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Title AIRCRAFT WASHRACK WASTES, THEIR CHARACTERISTICS AND TREATMENT

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Oils, greases, and grit which collect on an aircraft during flight are removed on the U. S. Air Force washracks using an alkaline, water-base cleaner. Waste-flows from these washracks may include in addition to free oils, emulsified oils, and alkaline, water-base cleaners several other constituents such as acid skin brightners, paint stripping solvents, paint scrapings, and volatile cleaning solvents.

A study of aircraft washrack waste characteristics and treatment methods is presented in this thesis. The first section is a review of available literature including past experimental analysis. A survey of current washrack installations and treatment facilities at 65 Air Force bases in the United States forms the second section. The final section of this thesis contains an experimental analysis of

the washrack wastes and the treatment facility at Portland AFB, Oregon.

Oil concentration, five-day BOD., suspended solids, total solids, and effluent over-flow are used to measure the waste characteristics and flow and to determine the efficiency of a gravity oil separator at the Portland base. A testing procedure for determining oil concentrations is developed.

Tests of the inflow and outflow of the gravity oil separator showed the following ranges.

Waste Characteristics	Influent	Effluent
5-day BOD. (mg/l)	530 - 3,300	350 - 1,250
Oil Content (mg/l)	1,450 - 6,400	240 - 1,130
Suspended Solids (mg/l)	34 - 270	28 - 80
Total Solids (mg/l)	690 - 2,400	500 - 2,070

The conclusions drawn from the test results are as follows:

1. An acclimated seed was required for the five-day BOD. test of aircraft washrack wastes.
2. For oil concentrations in washrack wastes, the testing procedure presented in this thesis measured oil concentrations with an error of less than four percent.
3. The gravity oil separator at the Portland AFB provided an average BOD. reduction of 37 percent and an oil

removal of 70 percent.

4. The effluent from the gravity oil separator contained only emulsified oils.

5. The average oil content of the treated effluent was 589 ppm. This value greatly exceeded the general limit of 30 ppm, established by states which had oil concentration standards.

6. An average of 410 gallons of water was required to wash a C-119 aircraft at Portland AFB.

AIRCRAFT WASHRACK WASTES, THEIR CHARACTERISTICS AND TREATMENT

by

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INTRODUCTION

Aircraft of the United States Air Force log countless air miles each year. Some of these aircraft are on routine training missions, some are on patrol flights, while other aircraft are transporting men and support materials. From these flights, oils, greases, dirt, and metal oxides collect on the aircraft surfaces. To remove these films the aircraft are washed at periodic intervals or when other maintenance operations are to be performed.

The aircraft washing procedure involves the spraying of specified cleaners on prescribed skin surfaces to loosen and emulsify the collected films. The surfaces are then brushed and rinsed off with hot or cold water. If need be, the procedure is repeated. Following the aircraft washing, the clad aluminum surfaces may be sprayed with an acid skin brightner designed to remove corrosion products and to improve the appearance of the aircraft. The brightner is applied with a nonatomizing spray, allowed to sit for five to twelve minutes, and then is rinsed off with water (7).

The wastes normally derived from the washracks are composed of free-floating oils and greases, settleable solids, and a milky, soap-like emulsion containing suspended oil and grease particles. The milky emulsion is extremely stable and resistant to many methods of cracking. Investigators have observed that the . . . "untreated emulsions would stand for months without any tendency to separate, retaining their milk-like appearance" (16, p. 436). Excluding free-floating oils, the oil concentration in the emulsion may vary from several ppm. to several thousand ppm. with most of the oil concentrations falling into the 100 to 1,000 ppm. range.

The discharge of untreated washrack wastes which can be (1) high in biochemical oxygen demand (BOD), (2) toxic to stream life, and may (3) reduce surface re-aeration, (4) cause taste and odor problems in drinking water supplies, and (5) cause offensive and unsightly conditions along stream banks may, but not necessarily, create pollution problems.

Air Force Regulation 91-9 states,

> Military authorities in the continental U. S. will co-operate with civil authorities in preventing the pollution of surface or underground waters by sewage or industrial wastes from Air Force installations by compliance with the laws of the state where the installation is located.

In the states where oil concentration limits exist, the acceptable limit of oil concentration in streams varies from 15 to 30 ppm. (22, p. 163).

Industrial wastes at U. S. Air Force installations arise chiefly from metal plating, aircraft and vehicle washing, and engine part cleanings.

> The extensive industrial activity carried on at Air Material Command installations results in more varied and complex wastes, but almost all installations generate wastes from aircraft washings and small plating operations (22, p. 162).

Thus not only aircraft washrack waste, but acids, alkalies, chromates, and heavy oils may in some cases be added to the treatment considerations.

Purpose of the Study

The purpose of this study is to develop a comprehensive picture of the past, present, and future problems and solutions connected with the examination and treatment of aircraft washrack wastes.

Statement of Scope

The body of this thesis is divided into three main sections. The first section traces the experimentation and development of methods to treat washrack wastes. A survey of current washrack installations and treatment facilities at 65 Air Force bases in the United States is presented in the second section. The third section is concerned with the development of experimental procedures to evaluate washrack wastes and treatment methods. These procedures are then applied to the analysis of washrack wastes and treatment facilities at Portland AFB, Oregon.

LITERATURE REVIEW

One method of studying an industrial waste problem is to investigate (1) the characteristics and quantity of the waste, (2) treatment theories on laboratory scale, and (3) to apply knowledge gained from laboratory studies to full scale operations.

The available literature on washrack wastes and methods of treatment have been arranged in this manner. Other related wastes sometimes combined with washrack wastes, such as wastes from metal plating and engine part cleaning, will be included when applicable in the discussion.

Composition and Quantity of Washrack Wastes

Cleaners. The Air Force specifications for cleaners are written on a performance basis. For this reason a number of different commercial cleaners are used (Appendix A).

Generally the cleaners are alkaline, water-base compounds made up of the following constituents: aromatic hydrocarbons or trisodium phosphate, an alkaline pH buffer such as caustic potash, emulsifying agents and glycol derivatives. "The emulsifying agents are nonionic detergents which are biologically degradable, and fatty acids which combine with caustic potash to form a potassium soap.

The glycols serve as couplers."[1]

An acid skin-brightner, sometimes used in conjunction with the alkaline, water-base cleaner to remove stains from clad aluminum surfaces, conforms to military specification MIL-C-25378.

Prior to about 1958, a commercially manufactured crude soap (often referred to as gunk) mixed with kerosene was used in place of the alkaline, water-base cleaner for washing aircraft. Depending on the strength required for aircraft cleaning, the ratio of gunk to kerosene usually varied between 1:7 and 1:10 (14, p. 284).

Composition of Wastes. Free and emulsified oils, and greases are found in the industrial wastes of most Air Force installations. Emulsified oils and greases are defined by the Air Force (24, Appendix p. 1) as "the type of waste resulting from the cleaning of engines, gears, and similar parts of machinery with gunk and kerosene or other solvents of grease and oil." Waste containing only free-floating oils and greases are referred to by the Air Force as "a waste resulting from the washing of aircraft using an alkaline, water-base washing compound as specified in MIL-C-25769. This waste does not contain emulsified oil or grease in significant quantity."[2]

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[1] For reference to quote see foot note 4, page 49.

[2] The reader is urged to study page 43 of this thesis in conjunction with this definition.

At the time when gunk was used for both aircraft washing and engine part cleaning, Koruzo (14, p. 284) reported the waste characteristics shown in Table 1.

Table 1. Characteristics of oil wastes from Air Force installations.

Oil and Grease (ppm.)	800-5,000
pH	7-9
Turbidity (ppm.)	1,600-8,500
Suspended Solids (ppm.) *	nominal
Total Solids (ppm.) *	nominal

* Exclusive of oil and grease.

Investigations by Coulter et al. (8, p. 111) at several Air Force bases showed that the wastes contained as much as two percent gunk and six percent kerosene. They found the stable emulsions formed by the gunk to be toxic to fish life, to exert approximately 13,000 ppm. five-day BOD. and to contain almost 14,000 ppm. oil expressed as kerosene.

Mahood (16, p. 435) reported the composition of the waste at the San Francisco International Airport, United Airlines maintenance station. The wastes were derived from numerous cleaning operations including washrack wastes, washing of engines, engine parts, accessories and airframe parts, and paint stripping. Cleaning agents used were petroleum solvents and detergents instead of gunk.

The resultant wastes contained both free oil and highly stable emulsions of oil and solvents. The test results are shown in Table 2.

Table 2. Characteristics of total combined waste flow from the San Francisco International Airport.

Total Oil	500 to 1200 ppm.
Emulsified Oil	250 to 700 ppm.
BOD.	400 to 800 ppm.
Suspended Solids	70 ppm.
Volatile Solids	40 ppm.
pH	6.8 to 7.2
Conductivity	330 micromhos

The composition of industrial wastes from various Air Force bases are summarized in the Appendix C.

Quantity of Waste. Before the change from gunk to the alkaline, water-base cleaner, the Robert A. Taft Sanitary Engineering Center (25, p. 5) reported that approximately 2,800 gallons of wash water per aircraft were used for large aircraft such as the C-124 and 1,500 gallons per aircraft for small aircraft such as the B-57. Koruzo (14, p. 284) stated that the total wash wastes from large aircraft varied from 8,000 to 12,000 gallons.

Air Force Manual 85-14 (22, p. 168) states that "The average flow of aircraft wash wastes under customary washrack use by the largest aircraft ranges from 0 to 25 gpm. with a peak flow of 75 gpm. for a period of one-half to one hour during hosing down operations."

McClellan AFB,[3] estimates the combined flow from their two washracks to be 13,000 gpd.

Treatment of Washrack and Related Wastes

Investigators have generally followed the pattern of first determining methods of cracking the oil-water-solvent emulsions to facilitate gravity separation. After cracking the emulsion, ways to treat the partially clarified liquid using chemical, biological, or physical means were studied.

Experimental Investigations. The experimental work reported in the literature was done prior to the adoption of the alkaline, water-base cleaner. However, because the gunk-kerosene cleaner is still used to clean engine parts and because future experiments will follow many of the same procedures this topic has been included. The wastes under discussion in this section are assumed to contain the gunk-kerosene cleaner unless otherwise specifically stated.

Studies of washrack waste samples by the R. A. Taft Engineering Center (25) showed that after free oils had been separated, the remaining emulsified oils after several months did not exhibit any tendency to separate.

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[3]The information was taken from the letter written by Base Engineering Office, McClellan AFB, California.

For complete treatment the R. A. Taft Engineering Center and others found it necessary to use chemicals to break the emulsions. J. B. Coulter, _et al._ (8, p. 100) states,

> A review of specifications and an approximate analysis indicate that various soaps and soap-like compounds make up a large fraction of the gunk. Therefore, it might be expected to react with mineral acids or hardness ions to form the typical insoluble curd common to household soaps.

Coulter investigated various chemicals for their efficiency in breaking emulsions. The results of his work are given in Table 3. The most effective chemical was ferric sulfate. This fact was probably due to the combined effects of the trivalent ferric ion and the lowering of pH. Both acids and calcium chloride behaved about the same.

Table 3. Relative efficiency of various chemicals, minimum dose required to break emulsions.

Chemical	Commercial Product	Commercial Product Per Gallon of Gunk	me/ml. of Gunk
Ferric sulfate	$Fe_2(SO_4)_3 9H_2O$	0.94 lbs.	1.2
Calcium chloride	$CaCl_2$	1.39 lbs.	3.0
Calcium oxide	$Ca(OH)_2$	6.48 lbs.	21.0
Hydrochloric acid	HCl, 12N	1.04 liters	3.3
Sulfuric acid	H_2SO_4, 36N	0.31 liters	3.0

The Water Pollution Research Board of England (12, p. 71) found that at least 4000 ppm. each of aluminum sulfate and sulfuric acid were required to break the emulsion. Sulfuric acid and common salts by themselves also produced satisfactory results. They also reported that unless the pH was reduced to 2.6, aluminum, ferric or calcium salts produced very bulky precipitates.

Jar tests by Coulter's group (8, p. 102) showed that the floc characteristics of both ferric sulfate and alum were pH dependent. Floc first formed at pH 5.0 - 4.7; poor floc was observed at pH 4.7-4.0; good results again were recorded at pH 4.0 and below.

The R. A. Taft Engineering Center (25, p. 2) came to the conclusion that calcium chloride had a number of "practical advantages" over ferric sulfate or alum.

> It is low in cost, easy to handle, readily soluble in the waste, requires only a flash mix, and produces a low volume of sludge even with excess doses. Moreover, optimum results are not pH dependent.

In the case of ferric sulfate, the Taft Center pointed out that the addition of alkalinity such as lime to the ferric sulfate produced a stronger floc over a wider range of chemical application with faster and better clarification. In one instance the net effect was to raise the pH from 2.8 to 5.7 and the light transmittance from ten percent to 75 percent.

After methods to break the emulsion were studied, the second step was to determine on a laboratory scale the best method to achieve a neutral, oil-free effluent. Investigations were conducted using filtration, lagooning, air flotation, and biological treatment.

