being discussed.

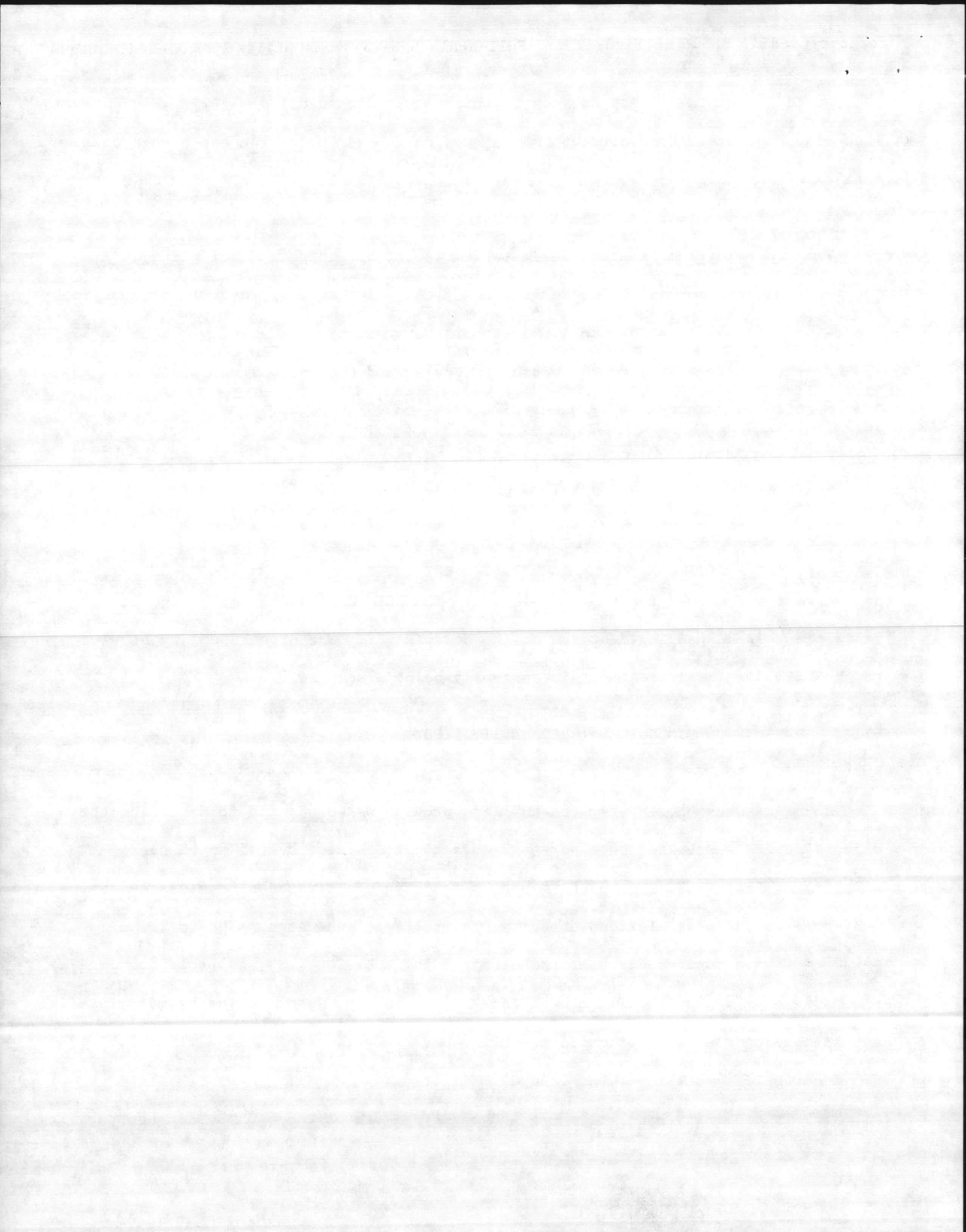
## VIII. PURE OXYGEN BIOLOGICAL TREATABILITY STUDY

### A. Summary

An eight week UNOX System treatability program was conducted to determine the effects of FFS wastewater on a pure oxygen activated sludge system to be constructed at the Army Base POTW. The performance of the oxygen activated sludge system, when subjected to various dilutions of FFS wastewater, was evaluated. The following parameters were monitored during the study; 5 day BOD, COD, TSS, and the Methylene Blue Active Substance (MBAS) removal capabilities of the system. The biomass settling and thickening characteristics of the activated sludge were also investigated.

### B. Treatability Facilities and Process Monitoring

1. Treatability Facilities - A schematic diagram of the UNOX System treatability



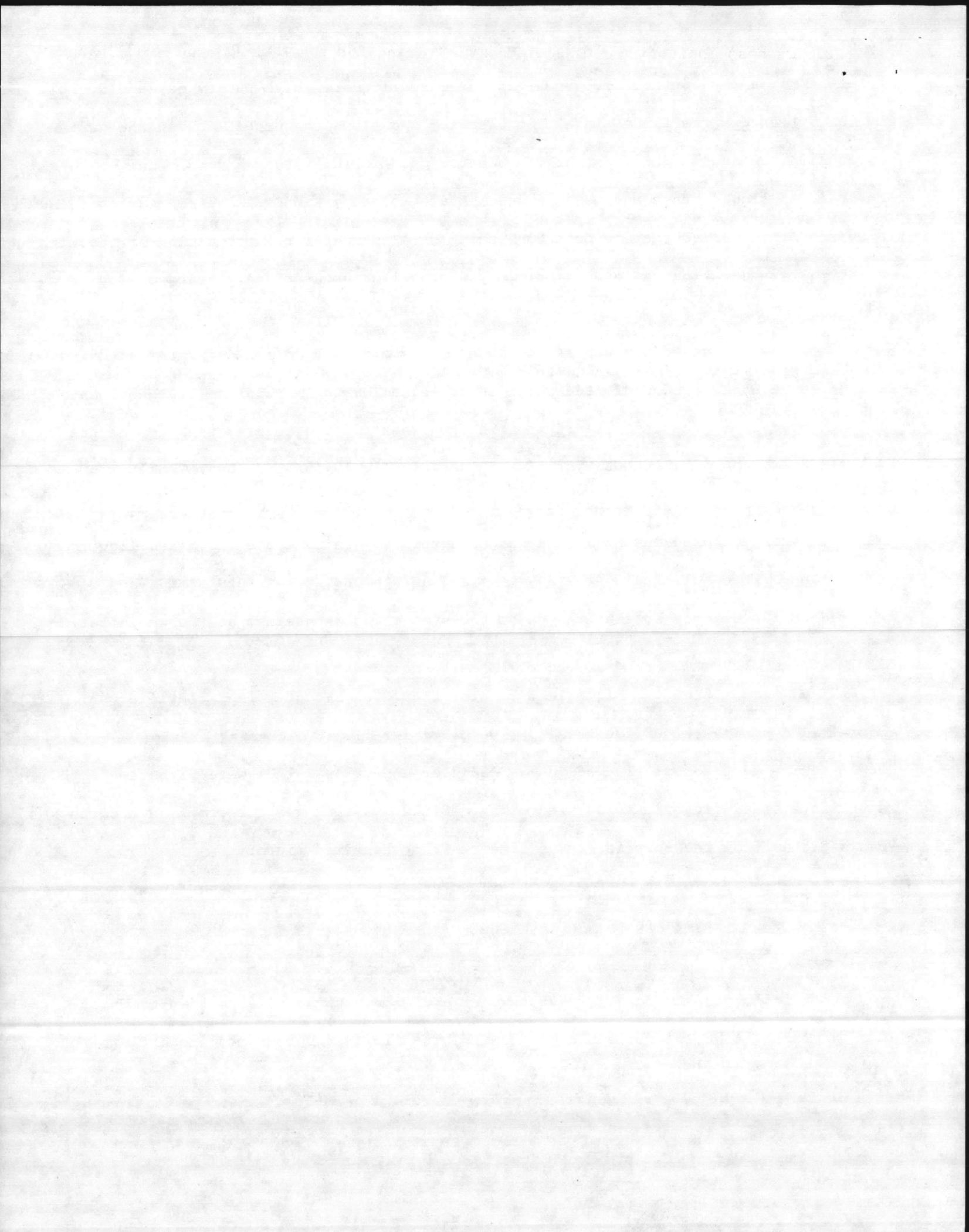
reactor used is shown in Figure 10. Full scale UNOX Systems utilize a covered, staged aeration basin for contact of oxygen gas and mixed liquor. High purity oxygen (90-98% by volume) enters the first stage of the system and flows concurrently with the wastewater being treated. The treatability reactor used in this study had only one uncovered gas-liquid stage and was operated as a complete mix unit. The reactor contains a sparger/impeller contacting unit consisting of a sparger for introduction of the high purity oxygen aerating gas and a marine type propeller used as the primary mixing device.

UNOX Systems generally operate at lower pH levels than do air activated sludge system because the carbon dioxide which is generated by the metabolism of the biomass is prevented from escaping directly to the atmosphere in the covered tanks. The gas space composition of the UNOX System vent is typically 10-15% CO<sub>2</sub> (by volume). The corresponding increase in dissolved CO<sub>2</sub> tends to depress the pH of the system. However, the reactor used in this study was open-topped. To simulate the mixed liquor conditions of the full scale Army Base system, an appropriate mixture of CO<sub>2</sub> and O<sub>2</sub> was fed to the reactor so that the pH of the system was maintained at the anticipated full scale pH of 6.5-6.8.

Mixed liquor from the biological reactor flowed to a center feed clarifier which contained a peripheral effluent weir. The clarifier had a thickening area of 0.025 square feet for settled solids. Clarifier underflow solids were withdrawn with a variable speed finger pump for recycling. Sludge wasting was performed on a batch basis either from the recycle sludge line or from the mixed liquor.

The wastewater was pumped into the first stage by a variable speed finger pump so that a range of feed rates, and a comparable range of liquid detention times, could be simulated.

Both influent Army Base T.P. wastewater and FFS wastewater were flown to Union Carbide daily. The two streams were then combined in the appropriate proportions to serve as the feed to the treatability reactor.



2. Process Monitoring - The process monitoring for the UNOX treatability system took two forms: Analytical and Operational. Table 9 summarizes the analytical monitoring and results obtained during the FFS study.

Operational monitoring took the form of measuring and calibrating influent and recycle flow rates as well as monitoring sludge wasting. Determination of pH and temperature on the influent, effluent and mixed liquor and dissolved oxygen concentrations in the mixed liquor were performed daily. Settling characteristics and 30 minute settled volumes with solids concentrations were also obtained. During each phase of the treatability study, two gallons of refrigerated effluent were shipped to the Bionomics lab for oyster larvae bioassay.

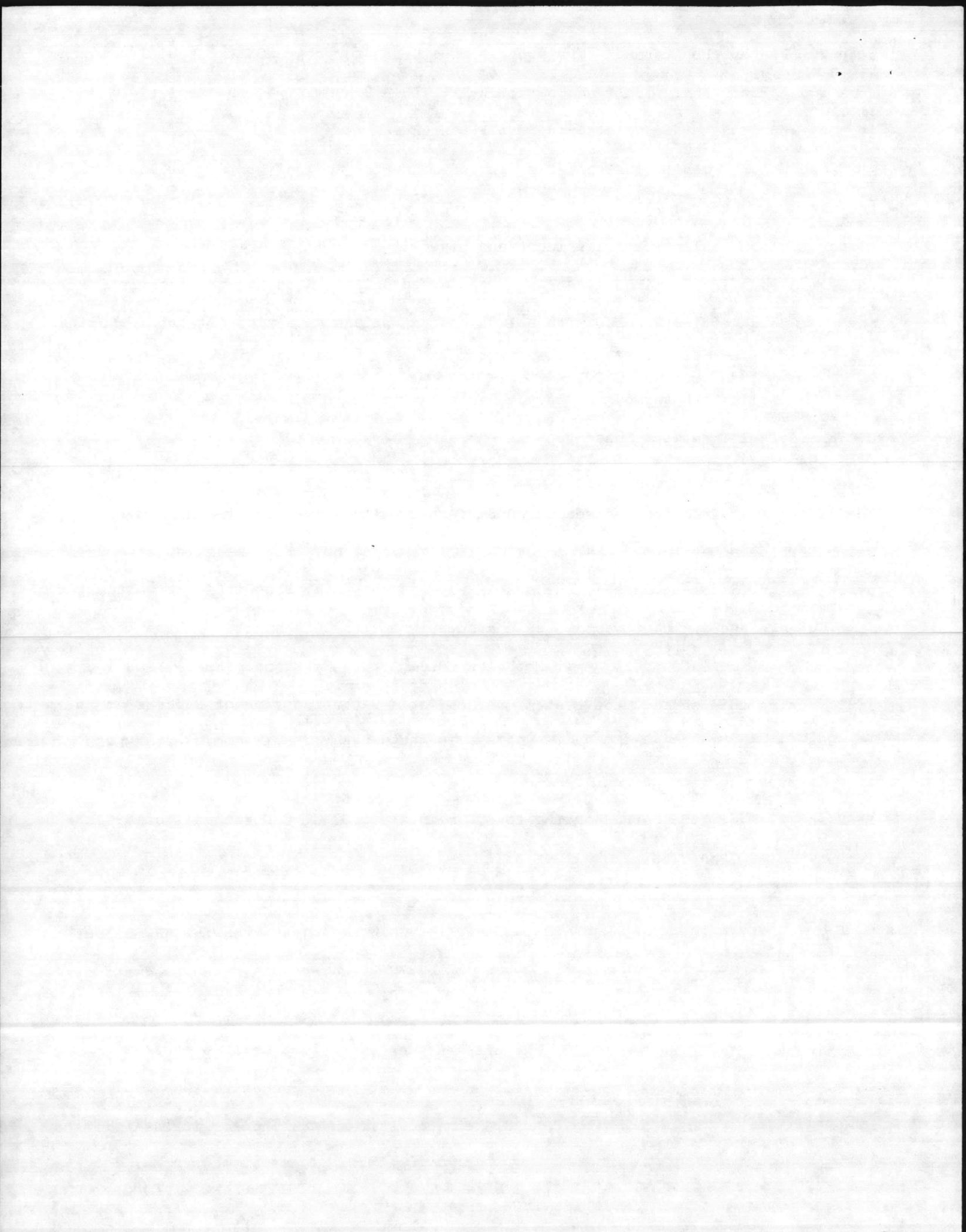
### C. Biological Treatment Phases

Table 9 summarizes the UNOX pilot plant performance for all phases of the program. The treatability reactor was seeded on September 6, 1977 with activated sludge from Union Carbide's Development Laboratories in Tonawanda, NY. For the first five days of operation (Start-up Phase), the system was fed only Army Base influent wastewater.

The average influent wastewater characteristics for the start-up phase were 258 mg/l BOD, 438 mg/l COD, 0.57 mg/l Methylene Blue Active Substance (MBAS), and 152 mg/l TSS. During this period, the system operated at a retention time of 2.52 hr at an average biomass loading of 0.93 lb BOD/day/lb MLVSS, and 1.58 lb COD/day/lb MLVSS.

Effluent quality during start-up averaged 79 mg/l BOD, 135 mg/l COD, 0.17 mg/l MBAS and 27 mg/l TSS, corresponding to BOD removals of 72%, COD removals of 69%, MBAS removals of 70% and TSS removals of 83%.

The last two days of the start-up period might be considered as the basis for predicting the performance of the oxygen activated sludge system in the absence of the FFS wastewater, although it is not known whether the system had achieved steady state after three days of operation. Substrate removals were quite low over the entire start-up phase. By September 10, the effluent concentrations were 25 mg/l BOD, 84 mg/l COD, 0.07 mg/l MBAS, and 18 mg/l TSS. These effluent concentrations indicated that 88% of the BOD, 80% of the COD, 87% of the MBAS, and 89% of the influent TSS had



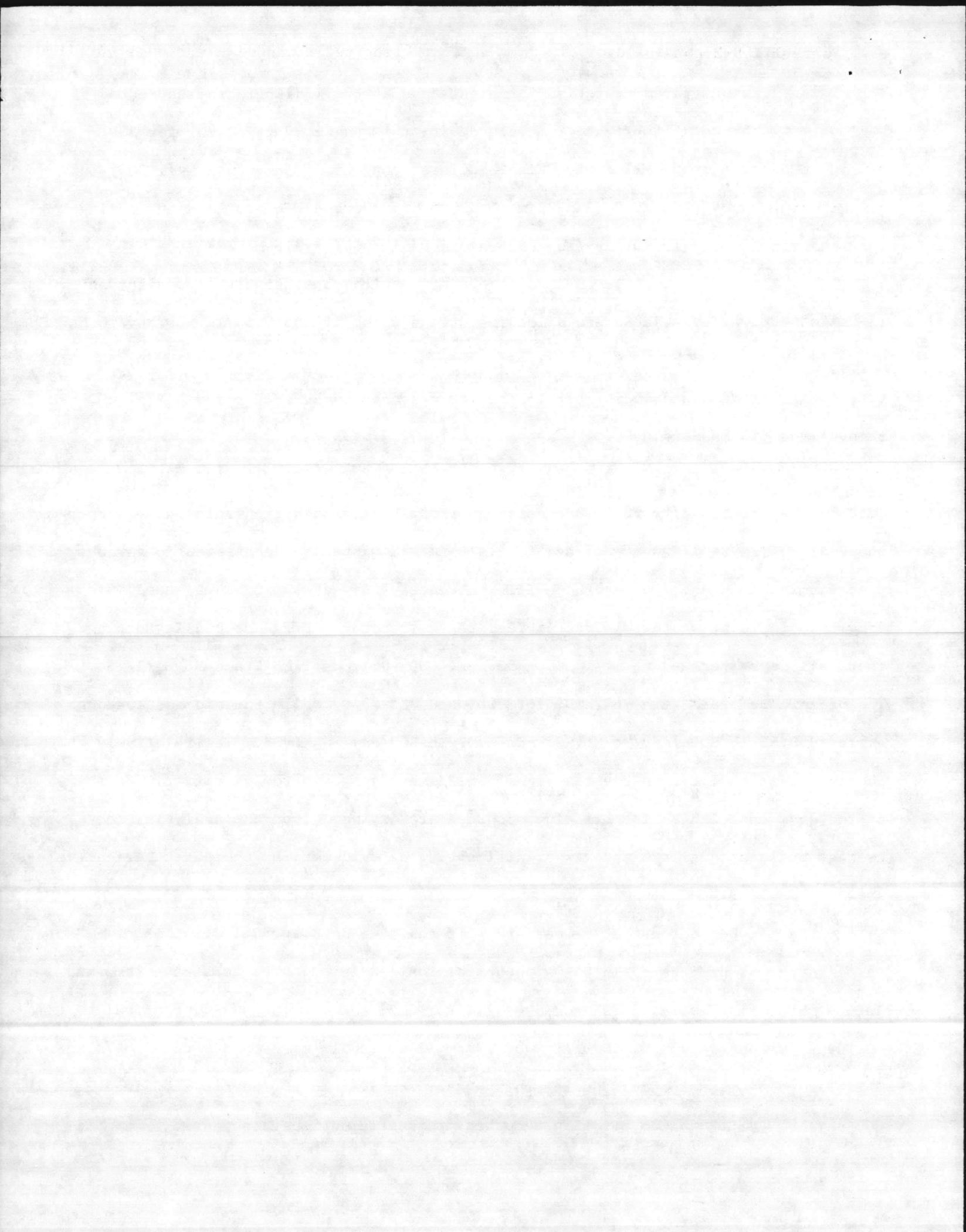
been removed by the system.

Phase I demonstrated operation for eight days at 300:1 dilution of untreated FFS wastewater. The total substrate removals during this phase averaged 73% for BOD, 75% for COD and 83% for MBAS; with final effluent concentrations of 42 mg/l BOD, 108 mg/l COD, 0.09 mg/l MBAS, and 29 mg/l TSS. The average biomass loadings during this phase were 0.38 lb BOD/day/lb MLVSS and 1.01 lb COD/day/lb MLVSS.

Phase II consisted of seven days of operation with considerable less dilution (100:1 of FFS waste). The average loading during Phase II was 0.51 lb BOD/day/lb MLVSS and 0.86 lb COD/day/lb MLVSS. Final effluent concentrations were 21 mg/l BOD, 86 mg/l COD, 0.11 mg/l MBAS and 15 mg/l TSS. This corresponds to 89% BOD removal, 76% COD removal and 81% MBAS removal.

Phase III began on September 26 and continued through the remainder of the study. Feed to the treatability reactor consisted of 50:1 dilution during this phase. Four subphases of Phase III were defined to evaluate FFS wastewater subjected to various pretreatment methods. During Phase III, untreated FFS wastewater was blended with Army Base influent waste to serve as feed to the reactor. Effluent quality during these six days averaged 65 mg/l BOD, 153 mg/l COD, 0.17 mg/l MBAS and 38 mg/l TSS. The organic removals were 76% BOD, 76% COD, and 73% MBAS, while the biomass loadings averaged 0.66 lb BOD<sub>5</sub>/day/lb MLVSS, and 1.59 lb COD/day/lb MLVSS. The relatively poor effluent quality was the result of "solids bridging" in the clarifier. However, if the days on which solids bridging occurred are excluded from the analysis, the average effluent quality improves significantly, as evidenced by the parenthetical values shown in Table 9.

Phase III B-1 demonstrated operation for thirteen days at 50:1 dilution of FFS waste which was pretreated in DAF without chemical addition. The substrate removals during this phase averaged 83% for BOD, 71% for COD, and 70% for MBAS with final effluent concentrations of 50 mg/l BOD, 139 mg/l COD, 0.19 mg/l MBAS, and 39 mg/l TSS. The average biomass loadings during this phase were 1.12 lb BOD/day/lb MLVSS and 2.14 lb COD/day/lb MLVSS. Solids bridging occurred frequently during this phase.



Phase III B-2 consisted of six days demonstrating performance at the same (50:1) dilution of DAF effluent pretreated with alum and cationic polymer. The average loading during Phase III B-2 was 0.26 lb BOD/day/lb MLVSS and 0.87 lb COD/day/lb MLVSS. Final effluent concentrations were 40 mg/l BOD, 122 mg/l COD, 0.14 mg/l MBAS and 42 mg/l TSS. This corresponds to 73% BOD removal, 69% COD removal and 75% MBAS removal. However, the rather high average effluent concentrations are primarily due to one day of shock loading. If this day is not included in the average values, the system may be considered to have produced acceptable effluent quality during this phase (see Table 9).

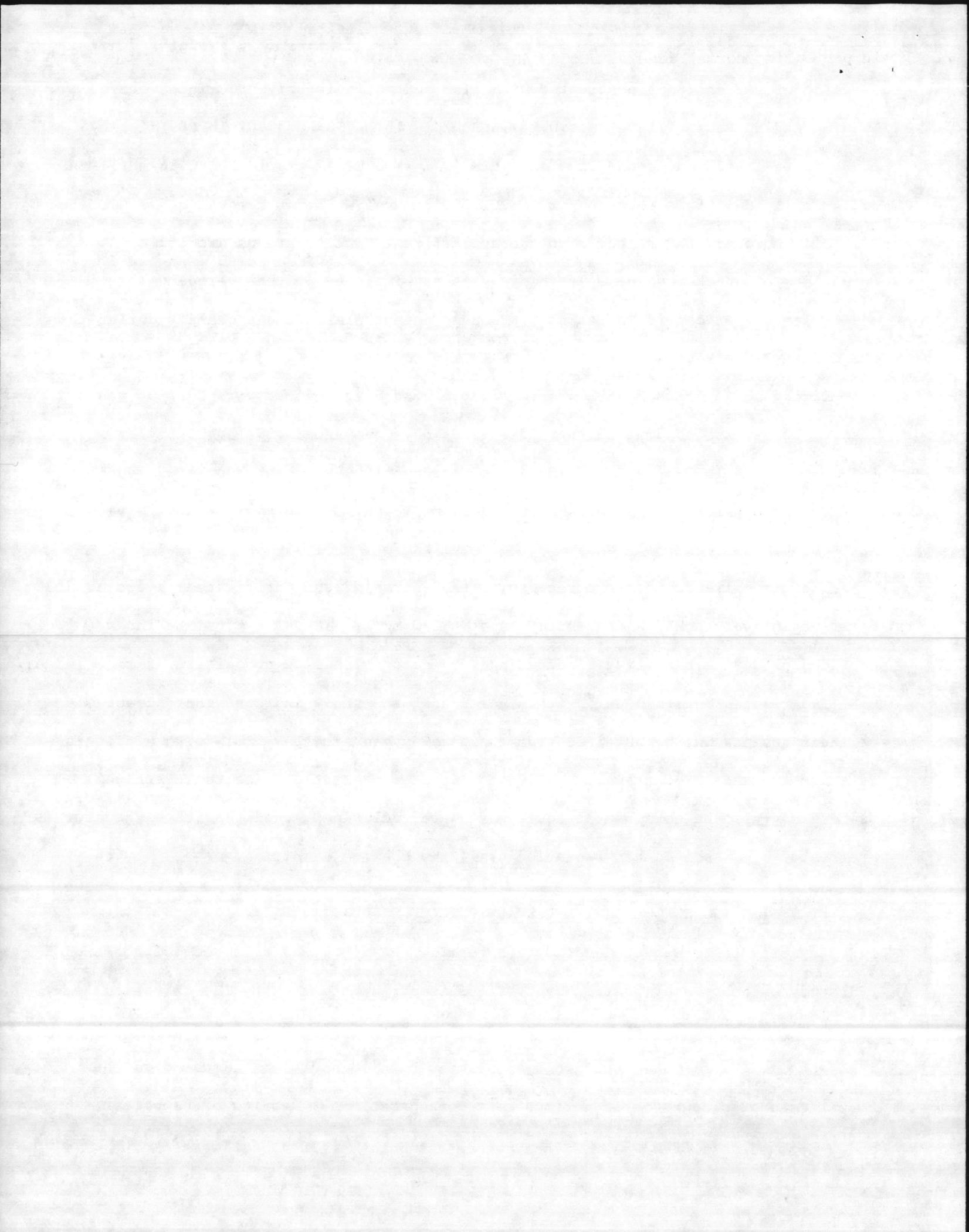
During Phase III B-3, FFS wastewater pretreated in the DAF with Surfloc was used. The biomass loading during these eight days averaged 0.30 lb BOD/day/lb MLVSS, and 0.70 lb COD/day/lb MLVSS. Effluent quality for this phase averaged 16 mg/l BOD, 54 mg/l COD, 0.14 mg/l MBAS and 15 mg/l TSS. The organic removals were 92% BOD, 88% COD, and 80% MBAS.

