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Technical Report 1789-TR

PROJECT BEARS (BACTERIOLOGICAL EFFECTS, AIRCRAFT REFUELING SYSTEMS)

by

Richard R. Rogowski
and
Robert N. Brown

9 October 1964

U. S. ARMY ENGINEER RESEARCH AND DEVELOPMENT LABORATORIES
FORT BELVOIR, VIRGINIA

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Report 1799-TR, 9 Oct 64, 136 pp, 33 illus, 44 tables
U. S. Army Task 1D643324D59209 and USAF Task 3(6199-720B-816906)

Unclassified Report

Report covers investigations carried out to determine characteristics and growth rates of microbial contaminants in Military fuels; to learn effects of such contaminants on performance of filter/separators and other fueling system components; and to ascertain effects of certain additives and biocides on microbial growth rates and fuel properties. Primary conclusions are: (a) Deleterious microbial growths do not occur in JP-4 or 115/145 Avgas fuel either in presence or absence of water bottom layer. (b) Slight amount of fungus was evident in JP-4 fuel, but not to degree which would adversely affect quality of fuel. (c) Tank water bottoms in both inoculated and noninoculated fuel storage tanks experienced significant increase in microbial growth over approximately 12 months, then relatively sudden decrease occurred. (d) Fungus growth present in water bottoms of two storage tanks developed heavy brown mycelial mat (scum) which floated at fuel-water interface. (e) Ability of filter/separators to remove contaminants from JP-4 consisting of AC Test Dust and sea water in presence of tank water bottoms containing high amounts of microbial contamination was not affected. (f) Filter/separators afford high degree of microbial decontamination, because they continue to remove free water from fuel in presence of microbial matter, and bulk of this contamination is associated with free water phase. (g) Filter/separators are capable of processing microbially contaminated fuel to MIL-F-8901 cleanliness requirements. (h) No deleterious effects were noted in filter/separator component parts. (i) Ability of filter/separators to remove water from fuel, as reflected by water separometer index, modified (WSIM), was decreased by addition of anti-icing, rust preventive and biotoxic additives. (j) Physical properties of fuel were not adversely affected by contact with microbially infected tank water bottoms and sea water. (k) Microbially infected tank water bottoms appear capable of accelerating corrosion on the interior surfaces of unprotected steel storage tanks.

UNCLASSIFIED

1. Fuel Equipment - Handling
2. Contracts - None

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PROJECT BEARS
(BACTERIOLOGICAL EFFECTS, AIRCRAFT REFUELING SYSTEMS)

US ARMY-USAF JOINT PROJECT

Tasks: US Army 1D643324D59209
USAF 3(6199-720B-816906)

9 October 1964

Distributed by

The Commanding Officer
U. S. Army Engineer Research and Development Laboratories

Prepared by

Richard R. Rogowski and Robert N. Brown
Petroleum Equipment Branch
Mechanical Department

SUMMARY

This report covers investigations carried out to determine characteristics and growth rates of microbial contaminants in Military fuels; to learn effects of such contaminants on performance of filter/separators and other fueling system components; and to ascertain effects of certain additives and biocides on microbial growth rates and fuel properties.

Primary conclusions are:

a. Deleterious microbial growths do not occur in JP-4 or 115/145 Avgas fuel either in the presence or absence of a water bottom layer.

b. Slight amount of fungus was evident in the JP-4 fuel, but not to a degree which would adversely affect the quality of the fuel.

c. Tank water bottoms in both inoculated and noninoculated fuel storage tanks experienced a significant increase in microbial growth over approximately 12 months, then a relatively sudden decrease occurred.

d. Fungus growth present in the water bottoms of the two storage tanks developed a heavy brown mycelial mat (scum) which floated at the fuel-water interface.

e. Ability of the filter/separators to remove contaminants from JP-4 consisting of AC Test Dust and sea water in the presence of tank water bottoms containing high amounts of microbial contamination was not affected.

f. Filter/separators afford a high degree of microbial decontamination because they continue to remove free water from fuel in the presence of microbial matter, and the bulk of this contamination is associated with the free water phase.

g. Differential pressure across the filter/separators did not increase significantly from the injection of microbial infected water bottoms. No clogging of filter/coalescer elements from microbial growth was evidenced.

h. Filter/separators are capable of processing microbially contaminated fuel to MIL-F-8901 cleanliness requirements, if they are maintained properly and if the fuel being processed is relatively free from surfactants.

i. No deleterious effects were noted in the filter/separator component parts.

j. Ability of filter/separators to remove water from fuel, as reflected by water separometer index, modified (WSIM), was decreased by the addition of anti-icing rust preventive and biotoxic additives.

k. The anti-icing and biotoxic additives tried were not found to have a marked biocidal effect under the conditions prevailing and in the concentrations used.

l. Physical properties of the fuel were not adversely affected by contact with microbially infected tank water bottoms and sea water. A complete analysis made on samples of the JP-4 and 115/145 Avgas in April 1964 indicated that this fuel met the specifications and was suitable for use in aircraft.

m. Microbially infected tank water bottoms appear capable of accelerating corrosion on the interior surfaces of unprotected steel storage tanks.

A pictorial record of Project BEARS has been prepared in the form of a documentary motion picture film in color with audio narration.

FOREWORD

Investigation of rate of growth and effects of microbiological contamination on Military fuels and fuel handling equipment was conducted under general authority of U. S. Army Task 1D643324D59209, "Quality and Quantity Control Equipment System" and USAF Task 816906, "Investigation of Microorganisms in Fuel Servicing Equipment." A copy of the U. S. Army task card is included as Appendix A, Exhibit 1, to this report.

The period covered by this final report was from January 1962 to January 1964, inclusive.

The project was conducted by technical personnel of the Fuels Decontamination Section, USAERDL, under the general supervision of Richard R. Rogowski, Group Chief. Thomas J. Drennen, Senior Project Engineer, Systems Engineering Group (SEG), Wright-Patterson Air Force Base (WPAFB), furnished AF coordination. After October 1963, Robert N. Brown, USAERDL, served as Group Chief. Dr. J. A. Krynitsky, Section Head, Naval Research Laboratory (NRL), was a technical consultant. C. W. Karstens, Chief, Petroleum Equipment Branch, USAERDL; V. J. Bagdon, Chief, Biodeterioration Research, USAERDL; L. L. Stark, Chief, Fuels Decontamination Section, USAERDL; E. F. Suhr, Chief, Ground Servicing Equipment Section, SEG, USAF; R. T. Whitaker, Liquid Fuels Facility Consultant, HQ, USAF, AFOCE-GD; Lt Col D. V. Sudbury, Director of Materiel (DM); and Thomas A. Hetzel, Assistant DM, Kindley AFB, Bermuda; were the project advisors.

The Maytag Aircraft Corporation of Colorado Springs, Colorado, was the fueling contractor for Kindley AFB. Under the direction of George W. Collom the following valuable services were performed: Supplied the test fuel; maintained the system between visits; supplied mechanical and electrical support; and supplied additional transportation when required.

Approximately 5,600 microbiological and chemical analyses were conducted in support of Project BEARS by the following USAERDL Materials Research Laboratory personnel:

a. Microbiological analyses were made by Vincent J. Bagdon, Chief, and Donald Salt, Microbiologist, Biodeterioration Research, USAERDL. Dr. Dorthea E. Klemme, Biological Chemist, NRL, assisted with these analyses on one of the trips.

b. Chemical analyses were made by Sidney Levine, Chief; Basil Zanedis; Erna J. Beal; and Robert W. Beadle; Chemistry Section, USAERDL. Cora A. McLean, Chemist, NRL, assisted with these analyses on one of the trips.

The mechanical and maintenance duties during the test period were performed by Melvin J. Albright, Robert Casteel, and Chester Hughes, USAERDL POL Test Area.

Personnel who visited the test site from time to time are listed in Appendix B.

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PROJECT BEARS

(BACTERIOLOGICAL EFFECTS, AIRCRAFT REFUELING SYSTEMS)

I. INTRODUCTION

1. Subject. This report covers investigations of characteristics and growth rates of microbial contamination in aviation fuels and the effects of such contamination on the performance of filter/separators and other fueling system components. The investigations were conducted in a full-scale Pritchard aircraft fueling system at Kindley AFB, Bermuda.

2. Background. Many incidents of Air Force and Army aircraft malfunctions have been attributed in various reports to fuel contamination caused by entrained solids, water, or microbial growths. Attention was focused on this situation at a Government-Industry symposium, entitled "Contamination of Jet Fuel," held at the Pentagon on 13-14 September 1961. The symposium was coordinated and moderated by the Office of the Director of Defense Research and Engineering. It was established at this symposium that water contamination had caused aircraft fuel system icing, filter blockage, and malfunction of fuel system components, with subsequent engine failure. The presence of microorganisms in JP-4 and other hydrocarbon fuels was suspected of contributing to severe corrosion damage to aircraft wet-wing fuel systems, with a serious decrease in effectiveness of the Strategic Air Command (SAC) weapons system. Because existing knowledge and techniques were inadequate for coping with these difficulties, applied research was required to contribute to the solution of the problem. Project BEARS is but one phase of the overall DOD effort applied to the microbial contamination problem.

In November 1961, Systems Engineering Group (SEG), SEMSF, Wright-Patterson Air Force Base (WPAFB), requested USAERDL assistance in initiating an applied microbiological research program, primarily to determine whether conventional filter/separators were capable of removing microbial contaminants from aircraft fuels. USAERDL was selected because of long experience in research, development, and evaluation of filter/separators, especially those types used by the AF. It was agreed that because new Army aircraft were using turbines as power units, the Army would also benefit from this study. Therefore, the decision was made to formulate a joint Army-USAF microbiological research program, the cost to be shared by the two services. Also, in support of the project, the Navy volunteered to furnish the services of a fuels consultant.

A project steering committee was established, staffed by one representative from each of the services. The Air Force was represented by Thomas J. Drennen, SEMSF, the Navy by Dr. John Krynitsky, NRL, and the Army by Richard R. Rogowski, USAERDL. In addition, Robert T. Whitaker, AFOCE-GD; LeRoy L. Stark, Chief, Fuels Decontamination Section; and Vincent J. Bagdon, Chief, Biodeterioration Research, USAERDL; served as advisors.

The personnel previously mentioned in this report evolved the BEARS program which reflected the collective coordinated concepts of the Army, the Navy, and the Air Force.

3. Preliminary Planning. After the steering committee had made a comprehensive study of the project objectives, they determined that the investigation should include:

a. Full-scale dynamic evaluation of fuel filter/separators in an actual microbially contaminated aircraft fueling system. Three different types of filter/separators in major use today were to be evaluated, as follows:

(1) Commercial, vertical, single-stage units, which use a wool-nylon sock to strip the coalesced water from the effluent fuel stream.

(2) Commercial two-stage units, which use separately located, pleated paper elements as a second-stage water stripper.

(3) The newly developed USAERDL Military design (MD) unit, which uses 100-mesh Teflon-coated screen as the water stripper.

b. A static or time-in-storage investigation to determine the rate of microbial growth in 50,000-gallon fueling system underground storage tanks.

c. An investigation involving a number of selected combinations of water types, microbial contaminants, fuel additives, and biocides in combination with JP-4 fuel and 115/145 Avgas, in 55-gallon drums, to determine microbial growth rates and effects on fuel properties.

It was also decided that the investigation would be conducted as an in-house effort because the Military services had the required personnel experienced in fuels chemistry, filtration, and applied microbiology.

Headquarters, Military Air Transport Service (MATS), Scott AFB, Illinois, was requested to select an aircraft fueling system suitable for conducting the investigation. Selection criteria were that the system must: (1) Be available for at least 12 months; (2) be at a base located between latitude 35° N and latitude 35° S; (3) operate under semi-tropical temperatures and in a relatively salty and humid climate; and (4) consist of two pumphouse segments of the Pritchard type.