Coulter et al. (8, p. 108) in their summary of the R. A. Taft Engineering Center report (25) stated that, when a previously cracked emulsion free of floating material was passed through filter paper, an effluent of tap water clarity was produced.

To explore the possibility of using filters in plant operation, small tubes of sand, excelsior, wood chips, glass wool, hay, activated carbon, and sawdust were tried as filter media. The test procedure followed was (1) emulsion cracking using an acid or calcium chloride in a flash mix, (2) 30 minute separation period, (3) removal of floating oil and scum, and (4) filtration of the subnatant.

The group found that sawdust produced the best effluent. Further tests were made using three inch diameter tubes filled with sawdust to a depth of 12 inches and packed to a density of approximately 13 pounds per cubic foot. Both untreated waste and cracked subnatant were filtered through the sawdust under a free head of two inches. Very poor results were obtained with the untreated waste. With pretreated wastes, at pH 7, the filtrate developed a yellow-green tinge and a slight turbidity in filter runs using both cracking agents. A faint odor characteristic of sawdust could be detected.

Color and odor were undetectable at a dilution of three parts tap water to one part filtrate. Studies showed that the residual oil in approximately 1,100 gallons of pretreated washrack waste could be removed with a cubic foot of sawdust.

The R. A. Taft Engineering Center (25, p. 20) reported that sawdust filtration reduced the toxicity to fat-head minnows by a factor of 10.

Coulter et al. (8, p. 102), and the R. A. Taft Engineering Center (25, p. 2) reported the effects of prolonged settling or lagooning. Untreated waste showed no clarification after several months, but pretreated wastes gradually cleared. Samples of the subnatant from the pretreated waste were taken after 30 minutes and 24 hours separation. After 30 minutes the BOD. was 1,800 ppm. and after 24 hours it was 500 ppm. The oil content was 1,000 ppm. at 30 minutes and 85 ppm. at 24 hours.

Dissolved air flotation was investigated by the R. A. Taft Engineering Center (25, p. 37) and reviewed by Coulter et al. (8, p. 103). To duplicate the air flotation process on a laboratory scale, a cylinder similar to that described by Rohlich (17, p. 304) was used. Using coagulants such as ferric sulfate, 90 percent of the cylinder volume was clarified nearly three times faster by the flotation process than by simple gravity separation. At the end of two hours the oil content of the subnatant was the same for the two cases.

Pilot plant studies were conducted at Carswell Air Force Base, Texas, to evaluate dissolved air flotation equipment. A "Sediflotor" air flotation unit was operated at a flow rate of 90 gpm., and at an air saturation tank pressure of 40 psi. gauge. Both ferric sulfate and alum were used as emulsion cracking agents (25, p. 39). Samples taken from a receiving stream at a point several hundred yards below the outfall showed oil contents less than 20 ppm. as measured by the direct extraction method (15, p. 1840). Alum and ferric sulfate produced the same oil removal; however, the rust colored floc of ferric sulfate in the effluent caused unsightly conditions along the stream banks.

Tests were also conducted by the R. A. Taft Engineering Center to determine the effect of untreated and pretreated aircraft washrack wastes on trickling filters being fed primarily with domestic sewage. An apparatus resembling that described by Gloyna (10, p. 1356) was used. The device consisted of three, 24 inch long plastic tubes three inches in diameter and mounted on a 2.5 percent slope. The tubes were rotated slowly while wastes pumped in at the upper end trickled slowly over a growth that developed on the inner walls of the tubes. A summary of results presented by

Coulter et al., (8, p. 108) is shown in Table 4.

Table 4. Biological treatment, summary of results.

Test	BOD. ppm. Inf.	BOD. ppm. Eff.	Oil ppm. Inf.	Oil ppm. Eff.
Tube No. 1 control -- sewage only	82	4	21	9
Tube No. 2 pretreated waste and sewage	137	7	51	17
Tube No. 3 untreated waste and sewage	609	48	579	565

The R. A. Taft Engineering Center (25) concluded that untreated aircraft washrack waste should not be discharged directly into sanitary sewer systems. Free oil concentrations of four percent or greater in sewage wastes would cause adverse effects on trickling filters. The laboratory model with untreated washrack wastes (Tube No. 3) developed an oil concentration in the biological media and bulking which would have clogged a full scale filter. The final effluent was cloudy and had poor settling characteristics.

The same study by the R. A. Taft Engineering Center showed that chemically pretreated wastes had no ill effect on the experimental trickling filters. Chemical pre-treatment consisted of a flash mix using calcium chloride followed by a 30 minute detention to allow the oil and gunk residue to separate from the subnatant.

Some testing has been done on aircraft washrack wastes containing the alkaline, water-base solvent as a cleaner instead of the gunk-kerosene cleaner. The British Water Pollution Research Board (11, p. 41) reported that a number of alkaline, water-base compounds used on aircraft were studied to determine the effect of these compounds on biological treatment processes. They found that the cleaning compounds had BOD. values approximately 100 times greater than strong domestic sewage. If the emulsified oil were first separated, they felt that wastes containing alkaline, water-base cleaners could be discharged to the sewers for biological treatment with sewage.

Mahood (16, p. 436) in his study of United Airlines washrack waste problems at the San Francisco International Airport reported that, "A number of commercial coagulant aids were tested and found to be ineffective as were simple acid or alkaline treatments." Pilot plant studies indicated that the addition of alum and activated silica followed by pressure flotation was the most effective method of treatment.

Treatment Methods. A number of methods have been used to treat washrack and related wastes with varied success. The treatment systems are most easily classified by the following: gravity separation, chemical coagulation, air flotation, lagoons, and filtration.

Gravity Separation At Air Force installations (22, p. 169), the gravity separation unit usually consists of a 5,000 gallon steel or concrete holding tank with a slotted pipe overflow or differential weir to recover the surface oils and greases. A weir system or pump is used to regulate the discharge of tank effluent. The separation tank is sometimes preceeded by a grit trap.

The Air Force (22, p. 169) pointed out that the only treatment normally required for aircraft washrack wastes was the removal of free oil and greases usually by gravity separation. Occasionally gravity separation tanks would be preceeded by chemical pretreatment units.

Gravity separators are designed to remove only the floating oils and greases. The American Petroleum Institute (2, p. 13) mentioned that emulsified oils would not be trapped by gravity separators unless the emulsion were first broken.

Chemical Coagulation A chemical coagulation plant treats aircraft washrack and related wastes by (1) coagulation, (2) flocculation, (3) sedimentation or flotation, and (4) filtration if necessary.

The Engineering News Record (7, p. 40) described an inexpensive operational chemical coagulation plant developed by William R. Stevens, sanitary engineer with the Wiesbaden Air Base, Wiesbaden, Germany. The cleaning agent being used was the gunk-kerosene mixture (1:9 by volume). During washing operations the

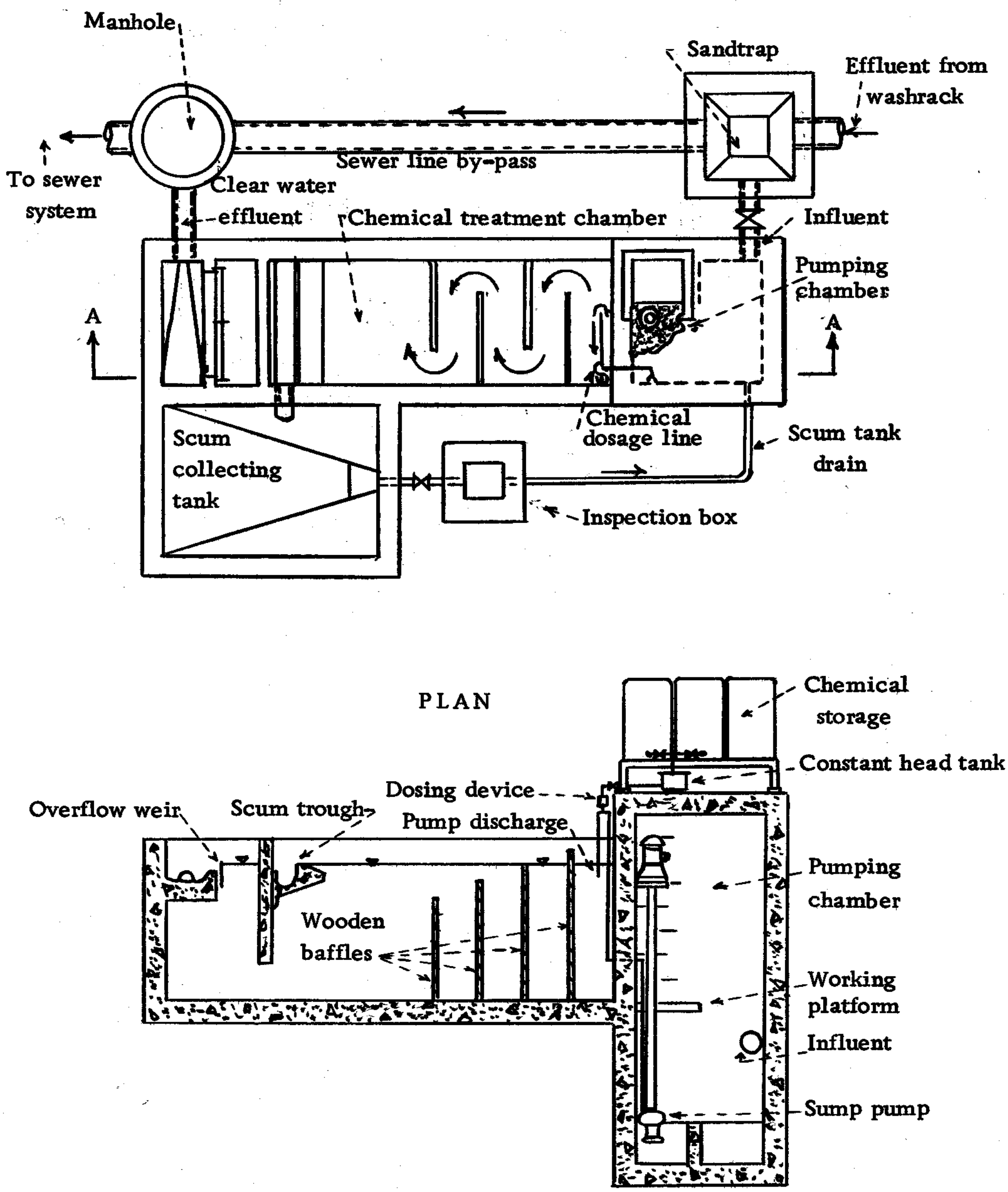
BOD. of the influent was about 800 ppm. Experimentation with several coagulants showed that 700 ppm. of aluminum sulfate produced the best results. BOD. and total solids were reduced by more than 90 percent. A schematic diagram of the plant is shown in Figure 1.

For the most efficient operation, API (2, p. 42) recommended that holding basins be used to provide uniform flow through the chemical coagulation plant.

Air Flotation The process of air flotation employs the dissolving of air into the waste water under pressure and then releasing the solution to atmospheric pressure thereby causing air bubbles to form and float certain waste fractions to the surface. D'Arcy (9, p. 39) presented a good description of air flotation. In his discussion, D'Arcy made a distinction between dissolved--air flotation and colloid--air flotation. He referred to air flotation processes using floc forming chemicals as colloid--air flotation. Units not using floc forming chemicals were referred to as dissolved--air flotation units. Unless a distinction is made, this thesis assumes the term air flotation to be synonymous with colloid--air flotation.

Flotation methods have been used to concentrate mineral ores for almost a century. Another early use of dissolved--air flotation was in the paper industry for the recovery of solids in the "White

Figure 1. Chemical coagulation plant, Wiesbaden Air Base, Germany.



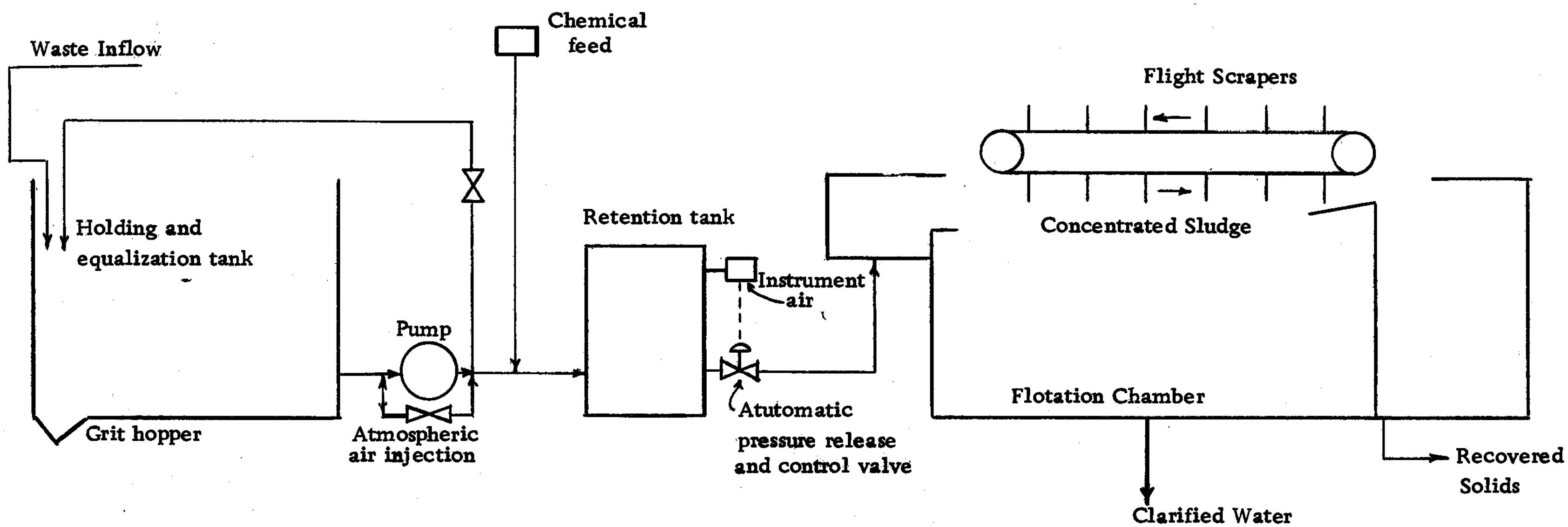
SECTION A-A

water" wastes (9, p. 34). Flotation in 1952 began to receive significant attention as a method to remove suspended solids and oils from waste waters.