The mixed liquor settling rates over the course of the entire study averaged 5.3 ft/hr at an average MLVSS concentration of 6,290 mg/l. The sludge volume index (mg/gm) averaged 43 during the study, indicating very good thickening properties of the sludge.

The results obtained during this portion of the study indicate that acceptable effluent quality may be obtained from the pure oxygen Army Base POTW with a dilution of the untreated FFS wastewater by 100 to 1. It appears that acceptable effluent quality may also be obtained at lower wastewater dilutions, when the FFS wastewater is pretreated by dissolved air flotation utilizing chemical addition.

#### IX. FIRE FIGHTING SCHOOL OYSTER LARVAE TOXICITY STUDY

Toxicity tests were conducted to determine the effect of selected samples from the FFS study on embryos of eastern oysters (Crassostrea virginica). The criterion for effect was reduction of the number of normal embryos (those which developed to the fully-shelled, straight-hinged veliger stage within 48 hours) as compared to the number of control embryos in various test concentrations. Results of each test are expressed as a 48-hour EC50 (the concentration of effluent estimated to be effective



in preventing normal development of 50% of the exposed embryos).

A. Materials and Methods 11,12,13,14

1. Test material - All samples were stored at 5°C from time of receipt until testing began. Concentrations are reported as percent (%) of test material in seawater, based on volume: volume measurements. Sample description and a summary of the toxicity data are shown in Table 10.

2. Test Animals - Oyster embryos were obtained by induced spawning of adult oysters naturally conditioned in the field or at the Bionomics Marine Research Laboratory (BMRL) in flowing, unfiltered seawater.

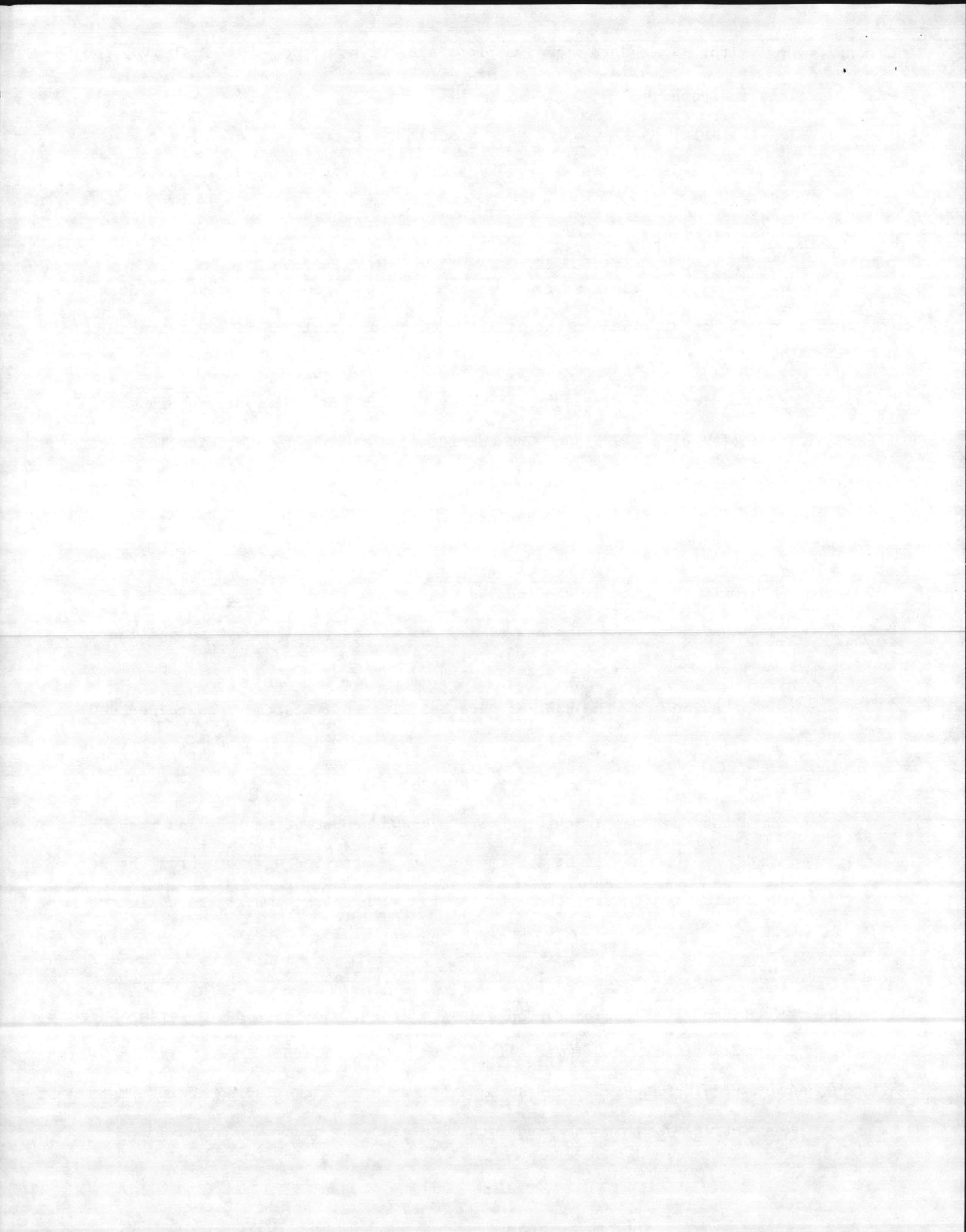
3. Test Conditions - Methods for testing with the 48-hour oyster embryos were based on those of Woelke (1972) and The Committee on Methods for Toxicity Tests with Aquatic Organisms (1975). Individual mature female oysters held in glass chambers containing 1 liter (l) of filtered (5-micrometer,  $\mu\text{m}$ ), natural seawater were induced to spawn by increasing the water temperature in the chamber from 26 to 35°C over a 60-minute interval. Density of the embryos was determined by averaging three 1-milliliter (ml) Sedgwick-Rafter counts of 1:99 dilutions (1 ml embryo suspension to 99 ml seawater) from the spawning chamber.

All concentrations and the control were triplicated. Test jars contained 900 ml of test solution with test concentrations prepared by adding appropriate volumes of test material to each container before the addition of embryos.

Each test container was inoculated with a known number of embryos and then maintained at  $20^{\circ} \pm 1^{\circ}\text{C}$  in a light and temperature controlled environmental chamber.

After 48 hours of exposure, the embryos from each test chamber were collected in a 37  $\mu\text{m}$  sieve, rinsed into a plastic bottle with filtered seawater, and preserved with neutralized formalin. The number of normally developed counts of three 1-ml subsamples from each triplicate test concentration and a control yielded a total of nine counts per treatment.

4. Statistical Analysis - When data were amenable to the moving average method of analysis (Harris, 1959), this was used for calculating 48-hour EC50's and 95%



confidence limits. When data were inappropriate for moving average analysis, the 48-hour EC50's and 95% confidence limits were calculated by probit analysis; that is, each test concentration was converted to a logarithm and the corresponding percentage reduction of normal embryos was converted to a probit (Finney, 1971). The 48-hour EC50 and 95% confidence limits were then calculated by linear regression.

#### B. Toxicity Data Analysis

Acute (48-hour) toxicity tests were conducted with embryos of eastern oysters on twenty samples collected from selected phases of the FFS study. In each test, the number of normal embryos in the control was compared to the number of normal embryos in the effluent concentrations and differences were expressed as percentage reduction of normal embryos. Then, a 48-hour EC50 was calculated, along with 95% confidence limits.

The toxicity of the samples ranged across four orders of magnitude (Table 10). The most toxic sample was FFSW - Pretreated (alum plus nonionic polymer) 10/27/77; the 48-hour EC50 was 0.06%. The least toxic effluent was FFSW - Pretreated (alum plus cationic polymer), 10/18/77; the 48-hour EC50 was 51%.

A Toxicity Potential Index (TPI) was defined in order to compare the toxicity data and is expressed:

$$\text{Toxicity Potential Index (TPI)} = \frac{100}{(\% \text{ dilution for EC50})}$$

In effect, the numerical value of the computed TPI is the number of times the particular sample requires dilution to meet 1 x EC50 criterion. The proposed criterion to be met is 0.01 EC50.

Indices were calculated from the toxicity data and plotted in Figures 11 and 12. Figure 11 describes toxicity relationships of both untreated and pretreated FFS waste. All the FFS pretreatment variations reduced waste toxicity except the DAF test run with alum plus nonionic polymer. The DAF test run with alum plus cationic polymer provided the best reduction in toxicity on one run but rather poor results on another. DAF with SEAR process provided consistently good results.

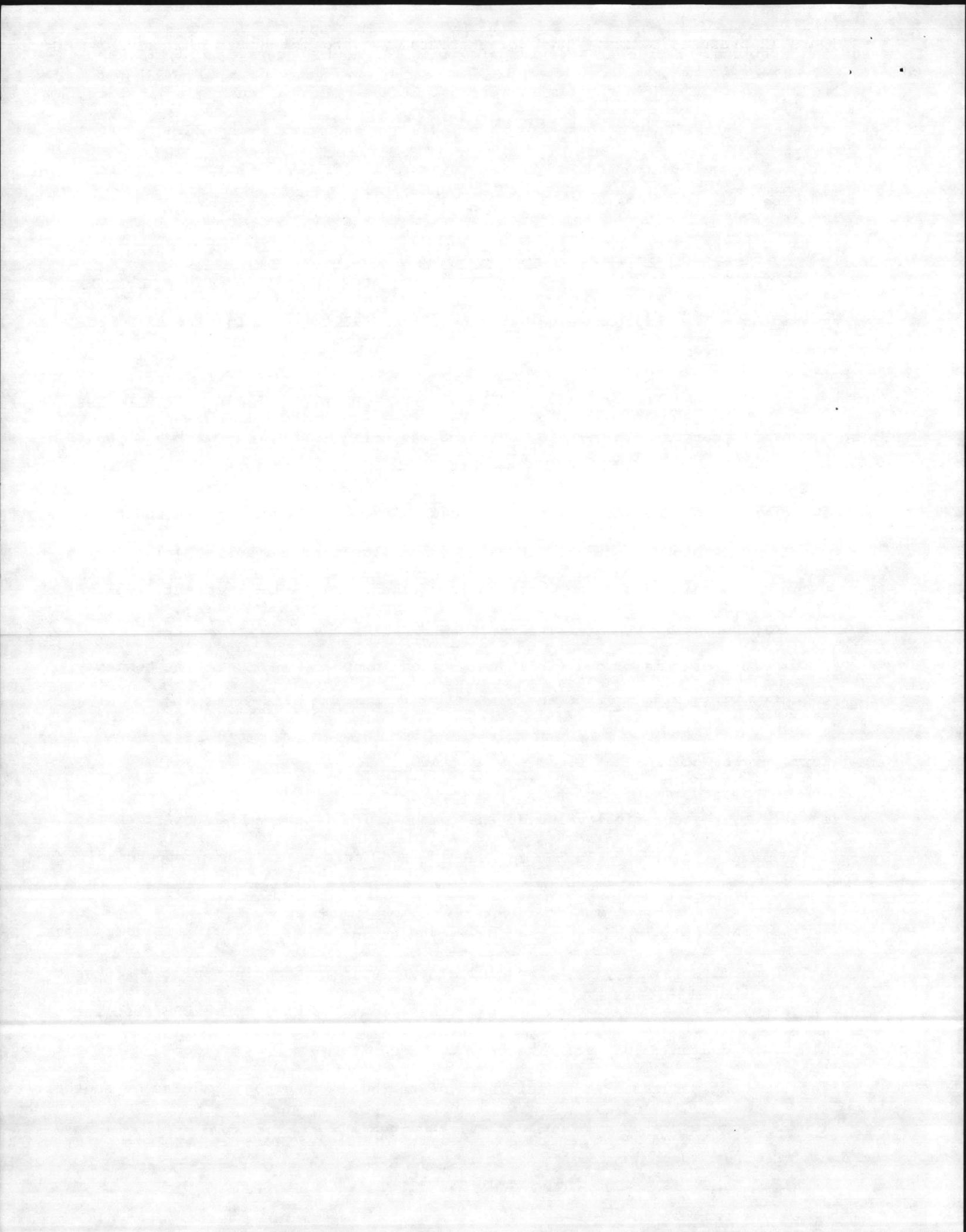
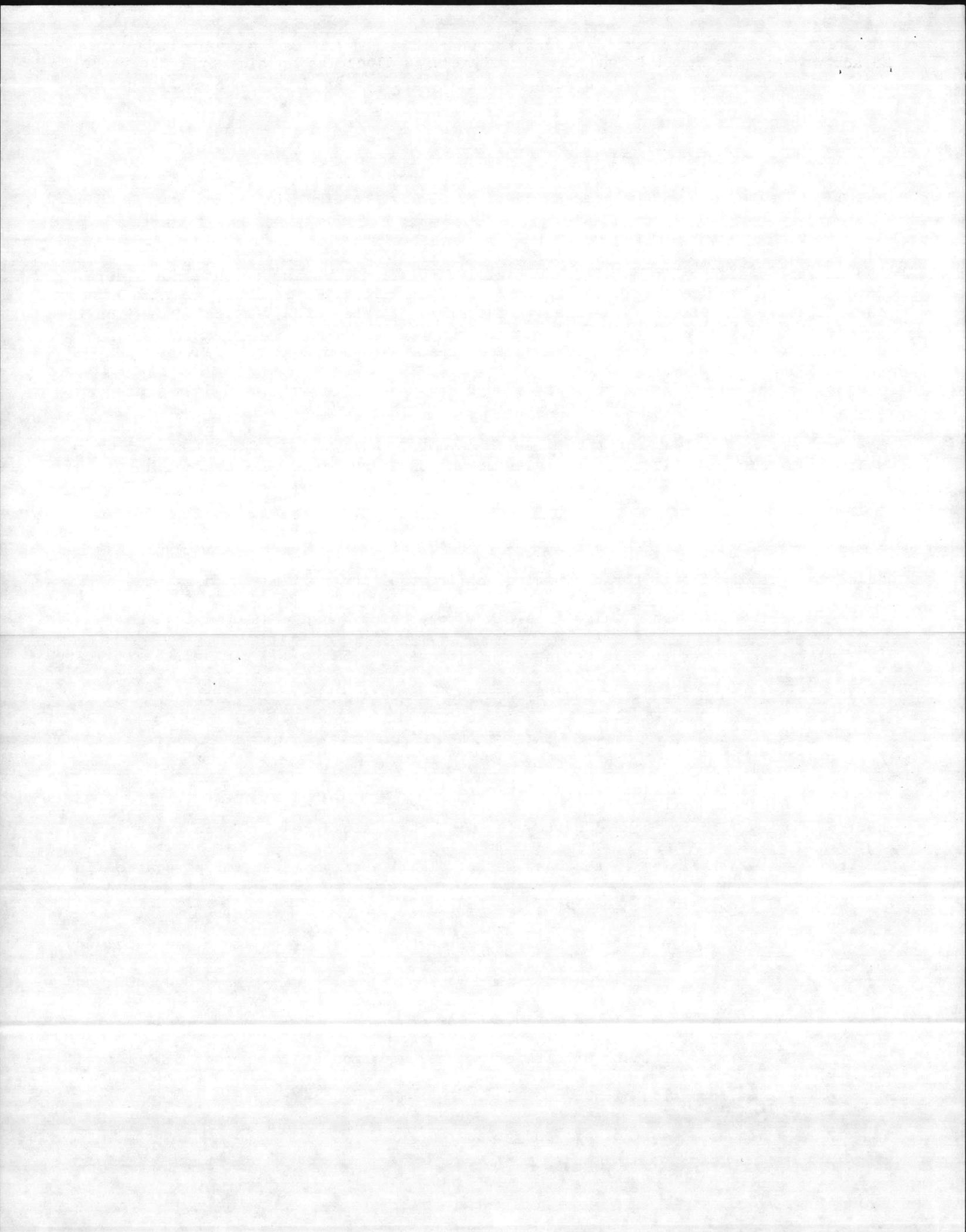


Figure 12 presents toxicity data for untreated and treated sewage with and without FFS waste. Note that untreated sewage toxicity is decreased in two cases by UNOX treatment to a level about 10 times the EC50. This, however, is still 1,000 times the proposed criterion. Addition of various concentrations of FFS pretreated and untreated waste to the UNOX process adds variability to effluent toxicity with the best results provided by the DAF with the SEAR's process.

A more conceptual view of these toxicity relationships is presented in Figure 13. Relative toxicity is presented in the diamond shape. The vertical dimension is a measure of the mean toxicity of a waste stream. The horizontal dimension is a measure of the variation in toxicity around the mean. (DAF with the SEAR's process toxicity data were used for this analysis). It is apparent that FFS pretreated waste adds some variability in toxicity to the UNOX treatment but does not alter mean toxicity. The resulting UNOX effluent with FFS waste is on the same order as UNOX effluent with no FFS waste. It is also important to note that FFS waste was added in a ratio of 50:1 for the biological treatability studies which assumes a FFS waste flow of 300,000 gpd, which is 6 times more volume than projected from the new FFS facility. Flow rate from the new facility will be 50 to 100 gpm and the toxicity data indicates that the biological system can adequately treat these flows.

## X. CONCLUSIONS

1. Alum (aluminum sulfate) at 120 mg/l is an effective coagulant for clarification of fire fighting school wastewater with the desired reduction in contaminants<sup>1</sup>. Due to the low alkalinity in the wastewater, alkali must be added for pH control in the range of 6 to 7 to insure floc formation.
2. There was no significant difference in the action of cationic, anionic, and nonionic polymers in combination with alum in removing oil and grease, COD, BOD, and MBAS.
3. The only significant effects of polymer addition at dosages of 3 mg/l are:
  - the formation of a dense floc
  - higher removal of oil and grease



No advantages were found in the use of polymers as flocculation aids over the use of alum only in the removal of BOD, COD and MBAS.

4. No one chemical DAF pretreatment approach clearly provides consistent removal of COD, BOD, TSS and surfactants, but all test runs comply with POTW pretreatment requirements.

5. The DAF with SEAR's Surfloc addition provided consistent toxicity reduction. However, the DAF with SEAR Surfloc pretreatment tends to add surfactant to the wastewater.

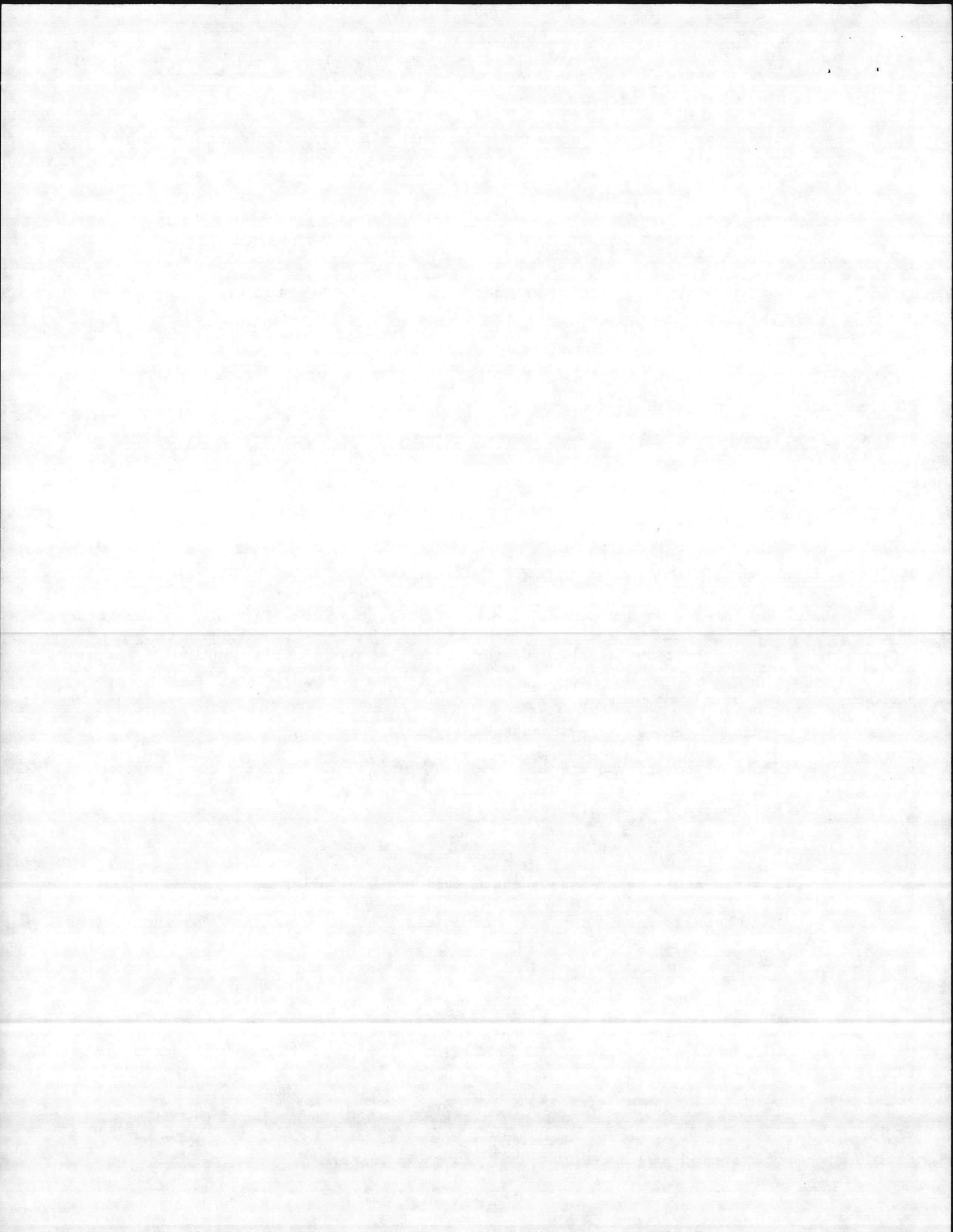
6. FFS waste had no effect on a pure oxygen biological treatment system in concentrations in excess of the expected FFS discharge.

7. Up to 50% of applied AFFF might be associated with the pad oil layer in the burn areas and could potentially be carried with combustion products contributing to the existing air pollution problem.