Headquarters MATS communicated with Kindley AFB in the Crown Colony of Bermuda, and obtained permission to use a Pritchard fueling system, one which was not continually required to maintain logistic capability. A team comprised of the members of the Steering Committee, its advisors, and chemistry experts from USAERDL, visited Kindley AFB during January 1962, and determined that the fueling system available was entirely suitable (Figs. 1 through 4). Further, an unused concrete block building located on the base was made available by Kindley AFB for the Project BEARS Laboratory (Fig. 5).

After the Project BEARS advisory team had evaluated the available investigative facilities at Kindley AFB, they evolved the pertinent technical objectives, which are listed in a Memorandum of Understanding (Appendix A, Exhibit 2), together with other information that pertains to project procedures. Additional objectives were evolved during the course of the project.

4. Technical Objectives. The objectives of the BEARS program were to obtain information in the following areas:

a. Characteristics and growth rates of microbial contaminants in aviation fuels.

b. Effects of microbial contamination on the water removing and filtering capabilities of filter/separators.

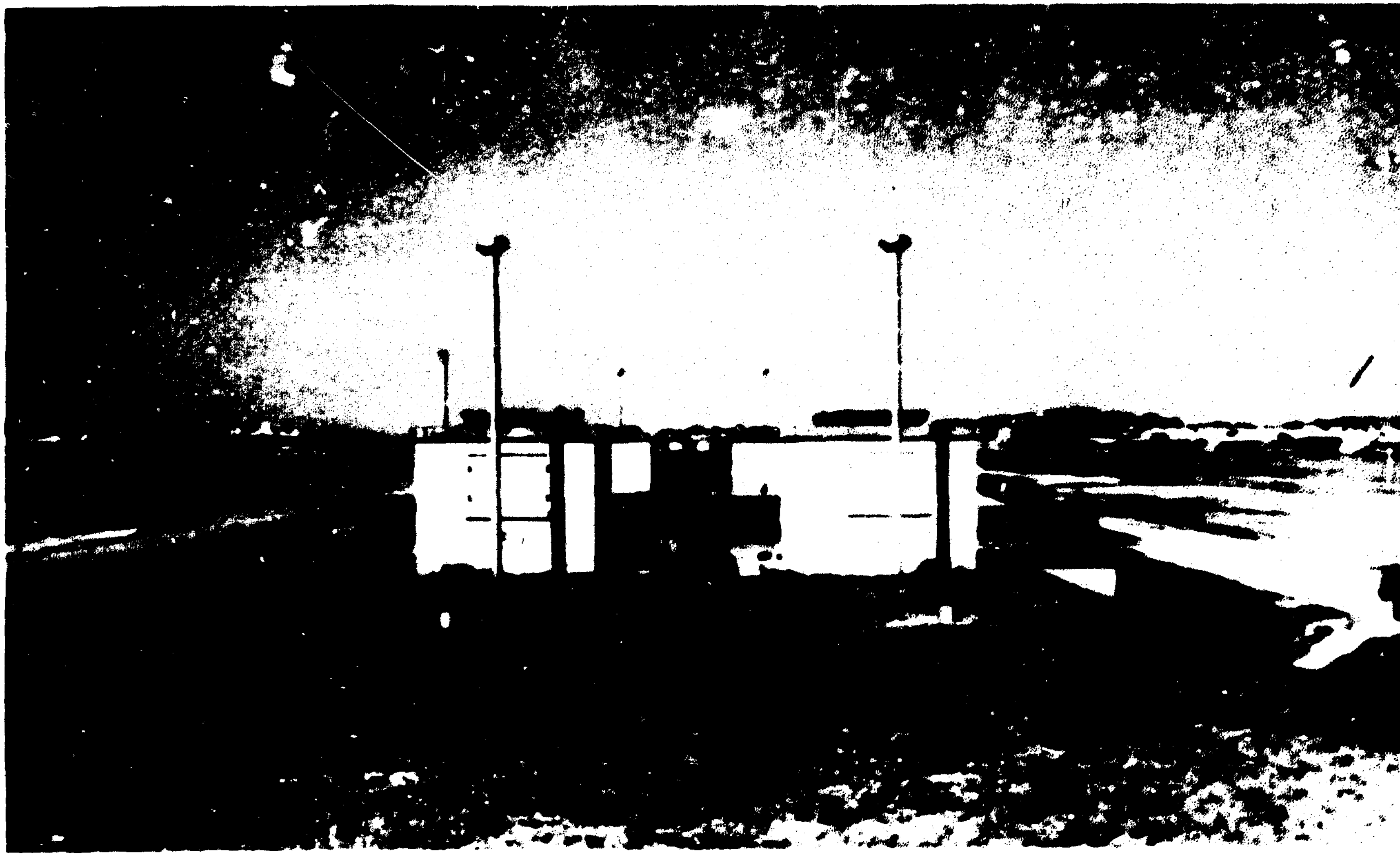
c. Clogging effects of microbial contamination on filter/coalescer elements.

L6316

Fig. 1. Pumphouse No. 4 on west side of Runway No. 19, Kindley AFB, Bermuda. Large, earthen mounds cover four 50,000-gal fuel storage tanks.

L6315

Fig. 2. Closeup of pumphouse No. 4. Low building in center houses fixed filter/separator equipment and electrical controls.



L6314

Fig. 3. Looking north from top of underground storage tanks. White concrete block buildings house vertical turbine pumps.

L6313

Fig. 4. Interior of pumphouse No. 4 showing permanently installed Bowser filter/separators. No. 1 was component of Control System (CS) and No. 2 of Inoculated System (IS).

L2274

Fig. 5. BEARS Laboratory building located on shore of Castle Harbor near eastern end of main runway.

d. Physical effects of microbial contamination on filter/separator vessels, components, and related equipment.

e. Effects of microbial contamination on the critical properties of JP-4 fuel and 115/145 Avgas.

f. Effects of various concentrations of anti-icing, corrosion preventive, and biocidal additives on the growth rate of microorganisms in the water bottoms and the stored fuel above the water bottoms.

g. Corrosion effect on sample sections of a KC-135 wing tank, when subjected to a combination of water, particulate, and microbial contamination.

h. Rate of growth of microorganisms in fuel when microbially contaminated water bottoms are removed from storage tanks.

i. Effects of temperature and time on the growth rate of microbial contaminants in stored fuel.

j. Ability of currently available fine filters or other ultrafiltration equipment to reduce or remove microbial contaminants from fuel.

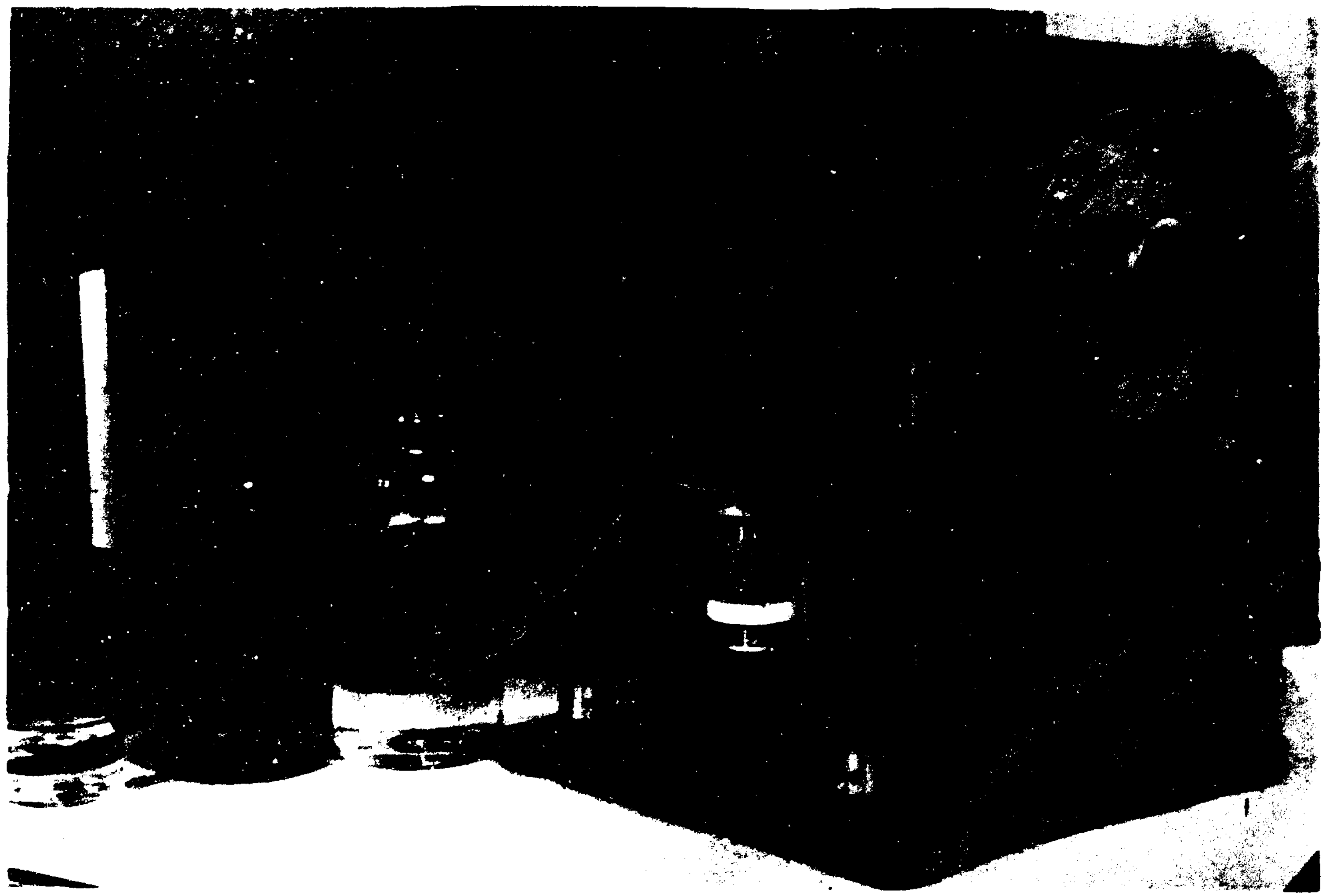
k. Capability of desiccants to retard microbial growth by removing free water.

Objectives h through k were later deleted when information obtained during the course of the program revealed that neither dry JP-4 fuel nor 115/145 Avgas supported microbial growth to any significant degree.

To simplify accomplishment of the outlined objectives, the project was divided into three parts, namely: (1) Underground storage tank investigation; (2) dynamic filter/separator investigation; and (3) static 55-gallon drum investigation.