A natural application of air flotation was in the treatment of washrack and other oil wastes found on air bases. Air flotation units are presently being used at various air bases, especially at Air Material Command bases where the types of wastes more generally warrant this method of treatment.

Air flotation units such as the unit shown in Figure 2 work in the following manner. The raw waste enters a gravity separator where free oils and greases are skimmed off the top and the grit is allowed to settle out. Air is then introduced into the waste stream at the suction side of the pump, and dissolved under pressure (25 to 40 psi.) in the retention tank. Flocculating chemicals, often aluminum or iron salts, are added to the waste stream prior to the retention tank. The purposes of the retention tank are to provide contact time for the flocculating chemicals, to provide time for the air to be dissolved, and to trap any undissolved air which may be present in the system. When the waste reaches the flotation chamber the dissolved air comes out of solution to aid in floating the floc particles to the surface where flight scrapers remove the concentrated float consisting of emulsified oils and greases. The

Figure 2. Air flotation plant diagram.



NOT TO SCALE

clarified water is withdrawn from near the bottom of the flotation tank.

Lagoons Secondary settling or lagooning has been used primarily for secondary treatment of aircraft washrack wastes. At some air bases in the southwest where washrack waste flows were small, the lagoons were used as primary or evaporation lagoons.

In aerobic lagoons carbonaceous matter is oxidized by aerobic bacteria to carbon dioxide which is used by the algea for photosynthesis. The algea in turn supply oxygen to the aerobic bacteria. "With oil wastes, the organic constituents are converted to algea or are directly oxidized to the extent that they physically separate from the waste water either by rising or settling" (2, p. 51).

Filtration Other methods such as vacuum filtration and sand or hay filtration were discussed by the American Petroleum Institute (2, p. 40). According to the available literature, filtration was not generally used as a method for treating washrack wastes. However, F. A. Sanders, Lt. Col. USAF (18, p. 387) reported that at Kelly Field AFB industrial oil wastes including washrack wastes, following coagulation with alum to remove emulsified oils, were passed through percolation filters before final sedimentation.

The American Petroleum Institute (2, p. 41) states that slow sand filters operated in the two to ten mgad range but would clog extremely fast when the turbidity exceeded 30-50 ppm.

SURVEY OF CURRENT WASHRACK INSTALLATIONS AND TREATMENT FACILITIES AT AIR FORCE BASES IN THE UNITED STATES

Aircraft Washrack Wastes Questionnaire

A questionnaire and letter of explanation were sent to 130 Air Force bases in the United States requesting information about their methods of treating washrack wastes. Replies from 50 percent of the contacted bases supplied the material for this section.

The information received was compiled into a description of the facilities and operations for each air base. The descriptions are arranged in alphabetical order according to the name of the base, assigned an index number, and are included in Appendix C. Table 5 serves as both a cross reference index and a summary of the questionnaire information. For example, item 1 (c) in Table 5 shows that nine Air Force bases make use of gravity separation followed by air flotation to treat their aircraft washrack wastes. The index numbers refer to the descriptions in Appendix C and indicate the air bases using this treatment method.

The questionnaire supplied the desired answers except in a few cases. A copy of the questionnaire and a list of suggested modifications have been included in Appendix C.

Table 5. Summary of washrack waste treatment practices at Air Force bases in the United States.

ITEM	INDEX NUMBERS	ITEM TOTAL
1. Method of Treatment		
(a) Gravity separation only	1, 26, 33, 34, 37, 47, 48, 52, 61,	9
(b) Air flotation only	5, 9, 12, 64,	4
(c) Gravity separation and air flotation	4, 22, 38, 39, 42, 44, 45, 50, 56,	9
(d) Other	10, 16, 27, 40,	4
(e) No treatment	2, 7, 14, 19, 23, 28, 29, 31, 35, 36, 41, 46, 49-51, 53, 54, 55-60, 62, 65, 66,	25
2. Final Disposal of Waste Water		
(a) Stream or river	1, 2, 4, 5, 7, 9, 12, 14, 19, 26, 27, 31, 33, 36, 38-40, 42, 45-48, 50, 51, 54, 56, 57, 64,	28
(b) Evaporation or leeching	10, 23, 29, 34, 37, 41, 53, 61, 62, 65,	10
(c) City sanitary sewer	22,	1
(d) Other practices	12, 16, 28, 35, 44, 49,	6
3. If Washrack Wastes are Treated		
(a) Disposal of oil and grease		
(1) by burning	4, 5, 22, 26, 33, 37, 48, 52, 61,	9
(2) by burying	12, 16, 39, 44, 45,	5
(3) other practices	27, 34, 38, 42, 64,	5
(b) Disposal of grit particles		
(1) by burying	1, 4, 12, 16, 22, 26, 33, 34, 38-40, 44, 45, 48, 52, 61, 64,	17
(2) other practices	5, 27, 37, 42,	4
(c) Name of chemicals used to break the oil emulsion	4, 5, 12, 22, 27, 38, 39, 42, 44, 45, 56,	11
(d) Air flotation		
(1) air pressure used	4, 5, 12, 22, 38, 39,	6
(2) name of manufacture	4, 5, 9, 12, 22, 39, 42, 45,	8

Table 5 (continued)

ITEM	INDEX NUMBERS	ITEM TOTAL
4. General Information		
(a) Approximate number of aircraft washed per month	1, 2, 4, 5, 10, 12, 14, 16, 19, 22, 23, 26, 27, 29, 33, 34, 36-40, 42, 47, 48, 50-52, 56, 57, 60-62, 65,	33
(b) Bases using acid skin brightner	12, 14, 19, 23, 27, 33, 36-38, 44, 45, 47, 48, 50, 56, 57, 61, 65	18
(c) Bases not having aircraft or not operational	3, 8, 11, 13, 15, 18, 21, 30, 43, 63,	10
(d) Base without washrack facilities	6, 17, 20, 24, 25, 32, 55,	7
5. Chemical Tests Performed on Washrack Wastes	12, 22, 26, 27, 38, 39, 42, 51,	8

Estimated washrack waste flows by Air Force personnel for a number of aircraft are listed in Table 6.

Table 6. Estimated flows from washracks by Air Force personnel.

Aircraft	Flow Estimates in gpm. Low	Average	High	Single Est.
B-52	30	77	100	
B-47	40	80	150	
KC-135	50	78	100	
F-105				100
F-101				20
F-100	30	40	50	
C-133				100
C-130	25	63	100	
C-124	100	100	100	
C-121				35
C-97				20
T-38	40	45	50	
T-37	5	31	50	
T-33	5	35	50	
T-29	50	50	50	

Six Air Force bases were able to supply information concerning chemical tests performed on aircraft washrack and related wastes. This information has been grouped together in Appendix C.

Miscellaneous Air Force Policies

Following the Air Force policy of combining industrial wastes when possible, bases which have air flotation processes make it their policy to save waste acids and alkalies from other base operations. The waste acids play a part in cracking the oil-solvent-water emulsions and alkalies a part in pH control.

Air flotation units now being built for the Air Force must meet the effluent requirements as shown in Table 7 (24, Appendix, page 3).

Table 7. Effluent requirements for air flotation units.

Item	Maximum Allowable, ppm.
Oil and Grease	30
Suspended Solids	30

The oil and grease is to be measured using the Petroleum-Ether Extraction Method as outlined in Standard Methods, 10th ed. The Air Force recommends that the extraction be performed within 12 hours of sampling to prevent the loss of volatiles in the sample. Suspended solids of 30 ppm. is exclusive of oil turbidity and floc.

ANALYSIS OF WASHRACK WASTES AND THE TREATMENT FACILITY AT PORTLAND AFB, OREGON

Introduction

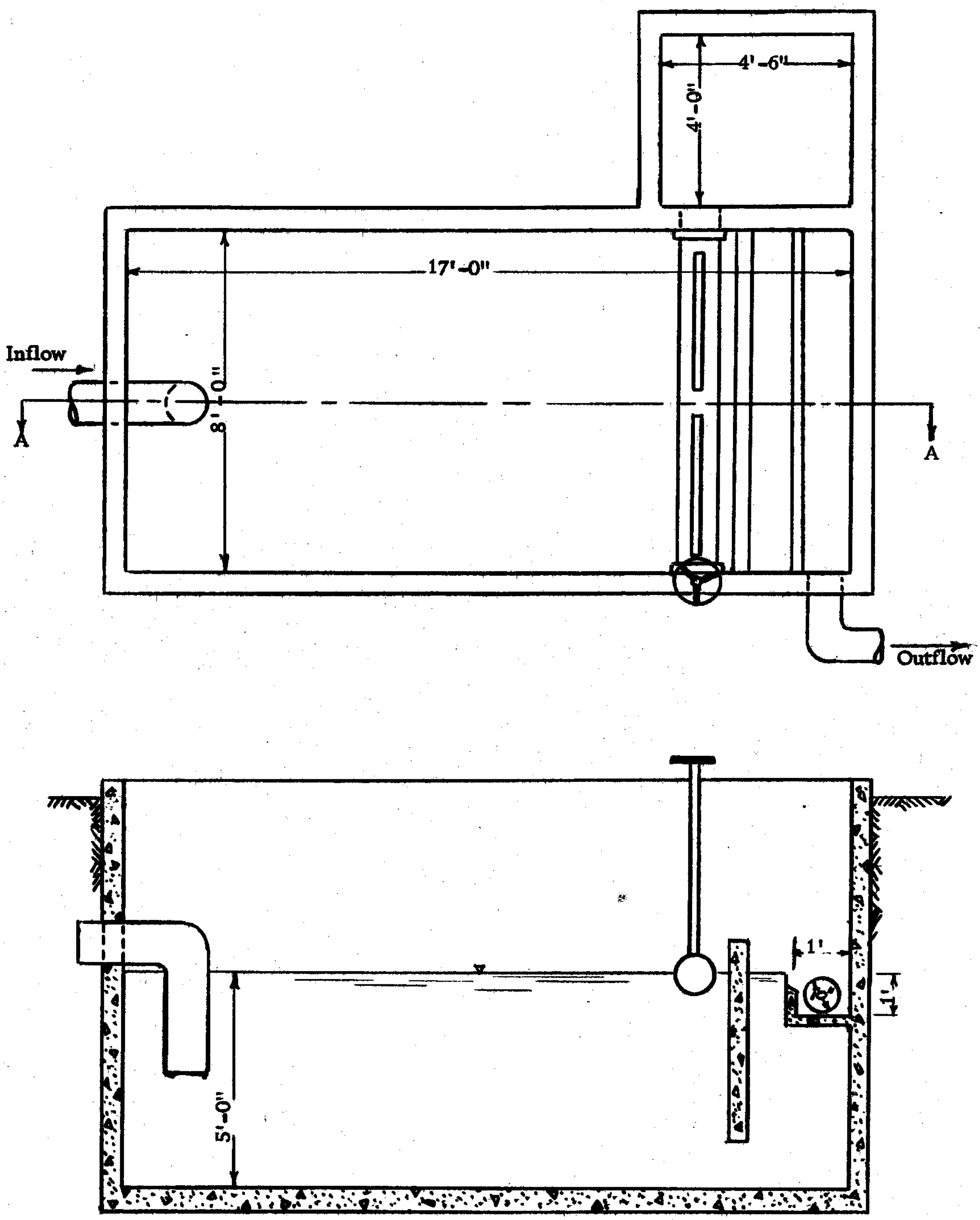
Portland Air Force Base is situated on the south side of a reclaimed Columbia River flood plane within the city limits of Portland, Oregon. The runways of the base are used jointly by the 337th Fighter Group, 939th Troop Carrier Squadron, Oregon Air National Guard, and the Portland International Airport. The climate of the area is moderate with a mean annual rainfall of about 35 inches occurring for the most part during the months of October through April. Average temperatures vary from 75^{o} F in the summer to 36^{o} F in the winter. Frost penetration seldom exceeds three inches. The base is drained by a series of open ditches, storm drains and small sloughs which all eventually reach the Columbia River. Flow in the ditches and sloughs is controlled primarily by the ground water table. Ponding and reversal of flow occurs frequently in the drainage ditches.