#### XI. FUTURE WORK

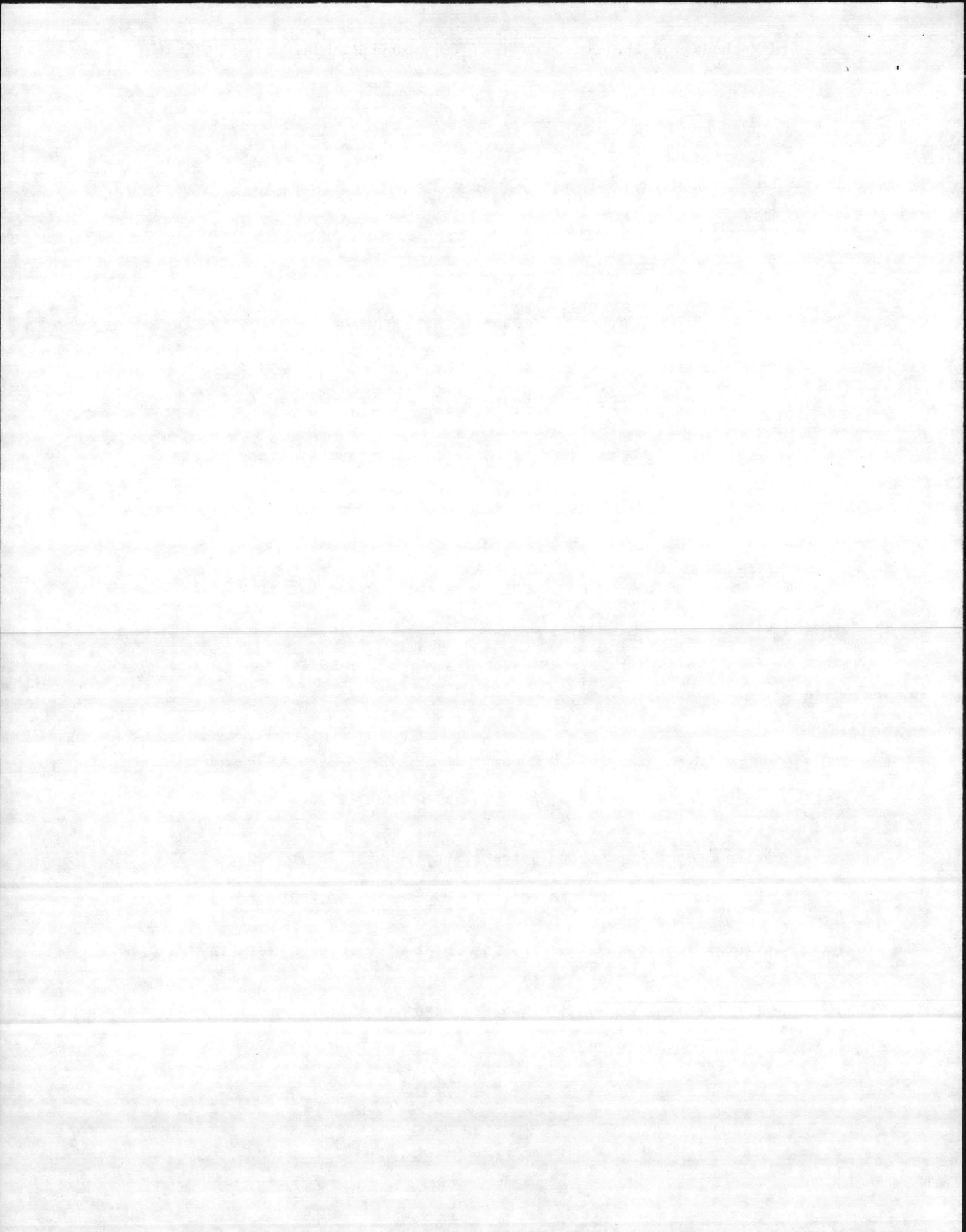
Based on this study and other efforts (Ref 15), the Civil Engineering Laboratory, at the Naval Construction Battalion Center, Port Hueneme, CA., is continuing research in the following areas:

1. Development of an AFFF standard analytical method
2. Establish toxicity criteria.
3. Development of cost-effective AFFF treatment alternatives.
4. Evaluate disposal options, and recovery and reuse potential.
5. Environmental Impact Assessment: Evaluate air pollution potential, soil absorption and biodegradation capacity and assess FFSW effect on soil microorganisms and vegetation.
6. Develop new AFFF formula: Investigate AFFF substitutes that are less toxic, easier to dispose of and are a more effective fire fighting agent. Develop new AFFF formula for testing.



## REFERENCES

1. "Physical-Chemical Treatment of Wastewater From Navy Firefighting Schools," Contract no. N00025-74-C-0004, Engineering Science, Inc., April, 1976.
2. Thomas, J.F., and LeFebvre, E.E., "Biodegradability and Toxicity of FC-200. Aqueous Film Forming Foam," Report No. EHL(K) 74-3, USAF Environmental Health Laboratory, Kelly AFB, Texas.
3. Kroop, R.K. and J.E. Martin, "Treatability of Aqueous Film-Forming Foams used for Fire Fighting," Technical Report AFWL-TR-279. Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico, February 1974.
4. LeFebvre, E.E. and Thomas, J.F. "Biodegradability and Toxicity of AER-O-WATER 3 and AER-O-WATER 6 Aqueous Film Forming Foam," Report No. EHL(K) 73-22, USAF Environmental Health Laboratory, Kelly Air Force Base, Texas, December 1973.
5. LeFebvre, E.E. and Inman, R.C., "Biodegradability and Toxicity of LIGHTWATER FC-206 Aqueous Film Forming Foam," Report No. EHL(K) 74-26, USAF Environmental Health Laboratory, Kelly Air Force Base, Texas, November 1974.
6. LeFebvre, E.E. and Inman, R.C., "Biodegradability and Toxicity of ANSUL K74-100 Aqueous Film Forming Foam," Report No. EHL(K) 75-3, USAF Environmental Health Laboratory, Kelly Air Force Base, Texas, January 1975.
7. Naval Environmental Protection Support Services (NEPSS), "Disposal of Aqueous Film Forming Foam (AFFF) Wastes," PS-003A (Rev. 18 Sept. 1975).
8. Annual Book of ASTM Standards, Part 31, Water, ASTM, Philadelphia, PA (1977).
9. Methods for Chemical Analysis of Water and Wastes, Environmental Protection Agency, Cincinnati, Ohio (1974).



10. Standard Methods for the Examination of Water and Wastewater, APHA-WPCF, 14th edition, Denver, CO (1977).
11. The Committee on Methods for Toxicity Tests With Aquatic Organisms. 1975. Methods for acute toxicity tests with fish, macroinvertebrates, and amphibians. U.S. Environmental Protection Agency, Ecological Research Series No. EPA-600/3-75-009.
12. Finney, D.J. 1971. Probit Analysis. Cambridge University Press, London.
13. Harris, E.K. 1959. Confidence limits for the LD50 using the moving average angle method. Biometrics, September.
14. Woelke, C.E. 1972. Development of a receiving water quality bioassay criterion based on the 48 hour Pacific oyster (Crassostrea gigas) embryo. Washington Department of Fisheries, Technical Report no. 9.
15. D.B. Chan, Disposal of Wastewater Containing Aqueous Film Forming Foam (AFFF), February 1978.

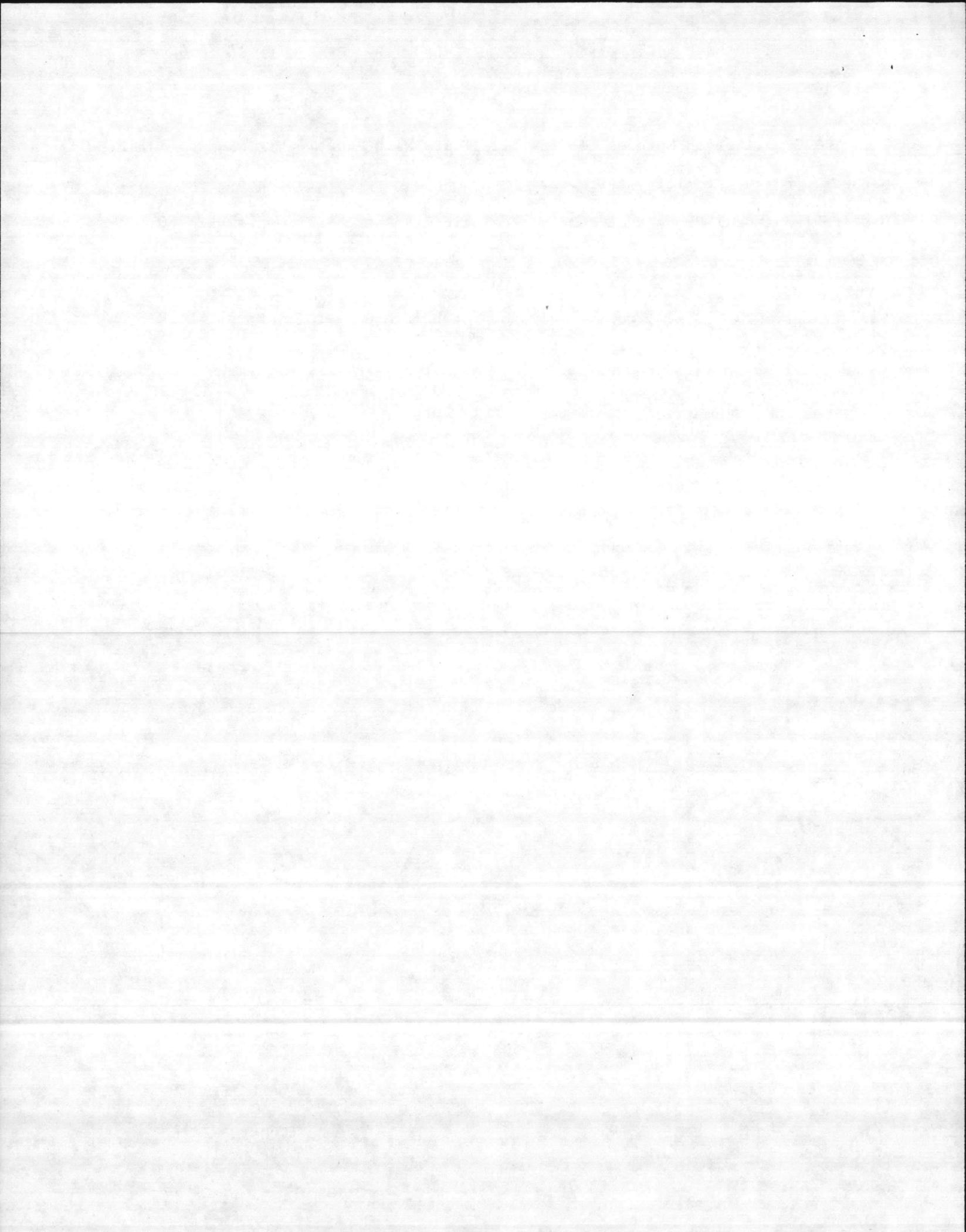


TABLE 1. HRSD PRETREATMENT LIMITS

<u>PARAMETER</u>	<u>CALENDAR MO. AVERAGE*</u> <u>(mg/l)</u>	<u>CALENDAR DAY MAXIMUM**</u> <u>(mg/l)</u>
Arsenic	0.1	0.1
Boron	1.0	1.0
Cadmium	0.1	0.1
Chromium, Total	2.0	5.0
Copper	2.0	5.0
Cyanide	0.5	1.0
Lead	1.0	2.0
Mercury	.01	0.02
Nickel	1.0	2.0
Phenolic Compounds	1.0	2.0
Silver	0.25	0.5
Zinc	2.0	5.0
Oil & Grease (Non-Saponifiable)	100	100
pH	6.0-9.0 pH units	6.0-9.0 pH units

\* Average of any number of daily values obtained during a calendar month.

\*\* Maximum for any sample obtained during any calendar day.

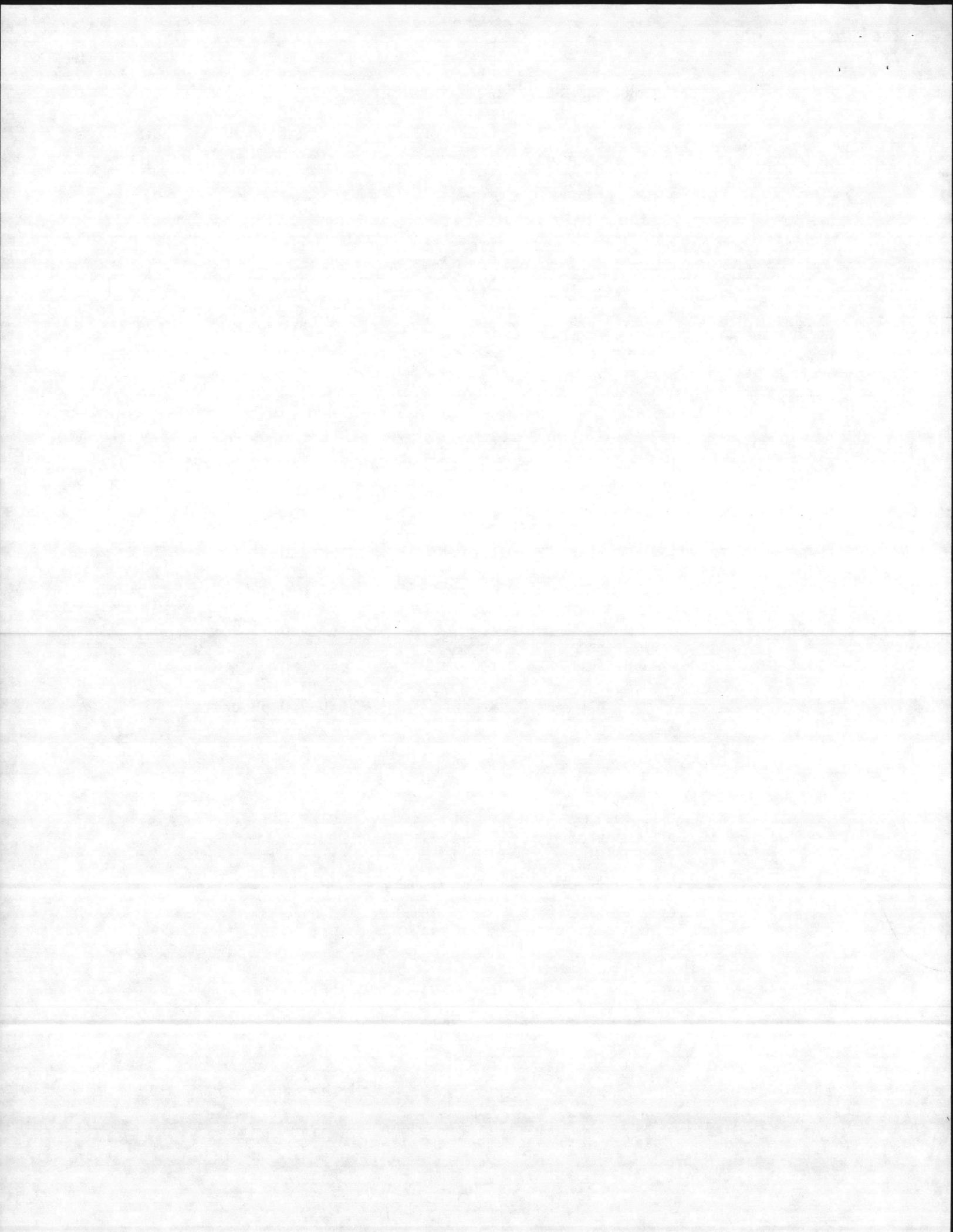


TABLE 2. PROJECTED AFFF & WASTEWATER GENERATION

	<u>AFFF (gal)</u>	<u>Wastewater (gal)</u>	<u>Concentration (%)</u>
Monday	134	10,625	1.3
Tuesday	390	24,100	1.6
Wednesday	212	6,145	3.4
Thursday	722	35,620	2.0
Friday	<u>284</u>	<u>19,610</u>	<u>1.4</u>
TOTAL	1,742	96,100	-
AVG.	348	19,220	1.8

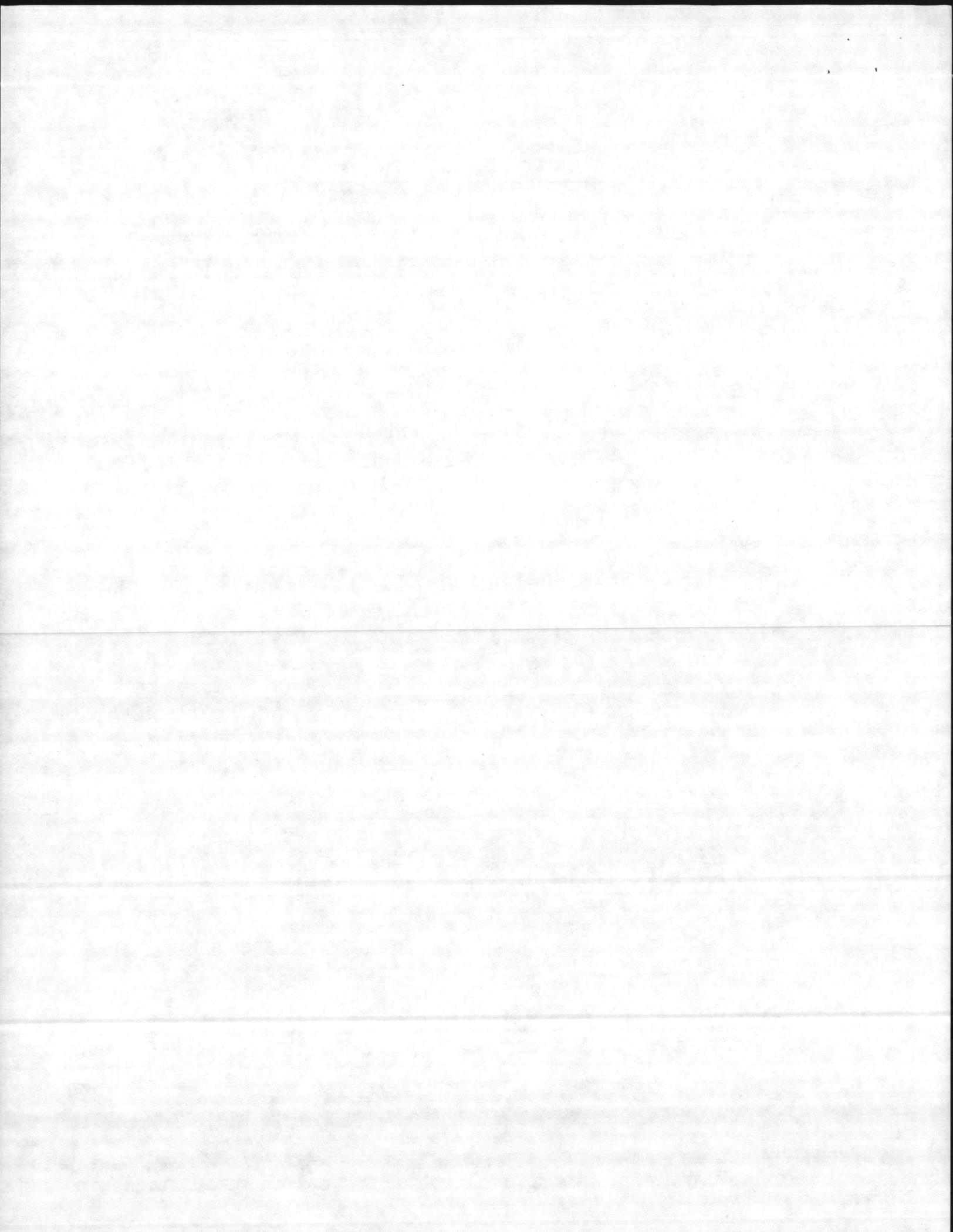


TABLE 3. FIRE FIGHTING EXERCISES  
(FIRE RATE WAS 500 GPM FOR ALL FIRES CONDUCTED.)

Date	Hose Connection*	Fire Cycle No.	Fire Cycle Time (min)		AFFF Usage (gal)	Waste Volume (gal)	Applied AFFF Concentration (%)
			Pieburn	Extinguish			
13 Oct 77	Close	1	2.0	0.82	16	410	3.9
		2	2.0	0.96	17	480	3.5
		3	3.08	0.82	16	410	3.9
		Avg	2.46	0.87	16.3	433	3.8
18 Oct 77	Far	1	1.58	0.85	19	425	4.5
		2	2.74	0.85	19	440	4.3
		3	2.0	0.85	18	425	4.2
		Avg	2.25	0.86	18.7	430	4.3
19 Oct 77	Close	1	1.08	1.2	5	600	0.8
		2	2.0	0.91	5	455	1.1
		3	1.34	1.5	8	750	1.1
		Avg	1.47	1.2	67	601	1.07
20 Oct 77	Far	1	2	1.16	40	580	6.9
		2	2	1.0	25	500	5.0
		3	2	1.59	17	795	2.1
		Avg	2	1.25	27.3	697	3.9
21 Oct 77	Close	1	1.92	1.0	30	500	6.0
		2	3.42	0.92	20	460	4.3
		3	6.34	0.63	17	315	5.4
		Avg	2.89	0.85	22	425	4.0
Avg of All Fires Monitored (8/77-10/77)			2.7	0.89	19	451	4.0

\* Close = Hoses connected to the closest hydrants near the AFFF proportioner.  
Far = Hoses connected to farthest hydrants from the AFFF proportioner.

NOTE: Approximately 10 gal of AFFF were used per exercise (three or more fire cycles) for nozzle check out and familiarization. Included in final usage figures.

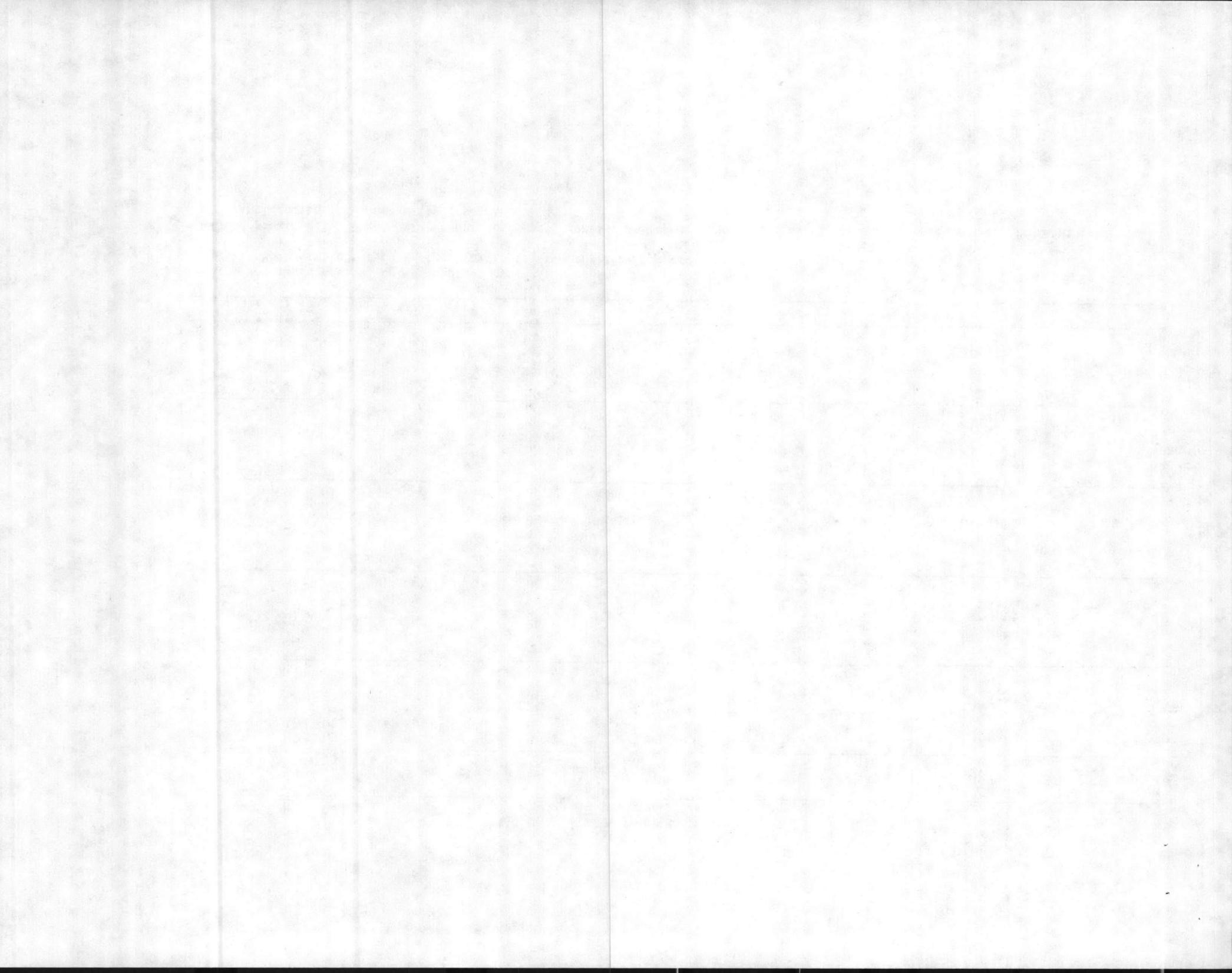


TABLE 4. WASTEWATER CHARACTERIZATION  
AND  
DAF PILOT PLANT RESULTS

DATE	BOD (a)			COD			OIL & GREASE			TSS			SURFACTANTS AS MBAS			pH	
	*INF	EFF	%R	INF	EFF	%R	INF	EFF	%R	INF	EFF	%R	INF	EFF	%R	INF	EFF
9/30 No chemicals	1,100	840	24	3,264	2,448	25	1,877	207	89	160	92	42	21.2	16.5	22	7.3	7.15
10/14 Alum only	1,648	1,009	39	2,597	1,945	25	108	15	86	14	8	43	28	16	43	6.35	6.08
10/13 Alum + Cationic	1,413	1,009	28	2,064	1,740	16	16.6	8.5	49	16.5	6.5	61	25	17	32	6.45	5.61
10/18 Alum + Cationic	1,406	360	74	3,748	1,489	60	12.6	5.13	59	130	14	89	33	15.8	58	6.32	6.11
AVG	1,410	685	50	2,906	1,614	38	15	7	56	73	10	75	32	16	45	6.4	5.8
10/19 Alum + SEAR	736	448	39	2,602	1,560	42	41.4	8.5	79	188	30	84	33	20.2	39	6.79	6.42
10/20 Alum + SEAR	713	621	13	5,180	4,094	21	45	29	36	52	24	54	40	48	-	6.71	5.7
AVG	725	535	26	3,891	2,827	32	43	19	57	120	27	69	36	34	-	6.7	6.1
10/21 Alum + Nonionic	877	645	26	3,788	3,119	18	44	-	-	46	15	67	42	35	17	6.74	6.17
10/27 Alum + Nonionic	1,450	151	89	2,951	1,832	26	361	17.5	95	316	11	96	27	24	11	6.78	5.7
11/2 Alum + Nonionic	4,070	444	89	2,851	2,188	23	101	2.3	77	41	40	-	27	17.4	36	6.40	6.51
AVG	2,132	413	68	3,196	2,406	22	169	9.9	86	134	22	82	32	25	22	6.6	6.1
TOTAL AVG(b)	1,480	614	59	3,227	2,208	28	91	12.3	66	157	16	75	31	23	26	6.6	6.0

\* INF - Influent  
EFF - Effluent  
%R - Per Cent Removal

(a) Results are in mg/l unless otherwise noted.