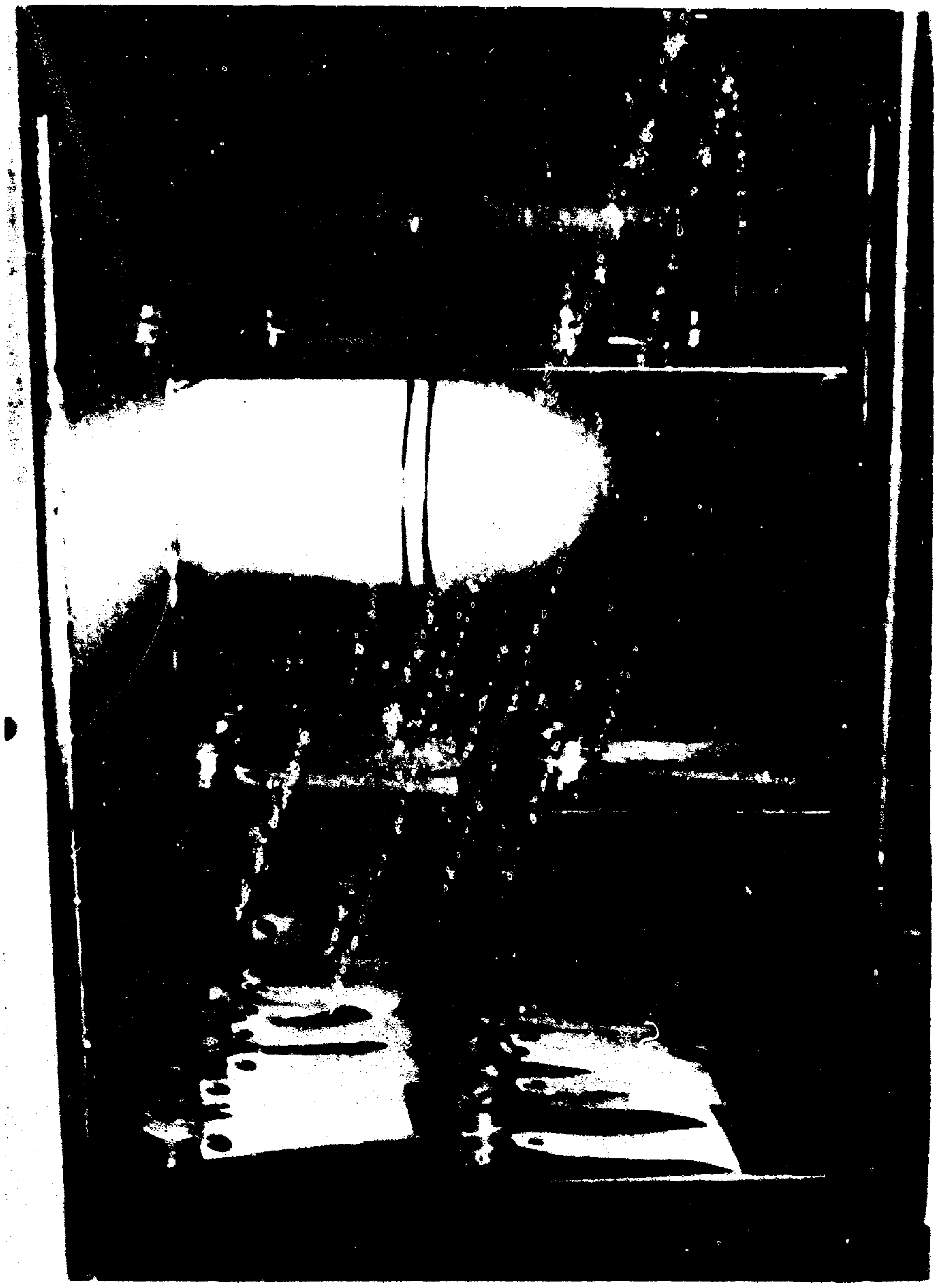
The laboratory equipment (Appendix C), shown in Figs. 6 through 9, was used in the sampling procedures discussed in this report in Appendix D. Procedures for physiochemical and microbiological analyses (Appendices E and F) were carried out on the samples obtained

Fig. 6. BEARS Laboratory showing water separometer apparatus at far left; Karl Fischer apparatus for water analysis at left center; constant temperature cabinets at right center; and digital balance at far right. L2362



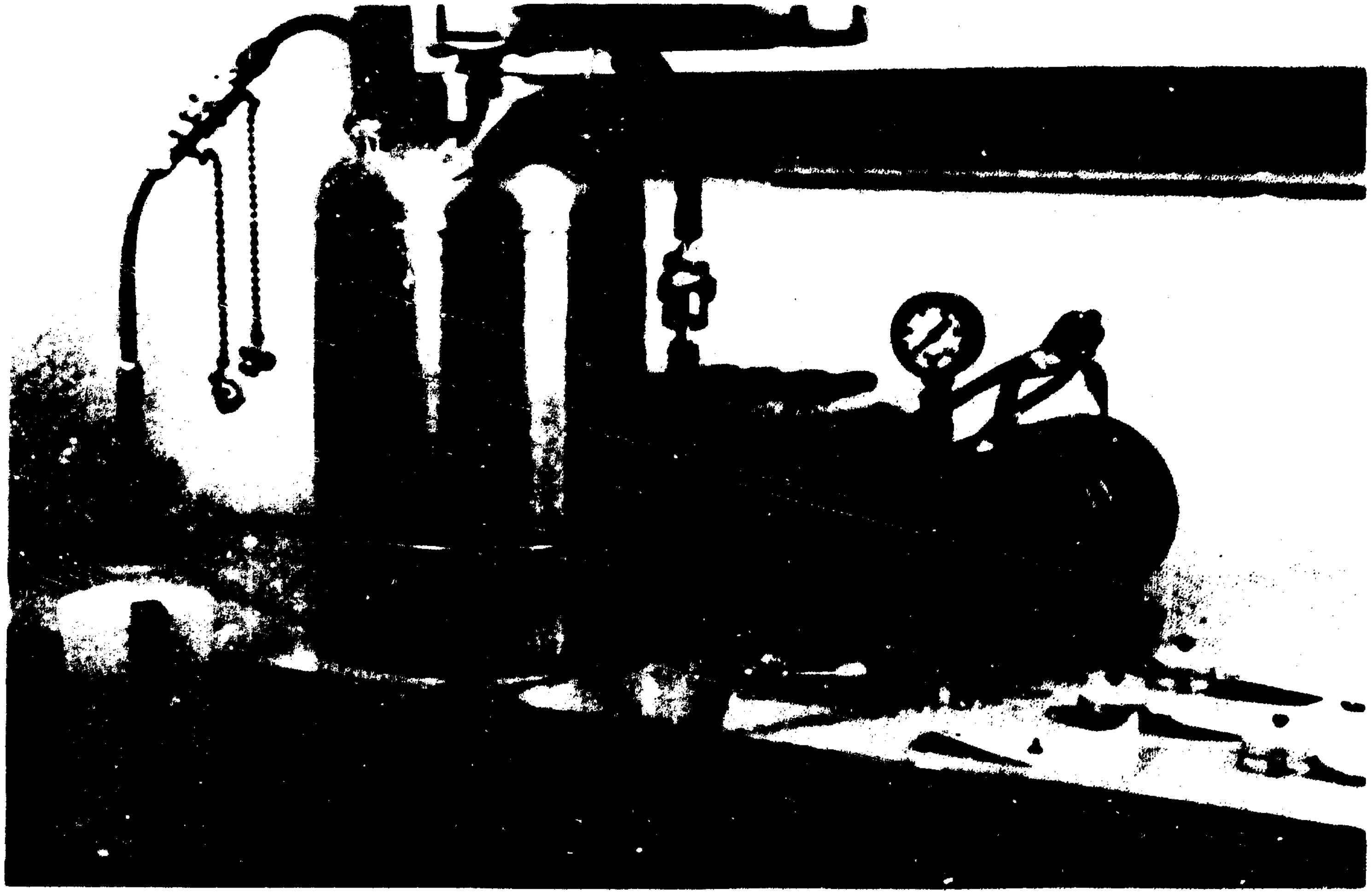
L2374

Fig. 7. Fischer Surface Tensiomat apparatus for determination of interfacial tension (IFT) between fuel sample and water.



L2370

Fig. 8. Interior of incubator used for microbiological analyses, showing Millipore monitors undergoing incubation.



L2369

Fig. 9. Apparatus for rinsing fuel from filter membrane used to filter microorganisms from fuel sample. Membrane is contained in metal holder attached to plastic bottle. Sterile rinse water is contained in stainless steel vessel in center.

II. UNDERGROUND STORAGE TANK INVESTIGATION

5. Objectives. This static or time-in-storage investigation was made to determine the rate of microbial growth in water bottoms and fuel stored in 50,000-gallon underground tanks and to learn what effects, if any, such growths have on the critical properties of the fuel.

6. Plan. For the underground storage tank investigation, two emplaced 50,000-gallon-capacity, horizontal, cylindrical steel tanks of the Pritchard fueling system were used.

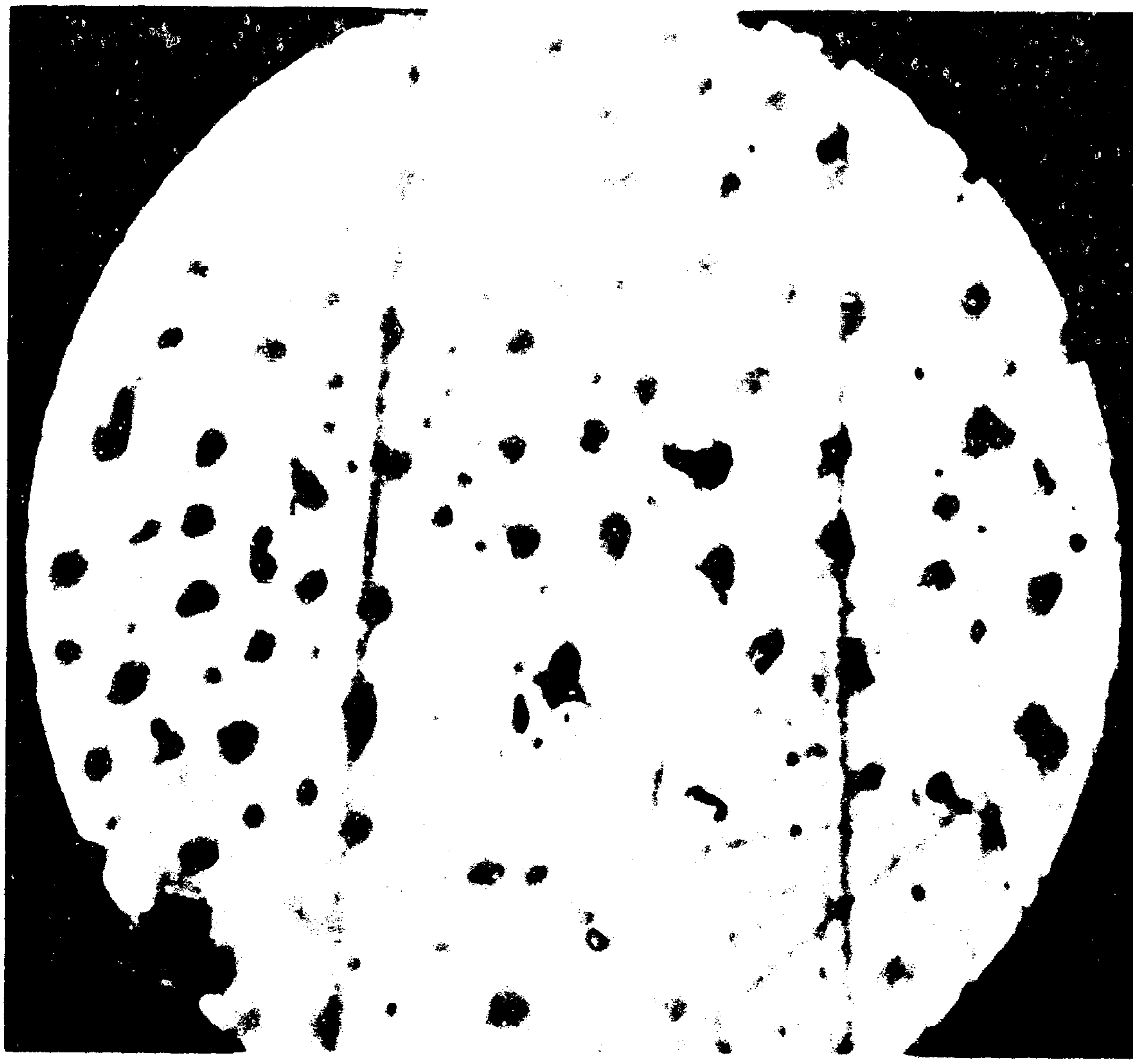
In brief, a single segment of a typical Pritchard fueling system consists of an underground storage tank in which is mounted a vertical 1,800-rpm, 300-gpm multistage centrifugal pump. The pump delivers the fuel from the tank through an installed 300-gpm filter/separator located in the pumphouse, and then to a hydrant located on the aircraft fueling apron. A portable filter/separator mounted on a 4-wheeled vehicle is connected between the hydrant and the aircraft, in an actual fueling operation. The fuel is cleaned, therefore, at two points in the fueling operation, once by the unit in the pumphouse and then again by the unit near the skin of the aircraft. The Pritchard system also has the ability to defuel an aircraft by using a 200-gpm pump located in a pit near the fueling apron. Here, the fuel is drawn from the aircraft tanks, through the portable filter/separator, the hydrant, the defueling pump, and then into the underground storage tank.