Prior to July of 1963, only the Oregon Air National Guard of the three military flying groups at Portland Air Force Base provided any treatment of washrack wastes. At the 337th Fighter Group and 939th Troop Carrier Squadron washing sites, the washrack wastes drained from the aprons into the open ditches and sloughs. Standing oils and solvents produced unsightly conditions and extreme fire hazards. A small gravity oil separator at the Oregon Air National Guard washrack removed the free oils and greases. The effluent which contained only emulsified oils was discharged to a nearby slough.

On July 24, 1963, a 5,000 gallon skimming tank or gravity oil separator for use by the 337th Fighter Group and the 939th Troop Carrier Squadron was completed. The design flow of 400 gpm. for the gravity oil separator was based on a flow of 30 gpm. from the washing operation and a storm flow of 363 gpm. The storm flow was arrived at by considering a storm frequency of two years with an intensity of 1.4 inches per hour and a maximum time of concentration on the apron of ten minutes. Figure 3 is a drawing of the gravity oil separator.

The effluent from the newly completed gravity separator flows through a storm sewer to one of the drainage ditches. Free oils trapped by the gravity separator will be burned or buried. At present, no attempt is made to crack the emulsified oils. The wastes which drain from the washing apron contain, oils, greases, grit, paint strippings, alkaline water-base cleaner, acid cleaner or skin brightner, paint stripper, and solvents similar to kerosene.

Figure 3. Gravity oil separator, Portland AFB.



SECTION A-A

Scale 1" = 4'

During the washing operation, the solvents are used to remove heavy greases from areas such as engine cowlings and wheel assemblies. Approximately ten C-119 aircraft are washed each month. The washing procedure for the C-119 involves the spraying of a small area of the aircraft with an alkaline, water-base cleaner, brushing the sprayed area, and then rinsing the area down using an 1-1/4 inch hose. The procedure is repeated until the complete aircraft has been cleaned. Following washing, an acid skin brightner is applied to corroded spots, brushed, and then rinsed off.

Method of Study and Experimental Design

Four tests, BOD., oil and grease, suspended and total solids, and flow measurements were chosen to determine the wash-rack waste characteristics and to measure the efficiency of the gravity separator used by the Fighter Group and Troop Carrier Squadron.

The first step involved determining modifications of the four above mentioned tests in order to make them suitable for determinations involving small concentrations of oils, greases, and solvents in waste water. Once analytical methods were formulated, and laboratory proficiency was obtained, tests were conducted on waste samples from the influent and effluent of the gravity separator during aircraft washings.

Analytical Methods

Biochemical Oxygen Demand. The five day, 20° C, biochemical oxygen demand of the aircraft washrack wastes was determined as outlined in Standard Methods (4, p. 309) using the Alsterberg azide modification of the Winkler method to measure the dissolved oxygen. An acclimated seed was maintained by regularly feeding small amounts of the alkaline, water-base cleaning solvent and other solvents present in the washrack wastes to a stock culture. The procedure for growing the modified BOD. seeding material has been included in Appendix B.

Oil and Grease. There are many methods available to test for oily matter in industrial waste waters. Attempts at standardization of these methods have not met with too much success. The ASTM Joint Committee on Uniformity of Methods of Water Examination (5, D 1340 - 60, p. 490) stated that... "uniformity of methods for the determination of grease and oily matter is not practicable on the basis of present technical knowledge." The four most popular methods being presently used to measure oil in water appeared to be the reflux distillation method, the infrared spectrophotometry method, the extraction-evaporation method, and the direct extraction-pycnometer method.

These four methods would probably produce different results; however, the results of any one method would be consistent provided the extraction solvent remained the same. According to ASTM (5, p. 490) the solvents most commonly used were hexane, petroleum ether, benzene, chloroform, or carbon tetrachloride. Each of these solvents has a particular affinity for specific greases and oils which may be of vegetable, mineral, or animal origin.

The definition of grease and oily matter due to the above consideration, must be based on the procedure used.

Reflux Distillation Both the American Petroleum Institute (3, API 731-53) and the American Society for Testing and Materials (5, ASTM D 1340-60) have published reflux distillation methods for measuring small amounts of greases and oils in waste waters. The two methods are essentially the same. In both cases the sample is refluxed through a trap which collects the volatile oily matter for volumetric measurement. The remaining sample is extracted with successive applications of solvent using mechanical agitation. The API method requires that benzene be used as the extraction solvent, whereas the ASTM method permits the use of benzene, chloroform, or carbon tetrachloride. After separating the solvent layer from the water, the extracts are distilled to remove the solvent. The residue is cooled and weighed.

Substances such as alcohols, phenolics and organic acids in addition to gasoline, fuel oil and hydrocarbons are measured. The API method provides a correction for organic acids.

ASTM (5, p. 491) defines oily matter as... "Hydrocarbons, hydrocarbon derivatives, and all liquid or unctuous substances that have boiling points of 90° C or above and are extractable from water a pH 5.0 or lower using benzene as solvent."

These two methods, by API and ASTM, are reported to measure better than 90 percent of the oily matter present, when the cut point between volatile and nonvolatile oily matter lies in the 230° to 260° C boiling range.

Extraction-evaporation. Standard Methods (4, p. 185) recommends an extraction-evaporation method for measuring small amounts of grease and oily matter in water.

The procedure involves using petroleum ether solvent under acid conditions to extract dissolved or emulsified oils and greases. After extraction, the petroleum-ether is evaporated at 70° C through a condenser. The remaining residue is cooled, weighed, and reported as oil.

Infrared Spectrophotometry. R. G. Simard *et al.* (20, p. 1384) explains that the infrared spectrophotometry method for determining oils is based on "bromination" of the phenols and oils in the water sample. Oil is determined in a carbon tetrachloride extraction from the phenol extraction (bromination) by optical density measurements in the 3.4 micron region. The API Committee on Analytical Research (1, p. 1682) reports that this method is reliable for oil concentrations as low as 0.1 ppm. with a standard deviation of less than ten percent. The deviations, API reports, seem to be caused by the variation in the absorptivity of different oil samples at 3.4 microns.

Direct Extraction-Pycnometer. The direct extraction-pycnometer method as developed by Levine, Maps and Roddy (15, p. 1840) is based...

> on the fact that carbon tetrachloride containing a small amount of oil will weigh less than an equal volume of pure carbon tetrachloride. The difference in weight is the difference between the weight of the oil dissolved in the carbon tetrachloride and the weight of the volume of solvent equal to that of the oil.

The amount of oil in the water is then calculated directly based on the assumption of an average specific gravity of the oil. The direct extraction-pycnometer method is sensitive to ten ppm.

Measurement of Oil and Grease. Each of the four methods has its own particular advantages and disadvantages. Considering (1) the type of oil waste generally found on Air Force bases, (2) the laboratory space and apparatus available, (3) the frequency of testing required, (4) the time required, and (5) availability of trained personnel, a modification of the extraction-evaporation method as outlined in Standard Methods (4, p. 185) was developed.

The modified extraction-evaporation procedure is included in Appendix B.

Suspended and Total Solids. A method outlined by the American Petroleum Institute (3, API method 709-53) was used to measure suspended and total solids in aircraft washrack wastes. The total solids were found by adding the results of the suspended and dissolved solids determinations. The API defined suspended solids as those solids remaining after the gooch crucible had been rinsed with 30 ml. of distilled water and 60 ml. of chloroform. The dissolved solids, in turn, were determined by evaporating the gooch filtrate excluding the rinsings. Oils not lost in the evaporation of the filtrate were included as dissolved solids.

Experimental Procedure

Evaluation of Test Procedures. A series of tests were performed to evaluate the BOD. and oil determination tests. The criteria used to evaluate the BOD. testing procedure was the consistency of results. For the oil determination tests, a series of ten samples were set up with known concentrations of the solvents used at Portland AFB. To duplicate the emulsion effect caused by the alkaline, water-base cleaner, one mililiter of one gram per liter ABS solution was added to each separatory funnel. The separatory funnels containing a known concentration of solvent and one ml. of ABS solution were shaken for two minutes and oil determinations as outlined in the previous section were performed.

Based on the ten oil determinations an average time period of 25 minutes was used for extending the tangent line in subsequent oil determinations.

Washrack Waste Test Procedure. At periodic intervals composite samples of the influent and effluent flow to and from the gravity oil separator were taken, and the constituents making up the influent were noted. Oil concentration, BOD., total solids, and suspended solids tests were then performed. The washrack waste samples were derived solely from washing and paint stripping C-119 aircraft. Depending on the dirtiness of the aircraft and the type of maintenance to be performed, an individual sampling period covering the complete washing and rinsing time ran from two to six hours.

The effluent flow from the gravity separator was measured using a seven day automatic stage recorder and a fixed 90° V-notch weir.

Experimental Results

Waste Analysis. The results of the analyses of the treated and untreated washrack wastes are presented in Table 8. The "waste composition" portion of the table indicates the type of cleaning operation being performed and the probable constituents in the wash water at the time of sampling. From the test results listed in the lower portion of Table 8 under "waste characteristics," the maximum, minimum, and average percent reduction or removal is shown in Table 9. To link "waste composition" with "waste characteristics" as shown in Table 8, a brief description of the washing operations at the time of sampling are included in Table 10. The sample numbers of Table 8 correspond to those in Table 10.

After the four waste analysis tests were performed, the wastes were allowed to stand for approximately one month. The treated waste samples or effluent samples showed no signs of free, floating oils at the end of this period.

Flow Rates. Effluent flow measurements, Table 11, were computed from stage changes over a 90° V-notch weir (13, p. 4-13). Due to the washing procedure and the damping effect of the gravity oil separator, the influent flow rate would be somewhat higher than the maximum effluent discharge rate shown in Table 11. The

Table 8. Experimental results.

	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	Effluent	Effluent	Effluent (t)
Sample Date	Aug. 23		Aug. 28		Aug. 28		Sept. 6		Sept. 9		Sept. 18	Sept. 27	Oct. 4
Sample Number	1	2	3	4	5	6	7	8	9	10	11	12	13
Waste Composition													
Oil	x		x		x		x		x				
Alkaline, water-base cleaner	x		x		x		x		x				
Acid skin brightner	?		x		x		x						
Cleaning solvent	?		x		x		x						
Paint stripper							x		x				
Paint particles							x		x				
Waste Characteristics													
Five-day BOD. (mg/1)	533	350	740	521	1032	812	3302	1127	1477	514	1252	489	(*) 1471
Oil concentration (mg/1)	1449	656	6398	580	2258	545	1757	1125	4248	243	724	249	1131
Suspended solids (mg/1)	90	-	34	28	110	51	266	80	240	54	40	44	125
Total solids (mg/1)	1105	-	694	498	2413	702	2126	2071	1505	697	1012	561	1775

(t) Weekly composite of three aircraft washings.

(*) Six-day BOD.

Table 9. Removal efficiencies of the gravity oil separator, Portland AFB.

Waste Characteristic	Reduction or Removal Efficiency in Percent		
	Maximum	Minimum	Average
Five-day BOD.	65	21	37
Oil	94	36	70
Suspended Solids	78	18	53
Total Solids	71	3	42

Table 10. Observations of washrack wastes from C-119 aircraft washings.

Sample Number	Observation
1.	Influent - The sample was taken during the sixth aircraft washing following the construction of the gravity oil separator. Dilution may have been a factor.
3.	Influent - The sample was taken in the morning during the washing of the more oily sections of the C-119 aircraft. Some solvent was used on the engines in preparation for engine maintenance. An acid skin brightner was used on the wing sections. Oil and the alkaline, water-base cleaner made up the majority of the waste.
5.	Influent - The sample was taken during the afternoon following sample Number 3. The oil content of the waste appeared to be light. However, solvent was used extensively throughout the afternoon. An acid skin brightner was also used.
7.	Influent - Two aircraft were on the washrack. One was being washed, while on the second, the paint was being removed. Paint stripping was begun September 3.
9.	Influent - The same C-119 as described in sample No. 7 was being stripped of paint. A small amount of washing was done on this aircraft at the same time.
10.	Effluent - The sample tested was a composite of three aircraft washings.

Table 11. Effluent overflow from gravity oil separator, Portland AFB, 1963.

Date	Overflow Time (hrs)	Maximum Overflow Rate (gph)	Total Overflow (gal)	Maximum Overflow Rate (gal/day-ft^2)[t]	Average Overflow Rate (gal/day-ft^2)
Sept. 26	16	606	275	127	4
Sept. 27	9	564	953	118	23
Sept. 27-Oct. 3*		815		171	
Oct. 4	13	521	678	109	14
Oct. 5	7	186	384	39	12
Oct. 5	16	228	53	48	1
Oct. 9	18	636	122	133	2

(t) Loading area of the gravity oil separator was 114.6 sq. ft.
(*) Clock mechanism on the stage recorder failed.

average maximum flow rate and total flow for the test period per washrack usage were respectively 505 gph. and 410 gallons.

Oil Test Procedure Analysis. For a series of ten samples each containing 1061 mg/l of the most volatile solvent used on the washrack, the measured mean oil content for the ten samples was 1062 mg/l and the standard deviation was 2.7 percent.