(b) TOTAL AVG - Average of all influent analysis and average of only the effluent from Pilot Plant runs utilizing alum + polymers

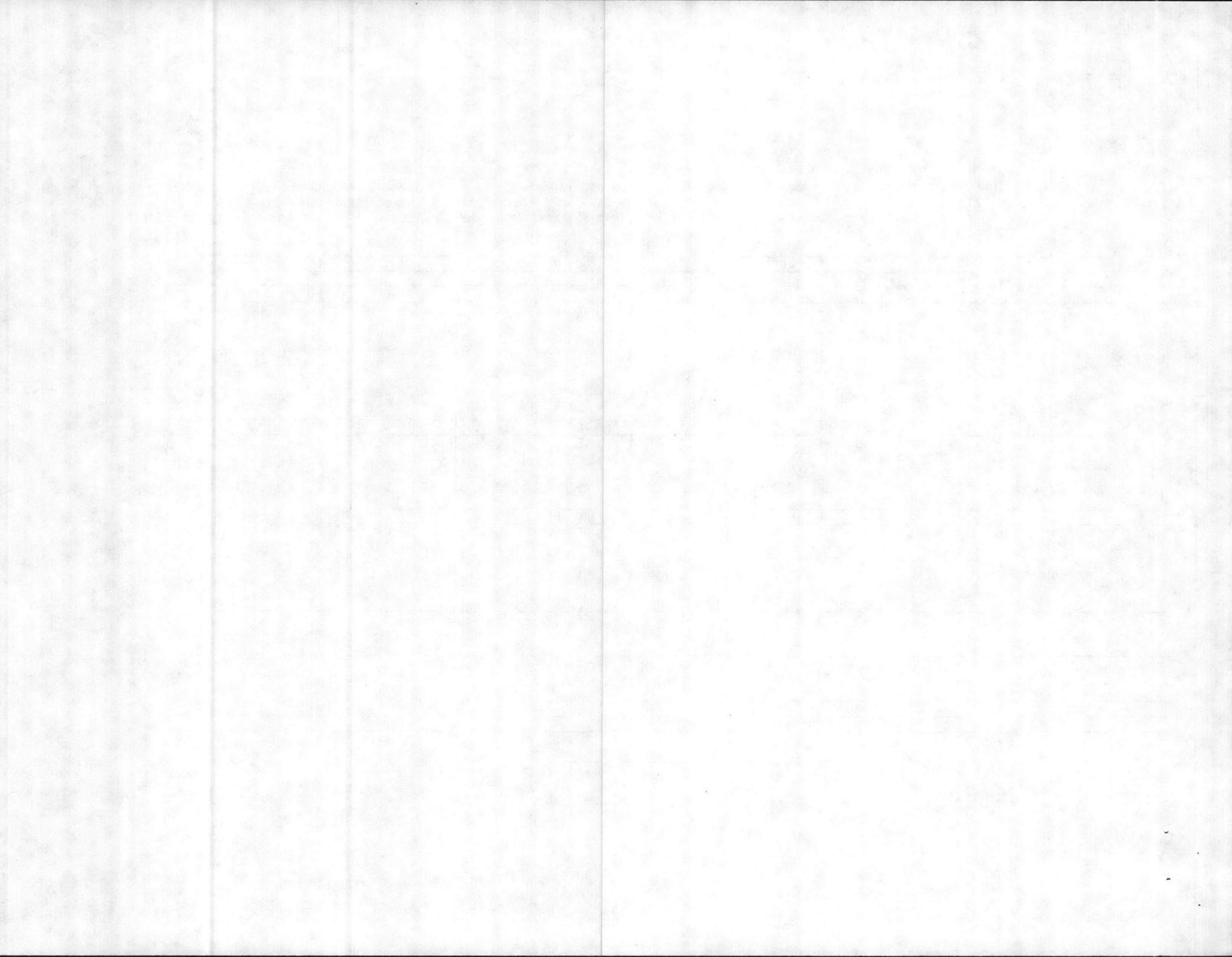


TABLE 5. WASTEWATER CHARACTERIZATION  
AND  
DAF PILOT PLANT RESULTS  
NUTRIENTS AND HEAVY METALS

<u>Parameter</u> <sup>a</sup>	<u>INF</u> <sup>b</sup>	<u>EFF</u>
NH <sub>4</sub> <sup>c</sup>	3.5	3.8
NO <sub>2</sub>	0.1	0.06
NO <sub>3</sub>	0.2	0.06
TKN	15.3	8.1
ORTHO PO <sub>4</sub>	0.13	0.03
TOTAL P	0.3	0.03
SULFATE	14.8	103
Cd	0.005	0.005
Cr (Total)	0.01	0.01
Cu	0.09	0.05
Fe	5.3	2.2
Pb	0.02	0.01
Mg	4.2	2.6
Hg	0.002	0.002
Ag	0.01	0.01
Zn	0.37	0.44

(a) Results are in mg/l unless otherwise noted.

(b) Inf = Influent; Eff = Effluent

(c) Average of all influent analysis and average of only the effluent analysis from pilot plant runs utilizing alum + polymers.

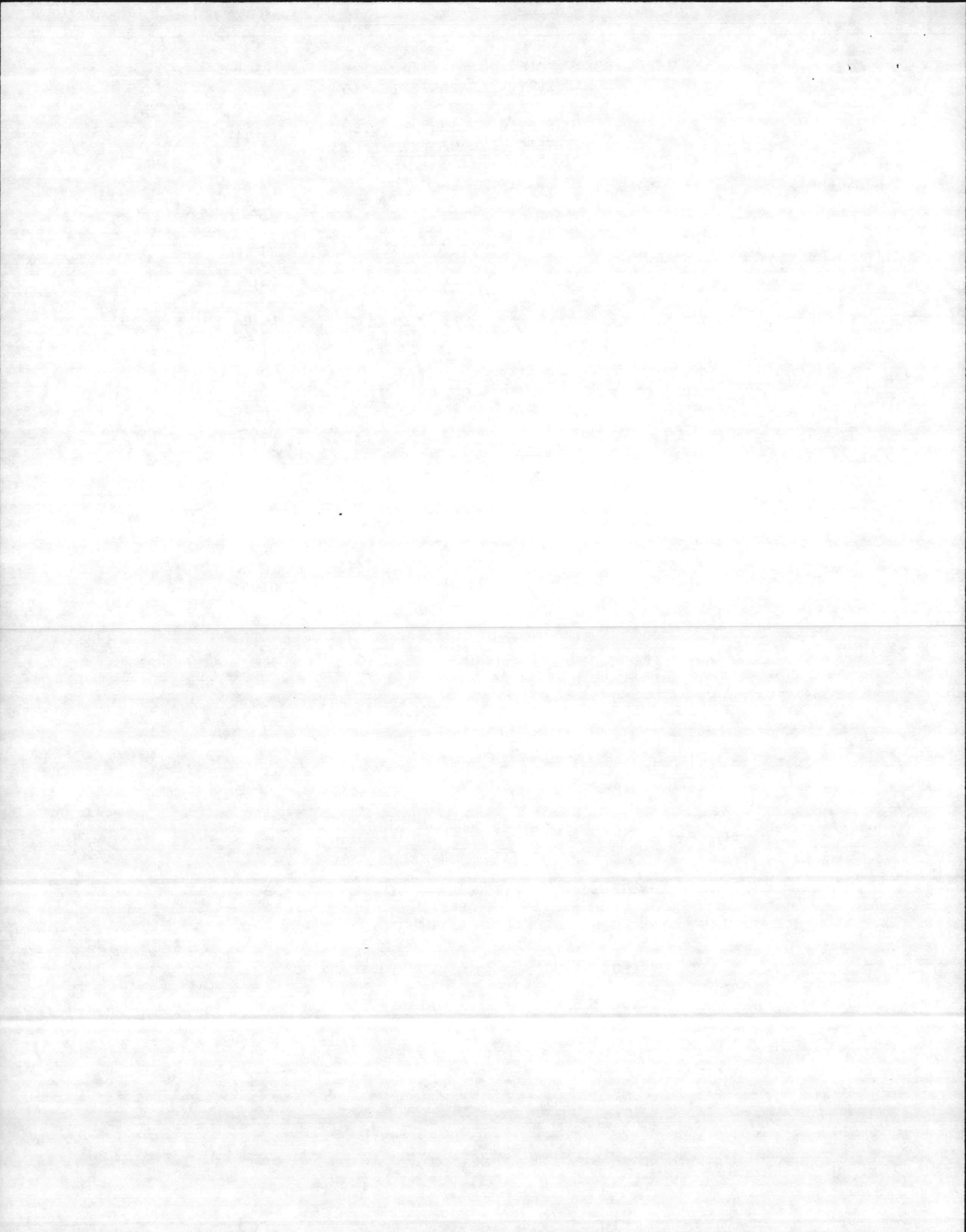


TABLE 6. BENCH SCALE COAGULATION TESTS  
ALUM PLUS POLYMERS

<u>COAGULANT</u>	<u>COD</u> ppm O <sub>2</sub>	<u>BOD</u> ppm O <sub>2</sub>	<u>MBAS</u> ppm	<u>OIL &amp; GREASE</u> ppm
Original (untreated)	3830	2620	35	960
Alum only	350	330	26	78
Alum + Primafloc C3 (cationic)	340	320	28	32
Alum + Hercufloc 834 (cationic)	340	310	23	37
Alum + Primafloc A10 (anionic)	340	320	25	50
Alum + Magnifloc 835A (anionic)	320	290	26	23
Alum + Purifloc N20 (nonionic)	330	290	25	47
Alum + Hercufloc 827 (nonionic)	370	340	28	40

Alum dosage all: 120 ppm  
 Caustic dosage all: 80 ppm  
 Polymer dosage all: 3 ppm

TABLE 7. PROJECTED EFFLUENT WASTEWATER CHARACTERISTICS

<u>Parameter</u>	<u>Minimum</u>	<u>Average</u>	<u>Maximum</u>
BOD	76	307	505
COD	745	1,104	2,047
Oil & Grease	10	10	15
TSS	5	8	20
MBAS	8	12	24

NOTE:

Example calculation for BOD:

From Table 4; Avg. Eff. BOD  $615 \times 0.5 = 307$  (projected wastewater concentration).

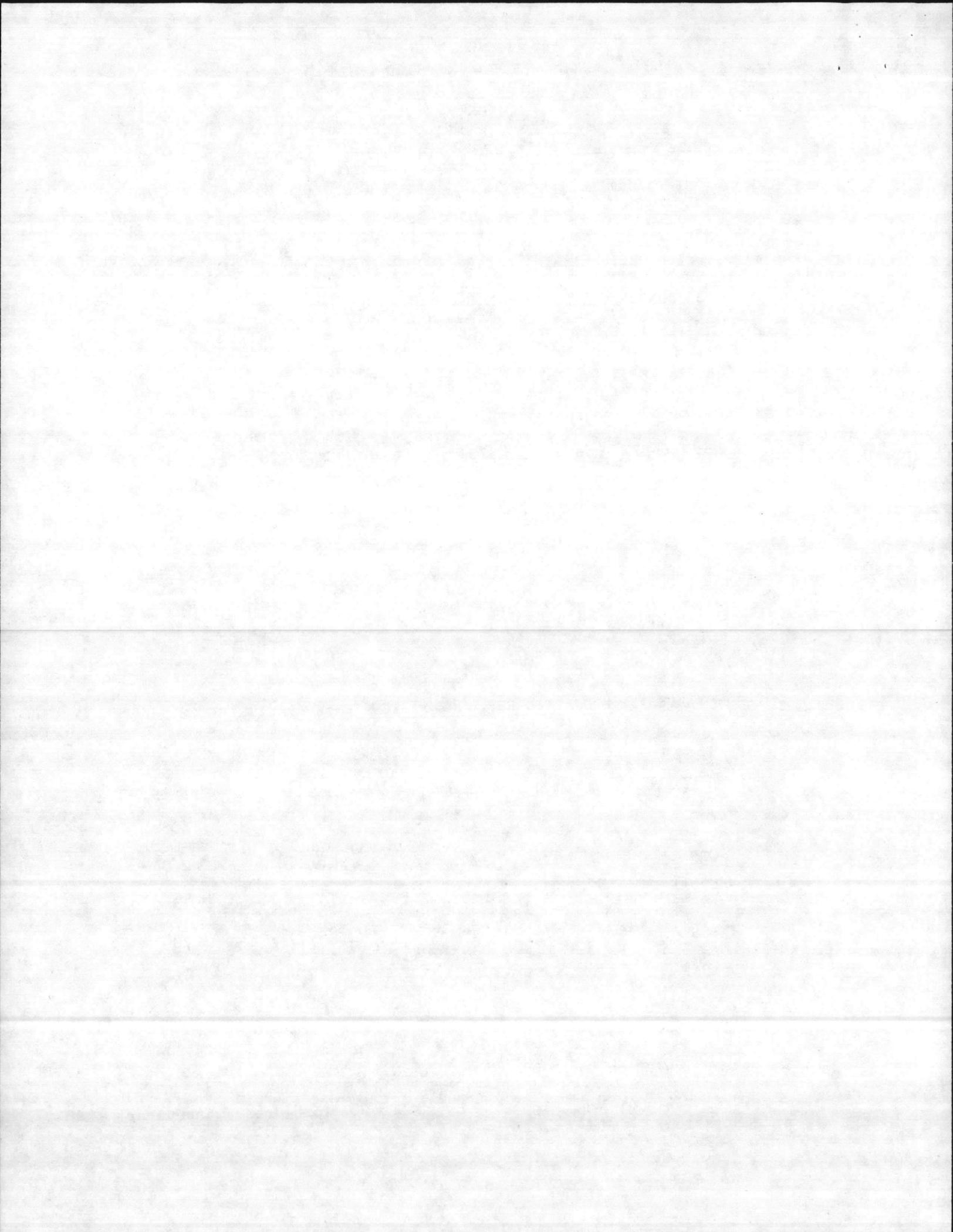


TABLE 8. DAF FLOAT/SLUDGE MATERIAL

DATE	BOD(a)	COD	OIL & GREASE	TSS	% TVS	% SOLIDS	HEAT CONTENT BTU/LB DRY SOLIDS	SURFACTANTS AS MBAS
10/14	15,512	91,676	20,160	50,020	3.17	4.5	10,035	291
10/13	9,091	15,102	8,988	36,670	2.98	4.2	4,747	163
10/18	5,800	23,318	7,082	52,500	2.26	4.9	4,051	2 249
10/19	2,544	119,923	42,836	29,800	5.59	8.2	7,953	1,950
10/20	2,474	130,410	34,680	33,821	5.62	8.2	6,952	590
10/21	4,128	44,298	4,146	30,440	1.73	2.44	7,046	255
10/27	16,610	13,670	5,928	8,240	0.32	.63	7,934	88
11/2	20,350	52,132	20,312	58,880	1.72	2.42	8,340	166
AVG	8,713	56,979	17,710	35,764	2.89	4.42	6,769	494

HEAVY METALS

	Cd(a)	Cr(Total)	Cu	Pb	Hg	Ni	Zn
AVG	0.07	0.37	1.14	1.67	0.002	0.37	4.3

(a) Results are in mg/l unless otherwise noted.

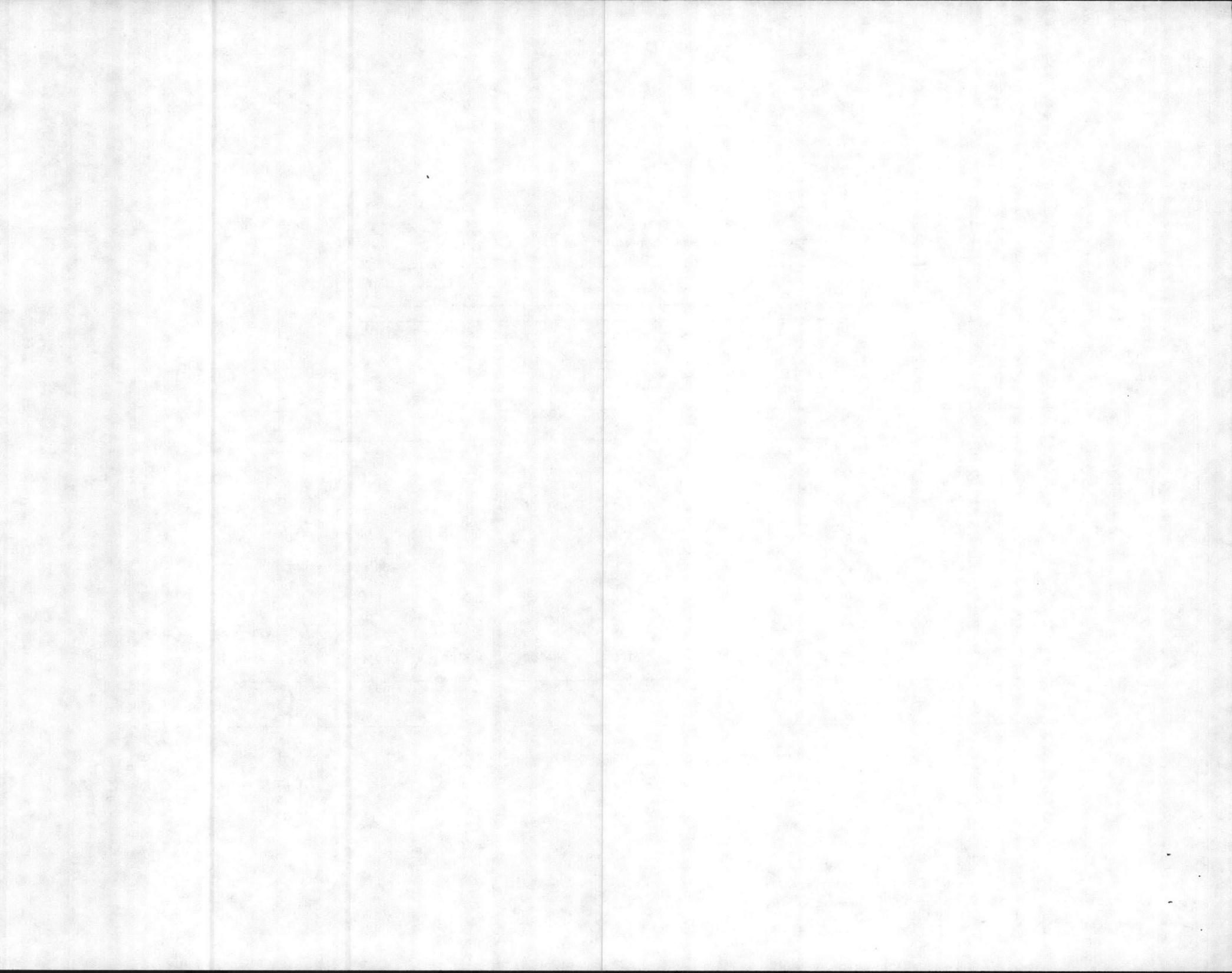


TABLE 9. UNOX SYSTEM  
PERFORMANCE SUMMARY

PARAMETERS	I	II	III A	III B-1	III B-2	III B-3
PHASE						
Duration, days	8	7	6	13	6	8
Oxygenation Time						
Q, hrs.	3.16	3.06	2.52	2.46	2.26	2.47
Q + R, hrs.	1.82	1.74	1.69	1.68	1.49	1.75
Recycle Fraction (R/Q)	46	52	43	73	77	49
Biomass Loading						
lb. BOD <sub>5</sub> /day/lb. MLVSS	0.38	0.51	0.66	1.12	0.26	0.30
lb. COD/day/lb. MLVSS	1.01	0.86	1.59	2.14	0.87	0.70
Organic Loading						
lb. BOD <sub>5</sub> /day/1000 ft <sup>3</sup>	82	110	146	175	119	122
lb. COD/day/1000 ft <sup>3</sup>	220	199	354	299	440	289
Mixed Liquor Suspended Solids, mg/l	4320	4640	4780	4230	10900	10060
Mixed Liquor Volatile SS, mg/l	3485	3650	3950	3340	8160	6930
Recycle SS, mg/l	7800	10400	14800	17400	22200	30000
Clarifier Overflow Rate, gal/day/ft <sup>2</sup>	121	122	148	152	166	151
Clarifier Mass Loading, lb. SS/day/ft <sup>2</sup>	7.4	8.4	8.7	7.9	23.3	19.3
INFLUENT CONCENTRATIONS						
Biochemical Oxygen Demand						
Total, mg/l	162	226	247	290	185	196
Soluble, mg/l	86	89	120	142	67	84
Chemical Oxygen Demand						
Total, mg/l	454	403	599	500	685	473
Soluble, mg/l	186	225	282	238	142	151
Suspended Solids						
Total, mg/l	175	132	118	183	583	365
Volatile, mg/l	139	102	102	149	339	241
Methylene Blue Active Substance, mg/l	0.55	0.59	0.63	0.64	0.53	0.70
EFFLUENT CONCENTRATIONS						
Biochemical Oxygen Demand						
Total, mg/l	42	21	65 (30)*	50	40 (23)*	16
Soluble, mg/l	17	11	27 (17)*	33	21 (14)*	14
Chemical Oxygen Demand						
Total, mg/l	108	86	153 (67)*	139	122 (95)*	54
Soluble, mg/l	58	55	113 (63)*	99	80 (69)*	43
Suspended Solids						
Total, mg/l	29	15	38 (19)*	39	42 (28)*	15
Volatile, mg/l	26	12	43 (22)*	31	31 (15)*	20
Methylene Blue Active Substance, mg/l	0.09	0.11	0.17 (0.13)*	0.19	0.14 (0.15)*	0.14
REMOVALS						
Biochemical Oxygen Demand						
(Based on Total in - total out), %	73	89	76 (86)*	83	73 (86)*	92
(Based on total in - soluble out), %	90	94	89 (91)*	89	85 (91)*	93
Chemical Oxygen Demand						
(Based on total in - total out), %	75	76	76 (35)*	71	69 (83)*	88
(Based on total in - soluble out), %	86	83	81 (85)*	79	81 (88)*	90
Suspended Solids						
Total, %	77	87	69 (82)*	77	83 (92)*	95
Volatile, %	72	90	62 (75)*	76	72 (88)*	92
Methylene Blue Active Substance, %	83	81	73 (78)*	70	75 (74)*	60
Sludge Volume Index	46	52	44	42	39	37
Initial Settling Velocity						
Stirred (10 RPH), ft/hr.	6.0	4.8	6.6	5.5	3.2	4.8