Approximately 40,000 gallons of JP-4 fuel were pumped into each of the two underground tanks. The JP-4 fuel was a portion of the Kindley AFB reserve, received without corrosion inhibitor or anti-icing compounds, at the Esso Ferry Reach Terminal, in Bermuda. The JP-4 fuel in both tanks was treated with 0.1 percent Phillips 55 MB anti-icing additive as required by USAF directives, effective 1 April 1962. Eight hundred forty gallons of water were dumped into each of the tanks. This water, composed of 20 percent sea water and 80 percent fresh water, settled to the bottom of each tank to a depth of approximately 6 inches. One of the tanks was then inoculated with 1,500 milliliters of a specially prepared inoculum which was essentially a composite of ten microbially contaminated JP-4 storage tank water bottom samples from Ramey AFB, Puerto Rico, and Bergstrom AFB, Texas. To insure that this inoculum included strains of both bacteria and fungi, it was fortified by the addition of seventeen bacterial cultures isolated from JP-4 storage tank sludge, eleven fungi cultures isolated from various JP-5 sludges; seven bacterial and six fungi cultures isolated from several different sludges collected at Lajes AFB, Azores (Appendix G and Fig. 10), Nouasseur AFB, Morocco, and Ascension Island AFB. Some of the representative genera included in the inoculum were: Pseudomonas, Serratia, Desulfovibrio, Cladosporium, Penicillium, and Fusarium. The first Pritchard system segment containing this tank was designated "Inoculated System" or "IS," and the second Pritchard segment was designated "Control System" or "CS."

The decision was made to conduct chemical and microbiological analyses on the various fuels used in all the investigations at Kindley AFB, once each 2 months, for a period of approximately 2 years. An investigative team of USAERDL personnel consisting of a project engineer (group chief), two microbiologists, two chemists, and two mechanics was designated. Shortly after each Kindley AFB investigative trip, the team reported to the Steering Committee on the data obtained. The Committee analyzed and evaluated the data and decided on the course of action to be followed, that is, the date and the program for the next trip.

For this underground storage tank investigation, the water and the inoculum were added to the 40,000 gallons of fuel treated with anti-icing additive on 19 April 1962. The first project team trip of 2 weeks' duration was made during June 1962. A total of nine trips was subsequently made. The final trip occurred in January 1964.

7. Results and Discussion. Results shown in Tables I and II consist of physiochemical and microbiological data pertinent to the underground storage tank investigation. During the June 1962 visit, after a quiescent 2-month period, separate samples of fuel were taken from the underground tanks, for microbial count and fungus determination, from a point 1 foot below the surface of the JP-4 fuel and identified as tank top (TT), at the JP-4 midpoint level (TMP), at 1 foot above the JP-4 water bottom interface (TIF+1), and at the tank water bottom (TWB). Additional JP-4 fuel samples, for the physiochemical analyses were taken at the TMP. The water separometer index, modified for severity (WSIM), was initially determined against distilled water, sea water, and the water bottom. After the third trip, because the values had not appreciably changed, the decision was made to utilize the water bottom only for WSIM, as this value would be indicative of field conditions. If the WSIM should change drastically, the distilled water and sea water values would again be determined. This same procedure was utilized for the interfacial tension values (IFT). All of the physiochemical and microbiological analyses were repeated during each subsequent trip. The tables indicate that neither the WSIM nor the IFT values drastically changed in either the CS or the IS during the entire period of investigation and that the values in both systems were similar. The microbial count in the VB of both the IS and the CS increased



J3660

Fig. 10. Photomicrograph of a polar-flagellated gram-negative rod, isolated from a JP-4 fuel storage tank, Lajes AFB, Azores, used as partial inoculum culture for BEARS investigation. (Magnification, 2,250 X)

Table I. Underground Storage Tank Investigation, CS Tank

Analysis Date	WSIM JP-4 Fuel vs: Dis-tilled Water			IFT (dynes/cm) JP-4 Fuel vs: Dis-tilled Water			Microbial Count (colonies/ml) TT				Fungi TT				JP-4 Fuel Corro-sion	pH TWB	Anti-Icing Additive (%) JP-4 Fuel	
	Dis-tilled Water	TWB	Sea Water	Dis-tilled Water	TWB	Sea Water	TT	TMP	TIF-1	TWB	TT	TMP	TIF-1	TWB			JP-4 Fuel	TWB
June '62	98	98	97.5	38.7	31.7	37.4	< 1	< 1	< 1	1.1×10^{2}	Yes	Yes	Yes	Yes	Neg	-	-	-
Aug. '62	92	98	99	40. [illegible]	29.3	37.1	< 1	< 1	< 1	7.0×10^{3}	Yes	Yes	Yes	Yes	Neg	-	-	-
Oct. '62	99	97	97	36.9	29.8	35.7	< 1	< 1	< 1	1.9×10^{5}	Yes	Yes	Yes	Yes	Neg	5.3	0.04	> 0.14
Jan. '63	-	99	-	-	27.5	-	< 1	< 1	< 1	2.4×10^{6}	Yes	Yes	Yes	Yes	Neg	5.5	0.04	-
Mar. '63	-	98.5	-	-	28.6	-	< 1	< 1	< 1	2.4×10^{7}	Yes	Yes	Yes	Yes	Neg	-	0.04	-
June '63	-	98	-	-	27.8	-	< 1	< 1	< 1	1.3×10^{8}	Yes	Yes	No	Yes	Neg	4.0	0.04	4.0
July '63	-	-	-	-	28.8	-	< 1	< 1	< 1	1.5×10^{8}	Yes	Yes	Yes	Yes	Neg	5.45	0.04	-
Oct. '63	-	95	-	-	-	-	< 1	< 1	< 1	1.1×10^{3}	Yes	Yes	Yes	Yes	-	5.70	-	-
Jan. '64	-	95	-	-	34.1		< 1	1	< 1	930	Yes	Yes	Yes	Yes		6.0		
Mar. '64																		

Note: 1. On 19 April 1962, 168 gal of sea water and 672 gal of fresh water were added to 40,000 gal of JP-4 fuel.

2. The JP-4 was treated with 0.1 percent anti-icing additive prior to the addition of the sea and fresh water.

3. Hyphens signify that no data were available.

4. Blank spaces indicate that no data were taken.

Table II. Underground Storage Tank Investigation, IS Tank

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water			IFT (dynes/cm) JP-4 Fuel vs: Distilled Water			Microbial Count (colonies/ml)				Fungus				JP-4 Fuel Corrosion	pH	Anti-Icing Additive (%)	
	Distilled Water	TWB	Sea Water	Distilled Water	TWB	Sea Water	TT	TMP	TIF+1	TWB	TT	TMP	TIF+1	TWB		TWB	JP-4 Fuel	TWB
June '62	97.5	84	98.2	40.7	28.6	33.1	<1	<1	<1	1.1×10^2	Yes	Yes	Yes	Yes	Neg	-	-	-
Aug. '62	98	99	99	41.2	30.6	38.2	<1	<1	<1	1.3×10^4	Yes	Yes	Yes	Yes	Neg	-	-	-
Oct. '62	99	97	97.5	38.7	29.2	37.9	<1	<1	<1	1.6×10^6	Yes	Yes	Yes	Yes	Neg	5.4	0.04	>0.14
Jan. '63	-	98	-	-	30.7	-	<1	<1	<1	9.0×10^6	Yes	Yes	Yes	Yes	Neg	5.4	0.04	-
Mar. '63	-	100	-	-	26.6	-	<1	<1	<1	1.8×10^7	Yes	Yes	Yes	Yes	Neg	-	0.04	-
June '63	-	98	-	-	27.4	-	<1	<1	<1	1.9×10^8	Yes	Yes	Yes	Yes	Neg	5.9	0.04	4.0
July '63	-	-	-	-	28.0	-	<1	<1	<1	2.2×10^8	Yes	Yes	Yes	Yes	Neg	5.15	0.04	-
Oct. '63	-	97	-	-	31.4	-	<1	<1	<1	2.9×10^3	Yes	Yes	Yes	Yes	-	5.70	-	-
Jan. '64	-	100	-	-	32.4		<1	<1	<1	2.8×10^3	Yes	Yes	Yes	Yes	-	5.9	-	-
Mar. '64																		

Note: 1. On 19 April 1962, 168 gal of sea water, 672 gal of fresh water, and 1,500 ml of inoculum were added to 40,000 gal of JP-4 fuel.

2. The JP-4 fuel was treated with 0.1 percent anti-icing additive prior to the addition of the sea and fresh water.

3. Hyphens signify that no data were available.

4. Blank spaces indicate that no data were taken.

substantially during the first 13 months, and a major decrease occurred by the fifteenth month. The microbial count in the TWB of the IS increased at a slightly greater rate than that in the CS during the first 6 months, but not substantially so. Although the JP-4 fuel was repeatedly subjected to contact with the infected water bottoms, it did not support active microbial growth and could be considered essentially sterile. Fungi was present in the JP-4 and the TWB in both systems during the investigation. The JP-4 copper corrosion analysis showed no change during this period, and the pH of the TWB's in the CS and the IS were similar and increased only slightly. The percentage of anti-icing additive at the TMP in both systems was the same. A similar condition existed at the TWB of both systems. In addition, a complete analysis conducted on the JP-4 fuel revealed that it satisfactorily met all specification requirements. Appendix H describes the condition of storage tanks during site restoration at the conclusion of the project.

8. Conclusions. It is concluded from the data obtained in the underground storage tank investigation after 18 months of storage that:

a. The JP-4 fuel did not support active microbial growth and could be considered essentially sterile.

b. A slight amount of fungus was evident in the JP-4 fuel, but not to a degree which would adversely affect the quality of the fuel.

c. The WSIM and IFT values of the JP-4 fuel were not decreased but remained at the initial acceptable level.

d. The JP-4 fuel met the specification requirements.

e. The TWB's in both the CS and IS experienced a significant increase in microbial growth over approximately 12 months, then a relatively sudden decrease occurred.

f. The microbial growth in the TWB's of both the CS and the IS remained relatively parallel throughout the investigative period.

g. Fungus growth present in the TWB's of both the CS and the IS developed a heavy brown mycelial mat (scum) which floated at the fuel-water interface.

h. The pH of the TWB in the CS and the IS did not significantly change and was relatively the same for both systems.

i. In both systems, anti-icing additive was partitioned into the aqueous phase. At the resultant concentration of 4 percent, this material failed to inhibit the rate of microbial growth in the TWB of either system.

j. Microbially infected TWB's appear capable of accelerating corrosion on the interior surfaces of unprotected steel storage tanks.