Conclusions

1. An acclimated seed was required for the five-day BOD. test of aircraft washrack wastes.
2. For oil concentrations in washrack wastes the testing procedure presented in this thesis measured oil concentrations with an error of less than four percent.
3. The gravity oil separator at the Portland AFB provided an average BOD. reduction of 37 percent and an oil removal of 70 percent.
4. The effluent from the gravity oil separator contained only emulsified oils.
5. The average oil content of the treated effluent was 589 ppm. This value greatly exceeded the general limit of 30 ppm. established by states which had oil concentration standards.

6. An average of 410 gallons of water was required to wash a C-119 aircraft at Portland AFB.

<u>Recommendations for Further Studies</u>

1. Investigate the possibility of using activated sludge or trickling filter units to treat the washrack waste effluent from a gravity oil separator.
2. Determine the characteristics of the washrack waste effluent if air flotation or lagooning were used to remove the emulsified oils.
3. Determine the oil and BOD. concentration of the alkaline, water-base cleaner, acid skin cleaner, and paint stripper for concentrations found at washracks.
4. Investigate using an absorbent material which has a strong affinity for oil as filter media.
5. Study further the oil concentration testing procedure as outlined in this thesis by investigating such factors as:
    a. evaporation rates of different solvents and oils,
    b. the effect that the air flushing rate has on the time-rate of evaporation of chloroform and extracted oils,
    c. measurement of oil concentrations below 100 mg/l,
    d. the effect that different water bath temperatures has on the results.

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APPENDICES

APPENDIX A

Summary of Military Specifications for Cleaning Compounds

Aircraft Surface, Alkaline Waterbase, MIL-C-25769D (USAF). The military specification for alkaline, water-base cleaning compounds covers the requirements for the liquid concentrate and the powder form types to be used for cleaning aircraft surfaces. The document contains the following information.

A. Requirements.
   Composition, pH value, Effect on painted surfaces, Insoluble matter, Heat stability, Cold stability, Hard-water stability, Flammability, Emulsibility, Corrosion of aluminum, Stress crazing of acrylic base plastic, Residue rinsability, Solids content, Cleaning ability, Penetration, Workmanship.

B. Quality Assurance Provisions.
   Inspection, Acceptance, Testing procedures for above requirements.

C. Delivery Specifications.

Metal Conditioner and Brightner, MIL-C-25379 (USAF). This specification covers the requirements for one type and one grade only of nonflammable phosphoric acid base metal conditioner and brightner compound for use on aluminum surfaces. The following information is contained in the specification.

A. Requirements.
   Composition, Toxicity and Odor, Emulsibility, Viscosity, Effect on painted surfaces,

Nonflammability, Immersion corrosion, Residual corrosion, Diffuse reflectance, Stress-crazing of acrylic base plastic, Cleaning characteristics.

B. Quality Assurance Provisions.
Acceptance tests, Testing procedures for above requirements.

C. Delivery Specifications.

Source for Military Specifications. The civil engineering office of a nearby Air Force base should be contacted for further information regarding these military specifications.

Chemical Composition of Aircraft Cleaners

The cleaners are single phase, liquid emulsifiable cleaners used to remove soil, grease, and oil from metal surfaces.

Lix 3852 Surface Cleaner:[4]

Aromatic hydrocarbon	50% min.
Caustic potash	2. 75% min.
Emulsifying agents	36% max.
Glycol derivatives	10% max.

Lix 3852 is an emulsified petroleum product which requires additional dilution with PS - 661 material before using. Rinsing is with water. Federal Specifications list PS - 661 as "Solvent, Dry Cleaning."

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[4]The information was taken from a letter dated 26 June 62; written to SSgt. Victor B. Skaar, 825th Medical Group, Little Rock AFB, Arkansas, from the Lix Corporation of Missouri, 300 West 80th Street, Kansas City 14, Missouri, Phone Delmar 3-4464.

Air Force Comparison Cleaning Formula as stated in MIL-C-2576D (USAF)

Trisodium phosphate (alkalinity as Na_2O, 16-19%)	10%
Non-ionic surface active agent (Triton X-100)	2%
Ethylene glycol monoethyl ether	6%
Distilled Water	82%
pH	10.0

Control Specification for a Commercial Cleaner, LIX 3852[4]

Specific Gravity - 0.970 at 70° F.

Flash Point - The compound shall not flash up to 195° F when tested with the Cleveland Open Flash Cup.

Alkalinity - The alkalinity of a 10 percent H_2O solution shall not exceed 9.8 or be less than 9.2.

Corrosion - The compound shall show no discoloration, pitting, or etching on magnesium or aluminum at 130° F for 24 hours.

Emulsion Stability - One part of the compound shall readily disperse in five parts to ten parts of dry cleaning solvent conforming to Type II of PS-661 to give a clear liquid. One part of any or all mixtures of the above shall produce a stable emulsion when diluted and shaken thoroughly with nine parts of distilled water. After standing for 24 hours, there shall be no more than ten percent floating or settling out of the emulsion with no breakdown of the remainder of the emulsion.

Paint Removal - The compound shall not strip or soften enamel or lacquer or metallic surfaces when exposed for eight hours providing it does not come into contact with broken edges or cracks in painted surfaces.

<u>Other Cleaning Compounds Sometimes Present in Washrack Wastes</u>

1. Compound, carbon-removal, cresol type

Water	8%
Soap (potassium oleate)	30%
(85% fatty acid, 15% alkali, as K_2O)	
Cresol	62%
pH of 1:4 water solution	7.8

2. Remover, paint & lacquer, solvent type

Paraffin wax	3%
Methylene chloride	72%
Wetting agent	5%
Methyl cellulose	2%
Methanol	6%
Ethylene glycol monoethyl ether	4%
Distilled water	3%
Monoethylamine	5%

3. WC-10 paint stripper (for specifications see MIL-25134)

Methylene chloride	65%
Toluene	5%
Methanol	5%
Monoethylamine	10%
Petroleum distillates	5%
pH of 1:4 water solution	8.8

The above information was supplied by:

Raymond S. Shiroma
2nd Lt., USAF, MSC
San. & Ind. Hyg. Eng.
Dyess AFB, Texas

APPENDIX B

Experimental Testing Procedures

Biochemical Oxygen Demand. The seed culture is started by adding 30 ml. of raw sewage influent to one liter of tap water under aeration. For a period of two weeks 10 ml. of feed are added each day. For a second period of two weeks in addition to adding the feed, one ml. of combined aircraft cleaners is added to the cultures every two days. Foaming caused by the air agitation of the cleaner is to be expected. At the end of four weeks the culture should be ready to be used in BOD. determinations.

To prepare the seeded dilution water, remove 25 ml. of the seed culture. Dilute to 250 ml. with distilled water. Blend the diluted seed culture for one minute. Add to the unseeded dilution water as prepared in Standard Methods (4, p. 319) five ml. of blended seed per liter of dilution water. Seeded dilution water should be used the same day it is made.

The feed as prepared by the following formula should be remade every two weeks or when the feed becomes cloudy from growths. The feed will last for longer periods if containers are acid washed before using and the feed is kept at 5^{o} C (6, p. 18). Refer to Table 12 for feed formula.

Table 12. Micro-organism feed.

Distilled water	1	l.
Glucose or dextrose anhyd.	4.5	gm.
Bacto dehydrated nutrient broth	3.0	gm.
Urea	1.25	gm.
Sodium biphosphate ($Na_2HPO_4 \cdot 7H_2O$)	0.75	gm.
Sodium chloride (Na Cl)	1.0	gm.
Potassium chloride (KCl)	1.0	gm.
Magnesium sulfate ($MgSO_4 \cdot 7H_2O$)	1.0	gm.

Oil and Grease. The following experimental procedure is patterned after the extraction-evaporation method outlined in "Oil and Grease" Standard Methods, 11th ed., p. 185.

Measurement of Oil and Grease in Aircraft Washrack Wastes

General Discussion

Principles. The extraction-evaporation method as applied to aircraft washrack wastes embodies the following three steps: cracking the detergent-oil-water emulsion, extracting the oil fractions from the emulsion using an organic solvent, and evaporating the solvent to leave the oil residue.

Care must be exercised in choosing the extraction solvent and the evaporation temperature. As Standard Methods points out "Even lubrication oil fractions evaporate at a significant rate at the temperature which is necessary for removal of the last traces of the extraction solvent" (4, p. 185).

Sampling. Care should be taken that the sample is representative. Samples should be taken in clean, glass-stoppered bottles, previously washed with solvent and air dried before use. The bottles should not be completely filled, as a loss of floating oil may occur in stoppering. It is advisable to collect the desired quantity of sample in an oversized bottle that has previously been marked on the outside at the desired volume (4, p. 185).

Storage of Sample. Stored samples should be kept under refrigeration to inhibit bacterial activity. Acidifying the sample at this point may break the emulsion and cause more oil to cling to the sides of the container. Storage should be avoided if possible.

Apparatus

Water Bath. A distilled water bath capable of maintaining a water temperature of 84° C to 87° C should be used.

Separatory Funnel. The separatory should be 125 ml. in size. Stopcocks should be of the non-lubricating type or should have all greasy lubricants removed from the ground-glass surfaces. A special stopcock lubricant can be prepared (4, p. 186).

Weighing Balance. A balance accurate to one miligram is required.

Air Condenser. An air condenser of low actinic glass, 23 inches long, and with a T. S. joint is required.

Reagents

Sulfuric Acid Solution. One part concentrated sulfuric acid to one part water.

Chloroform. The boiling point is 62.2° C.

Procedure

1. Place 75 ml. of sample in a separatory funnel. If the sample added is the total sample originally taken, rinse sample bottle carefully with 3 ml. of chloroform and add the rinsing to the separatory funnel. If the sample added is a fraction of the total sample taken, agitate while with-drawing 75 ml. for the separatory funnel.

2. Add 1 ml. of 1+1 H_2SO_4 and 15 ml. of chloroform to the separatory funnel.

3. Shake the separatory funnel gently for three minutes.

4. Pass the entire contents of the separatory funnel through a glass funnel containing a cotton pad which has been previously saturated with chloroform.

Collect the filtrate in a second separatory funnel. Add 3 ml. of chloroform to the original separatory funnel, shake vigorously, drain through the cotton pad, and collect in the second separatory funnel. Taking the cotton pad in hand, rinse down the glass funnel thoroughly by squeezing the cotton pad until free of excess liquid. Also collect this washing in the second separatory funnel. The purpose of step four is to first filter out unwanted solids, and secondly, to break any emulsion which may form in the chloroform layer due to the shaking action in step three.

5. Drain the chloroform layer from the second separatory funnel into a previously cleaned, oven dried, and weighed 300 ml. T. S. jointed flask. Scum particles which may appear just above the chloroform layer should not be withdrawn with the chloroform layer.

6. Perform a second extraction by adding 15 ml. of chloroform to the sample after the first extraction has been completed. Shake gently for three minutes and follow with step four if necessary. Drain the chloroform layer into the flask containing the first extracted solvent.

7. Allow the separatory funnel to sit for five minutes. If further liquid (chloroform) appears below the water layer, withdraw this chloroform into the flask also.

8. Repeat steps 1-7 with a second 75 ml. sample and add the extracted solvent portions to the flask containing the first extractions.

9. Attach the air condenser to the flask and place in an 84-87^{o} C water bath. Evaporate the chloroform for 30 to 60 minutes or until 2 to 5 ml. of liquid still remain in the flask. At this point condensed liquid should still be draining down the condenser and back into the flask.

10. Remove the unit from the water bath and allow to cool for two minutes. Then remove the air condenser, and slowly blow dry filtered air into the

flask for one minute, and then weigh the flask. The weighing will be approximate due to the chloroform escaping from the flask.

11. Return dry filter air to flask for five minutes, then weigh the flask again.

12. Plot the points on coordinate paper with axes of flask weight in grams vs. time after removing air condenser. The scale used on the vertical axis should be large enough to allow the plotting of points without estimation to one hundredth of a gram. See Figure 4, page 58 for an example curve.

13. Repeat items 11 and 12 until the curve has gone six points past its extreme change in slope.

14. Extend the constant slope portion back to the left as shown in Figure 4. From the point of tangency measure back along the horizontal axis a predetermined amount of time. (Refer to interpretation of results, page 59.)

15. The intersection of a vertical line lying a given number of minutes from the point of tangency and the tangent line is the weight of flask containing the oil residue when read on the vertical axis.