\* Excluding days of system upset

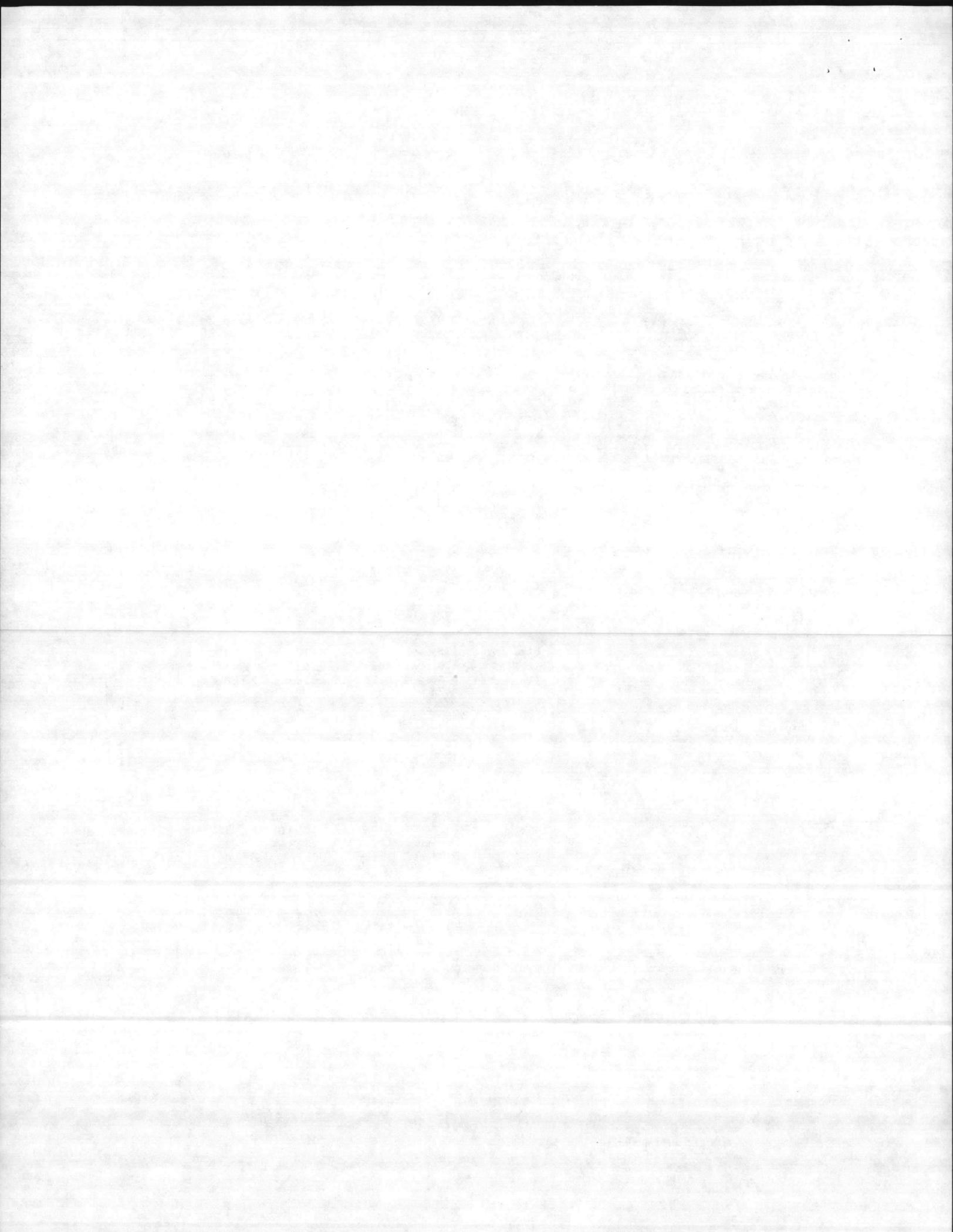
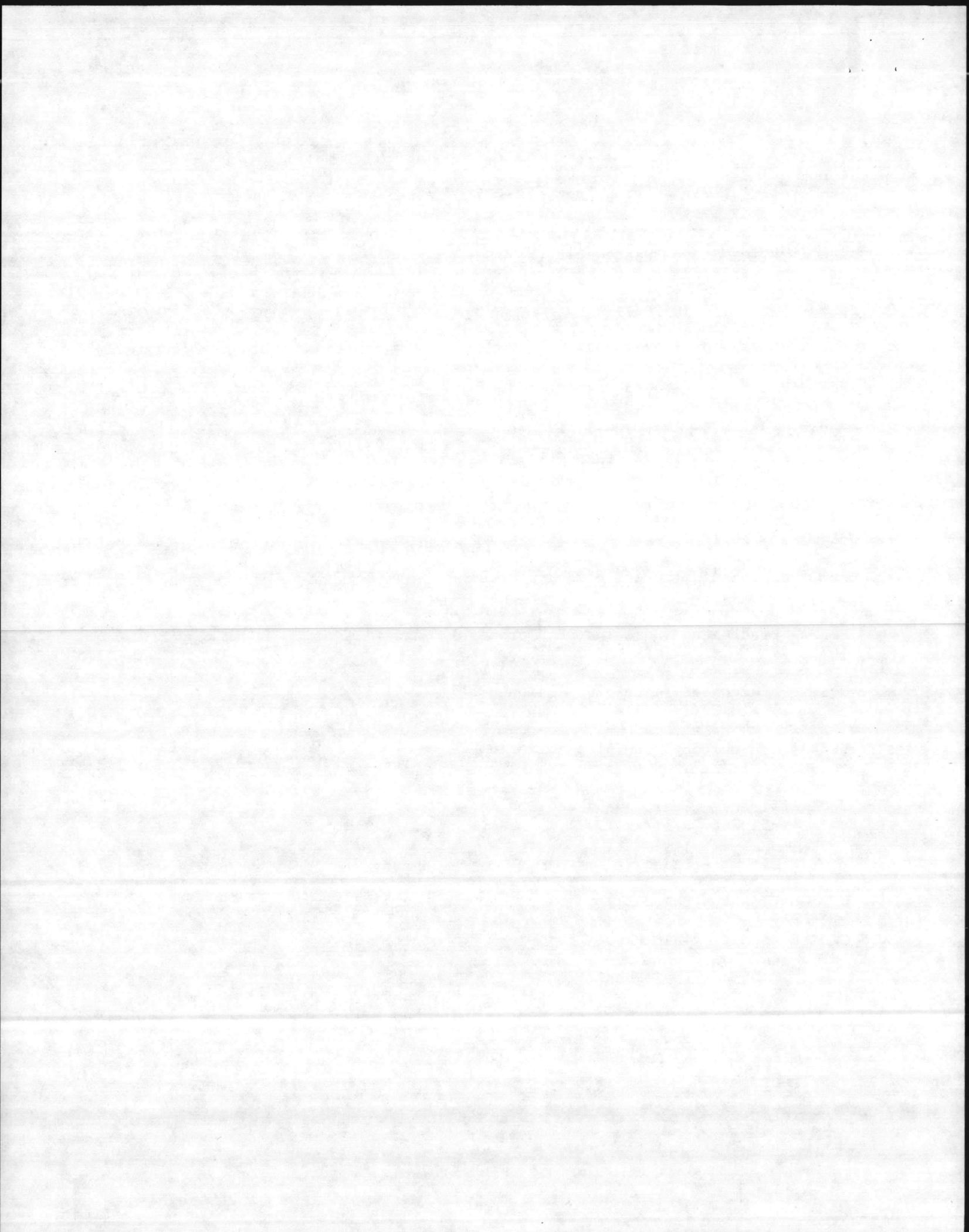
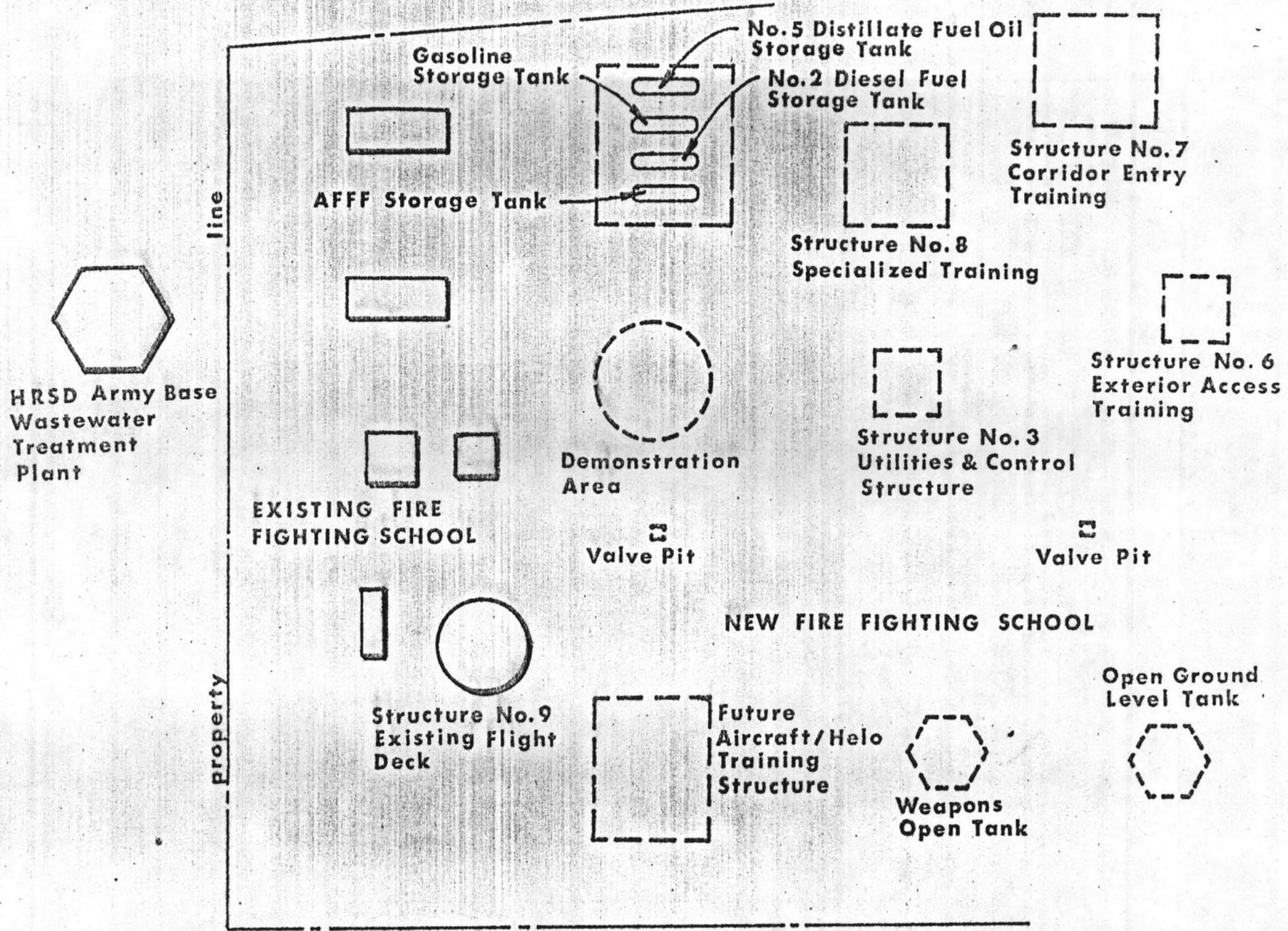


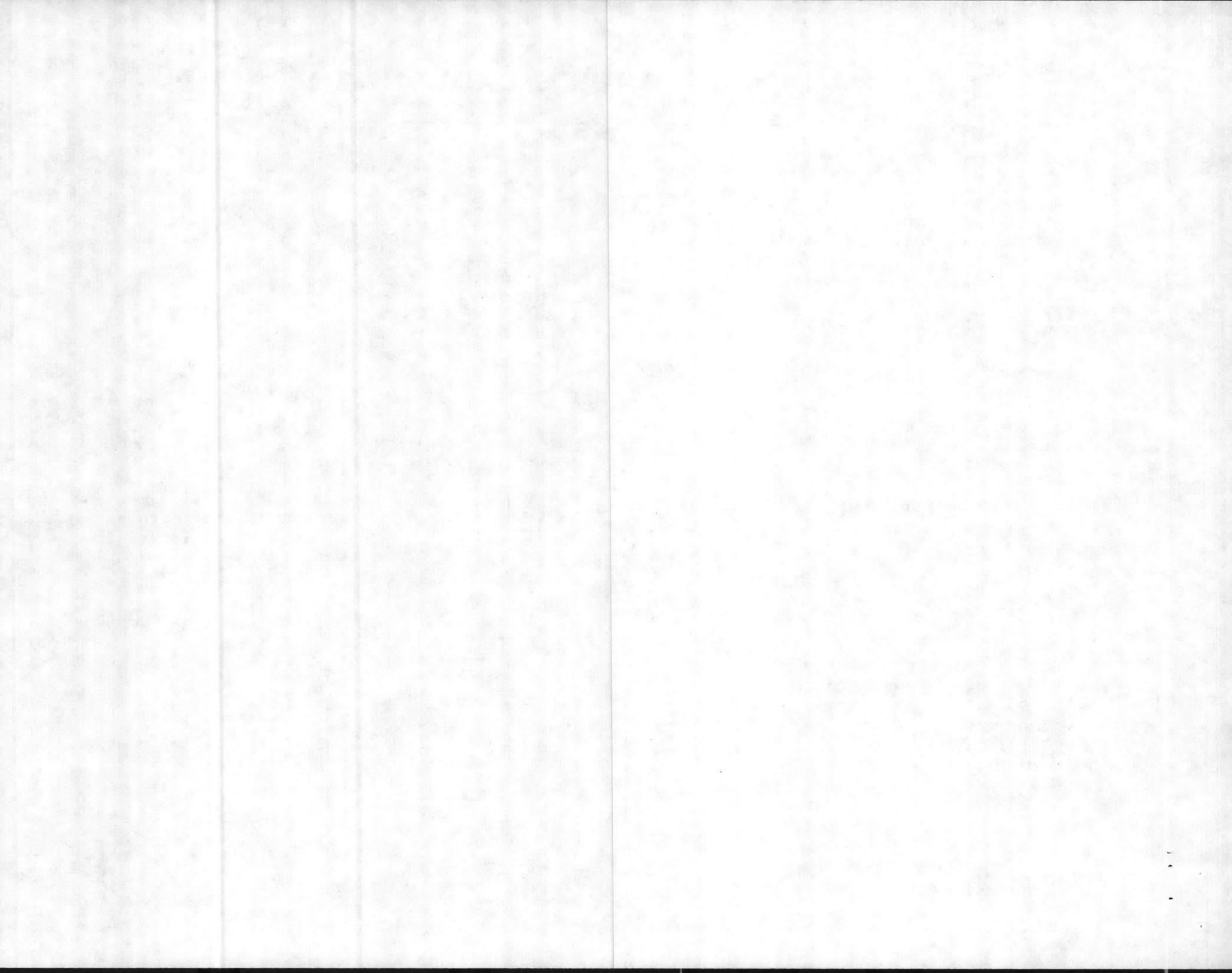
TABLE 10. TOXICITY RESULTS

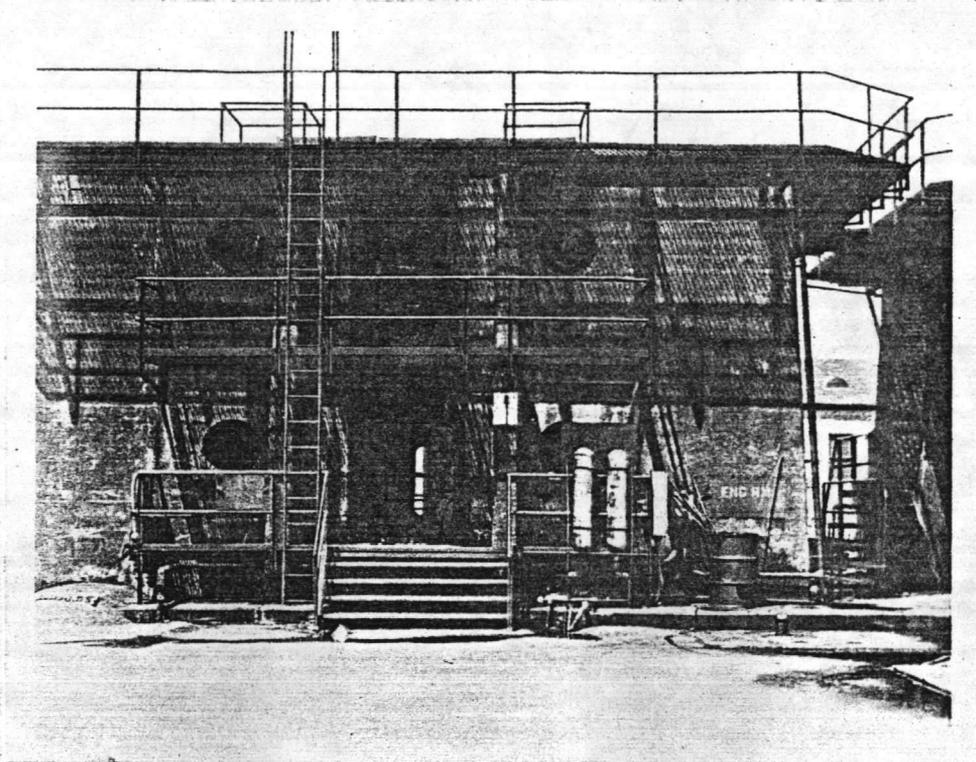
<u>Sample</u>	<u>48-hour EC50 (% Sample)</u>	<u>95% Confidence Limits (% Sample)</u>
1. HRSD Army Base (AB) Influent - Raw Sewage 9/14/77	0.4	0.2 - 0.5
2. Fire Fighting School Wastewater (FFSW) - Untreated 9/14/77	0.1	0.01 - 0.5
3. FFSW - Untreated 10/20/77	0.2	0.03 - 1.1
4. FFSW - Untreated 11/2/77	0.9	0.4 - 2.0
5. FFSW - Pretreated (No chemicals) 9/30/77	9.0	6.0 - 14.0
6. FFSW - Pretreated (alum only) 10/11/77	5.1	1.1 - 2.4
7. FFSW - Pretreated (alum plus cationic polymer) 10/13/77	0.2	0.05 - 0.5
8. FFSW - Pretreated (alum plus cationic polymer) 10/18/77	51	2.3 - 100
9. FFSW - Pretreated (Surefloc/SEAR process) 10/19/77	4.1	1.8 - 8.8
10. FFSW - Pretreated (Surefloc/SEAR process) 10/20/77	4.6	2.1 - 9.8
11. FFSW - Pretreated (alum plus nonionic polymer) 10/27/77	0.06	0.01 - 0.1
12. FFSW - Pretreated (alum plus nonionic polymer) 11/2/77	4.7	2.7 - 6.3
13. UNOX Effluent - Startup and acclimation to AB influent 9/11/77	12	7.0 - 19
14. UNOX Effluent - Phase I	0.5	0.2 - 7.3
15. UNOX Effluent - Phase II	2.3	0.4 - 16
16. UNOX Effluent - (a) Phase III A	5.4	0.1 - 27
(b) Phase III B-1	-	-
(c) Phase III B-2	19	4.0 - 89
(d) Phase III B-3	7.2	0.6 - 83
	5.6	4.1 - 7.0