III. DYNAMIC FILTER/SEPARATOR INVESTIGATION

9. Objectives. The objectives of this investigation were to determine:

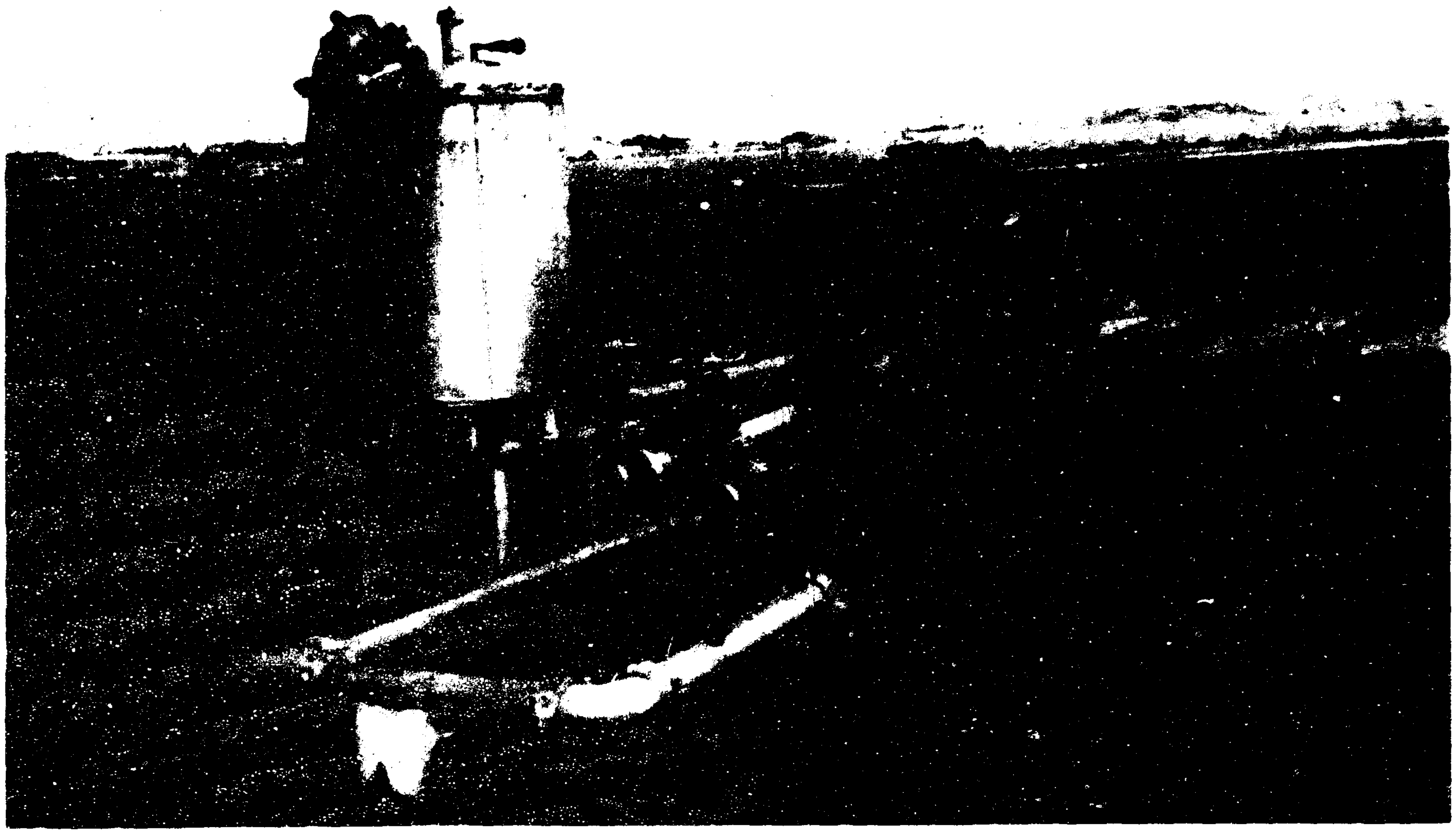
a. Effects of microbial contamination on the water removing and filtering capabilities of filter/separators (f/s).

b. Clogging effects of microbial contaminants on filter/coalescer elements.

c. Physical effects of microbial contamination on filter/separator vessels, components, and related equipment.

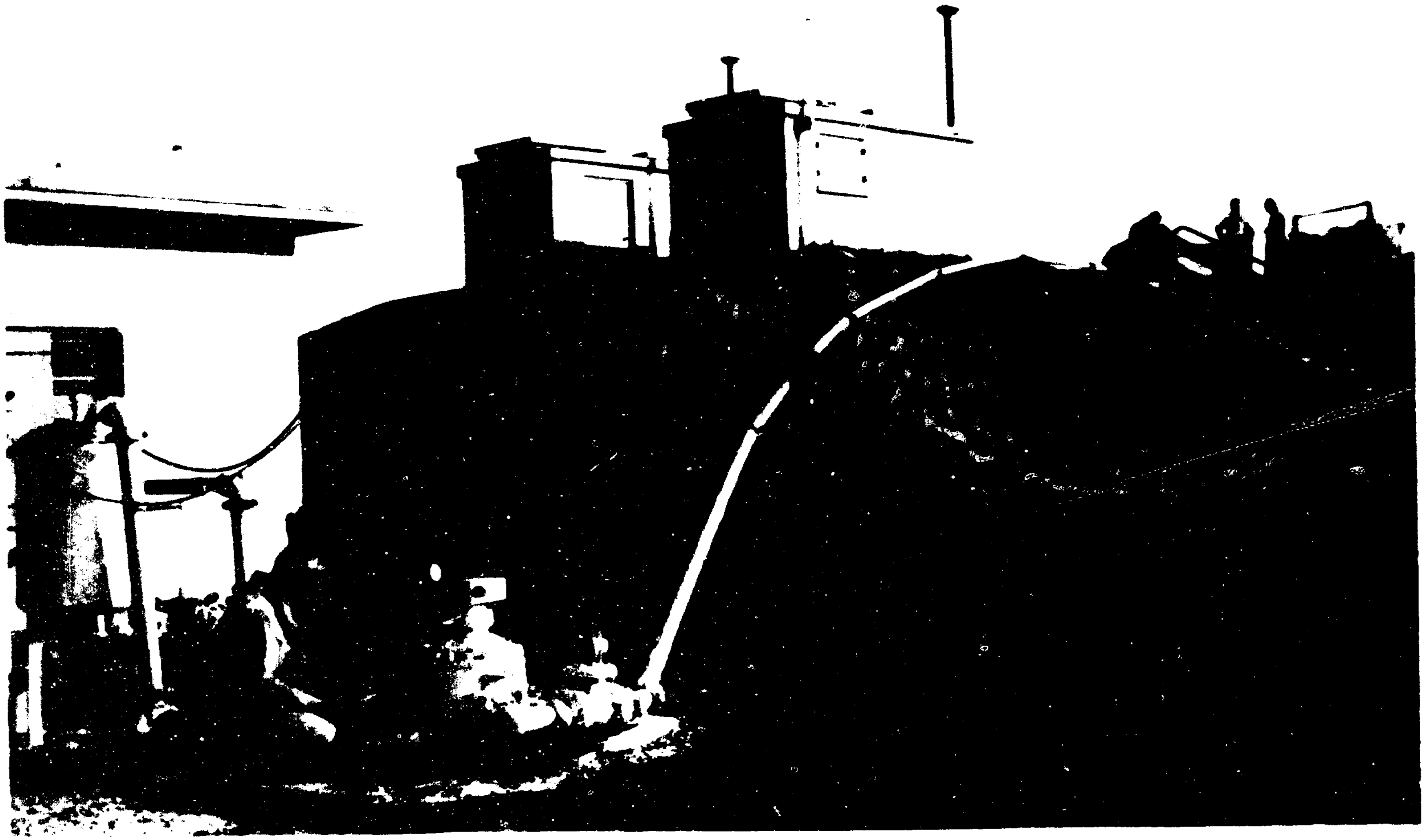
10. Plan. The Pritchard system fueling segment connected to the storage tanks used in the underground storage tank investigation was utilized to conduct the dynamic filter/separator performance evaluation. The vertical Bowser filter/separator No. 842, installed in the pumphouse (Fig. 4) utilizes twelve Bowser No. 47B37 filter/coalescer elements, which had been previously qualified to MIL-F-8508A, 23 October 1956. Each element in the filter/separator vessel is surrounded by a loosely fitted wool-nylon sock. As the contaminated JP-4 fuel is pumped through the Fiberglas, the emulsified water is coalesced into large drops. The water drops are emitted by the element, but are retained by the wool-nylon sock, clean JP-4 passing through to the effluent pipe of the unit. The drops of water, which are heavier than the fuel, fall by gravity within the confines of the sock, to the bottom of the vessel where they form a pool. This water is automatically discharged from the vessel.

Two different types of filter/separators were installed down stream from the Bowser f/s, and flow from this unit was alternated through each. The two vessels chosen were an F-6 qualified to MIL-F-26678B, 7 March 1960 and an MD qualified to MIL-F-8901, 14 February 1961 (Figs. 11 and 12). The Bowser, the F-6, and the MD f/s units were all rated at 300 gpm with JP-4 fuel. Pleated paper, 100-mesh Teflon-coated screen,



L2258

Fig. 11. Temporary filter/separators used as components of CS. F-6 vessel is on left, and MD vessel is on right.



L2339

Fig. 12. Filter/separators in IS. F-6 vessel is on left, and MD vessel is on right.

and a wool-nylon sock are utilized as second-stage water strippers to accomplish removal of coalesced water in the filter/separator vessel for the F-6, the MD, and Bowser units, respectively. The F-6 and MD f/s were also installed in the CS. New elements were installed in each unit. The Bowser f/s was fitted with elements manufactured by Bowser Inc.; the F-6, with elements manufactured by Fram Corp.; and the MD with 15 each, Bowser and Filters, Inc. Elements were donated by the manufacturers.

After samples had been taken for the previous underground storage tank investigation, the greater portion of the TWB's from both the IS and the CS were removed by slowly pumping them into separate collapsible rubber tanks (Figs. 13 and 14), so that accumulative microbial growth, if any, would not be lost by passing through the filter/separator. After the dynamic filter/separator investigation had been completed, the TWB's were pumped back into their respective tanks.

The dynamic investigation on the CS and the IS during each team trip to Kindley AFB, consisted primarily of:

a. Circulation of the JP-4 fuel from the storage tank through the Bowser and the MD f/s, then back to the storage tank for a period of 16 hours.

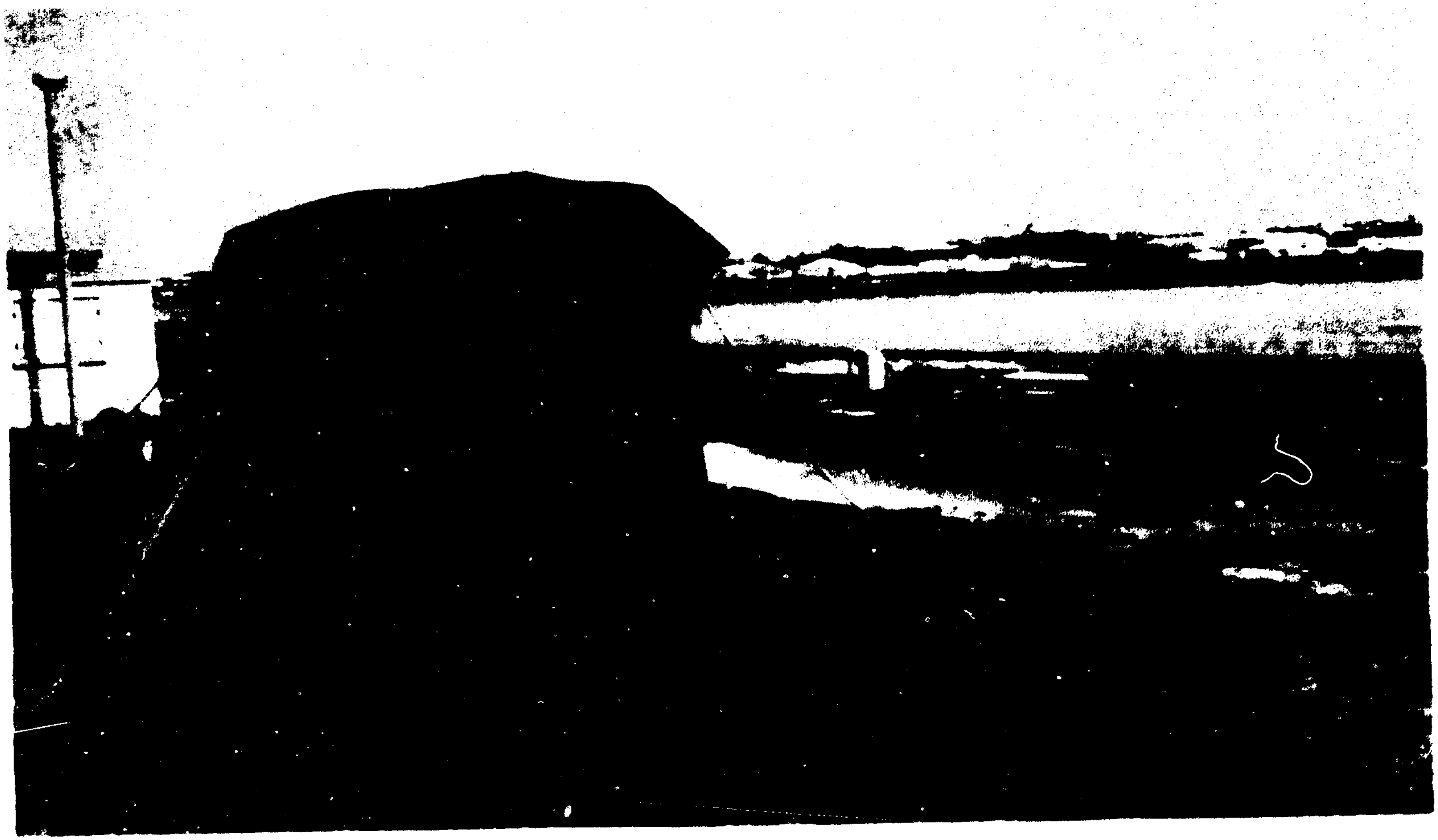
b. Again, circulation through the Bowser f/s and the F-6 for 16 hours.

c. Circulation of the Bowser f/s and the F-6 f/s for 8 hours, during 5 hours of which 0.1 ounce per minute of AC Test Dust and 0.3 gpm of sea water was injected into the Bowser f/s influent (Fig. 15).

d. Circulation the same as c, with flow through the MD f/s in lieu of the F-6 f/s (Fig. 16).