Calculation

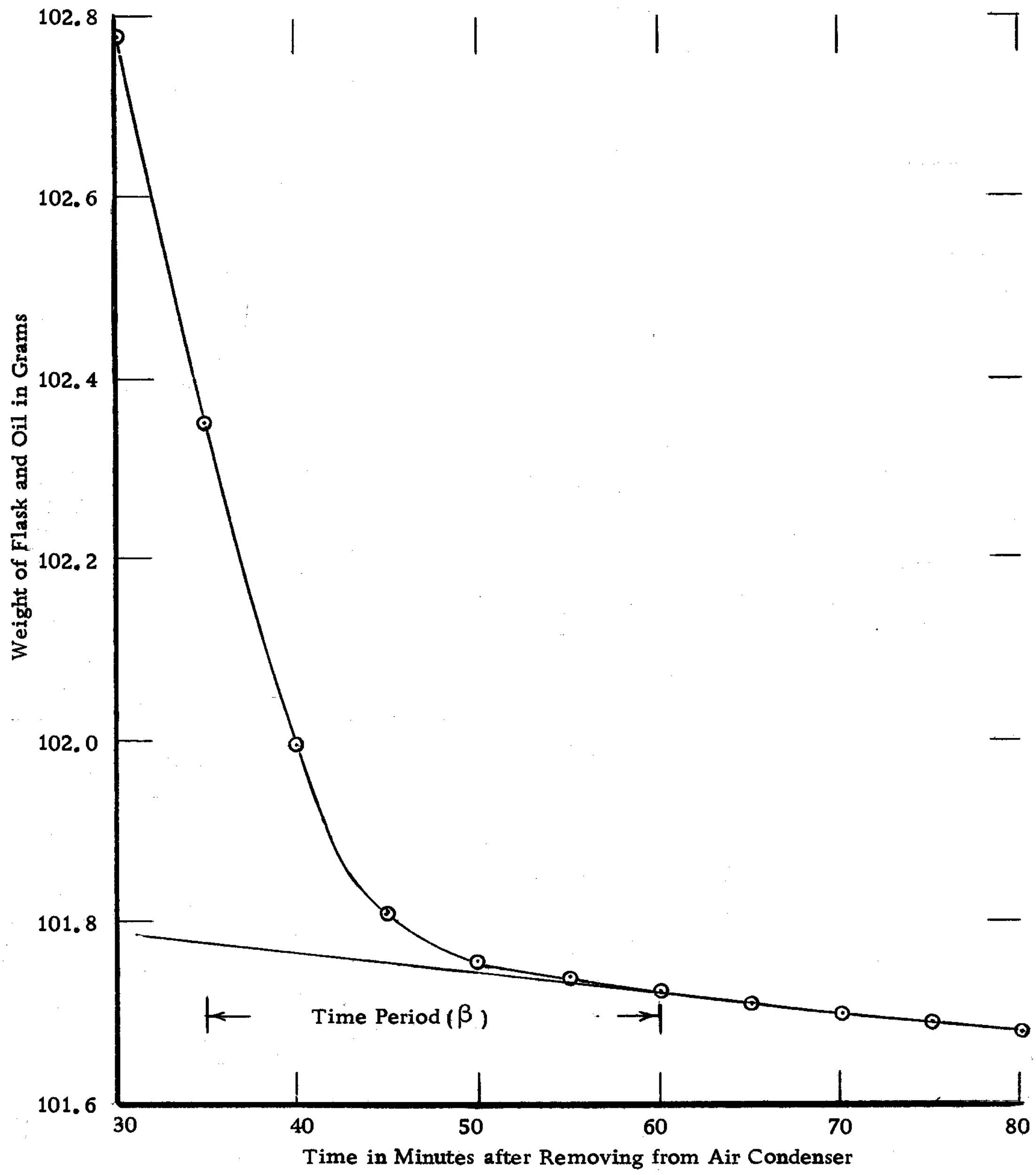
The gain in weight of the flask is due to the oil and grease in the airplane washrack wastes.

$$\text{mg/l (ppm.) of oil and grease} = \frac{(a-b)\,1000}{c}$$

where:

a = weight of flask containing oil residue in mg.
b = weight of flask empty (tare wt.) in mg.
c = volume of sample originally placed in separatory funnel in ml. For this procedure c = 150 ml.

Figure 4. Evaporation Curve.



Interpretation of Results

When reporting results the method of extraction and solvent used should be included.

To determine the period of time (β) to extend back from the point of tangency the preceding test should be performed on each of the washing solvents and oils known to be present in the waste stream. Ten tests should be run using a predetermined weight of a given solvent in each of the ten tests. Using the extended tangent and the true solvent weight, an average time period and tangent slope for a particular solvent may then be determined.

For all subsequent tests of samples containing unknown amounts of given oils and solvents, the predetermined standard tangent slopes and time periods will act as a guide for choosing the time period to extend back from the tangent point.

The rate at which air is bled into the flask should be kept constant for all tests once standard tangent slopes and time periods have been developed.

APPENDIX C

Aircraft Washrack Wastes Questionnaire

427 S. 5th Street
Corvallis, Oregon
21 April 1963

SUBJECT: Analysis of Aircraft Washrack Wastes

TO: Installations Engineer

1. I am preparing a thesis in connection with my advanced course of study at Oregon State University pointing toward a Masters Degree in Civil Engineering (sanitary engineering specialty) under the AFIT program.

2. My thesis is concerned with the problems of treating aircraft washrack wastes. I am planning to study and evaluate some of the problems connected with using sedimentation separately or combined with air flotation as a method of removing the grit, solvents, and oil particles from the washrack wastes.

3. I would like to include in my thesis a summary of present operational methods of treating washrack wastes. If time permits, would you please fill out and return the enclosed questionnaire. Thank you.

[redacted]

DAVID R. EVANS
2nd Lt., USAF

20 April 63

TREATMENT OF AIRCRAFT WASHRACK WASTES

I. Waste Treatment (check one)

1. Method of treatment at the Air Base
   (a) sedimentation only ___ (b) air flotation ___
   (c) sedimentation followed by air flotation ___
   (d) none ___ (e) other ___ (please explain) ______________________
   ____

2. Final disposal of waste
   (a) stream or river ___ . approximate size in ft^3 per second or width x depth at:
   low flow ___________. high flow ___________.
   (b) city sanitary sewer ___

3. If treatment is practiced, please check method of:
   (a) disposal of oil and grease by burning ___ by burying ___
   by other (please explain) ______________________________
   ____
   (b) disposal of grit particles by burying ___ , by other (please explain)
   ____
   (c) treatment of waste
   (1) continuous operation ___
   (2) intermittent as wastes are available ___
   (d) chemicals used to break the emulsion
   (1) chemicals (please name) ______________________________
   ____
   (2) no chemicals used ___
   (e) If air flotation is used
   (1) pressure applied by compressor _________ psi.
   (2) manufacture of air flotation unit ______________________
   ____

4. General information
   (a) approximate number of planes washed per month ________________
   (b) type of planes washed most often (size and/or type) ______________
   ____
   (c) estimated flow in gallons per minute from washrack during rinsing operation
   ____
   (d) is an acid skin brightner used? Yes ________ No ________
   (e) other comments ______________________________________
   ____
   ____
   ____
   ____
   ____

(if more room is needed the other side may be used)

II. Chemical Tests Performed on Waste from Washrack.

NOTE: Please record the units used on each test. If the data is from sampling points other than those listed below, please specify.

Specific Test	Minimum (date)	Yearly Average	Maximum (date)
1. pH (a) prior to treatment (b) after treatment			
2. BOD. (biochemical oxygen demand) (a) prior to treatment (b) after treatment (c) other ________________			
3. DO (dissolved oxygen) if waste is discharged into a stream (a) above sewer outfall distance ________________ (b) below sewer outfall distance ________________			
4. Oil and Grease (a) prior to treatment (b) after treatment			
5. Turbidity (a) prior to treatment (b) after treatment			
6. Total Solids (a) suspended solids (1) prior to treatment (2) after treatment (b) dissolved solids (1) prior to treatment (2) after treatment			
7. Temperature			
8. Toxic Materials (a) test performed ________________ (b) point where sample taken ________________			
9. If other tests are run, please list them on the reverse side using above as an outline.			

Corrections to Aircraft Washrack Waste Questionnaire

Several revisions based on the returned questionnaires should be made. These revisions are:

1. Add a blank for the name of the replying air base,

2. Substitute the words "gravity or free oil separator, or grease trap" for the word sedimentation, (I, 1, a & c),

3. Reword the question (I, 2, a) to read "(a) stream ___ , or river ___ , name ______________, and maximum flow ____________ cfs., minimum flow ____________ cfs.",

4. Add to the question (I, 2) the question "(c) Other _______,"

5. Reword the question (I, 4, c) to state "(c) time required to wash one aircraft _________ hrs., total volume from washrack per aircraft ___________ gallons, or flow in gpm _________________.

6. Add the question (I, 4, f) "Materials present in washrack wastes (paint stripping, solvents, cleaners, etc.) _______ ____."

7. Add the question (I, 4, g) "Other wastes combined with washrack wastes prior to treatment ___________________."

Results of Chemical Test Performed by the Air Force on Washrack Wastes

Table 13. Chemical tests, Fairchild AFB.

Specific Test	Minimum (date)	Yearly Average	Maximum (date)
1. pH			
(a) prior to treatment	5	5.5	6
(b) after treatment	6.5	6.9	7.2
2. BOD. (biochemical oxygen demand)			
(a) prior to treatment	250 ppm	275 ppm	300 ppm
(b) after treatment	35 ppm	40 ppm	75 ppm
3. DO (dissolved oxygen)			
(a) plant influent	.5 ppm	1.0 ppm	2.0 ppm
(b) plant effluent prior to discharge into lagoon	3.0 ppm	3.5 ppm	4.0 ppm
4. Oil and Grease			
(a) prior to treatment	200 ppm	250 ppm	350 ppm
(b) after treatment	20 ppm	30 ppm	40 ppm
5. Turbidity			
(a) prior to treatment	100 ppm	175 ppm	250 ppm
(b) after treatment	15 ppm	25 ppm	30 ppm
6. Total Solids	1125 ppm	1700 ppm	2100 ppm
(a) suspended solids			
(1) prior to treatment	625 ppm	900 ppm	1175 ppm
(2) after treatment	25 ppm	60 ppm	178 ppm
(b) dissolved solids			
(1) prior to treatment	500 ppm	650 ppm	925 ppm
7. Temperature (F °)	46	49	55

Comments: These tests were taken when a gunk-kerosene emulsion was used and are approximate averages.

Table 14. Chemical tests, Hill AFB.

Specific Test	Minimum (date)	Yearly Average	Maximum (date)
1. pH			
(a) prior to treatment	6.9	7.8	9.4
(b) after treatment	6.6	7.2	8.3
4. Oil and Grease			
(a) prior to treatment	0	10	64
(b) after treatment	0	1	3
6. Total solids	230	512	1170
7. Temperature (F^{o})	57	62	65
9. Cyanide			
(a) influent	0	.085	.885
(b) effluent	0	.074	.880
10. Fluoride			
(a) influent	4.5	9.0	12.5
(b) effluent	4.5	7.5	11.5
11. Chromate (Cr. +6)			
(a) influent	.20	27	109
(b) effluent	0	.63	2.5
12. Phenol			
(a) influent	0	1.57	3.20
(b) effluent	0	0.25	1.20

Comments: As test indicate the washrack wastes are combined with other industrial wastes. No units were supplied.

Table 15. Chemical tests, James Connally AFB (1962).

Specific Test	Minimum (date)	Yearly Average	Maximum (date)
1. pH			
(a) below grease trap		8.6+	
(b) 1 mile below sewage outfall		8.0	
(c) 2 miles below sewage outfall		8.0	
2. BOD. (biochemical oxygen demand) ppm.			
(a) 1/10 mile above sewage outfall	27 Dec	55	111 April
(b) 1 mile below sewage outfall	15 Dec	28	54 April
(c) 2 miles below sewage outfall	24 Dec	40	58 Aug
3. DO (dissolved oxygen) ppm			
(a) 1/10 mile above sewage outfall	2.8 Sept	5.8	9.1 Dec
(b) 1 mile below sewage outfall	4.0	7.9	11.9
(c) 2 miles below sewage outfall	1.0 Sept	2.9	4.5 Feb
7. Temperature (F ^{o})	41 Feb	89	91 Aug

Comments: The stream originates on base from treated sewage effluent, aircraft washrack waste, vehicle washing, and swimming pools. All waste water including swimming pools originates above sewage outfall and flows in open ditches to the sewage outfall. Approximately 80 percent of the sewage effluent is used for irrigation of the golf course. During irrigation periods, waste water from cleaning activities is the only water flowing off the base.

Table 16. Chemical tests, McCoy AFB.

Specific Test	Minimum (date)	Yearly Average	Maximum (date)
1. pH			
(a) prior to treatment	6.0	6.8	7.5
(b) after treatment	6.3	6.6	7.0
3. DO (dissolved oxygen)			
(a) above sewer outfall	3.2	6.4	10.0
(b) 2 miles below sewer outfall	2.4	6.0	9.8
7. Temperature (F ^{o})	44	70	84

Table 17. Chemical tests, Norton AFB.