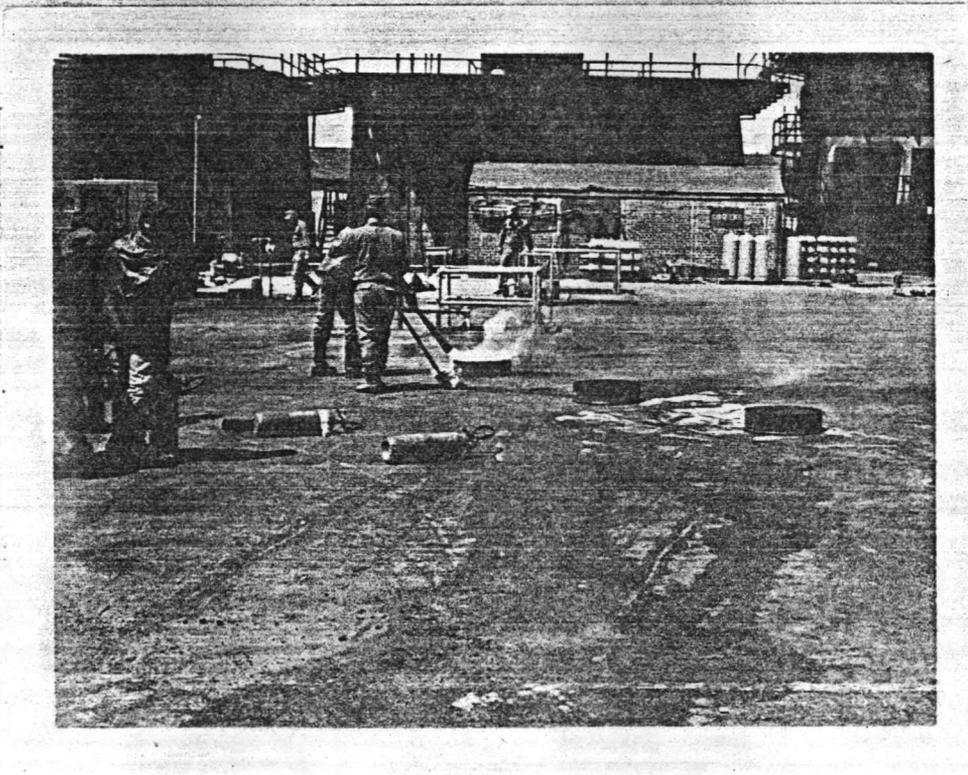


**FIGURE 1 FIRE FIGHTING SCHOOL SITE PLAN**



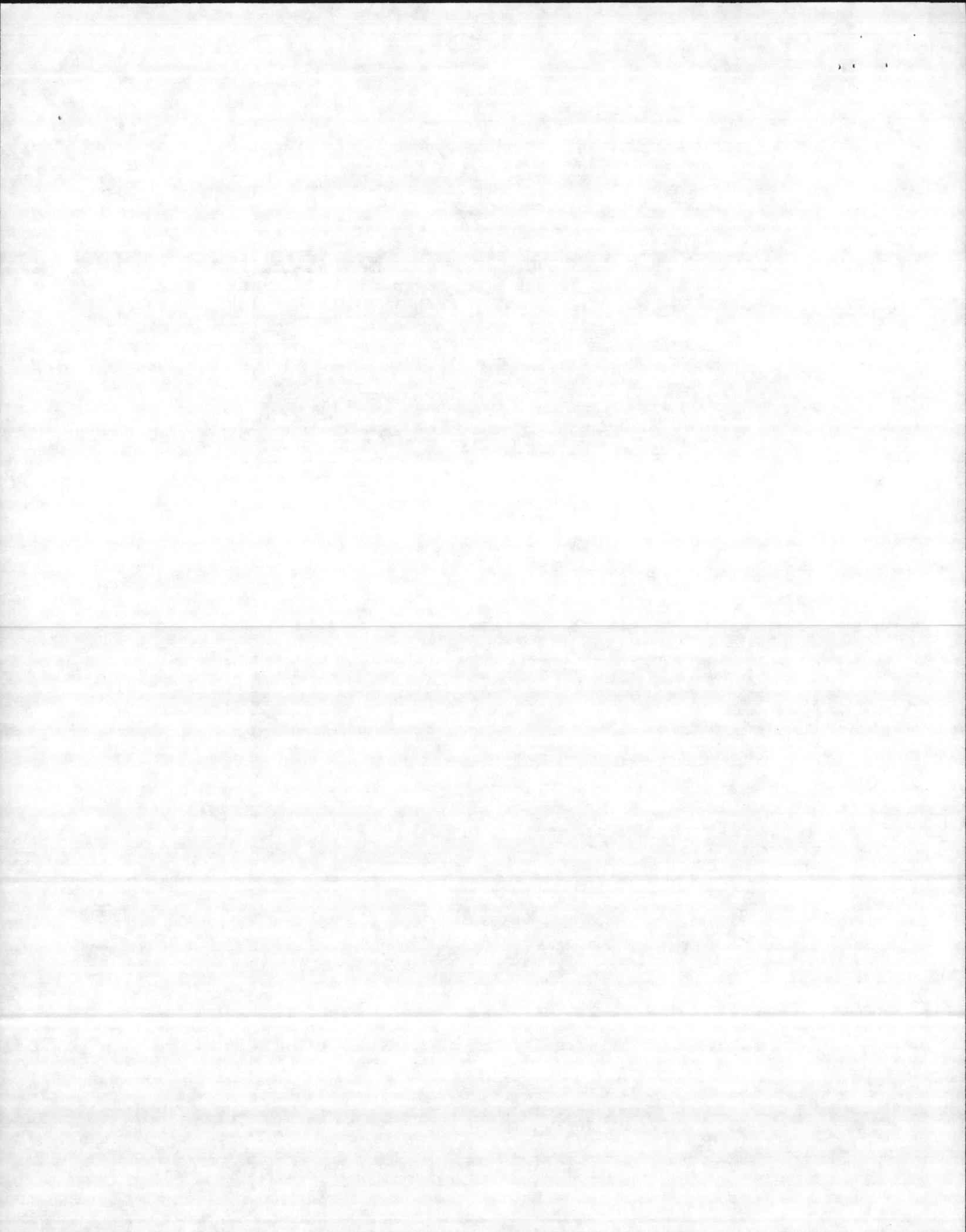


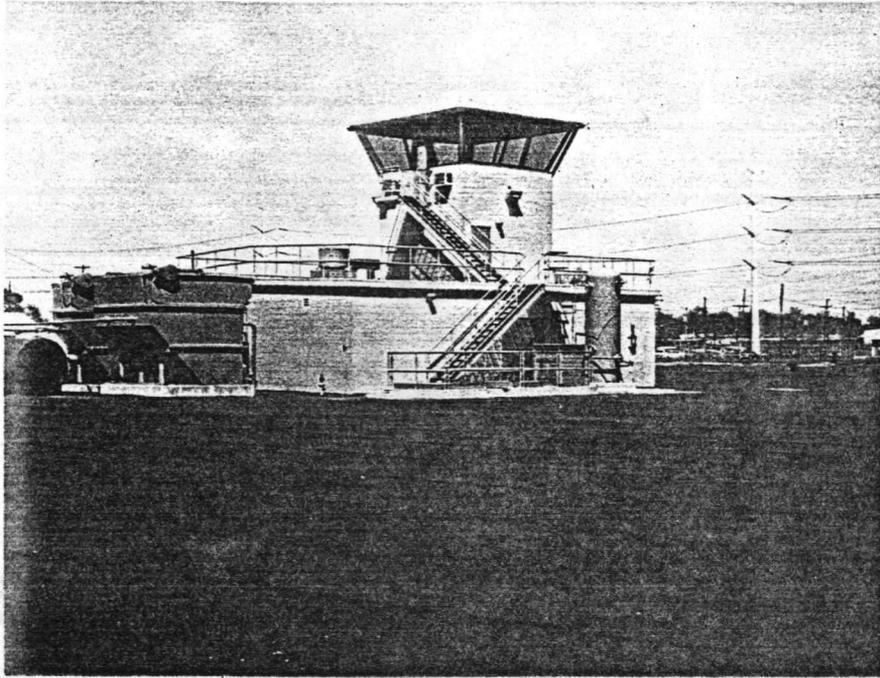
Corridor Entry Structure



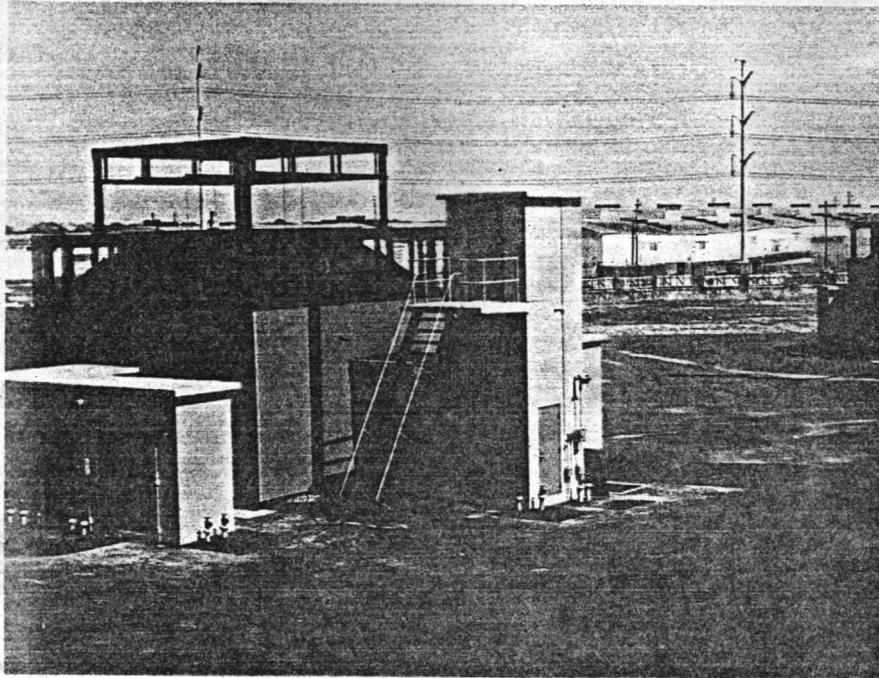
Pan Fires

Figure 2. Existing Fire Fighting School Facilities



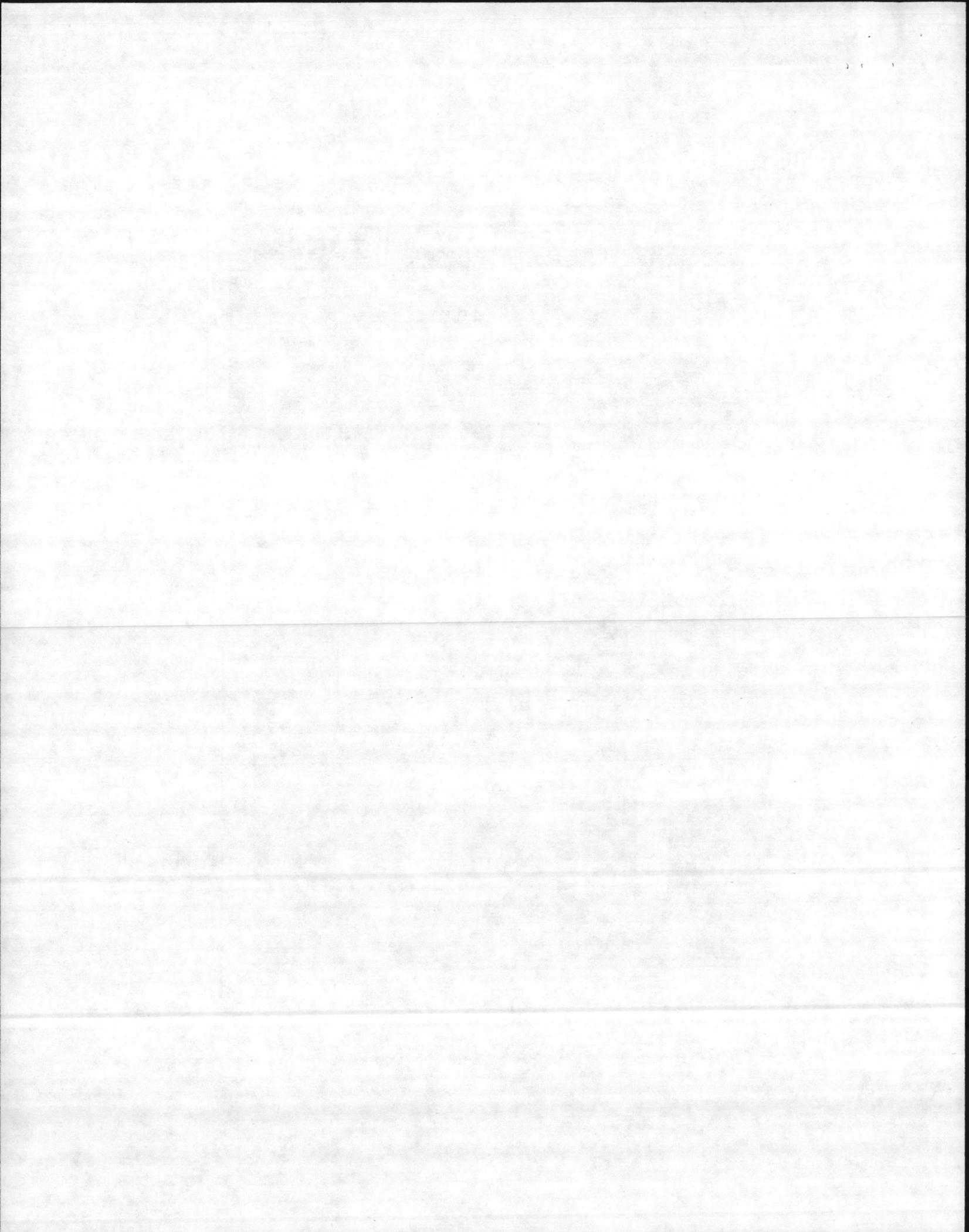


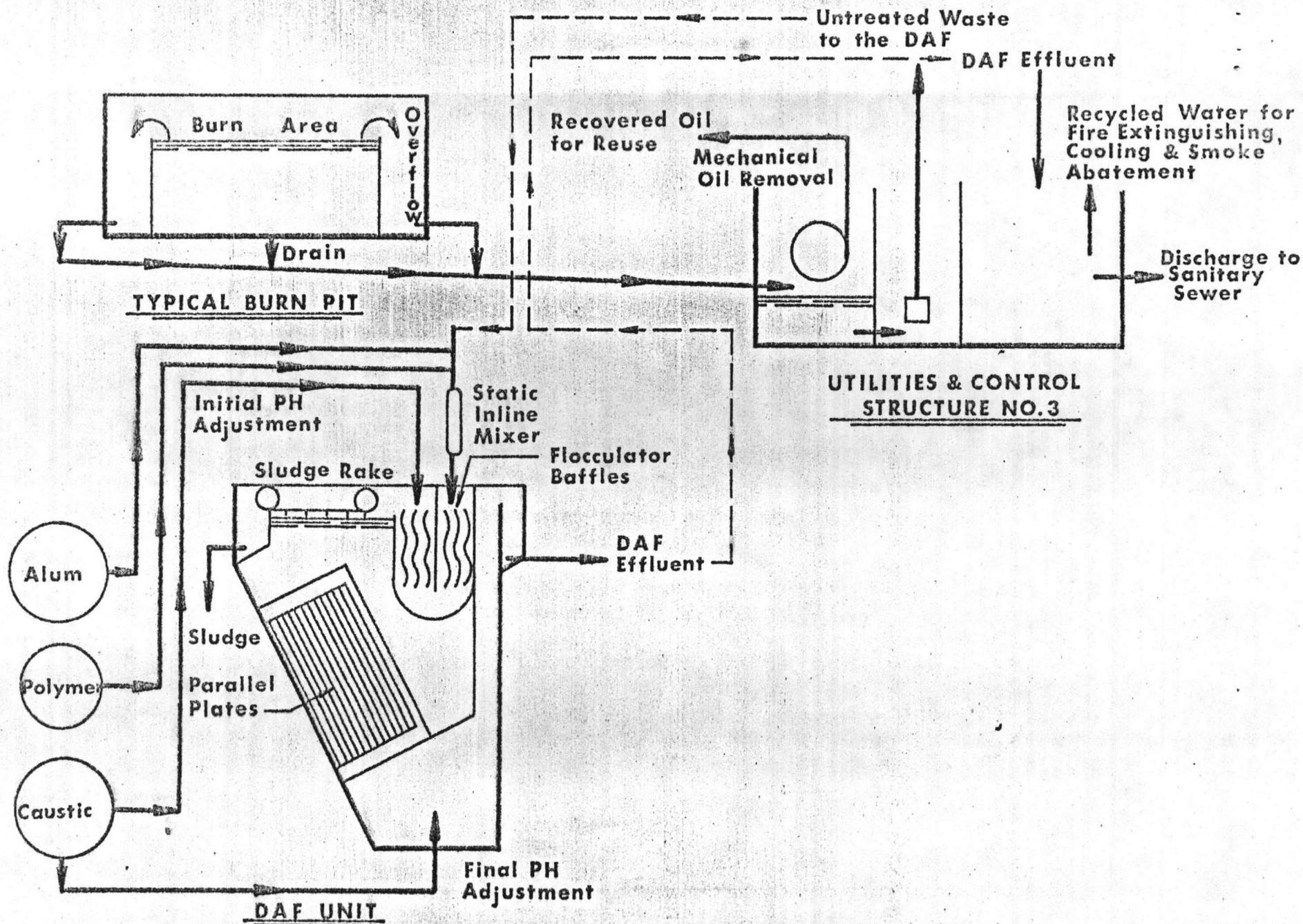
Utilities & Control Structure No. 3



Corridor Entry Structure No. 7

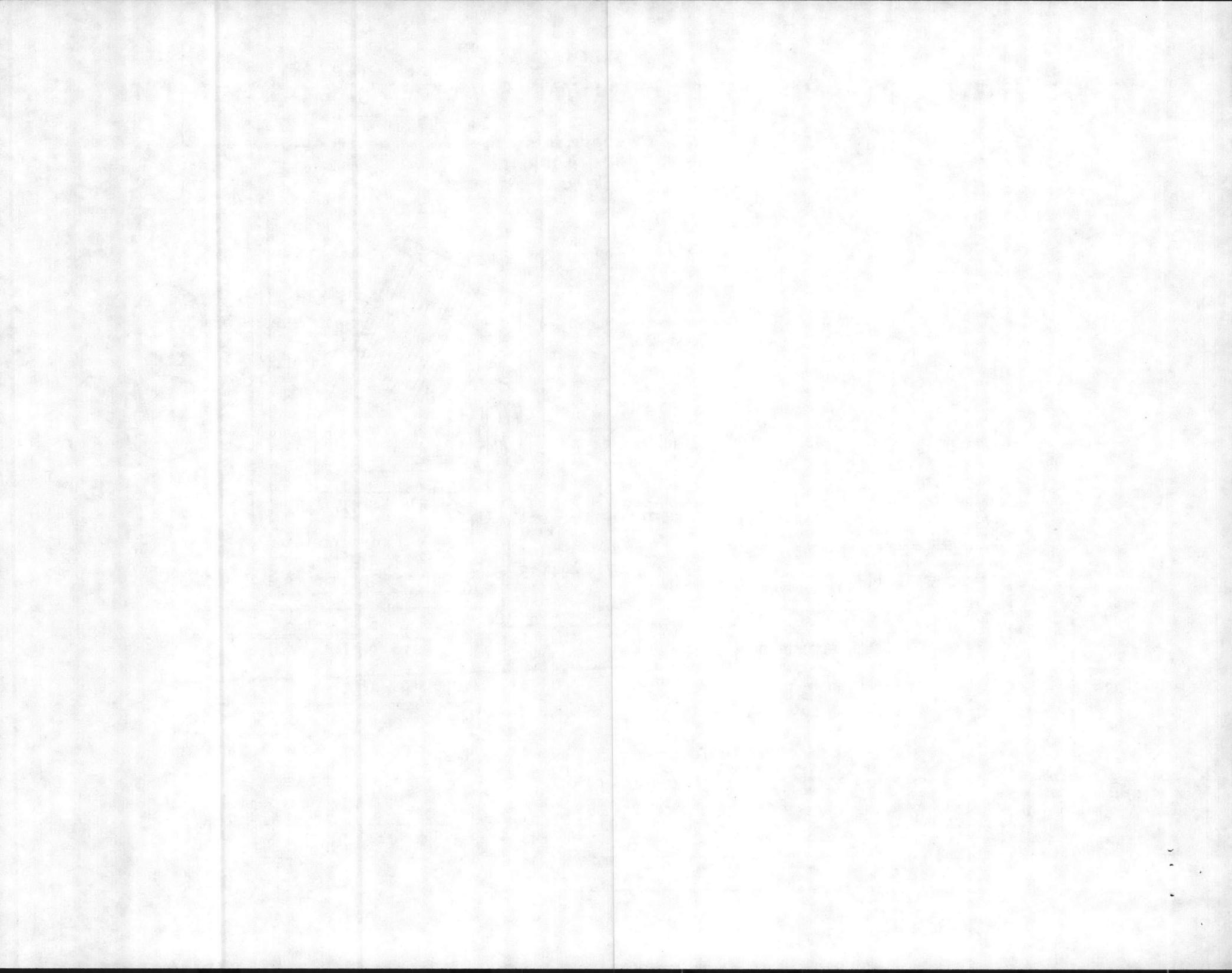
Figure 3. New Fire Fighting School Facilities





**FIREFIGHTING SCHOOL WASTEWATER COLLECTION & TREATMENT SYSTEM**

**FIGURE 4**



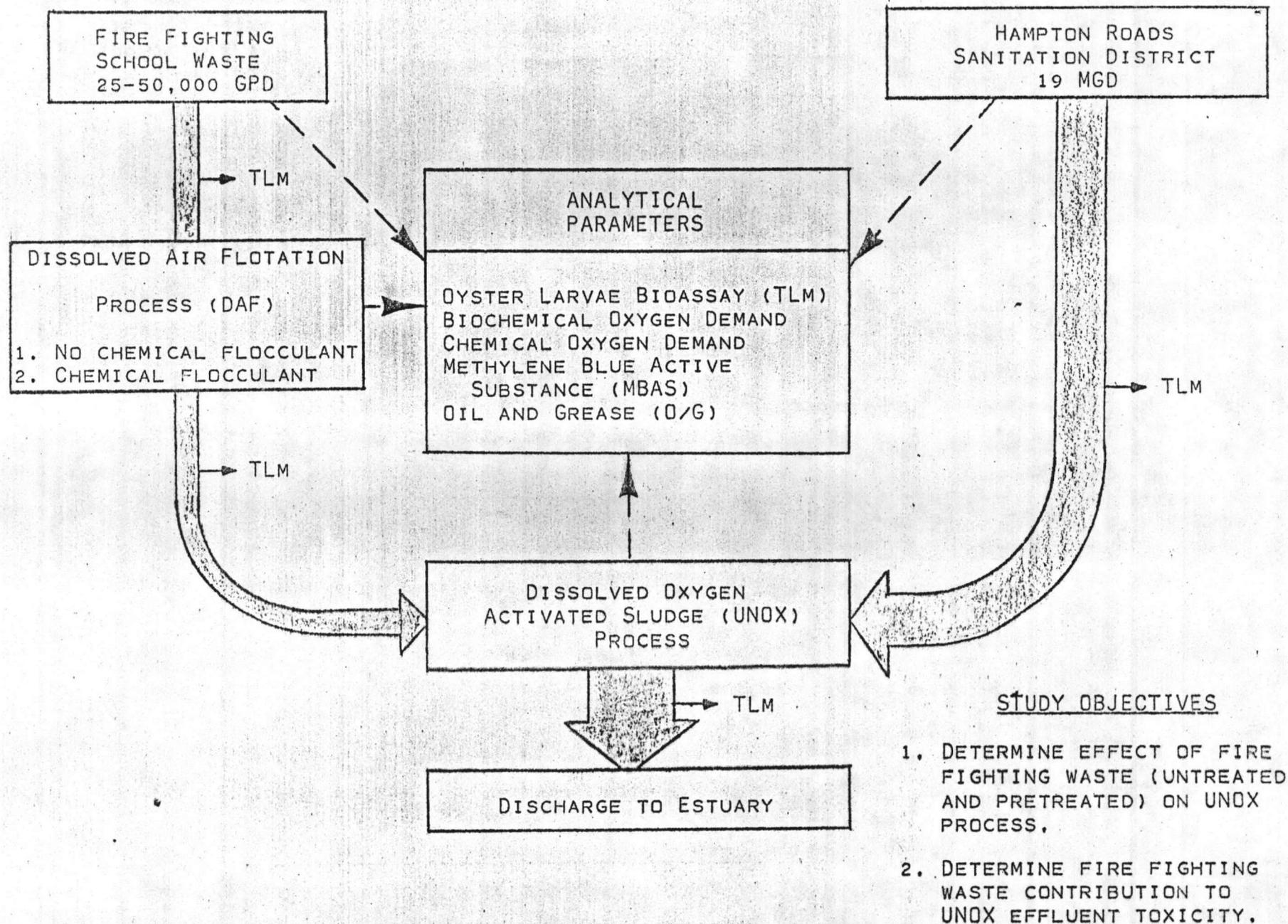
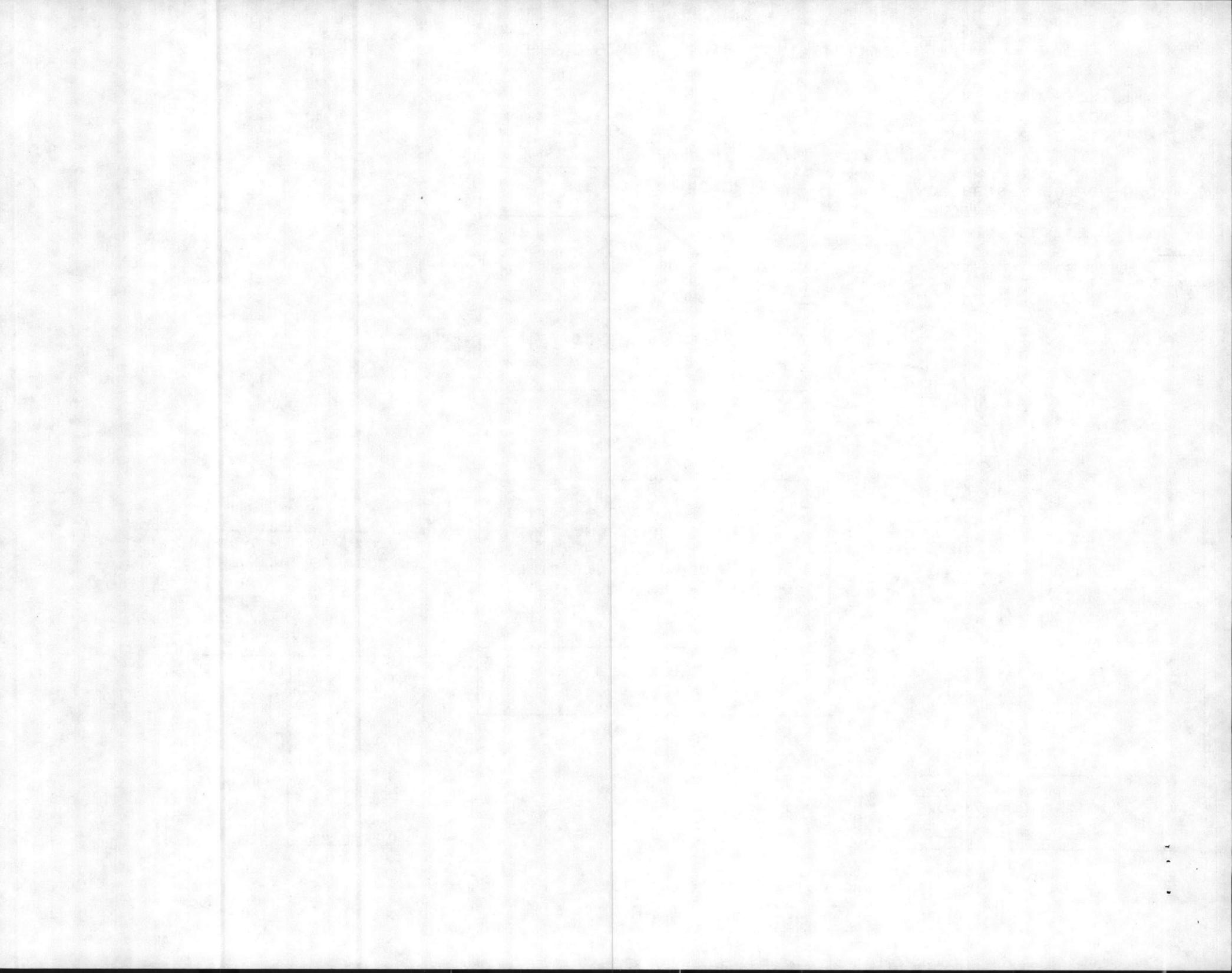
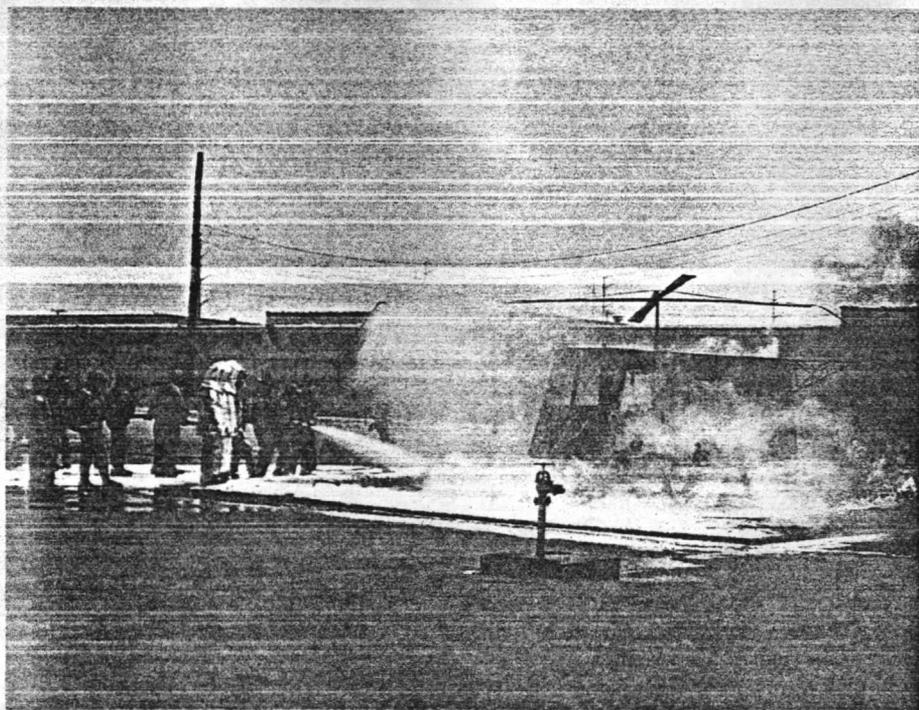