This plan was essentially followed throughout the 18-month investigative period. The plan was varied at times by injecting the TWB of the CS or the TWB of the IS into the MD and F-6 f/s influents, in lieu of sea water. During the October 1963 trip, the heavy microbial sludges were gathered from the TWB of each system, and injected into each filter/separator in each system.

11. Results and Discussion. Results shown in Tables III through VIII consist of physiochemical and microbiological data pertinent to the dynamic filter/separator investigation. These tables show performance data



L2267

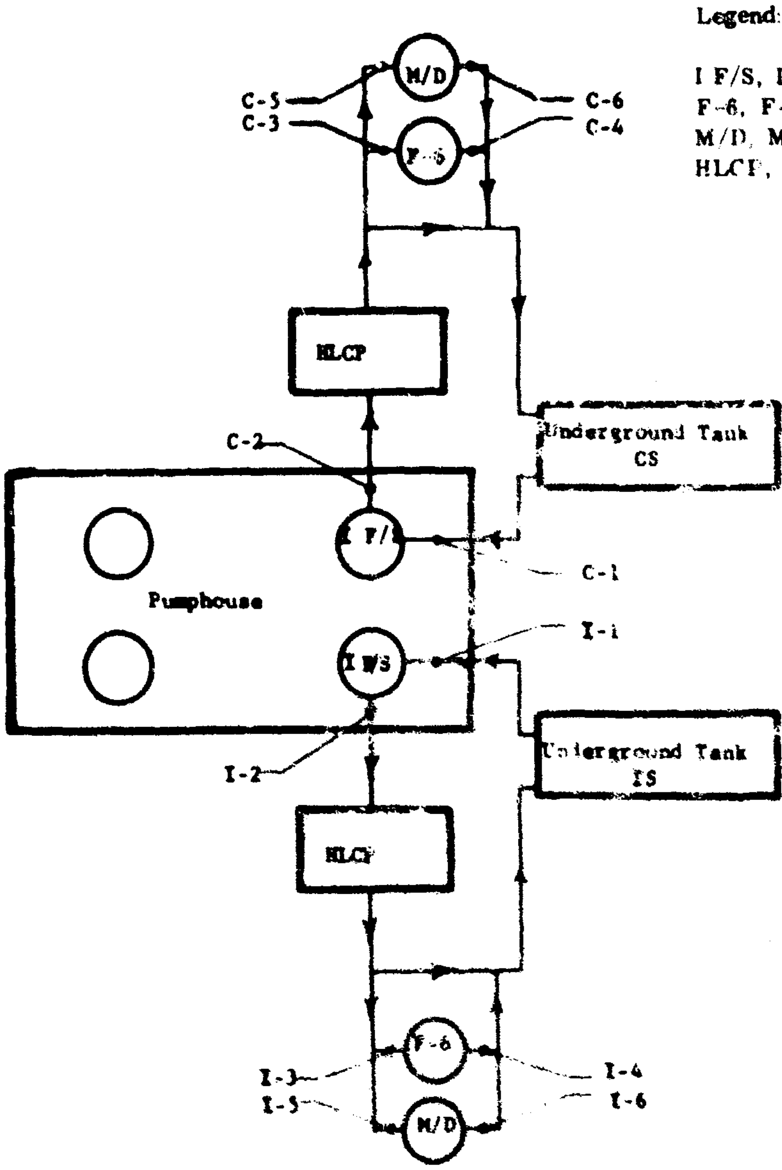
Fig. 13. Closeup of one of collapsible rubber tanks used to store contaminated water bottoms from main storage tanks during fuel circulation runs. Runway 19 is in background.

L2377

Fig. 14. Interior of collapsible rubber tank containing IS water bottoms. Note: Microbial sludge is floating on surface.

L2372

Fig. 15. Contaminant injection equipment, showing AC Test Dust feeder at top; blending tank at center; and progressive cavity feed pump at bottom.



Legend:

I F/S, Installed Filter/Separator
F-6, F-6 Filter/Separator
M/D, Military Design Filter/Separ tor
HLCP, Hydrant Lateral Control Pit

Fig. 16. Schematic of BEARS, showing sampling points (valving not shown). Samples taken from underground tanks are identified by TT, TMP, TIF+1, TIF, and TWB.

for each filter/separator in each system. Table III contains data on the Bowser f/s in the CS; after a throughput of 6.66 million gallons of JP-4 fuel the unit still performed satisfactorily, even after the injection of sea water, TWB of the CS, AC Test Dust, and heavy microbial sludges. After a throughput of 3.33 million gallons, the F-6 and MD f/s were still performing satisfactorily, as indicated by data in Tables IV and V.

The filter/separators in the IS performed equally as well. After 4.4 million gallons had been circulated through the Bowser f/s, and 2.2 million gallons through both the F-6 and MD f/s, injecting the same contaminants as in the CS investigation, water and solids removal performance remained satisfactory. Tables VI, VII, and VIII contain data on this investigation.

During the first two trips in June and August 1962, analyses of the outlet samples taken for free water determination indicated the presence of free water in excess of the specification limit. This was attributed to high laboratory humidity and temperature resulting from insufficient air conditioner capacity. This condition interferes with correct operation of the Karl Fischer apparatus and results in an erroneous high free water reading. Careful examination, by personnel experienced in visual analysis, disclosed no trace of the haze which always indicates the presence of free water.

12. Conclusions. It is concluded from the data obtained in the dynamic investigation conducted over an 18-month period on filter/separators in both CS and IS systems that:

a. The ability of the filter/separators to remove from JP-4 fuels, contaminants consisting of AC Test Dust, sea water, and TWB's containing high amounts of microbial contamination, was not affected (Figs. 17 through 24).

b. The differential pressure across the filter/separators did not increase significantly from injection of microbial infected TWB's; rather, it slowly increased during the whole investigative cycle as is normal in field aircraft fueling systems. No clogging was evidenced.

c. Filter/separators afford a high degree of microbial decontamination, because they continue to remove free water from fuel in the presence of microbial matter, and the bulk of this contaminant material is associated with the removed water.

Table III. Dynamic Filter/Separator Investigation of CS, Installed Filter/Separator, Bowser Unit No. 842

Test Date	Throughput (M gal)	Solids (mg/1) (inlet)	Solids (mg/1) (outlet)	Free Water (mg/1) (inlet)	Free Water (mg/1) (outlet)	Microbial Count (colonies/ml) (inlet)	Microbial Count (colonies/ml) (outlet)	Fungus (inlet)	Fungus (outlet)	Delta P (in. of Hg)	Fuel Temperature (°F)
June '62	18	-	-	38.7	-	<1	<1	Yes	Yes	1.1	73.5
↓	44	-	1.3	-	0.0	-	-	-	-	1.3	74.5
	90	-	1.3	-	15.1	<1	<1	No	Yes	1.3	76.5
	162	-	-	19.0	-	<1	<1	Yes	Yes	1.3	77.5
	198	-	0.8	-	3.5	-	-	-	-	1.5	78.5
June '62	234	-	0.4	-	9.9	<1	<1	No	No	1.6	79.0
Aug. '62	288	1.9	1.7	Ex.	5.2	<1	<1	Yes	Yes	1.7	78.0
↓	306	-	-	389.0	7.2	<1	<1	Yes	No	1.9	79.0
	576	0.5	0.6	35.0	0.0	<1	<1	Yes	Yes	1.9	85.0
	594	-	-	53.5	0.0	<1	<1	Yes	No	1.7	86.0
	882	0.6	0.5	79.0	-	<1	<1	Yes	Yes	1.9	87.0
	900	*	0.3	*	11.5	-	-	-	-	2.1	88.0
	972	*	0.2	*	6.0	<1	<1	Yes	Yes	2.1	89.0
	1,026	0.7	0.3	43.5	-	<1	<1	Yes	No	1.9	90.0
	1,044	*	0.4	*	1.5	-	-	-	-	2.0	86.0
Aug. '62	1,116	*	0.4	*	0.0	<1	<1	Yes	Yes	2.3	90.5
Oct. '62	1,152	0.8	0.5	92.0	2.6	2	13	Yes	Yes	2.7	78.0
↓	1,170	-	-	0.0	0.0	1	1	Yes	Yes	2.2	79.0
	1,440	1.1	0.6	41.0	0.0	22	19	Yes	No	2.4	82.0
	1,458	-	-	3.5	0.0	16	19	Yes	No	2.3	83.0
	1,746	0.8	1.0	21.0	-	8	2	No	No	2.3	86.0
	1,782	*	0.5	*	0.0	-	-	-	-	2.6	84.0
	1,872	*	0.4	*	0.5	2	3	Yes	Yes	2.6	86.0
	1,906	0.6	0.6	6.9	-	5	11	Yes	Yes	2.3	86.0
	1,944	*	0.3	*	3.5	-	-	-	-	1.9	86.0
	1,984	*	0.2	*	6.0	14	12	No	No	2.7	87.0
Jan. '63	2,016	6.0	0.3	8.5	4.9	<1	<1	-	-	2.3	69.0
↓	2,034	-	-	2.5	1.4	<1	<1	-	-	2.6	69.5
	2,592	6.2	0.2	7.4	0.0	<1	<1	-	-	2.8	76.0
	2,610	-	-	9.0	0.0	<1	<1	-	-	2.8	76.5
	3,204	0.7	0.2	0.0	-	<1	<1	-	-	2.9	75.0
	3,222	*	0.2	*	0.0	-	-	-	-	2.9	78.0
	3,294	+	0.2	+	0.0	<1	<1	-	-	3.2	78.0
	3,303	-	0.2	-	-	-	<1	-	-	3.1	78.0
	3,330	1.3	0.6	0.0	-	<1	<1	-	-	2.6	74.5
	3,348	*	0.2	*	0.0	-	-	-	-	3.0	77.0
	3,420	+	0.8	+	0.0	<1	<1	-	-	3.3	78.0
Jan. '63	3,429	-	0.2	-	-	-	<1	-	-	2.8	78.0

Table III (cont'd)