Specific Test	Minimum (date)	Yearly Average	Maximum (date)
1. pH			
(a) prior to treatment	1.0 4/10	5.7	8.2 9/13
(b) after treatment	3.7 2/26	6.2	8.9 1/5
(c) primary tank	2.1 1/8	5.6	8.7 1/5
4. Oil and Grease (ppm.)			
(a) prior to treatment	2000 -	3870	66000 10/31
(b) after treatment	0 -	1.2	7 1/19
5. Turbidity (ppm.)			
(a) prior to treatment	160 12/7	1020	5000 9/7
(b) after treatment	25 12/7	127	750 4/23
6. Total Solids (ppm.)			
(a) suspended solids			
(1) prior to treatment	50 -	1400	30000 1/9
(2) after treatment	50 -	19000	220000 5/17
(b) dissolved solids			
(1) prior to treatment	316 3/23	884	2064 4/13
(a) after treatment	296 6/29	1100	2508 1/15
8. Phenolic materials as Phenol (ppm.)			
(a) influent	0	4.4	2.5 6/22
(b) effluent	0	0.44	10.0 10/13
9. Hexavalent Chromium (ppm.)			
(a) influent	0	0.3	8.0 10/20
(b) effluent	0	0.18	18.0 10/19
10. Fluoride (ppm.)			
(a) influent	0.8 3/16	2.5	4.0 4/20
(b) effluent	0	2.75	6.0 8/29
11. Sodium (ppm.)			
(a) influent	255 7/28	235	1135 10/16
(b) effluent	18 3/14	191	755 1/19

Comments: Tests were made on the combined wastes which included washrack wastes. Suspended solids increase is a result of floc carryover.

Table 18. Chemical tests, Sewart AFB.

Specific Test	Minimum (date)	Yearly Average	Maximum (date)
1. pH	6.4	7.7	9.5
2. BOD. (biochemical oxygen demand) ppm.		240	
3. DO (dissolved oxygen) ppm.			
(a) 1/2 mile above sewer outfall		11	
(b) 1/2 mile below sewer outfall		11.1	
5. Turbidity (ppm.)		70	
6. Dissolved Solids (ppm.)		80	
7. Temperature (C °)	9	17	24

Comments: All tests were made 3 May 63. The washrack wastes receive no treatment.

Descriptions of Washrack Waste Treatment Facilities at U. S. Air Force Bases

1. BERGSTROM AFB, Austin, Texas. The washrack wastes at Bergstrom AFB pass through a sedimentation basin before discharge into a nearby river. Free oils and greases are not removed from the waste water. No attempt is made to separate the emulsified oils. The grit particles collected from the sedimentation unit are buried. An acid skin brightner is not used. Approximately 60 aircraft are washed each month. No chemical tests are run on the washrack wastes.

2. BOLLING AFB, Washington, D. C. Washrack wastes are discharged untreated by storm sewer into the Potomac River. Approximately 54 helicopters are washed each month. No acid skin brightner is used. It is not known if chemical tests are run on the washrack wastes.

3. BROOKS AFB, San Antonio, Texas. "Brooks AFB does not operate an active flight line. Flying was discontinued at this installation in June 1960."

4. CARSWELL AFB, Fort Worth, Texas. Aircraft washrack wastes at Carswell AFB are treated by passing the wastes through two gravity oil separation units and an air flotation unit. The air flotation system, built by Infilco Inc. of Phoenix, Arizona, operates at 35 psi., ferric sulfate is used to separate the emulsified oils. The waste components are disposed of in the following manner: treated effluent to a stream, trapped oil by burning, and settled grit by burying. An acid skinbrightner is not used. Approximately 23 large aircraft are washed each month. It is not known if chemical tests are run on the aircraft washrack wastes.

5. CASTLE AFB, Merced, California. An air flotation unit built by Infilco Inc. is used to treat the aircraft washrack wastes. Characteristics of the industrial wastes treatment plant include: using lime and ferric sulfate to break the emulsion, dissolving air at 30 psi., disposal of floated sludge containing oil by burning, and operation on an intermittent basis as wastes become available. The final effluent is discharged into a stream which is dry at low flows. Approximately 20 aircraft are washed each month. An acid skin brightner is not used. No chemical tests are performed on the washrack waste.

6. CLINTON COUNTY AFB, Wilmington, Ohio. There is no washrack at this installation.

7. CRAIG AFB, Selma, Alabama. "At present, all waste material is dumped untreated into the Alabama River."

8. DONALDSON AFB, Greenville, S. C. "Headquarters USAF directed the latter part of December 1962 that Donaldson AFB be deactivated and declared excess property to the needs of the Air Force."

9. DYESS AFB, Abilene, Texas. Aircraft washrack wastes in the past have been treated using an air flotation unit manufactured by F. S. Gibbs Inc., Newton 62, Massachusetts. At the present time no aircraft are on base due to a major renovation of the runways and modification of the washrack. The final effluent was discharged into a nearby river through a storm sewer. Chemical tests have been run on the river below the sewer outfall.

10. ENT AFB, Colorado Springs, Colorado. The washrack is connected to an industrial waste collection system. The collected waste from the washrack is directed through a concrete catch basin before it enters the industrial waste system. The waste material then flows through a grease trap, and drains into a leaching field. No special treatment has been provided for this waste material. An acid skin brightner is not used. Approximately 15 aircraft are washed each month. Chemical tests are not run on the washrack wastes.

11. ETHAN ALLEN AFB, Winooski, Vermont. This installation was deactivated 25 June 1960.

12. FAIRCHILD AFB, Spokane, Washington. An air flotation unit is used to treat the washrack wastes. The unit which operates under a compressor pressure of 50 psi. was built by the Infilco Co. and is called a Sediflotor Clarifier. Ferric sulfate is used to break the emulsion and caustic soda is used for pH control. The treated effluent flows from the "Sediflotor" to a lagoon for secondary clarification and then is discharged to a stream. The floated oil, grease sludge, and grit are buried. Chemical tests run when a gunk-kerosene solvent was used are available. (See page 64) Approximately 18 large aircraft are washed each month. An acid skin brightner is used.

13. FRANCIS E. WARREN, AFB, Cheyenne, Wyoming. Due to the mission of this base no information was available pertaining to aircraft washrack wastes.

14. GLASGOW AFB, Glasgow, Montana. Due to extreme weather conditions at Glasgow AFB, corrosion control treatment (washing) is limited to about four aircraft each month. The acid skin brightner is used only on administrative aircraft (2 per month). Washrack wastes are discharged untreated to a nearby river. No chemical tests are performed on the washrack waste.

15. GOODFELLOW AFB, San Angelo, Texas. There is no flying mission at this base. The aircraft washracks are not being utilized.

16. GRAND FORKS AFB, Grand Forks, N. D. Intermittent washrack wastes are treated by means of oil traps. The wastes are given no chemical treatment. The final effluent passes through a drainage ditch to a slough area. Trapped oil, grease and grit particles are buried. Approximately 45 aircraft are washed each month. No acid skin brightner is used. Chemical tests are not run on the washrack wastes.

17. GRAY AFB, Killeen, Texas. No washrack facilities are located at this base.

18. GREENVILLE AFB, Greenville, Miss. At the present no aircraft are stationed at this base. The flow in a river near this installation varies from approximately 50 cfs. to 1500 cfs.

19. GRENIER AFB, Manchester, N. H. The untreated aircraft washrack wastes are discharged to the Mennimac River. An average of 18 aircraft are washed per month. No chemical tests are run on washrack wastes. An acid skin brightner is used.

20. GRIFFIS AFB, Rome, New York. This installation has no aircraft washracks.

21. HARLINGEN AFB, Harlingen, Texas. This base is closed with only a caretaker force remaining.

22. HILL AFB, Ogden, Utah. Wash and rinse water from the washrack are mixed with other industrial wastes generated in maintenance operations before entering the industrial waste treatment plant. The treatment plant consists of a sedimentation unit followed by an Infilco air flotation unit operating at 30 psi. Chemicals used to break the emulsion are ferrous sulfate and hydrated lime. The treated effluent is discharged to a city sanitary sewer. Separated oil and grease particles are burned, and settled grit particles are buried. The 50 or more aircraft washed each month and other industrial wastes are enough for continuous operation of the plant. Chemical tests of the waste are run. (See page 65).

23. HOLLOMAN AFB, Alamogordo, N. M. Wastes arising from the aircraft washrack are discharged untreated through a base storm sewer into a desert lake. An average of 20 small and medium sized aircraft are washed each month. The acid skin brightner is used intermittently. No chemical tests are run on the washrack wastes.

24. HUNTER AFB, Savannah, Georgia. No physical or chemical data is available concerning treatment of washrack wastes. Shortly after the completion of the plant, operations were suspended due to a change of materials used in the working of the aircraft.

25. INDIAN SPRINGS AFB, Indian Springs, Nevada. An operational washrack is not in use at this base.

26. JAMES CONNALLY AFB, Waco, Texas. Oil and grease are removed from washrack wastes by means of oil trap. The final effluent is discharged to a stream which begins on base from treated sewage effluent, aircraft washrack wastes, vehicle washings, and swimming pools. All waste water including swimming pools originates above sewage outfall. Trapped oils are burned and the settled grit buried. No chemicals are used in the treatment of the waste. An average of 20 small aircraft are washed each month. Test data - pH, BOD., DO., temperature - is available for the following reaches of the drainage ditch: at 1/10 mile above sewage outfall, and at one and two miles down stream from sewage outfall. (See page 66).

27. KELLEY AFB, San Antonio, Texas. At Kelly AFB, industrial wastes containing washrack wastes are treated in a continuous operation using sedimentation and aeration. The components of the waste are disposed of in the following manner: treated effluent is discharged into a nearby river which is dry at low flows, separated oil is salvaged by a waste oil reclaimer, and skimmings and grit are trucked to a sludge drying bed. Alum and lime are used to break the emulsion. An acid skin brightner is used. Approximately 20 aircraft are washed each month. Chemical tests are performed on the combined wastes.

28. KINCHELOE AFB, Kinross, Michigan. The untreated washrack wastes are discharged directly into a storm drain which in turn empties into a swamp. No chemical tests are performed on the washrack wastes. An acid skin brightner is not used.

29. KIRTLAND AFB, Albuquerque, N. M. Untreated aircraft washrack wastes flow through storm sewers into an arroyo where the wastes are absorbed and/or evaporated before reaching the river. About 20 aircraft are washed each month. An acid skin brightner is not used. Chemical tests are not performed on the washrack wastes.

30. LACKLAND AFB, San Antonio, Texas. There is no air field at Lackland AFB; this is a basic training center.

31. LAREDO AFB, Laredo, Texas. Wastes from the washrack empty untreated into the storm sewer system of the city of Laredo. From this point. the waste flows untreated to the Rio Grande River. Small aircraft make up the majority of planes being washed. An acid skin brightner is not used. No chemical tests are performed on the washrack wastes.

32. LINCOLN AFB, Lincoln, Nebraska. "The washrack at LAFB has not been in operation for the past five years. Records of previous periods of operation are not available."

33. LITTLE ROCK AFB, Little Rock, Arkansas. The aircraft washrack wastes pass through a gravity oil separation unit before being discharged into a base storm sewer. Trapped oils and greases are burned while the settled grit particles are buried. No chemicals are used to crack the emulsion. Approximately 25 large aircraft are washed during the winter and about twice this number in the summer season. An acid skin brightner is used intermittently. No chemical tests are performed on the washrack wastes. The influent to the oil separator also contains paint remover solvent. Although an industrial waste treatment plant was designed and built. it is not being used at the present time.

34. LUKE AFB, Phoenix, Arizona. A gravity oil separator is used to treat washrack wastes at Luke AFB. The components of the washrack wastes are disposed of in the following manner: oil skimmings are used for road dust control, grit particles are buried, and final effluent is discharged to an aroyo. An acid skin brightner is not used. Chemical tests are not performed on the washrack wastes. An average of 200 aircraft are washed each month.

35. MacDILL AFB, Tampa, Florida. "Wastes from this base receive no treatment. The waste flows from the washracks into open ditches and then into Tampa Bay. No chemical tests are performed on waste from the washracks."

36. MALMSTROM AFB, Great Falls, Montana. The aircraft washrack wastes are discharged untreated to a river. No chemical tests are performed. Approximately ten aircraft are washed each month. An acid skin brightner is used.

37. McCHORD AFB, Tacoma, Washington. Aircraft washrack wastes are treated by gravity separation in a continuous operation. Waste solids are skimmed and removed for burning. The effluent is piped into a lagoon for leaching and percolation. Grit is also sent to the lagoon. No chemicals are used to break the emulsion. Test data is not available. The acid skin brightner used conforms to MIL-C-25378. About 32 aircraft are washed each month.

38. McCLELLAN AFB, Sacramento, California. "McClellan Air Force Base has as one of its principal activities the cleaning. disassembly. and reconstruction of planes and vehicles" (23). Wastes arising from this industrial complex, including washrack wastes but excluding domestic wastes, are treated at four industrial waste treatment plants on the base. Free and emulsified oil, chromium, solvents, greases, soaps, paint skims, phenols, acids and alkalies, and washrack wastes are treated in plants No. 1 and No. 2. Plant No. 3 treats phenols, and both free and emulsified oil wastes from the engine repair shops by means of air flotation. Plant No. 4 handles chrome recovery and reduction, and destruction of cyanide waste from metal finishing. Treatment facilities at plants No. 1 and No. 2 consist of gravity oil separation and chemical coagulation. Plant No. 1 also makes use of sedimentation and air flotation. The Base estimates that washrack wastes make up one fiftieth and one third of waste flows from plants No. 1 and No. 2 respectively. Plants No. 1 and No. 2 operate continuously and use lime and alum to break the emulsion. In the air flotation units the

air is released at 35 psi. The wastes are disposed of in the following manner: oil and grease from the gravity separator by contract sale, and grit particles by burying. The final effluent is discharged into Magpie Creek (flow 6-10 cfs) located on the water shed of the Sacramento River. Chemical tests are run on the combined wastes. About 45 large aircraft are washed each month. See page 74 for schematic diagram of waste treatment Plant No. 1.