FIGURE 5. FIRE FIGHTING SCHOOL PILOT TREATABILITY STUDY

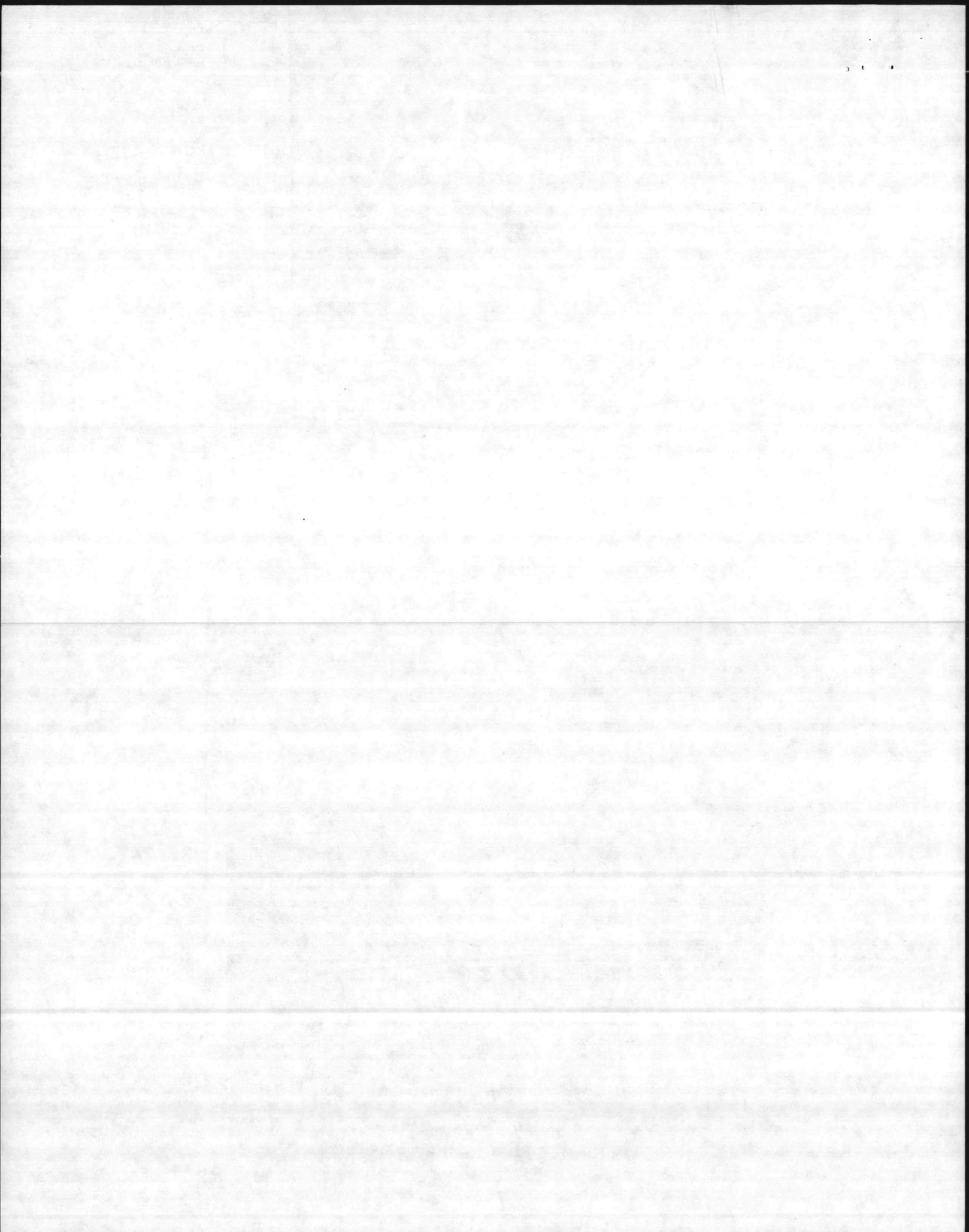


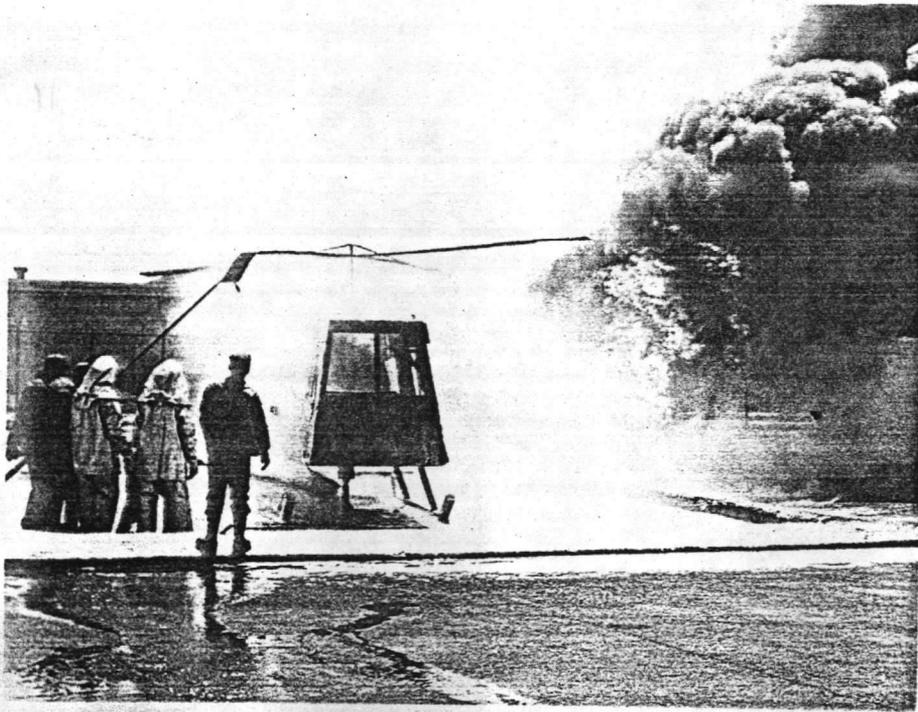


Preburn



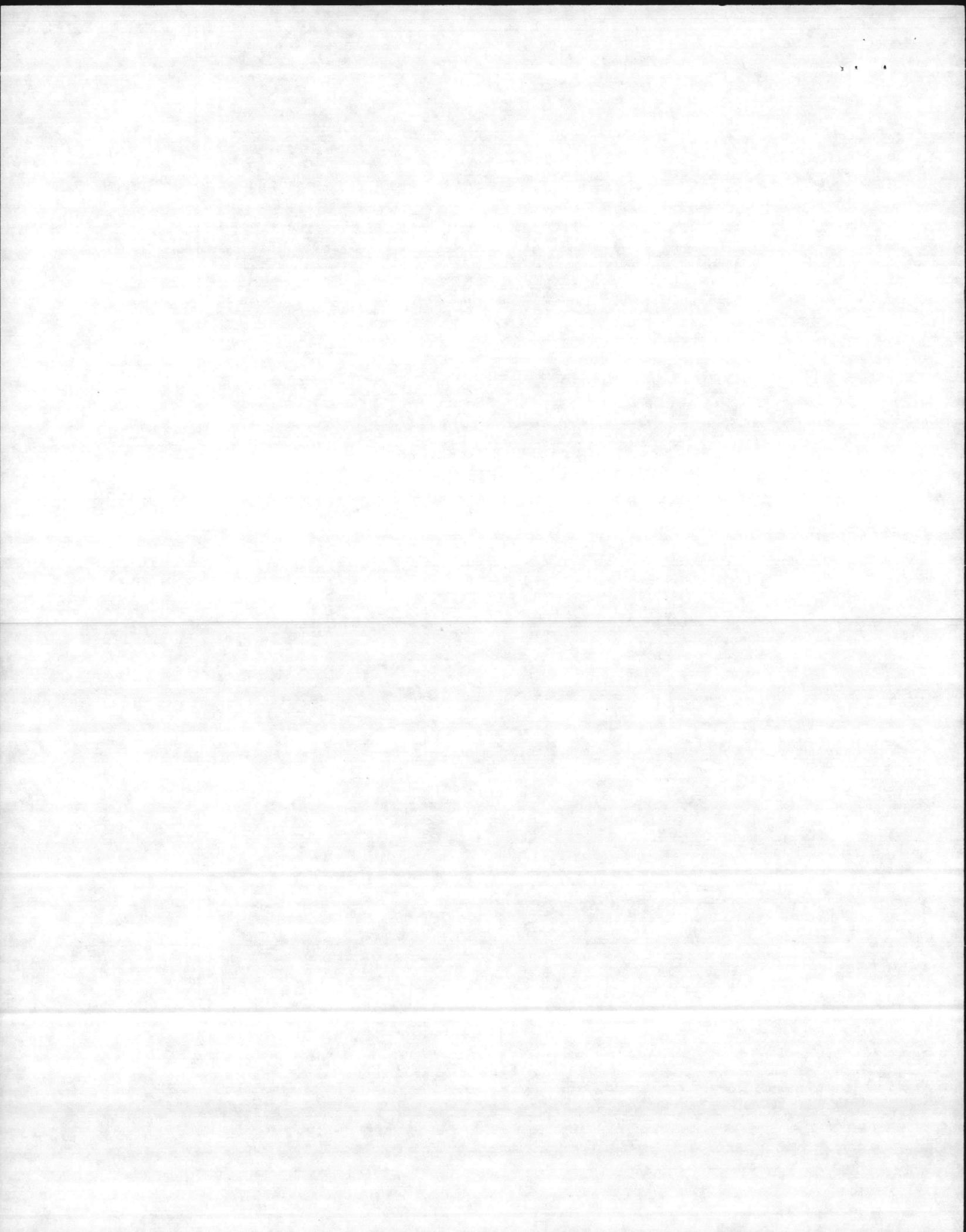
Fire Teams Advance  
Figure 6. Fire Fighting Exercises





Fire Extinguished

Figure 7. Fire Fighting Exercises



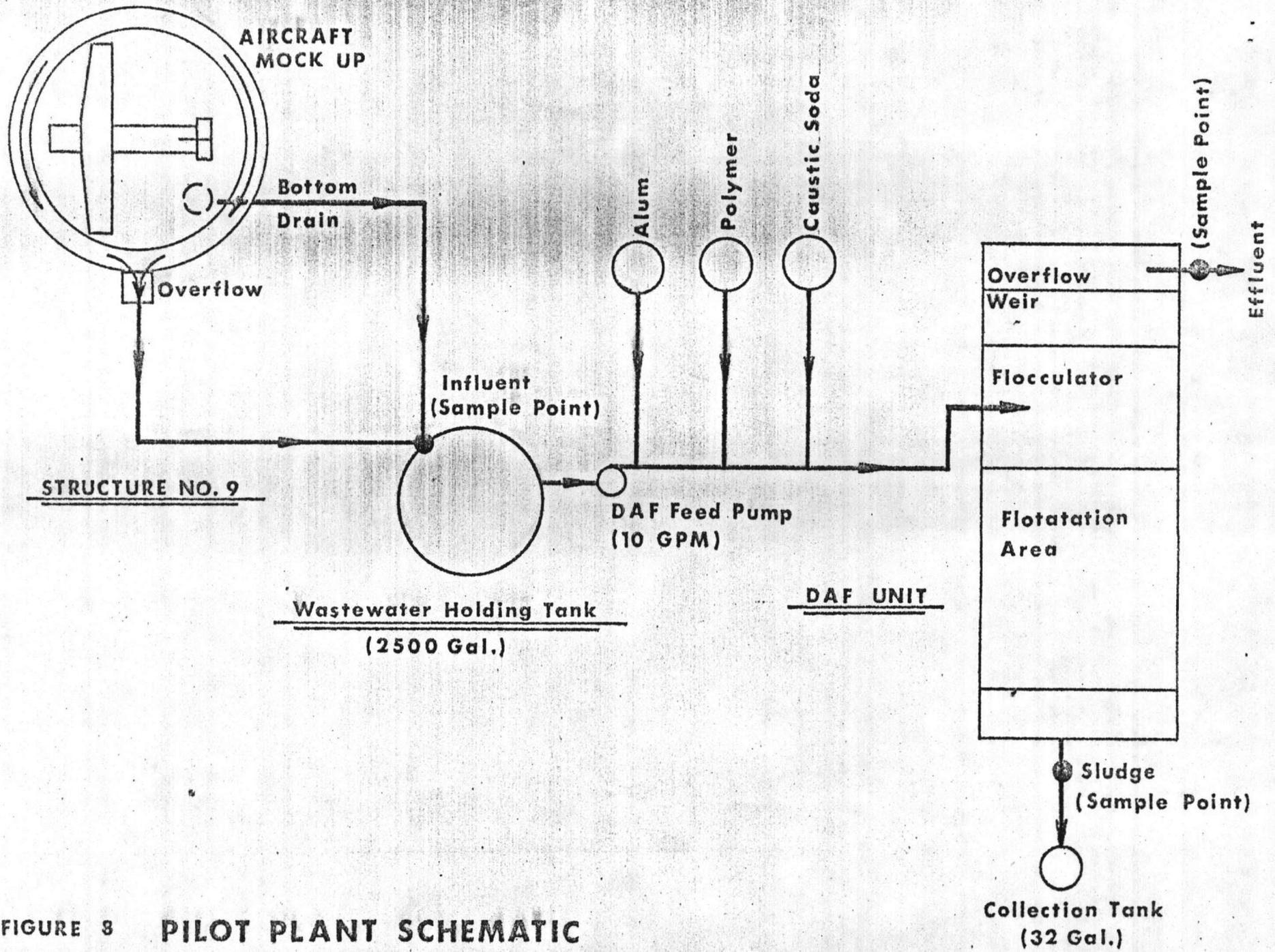
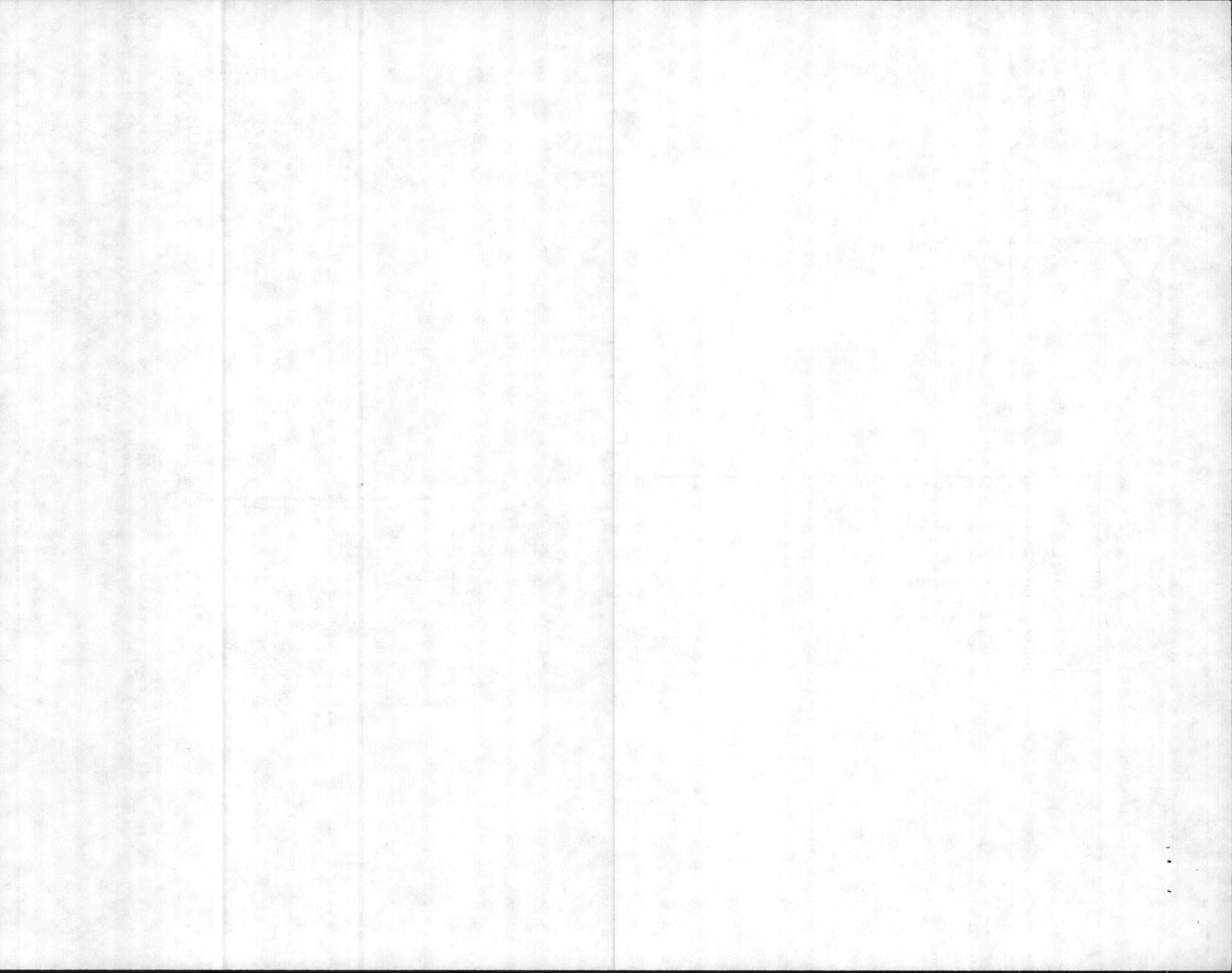


FIGURE 8 PILOT PLANT SCHEMATIC



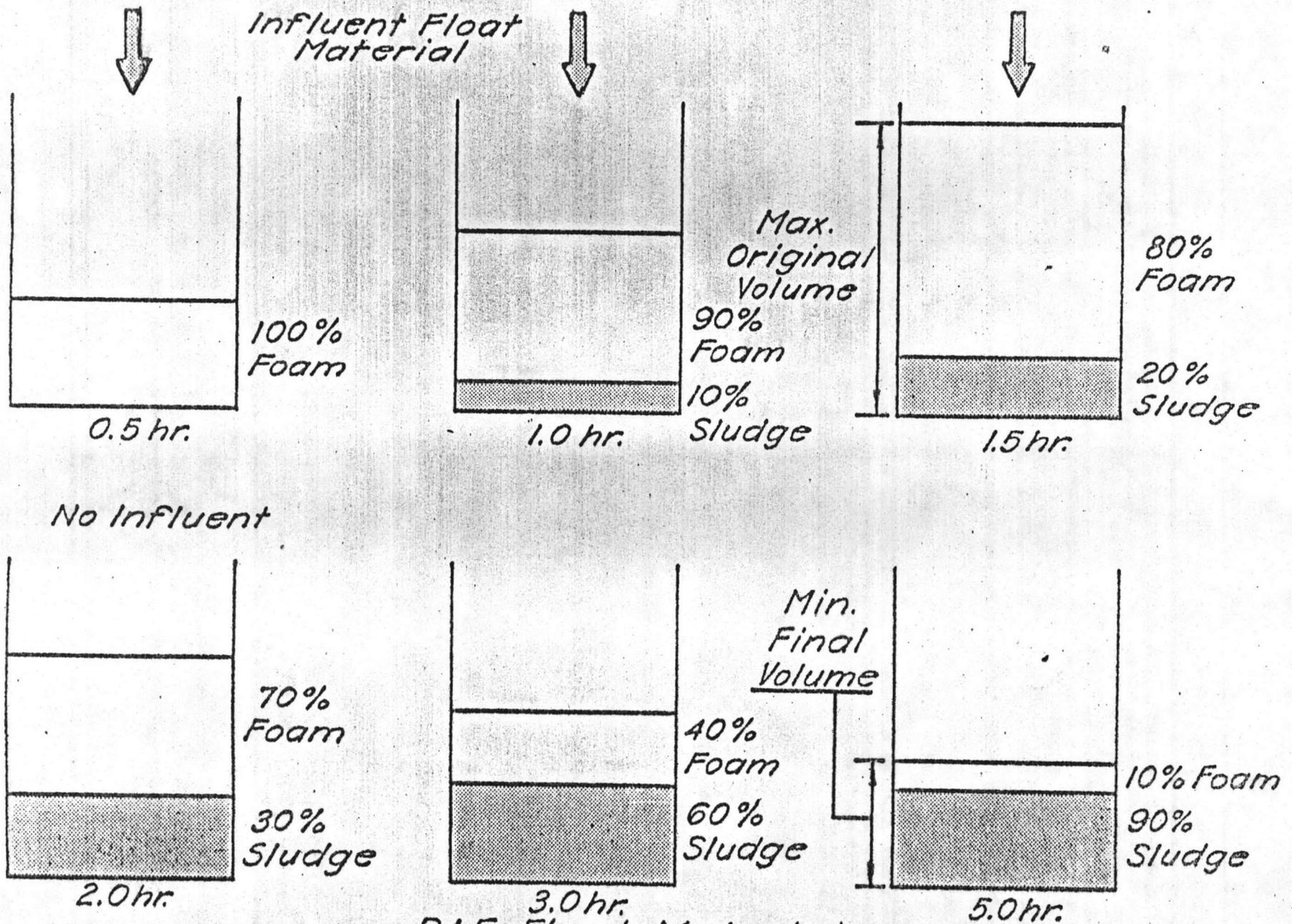


FIGURE 9

DAF Float Material  
Compaction Schematic

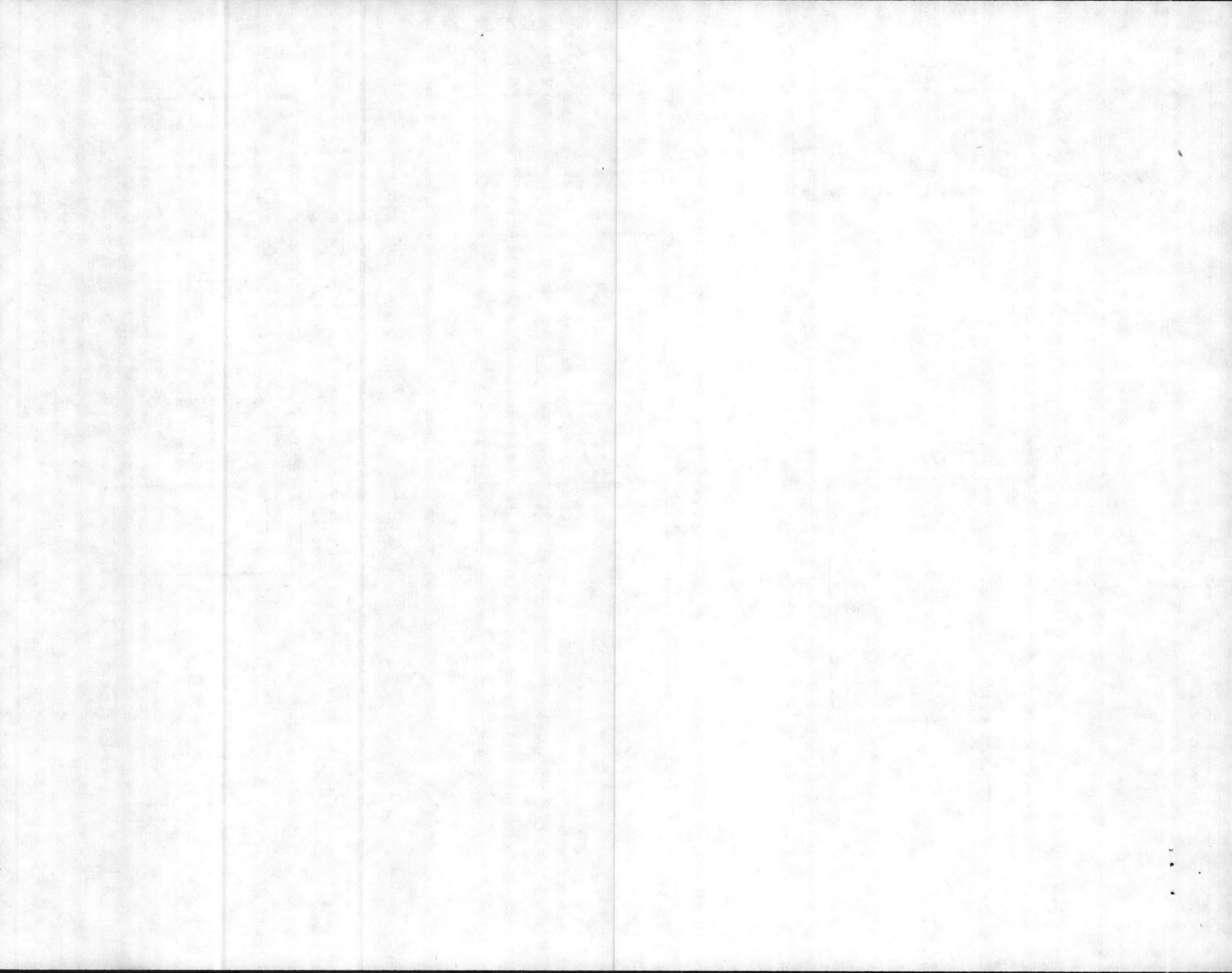
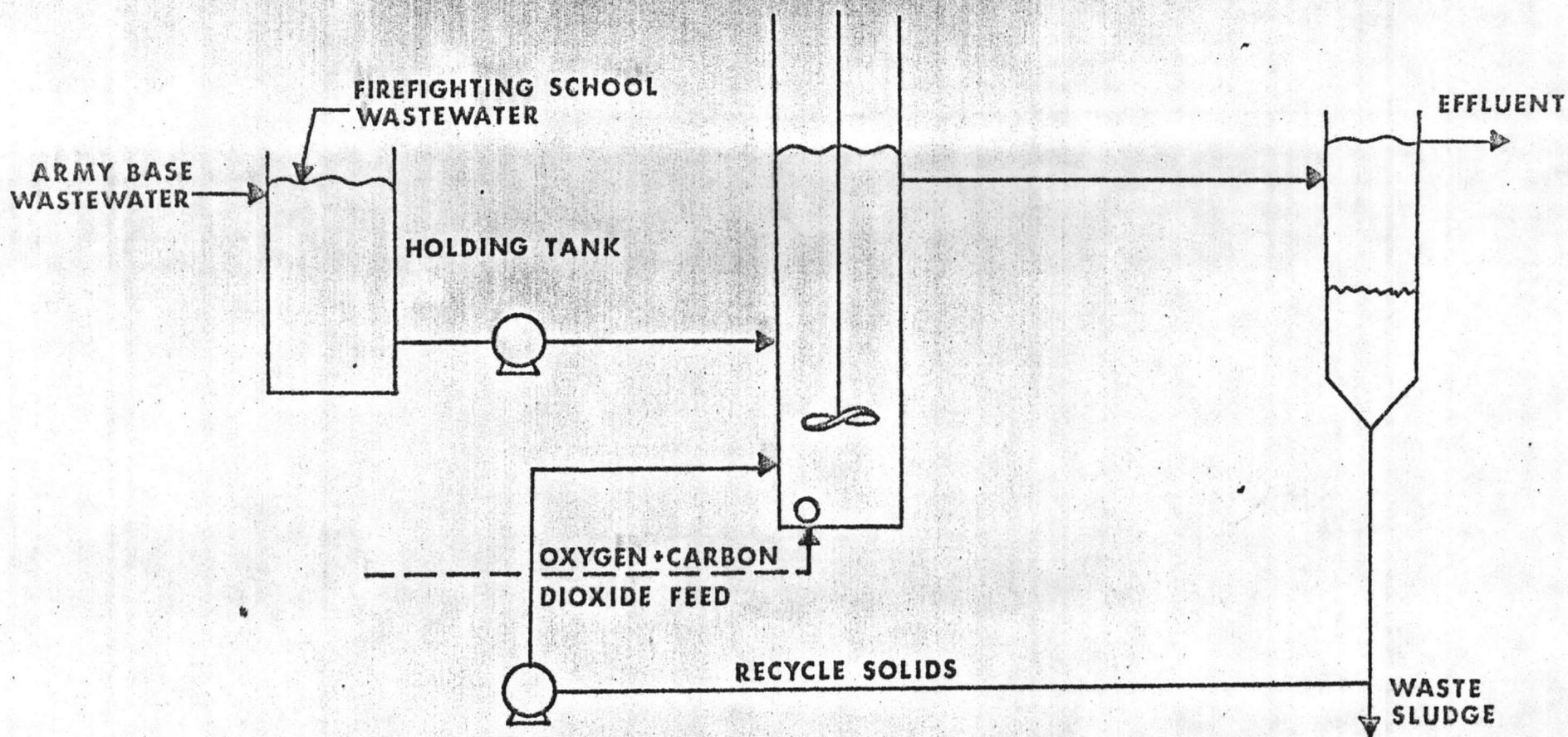
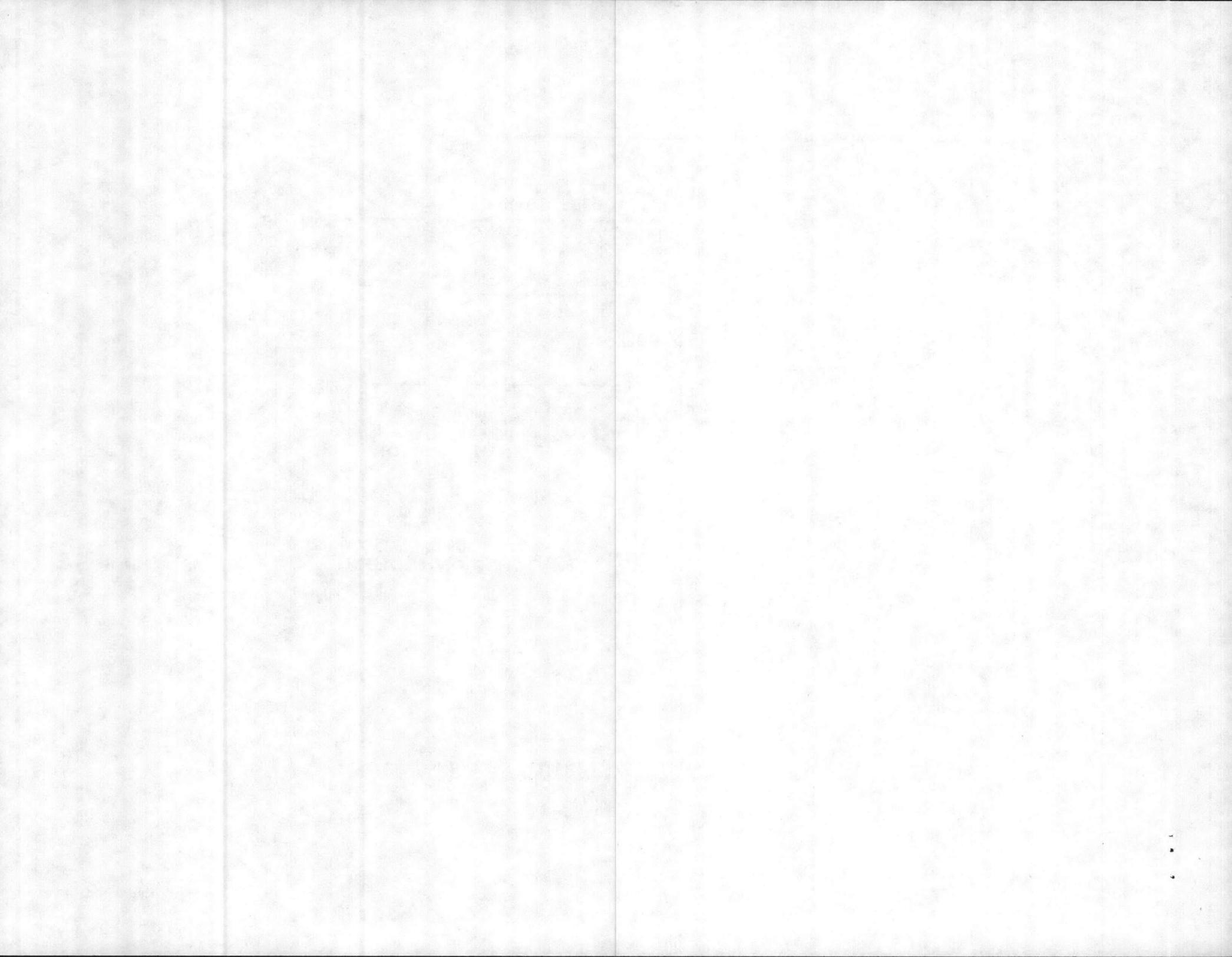