Test Date	Throughput (M gal)	Solids (mg/1) (inlet)	Solids (mg/1) (outlet)	Free Water (mg/1) (inlet)	Free Water (mg/1) (outlet)	Microbial Count (colonies/ml) (inlet)	Microbial Count (colonies/ml) (outlet)	Fungus (inlet)	Fungus (outlet)	Delta P (in. of Hg)	Fuel Temperature (°F)
Mar. '63	3,744	0.9	0.3	148.0	0.0	<1	<1	-	-	4.2	73.0
↓	4,032	0.8	0.4	65.9	0.0	<1	<1	-	-	4.0	76.5
↓	4,086	*	0.5	*	0.0	<1	<1	-	-	4.3	74.0
↓	4,158	*	2.1	*	0.0	-	-	-	-	4.7	76.5
↓	4,230	*	0.9	*	0.0	<1	<1	-	-	5.1	77.0
Mar. '63	4,302	*	0.4	*	0.0	-	-	-	-	5.3	77.0
June '63	4,500	0.8	0.7	5.8	0.0	<1	<1	-	-	5.1	77.0
↓	4,788	0.8	0.2	9.3	4.0	<1	<1	-	-	5.1	80.0
↓	4,932	*	0.3	*	3.2	<1	<1	-	-	5.7	83.0
↓	5,022	*	-	*	-	-	-	-	-	5.9	83.0
↓	5,076	*	0.8	*	0.0	<1	<1	-	-	5.0	81.0
June '63	5,176	*	-	*	-	-	-	-	-	5.6	83.0
July '63	5,455	0.3	0.1	217.2	0.0	<1	<1	-	-	6.3	85.0
↓	5,681	0.4	0.2	113.0	0.0	<1	<1	-	-	6.7	88.0
↓	5,832	*	-	-	-	<1	-	-	-	6.5	91.0
↓	5,922	*	-	*	-	-	-	-	-	7.2	91.0
↓	5,976	+	0.2	+	0.0	<1	<1	-	-	6.5	88.0
July '63	6,066	+	0.2	+	0.0	<1	<1	-	-	6.7	92.0
Oct. '63	6,336	∴	-	-	-	-	-	-	-	6.7	84.0
↓	6,534	∴	-	-	-	-	-	-	-	8.1	87.0
↓	6,642	∴	-	-	-	-	-	-	-	8.6	85.0
Oct. '63	6,660	#	0.0		0.0	1	1	No	No	10.1	84.0
Jan. '64	6,660	+	2.8		4.0	1	<1	Yes	Yes	9.2	63.0
Jan. '64	6,666	+	0.8	+	2.1	1	<1	Yes	Yes	11.0	67.0
Jan. '64	6,678	+	0.4	+	0.0	1	<1	Yes	Yes	12.2	67.5

* Indicates injection of 0.1 oz/min of AC Test Dust plus 0.3 gpm of sea water

\+ Indicates injection of 0.1 oz/min of AC Test Dust plus 0.3 gpm of TWB of the IS.

∴ Indicates injection of 0.3 gpm of TWB of the IS, only.

\# Indicates injection of 0.3 gpm of TWB of the IS, plus 2.5 gal of heavy interfacial microbial slimes.

M indicates 1,000.

Delta P indicates pressure differential.

Note: 1. Inlet values for microbial count indicate the count in the JP-4 fuel ahead of the injection point. The symbols *, +, ∴, and # indicate that the microbial colonies in the inlet samples were too numerous to count. Outlet values indicate actual counts in the effluent samples.

2. Hyphens signify that no data were available.

Table IV. Dynamic Filter/Separator Investigation of CS, MD, Portable Filter/Separator

Test Date	Throughput (M gal)	Solids (mg/1) (inlet)	Solids (mg/1) (outlet)	Free Water (mg/1) (inlet)	Free Water (mg/1) (outlet)	Microbial Count (colonies/ml) (inlet)	Microbial Count (colonies/ml) (outlet)	Fungus (inlet)	Fungus (outlet)	Delta P (in. of Hg)	Fuel Temperature (°F)
June '62	18	-	-	-	9.6	<1	<1	Yes	Yes	0.7	73.5
June '62	44	1.3	0.8	0.0	0.0	-	-	-	-	0.7	74.5
June '62	90	1.3	1.1	15.1	20.7	<1	<1	Yes	No	0.8	76.5
Aug. '62	145	1.7	0.6	5.2	6.2	<1	<1	Yes	Yes	0.9	78.0
↓	162	-	-	7.2	1.4	<1	<1	No	Yes	0.7	79.0
↓	450	0.3	0.2	-	0.0	<1	<1	No	Yes	0.7	90.0
↓	468	0.4	0.4	1.5	3.5	-	-	-	-	0.7	86.0
Aug. '62	540	0.4	0.3	0.0	0.0	<1	<1	Yes	Yes	0.8	90.0
Oct. '62	576	0.5	0.2	2.6	0.0	13	15	Yes	Yes	0.6	78.0
↓	584	-	-	0.0	0.0	1	13	Yes	Yes	0.6	79.0
↓	854	0.6	0.5	-	0.0	11	13	Yes	No	0.7	86.0
↓	862	0.3	0.7	3.5	0.0	-	-	-	-	0.6	86.0
Oct. '62	962	0.2	0.5	6.0	0.5	12	23	No	Yes	0.7	87.0
Jan. '63	1,008	0.3	0.1	4.9	2.6	<1	<1	-	-	0.6	69.0
↓	1,026	-	-	1.4	2.1	<1	<1	-	-	0.7	69.5
↓	1,620	0.6	0.2	-	0.0	<1	<1	-	-	0.8	74.5
↓	1,638	0.2	0.3	0.0	0.0	-	-	-	-	0.8	75.5
↓	1,692	0.8	0.2	0.0	0.0	<1	<1	-	-	0.8	78.0
Jan. '63	1,701	*	0.2	*	0.0	<1	<1	-	-	1.8	78.0
Mar. '63	2,016	0.3	0.6	0.0	0.0	<1	<1	-	-	1.1	73.0
Mar. '63	2,070	0.9	0.4	0.0	0.0	<1	<1	-	-	1.0	77.0
Mar. '63	2,142	0.4	0.3	0.0	0.0	-	-	-	-	1.0	77.0
June '63	2,340	0.7	0.9	0.0	0.0	<1	<1	-	-	0.8	77.0
June '63	2,484	0.2	0.4	4.0	0.0	<1	<1	-	-	1.2	81.0
July '63	2,863	0.1	0.1	0.0	0.0	<1	<1	-	-	1.2	85.0
July '63	2,962	+	0.4	+	0.0	<1	<1	-	-	1.5	88.0
Oct. '63	3,312	∴	-	∴	0.2	<1	<1	-	-	3.3	85.0
Oct. '63	3,330	#	0.0	#	0.1	1	<1	Yes	No	4.0	85.0
Jan. '64	3,330	+	0.7	+	8.0	<1	<1	Yes	Yes	5.0	67.0
Jan. '64	3,336	+	0.2	+	0.5	-	<1	Yes	Yes	6.1	67.0
Jan. '64	3,348	+	0.0	+	2.5	-	<1	Yes	Yes	7.6	68.0

* Indicates injection of 0.1 oz/min of AC Test Dust plus 0.3 gpm of sea water.
\+ Indicates injection of 0.1 oz/min of AC Test Dust plus 0.3 gpm of TWB of the IS.
∴ Indicates injection of 0.3 gpm of TWB of the IS, only.
\# Indicates injection of 0.3 gpm of TWB of the IS, plus 2.5 gal of heavy interfacial microbial slimes.
M indicates 1,000.
Delta P indicates pressure differential.
Note: 1. Inlet values for microbial count indicate the count in the JP-4 fuel ahead of the injection point. The symbols *, +, ∴, and # indicate that the microbial colonies in the inlet samples were too numerous to count. Outlet values indicate actual counts in the effluent samples.
2. Hyphens signify that no data were available.

Table V. Dynamic Filter/Separator Investigation of F-6, CS, Portable Filter/Separator

Test Date	Throughput (M gal)	Solids (mg/1) (inlet)	Solids (mg/1) (outlet)	Free Water (mg/1) (inlet)	Free Water (mg/1) (outlet)	Microbial Count (colonies/ml) (inlet)	Microbial Count (colonies/ml) (outlet)	Fungus (inlet)	Fungus (outlet)	Delta P (in. of Hg)	Fuel Temperature (°F)
June '62	18	-	-	-	12.8	<1	<1	Yes	Yes	2.5	77.5
June '62	44	0.8	0.6	3.5	0.0	-	-	-	-	2.5	78.5
June '62	90	0.4	0.3	9.9	12.6	<1	<1	No	No	2.7	79.0
Aug. '62	145	0.6	0.5	0.0	0.0	<1	<1	Yes	Yes	2.7	85.0
	162	-	-	0.0	0.0	<1	<1	No	Yes	2.6	86.0
	450	0.5	0.2	-	0.0	<1	<1	Yes	No	3.2	87.0
	468	0.3	0.2	11.5	0.5	-	-	-	-	3.2	88.0
Aug. '62	540	0.2	0.2	6.0	0.0	<1	<1	Yes	Yes	2.9	89.0
Oct. '62	576	0.6	0.2	0.0	0.0	19	14	No	Yes	2.6	82.0
	584	-	-	0.0	0.0	19	14	No	Yes	2.6	83.0
	854	1.0	0.5	-	0.0	2	1	No	No	2.8	86.0
	862	0.5	0.3	0.0	0.0	-	-	-	-	2.9	84.0
Oct. '62	952	0.4	0.3	0.5	0.0	3	3	Yes	Yes	2.8	86.0
Jan. '63	1,008	0.2	0.1	0.0	0.0	<1	<1	-	-	2.8	76.0
	1,026	-	-	0.0	0.0	<1	<1	-	-	2.8	76.5
	1,630	0.2	0.1	-	0.0	<1	<1	-	-	2.7	77.0
	1,638	0.2	0.0	0.0	0.0	-	-	-	-	2.7	76.5
	1,692	0.2	0.2	0.0	0.0	<1	<1	-	-	2.9	79.0
Jan. '63	1,701	*	0.2	*	0.0	<1	<1	-	-	3.9	78.5
Mar. '63	2,016	0.4	0.5	0.0	0.0	<1	<1	-	-	3.2	76.5
Mar. '63	2,070	0.5	0.5	0.0	0.0	<1	<1	-	-	3.3	74.0
Mar. '63	2,142	2.1	0.4	0.0	0.0	-	-	-	-	3.3	76.5
June '63	2,340	0.3	0.3	0.0	0.0	<1	<1	-	-	3.1	80.0
June '63	2,484	0.2	0.3	4.0	0.0	<1	<1	-	-	3.4	83.0
July '63	2,862	0.2	0.2	0.0	0.0	<1	<1	-	-	3.5	88.0
July '63	2,952	+	0.2	+	0.0	<1	<1	-	-	3.7	91.0
Oct. '63	3,312	∴	-	∴	0.2	<1	<1	-	-	5.6	85.0
Oct. '63	3,330	#	0.1	#	0.0	1	1	Yes	Yes	6.2	85.0
Jan. '64	3,330	+	0.7	+	0.5	<1	<1	Yes	Yes	11.2	68.0
Jan. '64	3,326	+	0.6	+	4.6	-	<1	Yes	Yes	11.2	68.5
Jan. '64	3,348	+	0.4	+	0.0	-	<1	Yes	Yes	12.0	69.0

* Indicates injection of 0.1 oz/min of AC Test Dust plus 0.3 gpm of sea water.
\+ Indicates injection of 0.1 oz/min of AC Test Dust plus 0.3 gpm of TWB of the IS.
∴ Indicates injection of 0.3 gpm of TWB of the IS, only.
\# Indicates injection of 0.3 gpm of TWB of IS, plus 2.5 gal of heavy interfacial microbial slimes.
M indicates 1,000
Delta P indicates pressure differential.
Note: 1. Inlet values for microbial count indicate the count in the JP-4 fuel ahead of the injection point. The symbols *, +, ∴, and # indicate that the microbial colonies in the inlet samples were too numerous to count. Outlet values indicate actual counts in the effluent samples.
2. Hyphens signify that no data were available.