39. McCOY AFB, Orlando, Florida. Aircraft washrack wastes are treated using gravity separation and air flotation. Ferrous sulfate is used to crack the emulsion, and for pH control alum is used. The plant is run on an intermittent basis as wastes become available. The effluent is discharged to a small drainage ditch (2 ft. x 0.5 ft.). Oil and grit collected from the gravity separation and flotation processes are carried by dumpster to a sanitary fill. The flotation unit built by Graver is operated at 29 psi. Approximately 40 aircraft are washed each month. Chemical data is available. (See page 66). The base stated that "Kerosene-Gunk was initially used. Later a soap base cleaner was and is used, eliminating the use of flocculation processing."

40. MINOT AFB, Minot, N. D. Sedimentation is the only treatment given to the washrack waste. The final effluent is discharged to a normally dry stream. Grit particles are hauled to a dump. Approximately six large aircraft are washed each month. An acid skin brightner is not used. No chemical tests are made on the waste.

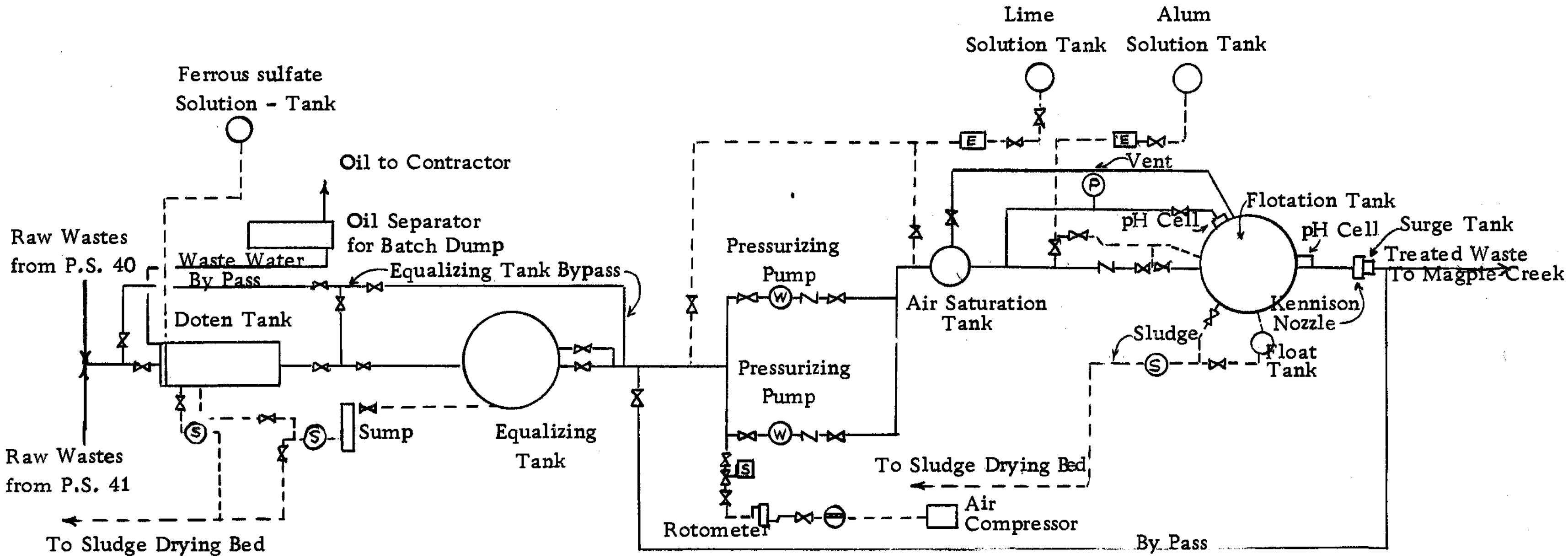
41. MOUNTAIN HOME AFB, Mountain Home, Idaho. "Waste water from the aircraft washrack drains into the storm sewer system which is an open ditch draining the flight line and aircraft parking area. This ditch extends approximately two miles into a waste land area where the waste disappears into a lava formation." No chemical treatment is applied to the waste nor are chemical tests performed. An acid skin brightner is not used.

42. NORTON AFB, San Bernardino, California. At present aircraft washing at this base is minimal. The following information represents operations during FY-62. It is pointed out that wastes from numerous industrial operations at Norton are intermingled with the aircraft washrack wastes before being treated. The combined wastes are treated using gravity separation and air flotation on an intermittent basis. Chemicals used to crack the emulsion included lime, alum, ferric sulfate, waste acid and Hagan coagulant aid No. 50. Process Engineers Inc., San Matio, California, supplied the air flotation unit. The Base points out that ... "the Santa Ana River to which the industrial waste plant effluent is discharged is a dry bed except on rare occasions. Further, although evaporation and burning lagoons were provided, these facilities cannot be used because of Air Pollution Regulations." Following separation, oil and grease skimmings are hauled to a waste disposal site approved by the State Water Pollution Control Board. Grit is discharged with the sludge to a drying bed. Chemical tests are performed on the waste (See page 67). Approximately 30 large aircraft are washed each month. An acid skin brightner is not used. A schematic diagram of the treatment operations is available.

43. ORLANDO AFB, Orlando, Florida. This base is without operational aircraft and airfield pavements.

44. PEASE AFB, Portsmouth, N. H. Washrack wastes are treated using gravity separation followed by air flotation. Sand and grit particles removed in the gravity separation tank are disposed of by burying. Oil and grease skimmed from the flotation unit are also buried. The final effluent is discharged to a tidal estuary. The intermittent treatment

Figure 5. Industrial Waste Treatment Plant No. 1, McClellan AFB.



SCHEMATIC FLOW DIAGRAM

Types of waste

Free and Emulsified Oil
Chromium
Paint Skims
Wash Rack Waste
Acids and Alkalies

Flow Data

Design Flow 0.864MGD
Calendar Year 1961
Ave. 0.278MGD
Max. 0.672MGD
Min. 0.071MGD

Legend

——— Principal Waste Flow
– – – Waste Concentrates, Sludge, Skimming or Float Treatment Chemicals, Compressed Air.

Valve
Check Valve
(W) Pump Waste
(E) Ejector Chemical Feed
(S) Pump Sludge, Skimmings or Float
Solenoid Valve
(P) Pressure Relief Valve Regulator
Combination Filter Regulator

operation uses lime, soda ash, and ferric chloride to break the emulsion. The following chemical tests are run per operation: pH, oil and grease (visual check), turbidity (visual check) and temperature. An acid skin brightner is used.

45. PLATTSBURGH AFB, Plattsburgh, N. Y. An industrial treatment operation employing gravity separator followed by air flotation is used to treat the wastes arising from the aircraft washrack. Alum is used to break the emulsion. The separated wastes are disposed of in the following manner: final effluent to Saranac River, and oil, grease, and grit by burying. The treatment plant is operated continuously. The air flotation was manufactured by Gibbs Flotation Unit, Newton 62, Massachusetts. An acid skin brightner is used. No chemical test are performed on the washrack waste.

46. POPE AFB, Fort Bragg, N. C. The waste from a temporary washrack flows untreated to a stream. A standard washrack is now being constructed. No chemical tests are performed on the washrack waste.

47. PORTLAND AFB, Portland, Oregon. Refer to section three of this thesis, page 29.

48. RANDOLPH AFB, San Antonio, Texas. Washrack wastes are treated using gravity separation. Oil skimmings are burned, and grit particles are buried. The final effluent flows by storm sewer to a creek. The flow in the creek normally consists of only sewage plant effluent (1 cfs). No chemicals are used to break the emulsion. Approximately 60 small aircraft are washed each month. An acid skin brightner is used. No chemical tests are performed on the aircraft washrack wastes.

49. REESE AFB, Lubbock, Texas. The regular washrack is not used. A small amount of washing is done in an open hanger. The washrack wastes are disposed of untreated in a lake on the base. No chemical tests are run.

50. ROBINS AFB, Macon, Georgia. At present the untreated aircraft washrack wastes are discharged into a river (average flow 2800 cfs) near the base. The acid skin brightner is used on approximately 30 of the 40 aircraft washed per month. An industrial waste treatment plant is scheduled for completion in October 1963. Data from chemical tests will be available. The plant being built is to include a gravity oil separator and an air flotation unit. A schematic diagram of the plant is available.

51. SEWART AFB, Smyrna, Tennessee. No treatment is given the aircraft washrack wastes before they are discharged into a large stream. An acid skin brightner is not used. Approximately 30 aircraft are washed each month. Chemical tests of washrack wastes were run for the questionnaire. (See page 68).

52. SIOUX CITY AFB, Sioux City, Iowa. The intermittent washrack wastes are treated by gravity oil separation. No chemicals are used to break the emulsion. The free oils and greases are disposed of by burning and the grit particles by burying. Approximately five aircraft are washed each month. It is unknown if chemical tests are run. An acid skin brightner is not used.

53. STEAD AFB, Reno, Nevada. Washrack volume is small at Stead AFB. The washrack drains into the dry lake beds at either end of the field for natural leaching.

54. STEWART AFB, Newburgh, N. Y. "Stewart AFB does not have any industrial waste treatment of the washrack wastes. The washrack wastes empty directly into a nearby surface stream."

55. SUFFOLK COUNTY AFB, Westhampton Beach, New York. There is no washrack at this installation.

56. TINKER AFB, Oklahoma City, Oklahoma. At present the untreated washrack wastes from approximately 25 aircraft washings per month are discharged directly to a stream (3.0 cfs to 6.6 cfs). No chemical tests are being performed. An acid skin brightner is used.

According to TAFB..."An industrial waste plant is now being constructed here and will be completed some time in October 1963. This plant will be used to treat all industrial wastes originating on Tinker Air Force Base including the wastes from aircraft washracks. The plant will consist of an air flotation unit with the addition of flocculation chemicals, ferrous sulfate and lime, to remove oils, greases, chromatic wastes, and other metallic substances. The effluent will then be processed through the existing sewage treatment plant which is a biological trickling filter type. The biological filtration will be used to remove phenolic wastes containing a mixture of ortho, meta, and para cresols which will be a result of aircraft washing and engine cleaning operations. Pilot plant studies here indicated that the bacteria on a trickling filter could withstand concentrations of 100 ppm. of phenols and that 80 percent removal could be effected at this concentration. If the concentrations of phenols exceeds 100 ppm., it is proposed to add a commercial fertilizer to the trickling filter at the rate of .025 percent per 1000 ppm. concentration of phenol or 25 percent of the phenolic concentration. The grit, oils, chromates, and other sludge removed from the air flotation unit will be dried and disposed of on land fills."

57. TURNER AFB, Albany, Georgia. The washrack wastes from this base are discharged untreated to a river. Approximately ten large aircraft are washed each month. An acid skin brightner is used. No chemical tests are performed on the washrack wastes.

58. TYNDALL AFB, Panama City, Florida. No treatment is given to the washrack wastes at this base. Chemical tests on the waste are not performed.

59. VANCE AFB, Enid, Oklahoma. Aircraft washrack wastes are not treated at this base.

60. VANDENBERG AFB, Lompoc, California. "Aircraft washing is a very minor item at this base. The average is about one a day; therefore, no analysis or treatment is made on this waste."

61. WALKER AFB, Roswell, New Mexico. "Drainage from the washrack is passed through a gravity type P. C. concrete grease trap and then to the storm sewer system from which it emerges into open drainage ditches and eventually into an on-base evaporation pond." The trapped oils and greases are burned and sediment is buried. No chemicals are used to break the emulsion. Wastes flows are intermittent. A priority demand for water is experienced during the summer months due to shortages. On the average. 40 aircraft are washed each month. An acid skin brightner is used. No chemical tests are performed on the washrack water.

62. WEBB AFB, Big Spring, Texas. The aircraft washrack wastes are discharged directly to evaporation pits with no other treatment being given to the waste. Chemical tests are not performed. Approximately 35 small aircraft are washed each month. An acid skin brightner is not used.

63. WENDOVER AFB, Wendover, Utah. "This installation is now in a caretaker status."

64. WHITEMAN AFB, Knob Noster, Mo. Aircraft washrack wastes are treated using air flotation. Treatment is on an intermittent bases as wastes are available. No chemicals are used to break the emulsion. The final effluent is discharged to a stream which is normally dry. Oil and grease are disposed of using a sand grease trap and the grit particles by a sanitary land fill. No chemical tests are performed at present on the washrack wastes.

65. WILLIAMS AFB, Chandler, Arizona. The aircraft washrack wastes flow untreated to evaporation and leaching beds. No chemical tests are performed. Approximately 42 aircraft are washed each month. Acid skin brightners are used on about five aircraft per month.

66. WRIGHT-PATTERSON AFB, Dayton, Ohio. No information was given concerning the washrack and treatment facilities. However, the statement was made: "An alkaline cleaner is used in the aircraft washracks at this facility which eliminates any requirement for treatment of wastes."