FIGURE 10

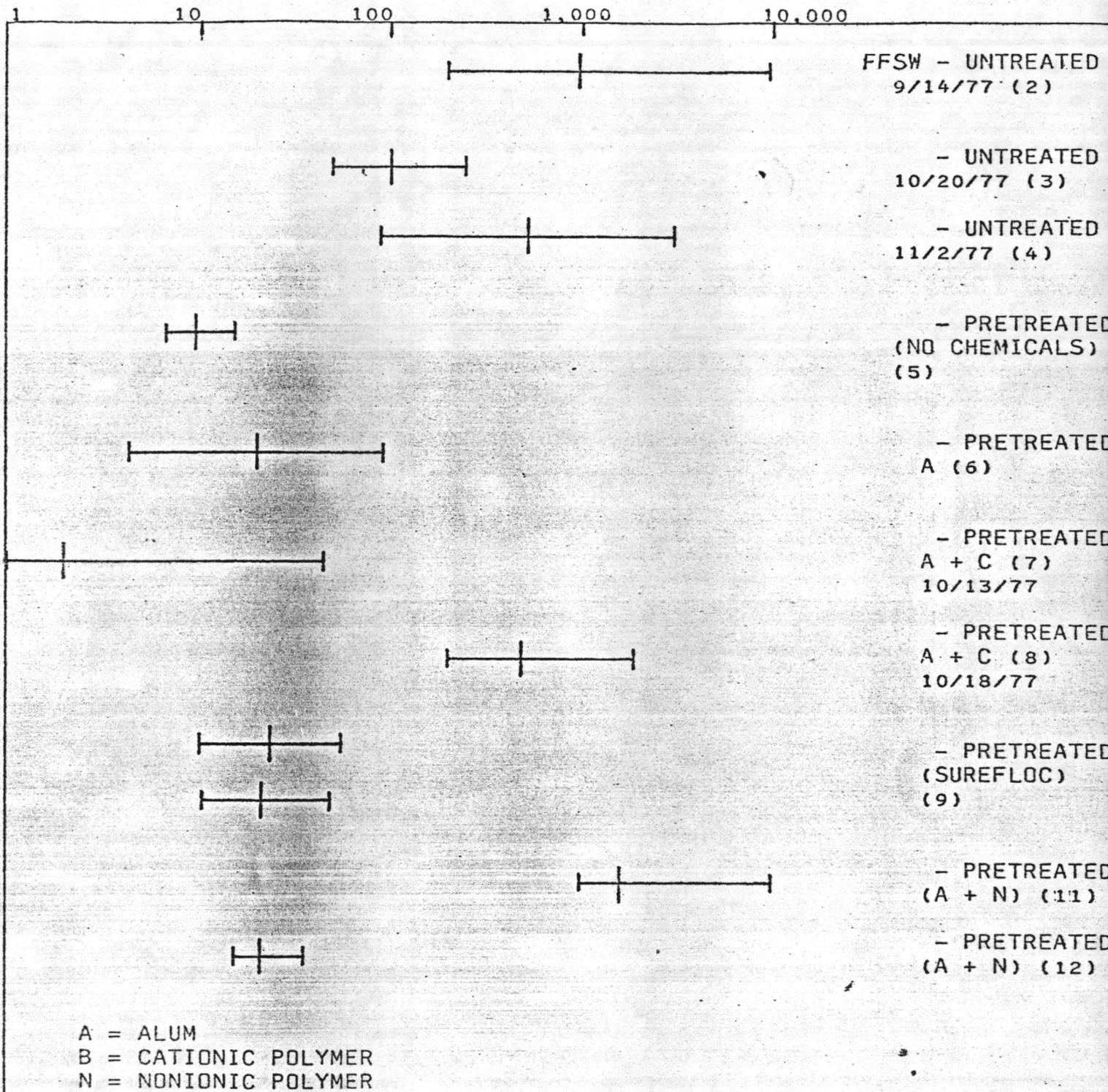
# UNOX SYSTEM

## TREATABILITY REACTOR SCHEMATIC



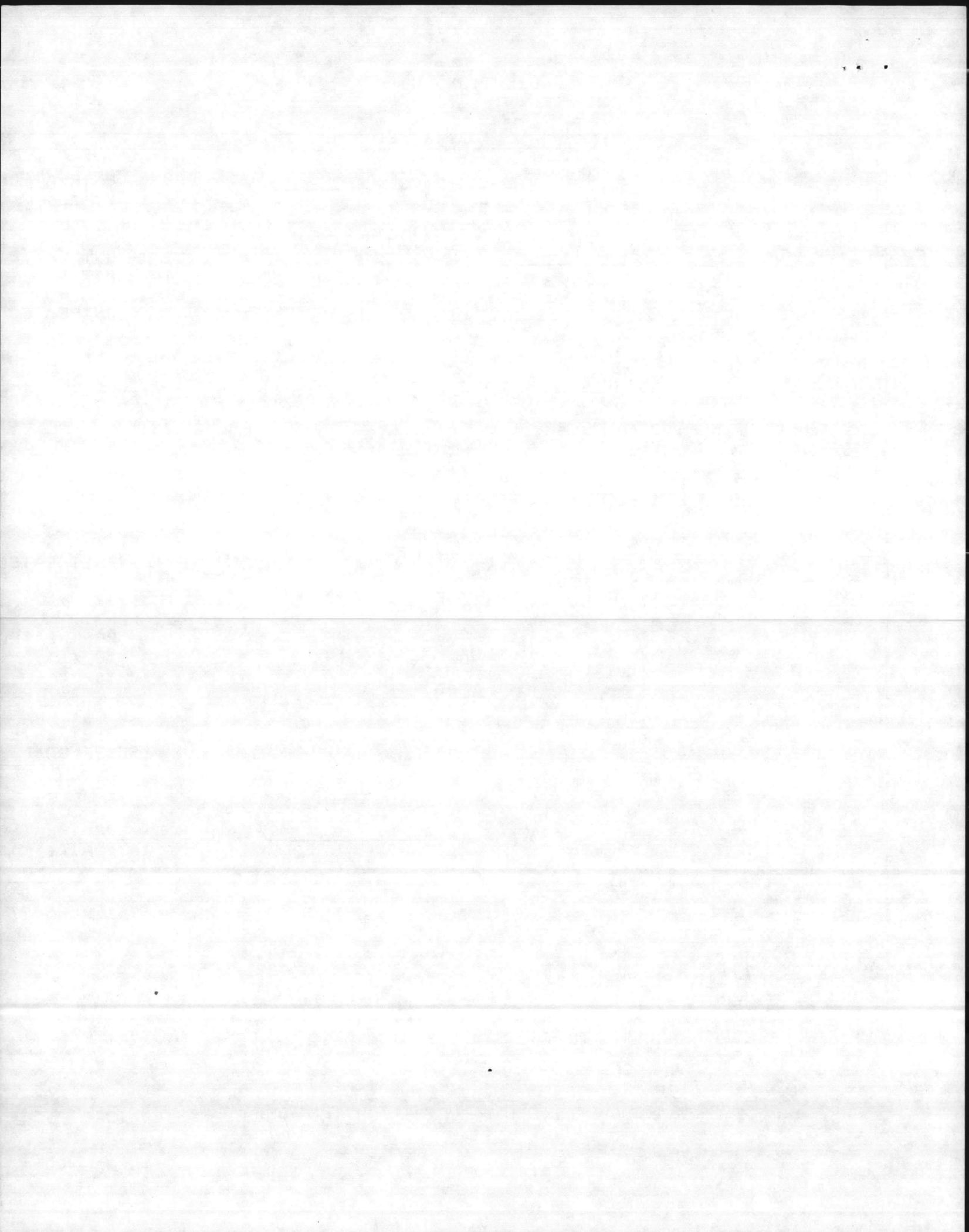


DILUTION INDEX (TPI)

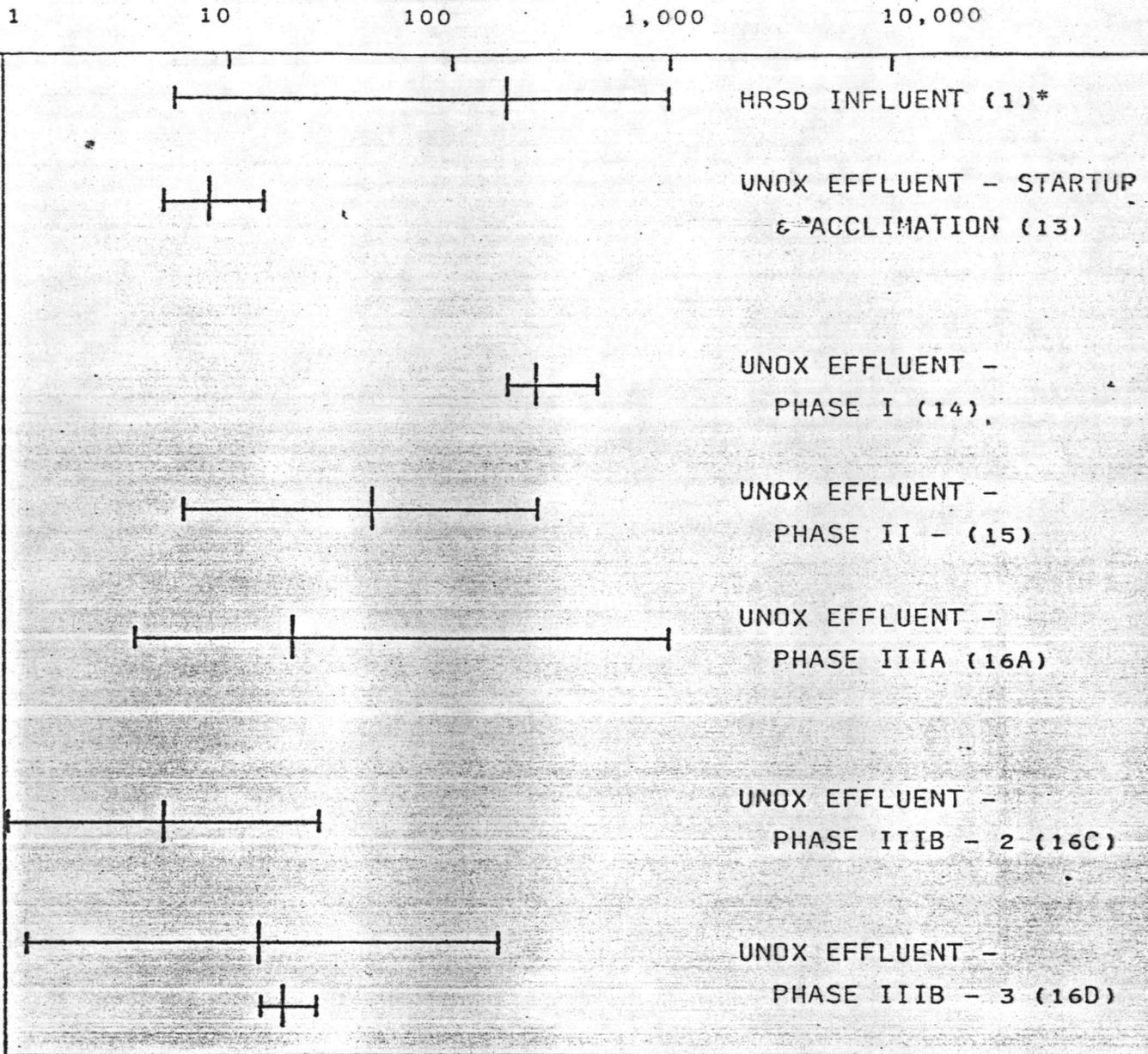


\*(2) NUMBERS CORRESPOND TO THE SAMPLES LISTED IN TABLE 9. TOXICITY RESULTS.

FIGURE 11. OYSTER LARVAE TOXICITY.- FIREFIGHTING SCHOOL WASTEWATER

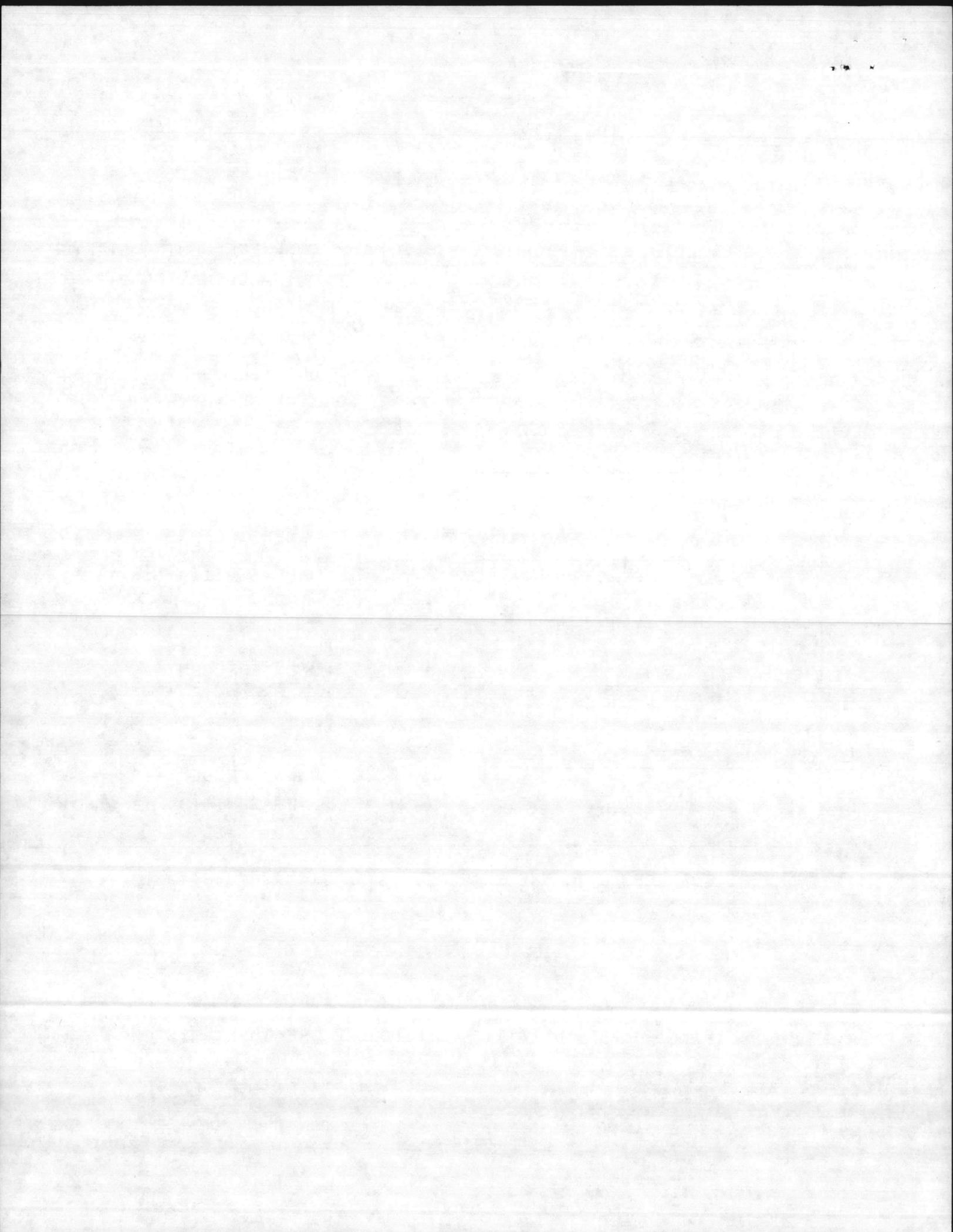


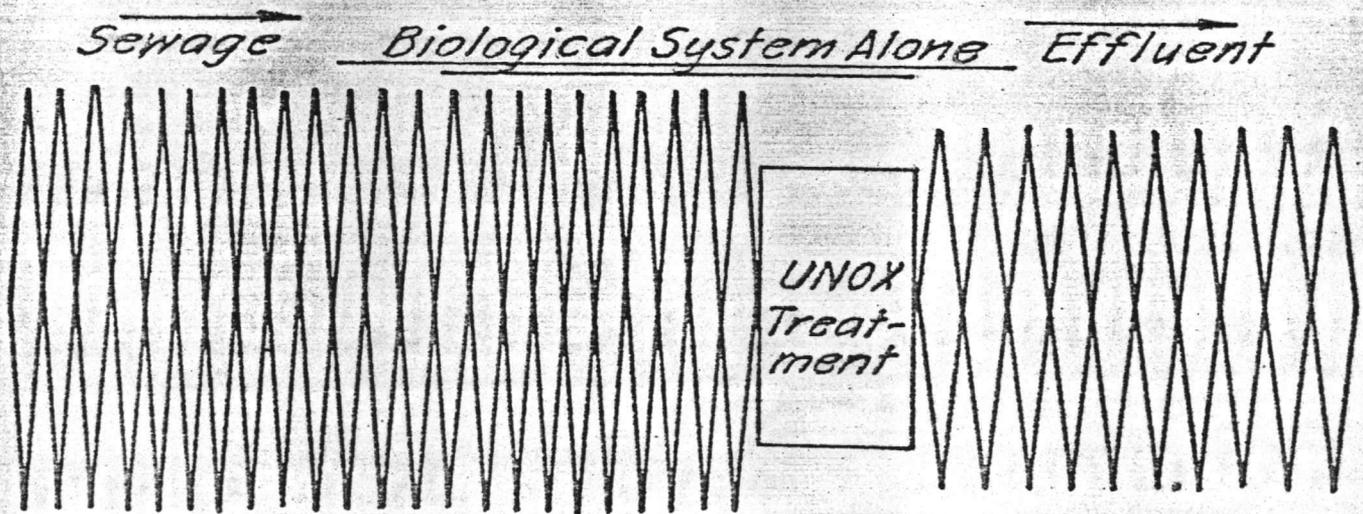
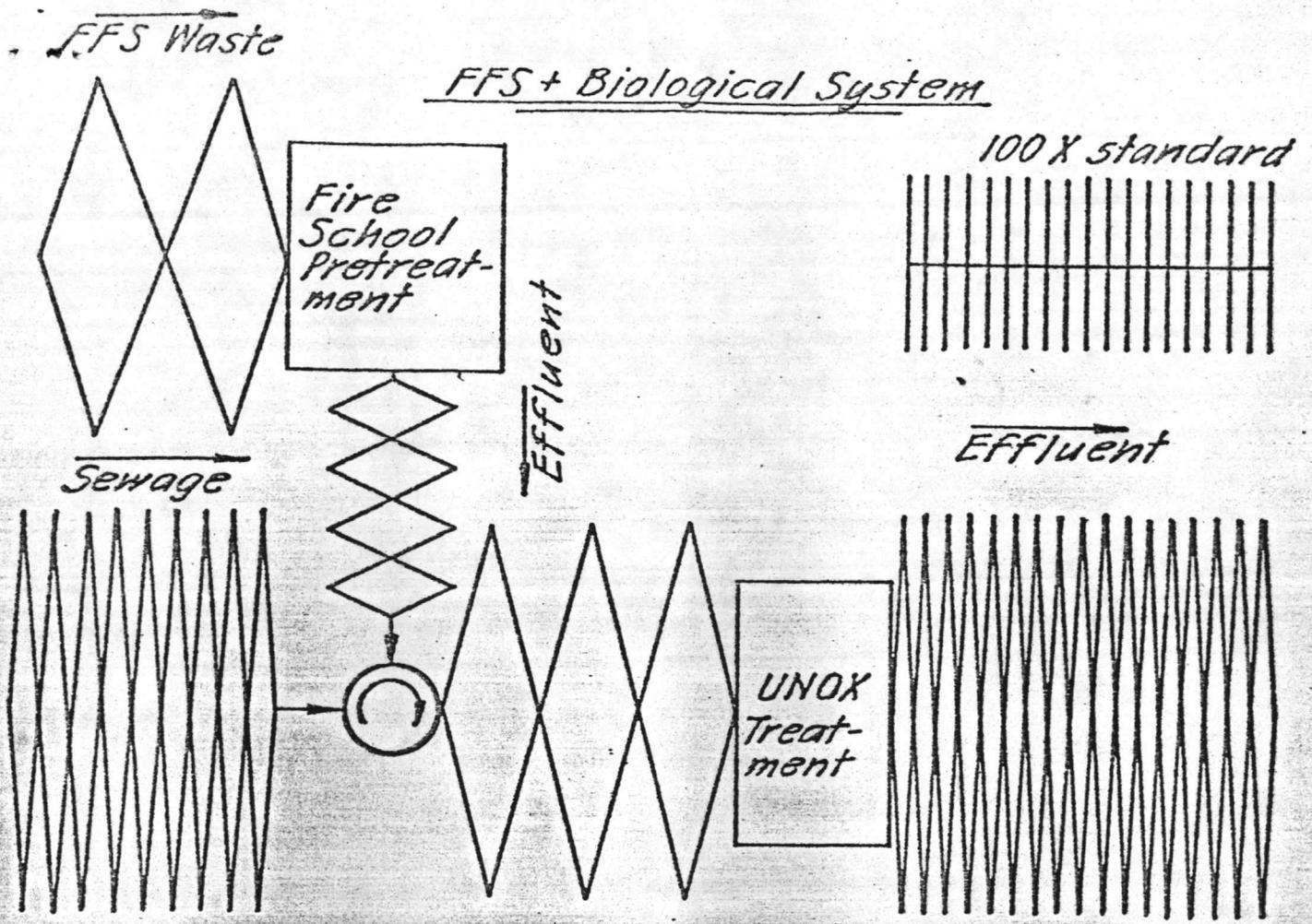
DILUTION INDEX (TPI)



\*(1) NUMBERS CORRESPOND TO THE SAMPLES LISTED IN TABLE 9, TOXICITY RESULTS

FIGURE 12. OYSTER LARVAE TOXICITY - BIOLOGICAL TREATMENT SYSTEM





Conceptual view of relative wastestream toxicities  
Figure 13.