Table VI. Dynamic Filter/Separator Investigation of IS, Installed Filter/Separator, Bowser Unit No. 842

Test Date	Throughput (M gal)	Solids (mg/1) (inlet)	Solids (mg/1) (outlet)	Free Water (mg/1) (inlet)	Free Water (mg/1) (outlet)	Microbial Count (colonies/ml) (inlet)	Microbial Count (colonies/ml) (outlet)	Fungus (inlet)	Fungus (outlet)	Delta P (in. of Hg)	Fuel Temperature (°F)
June '62	18	-	-	9.4	-	<1	<1	Yes	Yes	0.7	76.9
	44	-	-	-	8.6	-	-	-	-	0.7	77.0
	90	-	0.6	-	0.0	<1	<1	Yes	Yes	0.9	80.0
	162	0.5	0.3	6.9	-	<1	<1	No	No	0.8	80.0
	198	-	0.5	-	10.0	-	-	-	-	1.0	81.0
June '62	234	-	0.3	-	0.0	<1	<1	Yes	No	1.1	82.0
Aug. '62	268	1.3	0.5	165.5	0.0	<1	<1	Yes	Yes	1.1	81.0
	306	-	-	205.5	11.5	<1	<1	Yes	No	1.1	81.0
	576	0.7	0.3	2.0	0.0	<1	<1	Yes	No	1.3	86.0
	882	0.9	0.2	62.5	-	<1	<1	Yes	Yes	1.4	88.0
	900	*	0.0	*	1.2	-	-	-	-	1.7	90.0
	972	*	0.0	*	0.5	<1	<1	Yes	No	1.6	90.0
	1,026	0.4	0.2	5.5	-	<1	<1	Yes	No	1.3	90.0
	1,044	*	0.2	*	0.0	-	-	-	-	1.5	93.0
Aug. '62	1,116	*	0.3	*	0.0	<1	<1	Yes	Yes	1.7	93.0
Oct '62	1,152	0.4	0.1	0.0	3.2	13	10	Yes	Yes	1.6	78.0
	1,170	-	-	0.0	0.0	6	11	Yes	No	1.4	79.5
	1,440	0.5	0.5	0.0	0.0	14	14	Yes	Yes	1.5	82.0
	1,458	-	-	0.0	0.0	20	19	No	Yes	1.5	84.0
	1,746	0.2	0.7	10.0	-	8	2	Yes	Yes	1.6	87.0
	1,782	*	0.3	*	0.0	-	-	-	-	1.6	87.0
	1,872	*	0.3	*	0.0	10	25	Yes	Yes	1.8	87.0
	1,908	0.1	0.1	5.0	-	10	13	No	Yes	1.4	88.0
	1,944	*	0.2	*	0.0	-	-	-	-	1.6	88.0
Oct. '62	1,984	*	0.3	*	0.0	15	13	No	Yes	1.8	88.0
Jan. '63	2,016	0.6	0.2	0.0	0.0	<1	<1	-	-	2.0	72.5
	2,034	-	-	0.0	12.6	<1	<1	-	-	2.1	71.5
	2,592	0.5	0.1	0.0	0.0	<1	<1	-	-	2.3	78.0
	2,610	-	-	2.2	0.0	<1	<1	-	-	2.5	79.0
	3,204	*	0.2	*	-	<1	<1	-	-	2.7	78.0
	3,222	*	0.3	*	0.0	-	-	-	-	2.7	80.0
	3,294	*	0.4	*	0.0	<1	<1	-	-	2.7	79.5
	3,303	-	-	-	-	-	-	-	-	2.7	79.5
	3,330	*	0.2	*	0.0	<1	<1	-	-	2.6	79.0
	3,348	*	0.1	*	0.0	-	-	-	-	2.7	70.5
	3,420	*	0.1	*	0.0	<1	<1	-	-	2.9	80.0
Jan. '63	3,429	-	-	-	-	-	-	-	-	2.7	79.5

Table VI (cont'd)

Test Date	Throughput (M gal)	Solids (mg/1) (inlet)	Solids (mg/1) (outlet)	Free Water (mg/1) (inlet)	Free Water (mg/1) (outlet)	Microbial Count (colonies/ml) (inlet)	Microbial Count (colonies/ml) (outlet)	Fungus (inlet)	Fungus (outlet)	Delta P (in. of Hg)	Fuel Temperature (°F)
Mar '63	3,459	+	-	+	0.0	<1	<1	-	-	2.8	69.0
↓	3,474	+	0.3	+	0.0	<1	<1	-	-	2.9	70.0
	3,477	-	-	-	-	-	-	-	-	2.8	70.5
	3,492	-	-	-	-	-	-	-	-	2.7	72.0
	3,496	-	-	-	-	-	-	-	-	2.7	72.5
Mar. '63	3,510	-	-	-	-	-	-	-	-	2.7	74.0
July '63	3,777	0.1	0.0	0.0	0.0	<1	<1	-	-	2.8	88.0
↓	4,038	0.1	0.0	0.0	0.0	<1	<1	-	-	2.9	92.0
	4,211	∴	0.2	∴	0.1	<1	<1	-	-	3.1	94.0
July '63	4,343	∴	0.2	∴	0.0	<1	<1	-	-	3.3	90.0
Oct. '63	4,387.5	#	0.0	#	0.0	<1	<1	No	No	4.4	85.0
Oct. '63	4,401	-	-	-	-	-	-	-	-	3.3	87.0
Oct. '63	4,414.5	-	-	-	-	-	-	-	-	3.2	86.0
Jan. '64	4,414.5	+	0.6	+	0.0	<1	<1	Yes	Yes		65.5
Jan. '64	4,420.5	+	0.2	+	0.0	-	1	Yes	Yes		69.0
Jan. '64	4,432.5	+	0.2	+	0.0	-	1	Yes	Yes	4.6	70.0

* Indicates injection of 0.1 oz/min of AC Test Dust plus 0.3 gpm of sea water.
\+ Indicates injection of 0.1 oz/min of AC Test Dust plus 0.3 gpm of TWB of the IS.
∴ Indicates injection of 0.3 gpm of TWB of the IS, only.
\# Indicates injection of 0.3 gpm of TWB of the IS, plus 2.5 gal of heavy interfacial microbial slimes.
M indicates 1,000.
Delta P indicates pressure differential.

Note: 1. Inlet values for microbial count indicate the count in the JP-4 fuel ahead of the injection point. The symbols *, +, ∴, and # indicate that the microbial colonies of the inlet samples were too numerous to count. Outlet values indicate actual counts in the effluent samples.
2. Hyphens signify that no data were available.
3. Blank spaces indicate that no data were taken.

Table VII. Dynamic Filter/Separator Investigation of IS, MD, Portable Filter/Separator

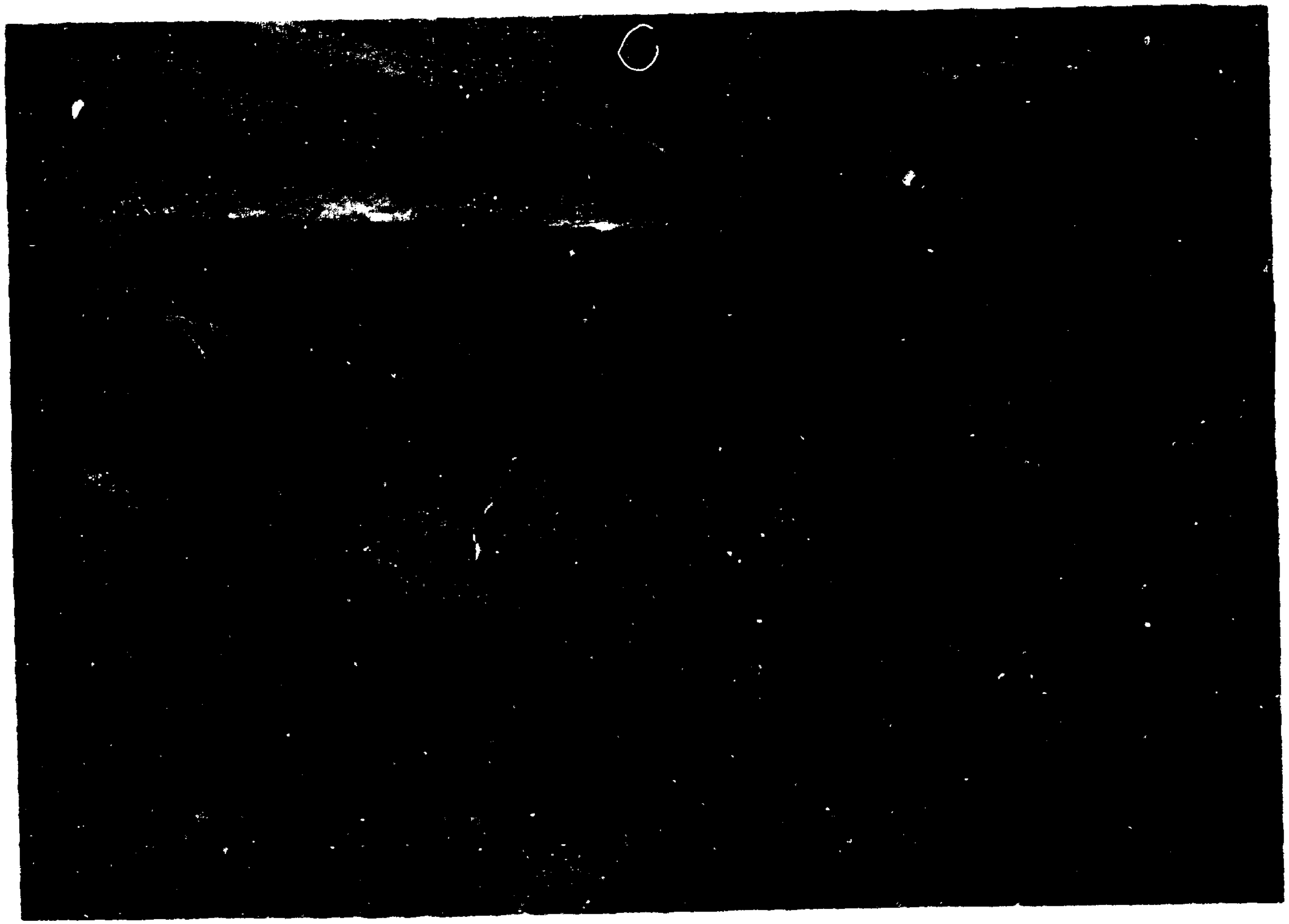
Test Date	Throughput (M gal)	Solids (mg/1) (inlet)	Solids (mg/1) (outlet)	Free Water (mg/1) (inlet)	Free Water (mg/1) (outlet)	Microbial Count (colonies/ml) (inlet)	Microbial Count (colonies/ml) (outlet)	Fungus (inlet)	Fungus (outlet)	Delta P (in. of Hg)	Fuel Temperature (° F)
June '62	18	-	-	-	8.6	<1	<1	Yes	Yes	0.8	76.0
June '62	44	-	-	8.6	13.8	-	-	-	-	0.7	77.0
June '62	90	0.6	0.7	0.0	0.0	<1	<1	Yes	Yes	0.7	84.0
Aug. '62	144	0.5	0.6	0.0	0.9	<1	<1	Yes	No	0.8	81.0
↓	162	-	-	11.5	12.0	<1	<1	No	Yes	0.8	81.0
↓	450	0.2	0.3	-	0.0	<1	<1	No	Yes	0.7	90.0
↓	468	0.2	0.2	0.0	0.0	-	-	-	-	0.7	93.0
Aug. '62	540	0.3	0.2	0.0	0.0	<1	<1	Yes	Yes	0.8	93.0
Oct. '62	576	0.1	0.3	3.2	0.0	10	4	Yes	No	0.8	78.0
↓	584	-	-	0.0	0.0	11	7	No	Yes	0.8	79.5
↓	854	0.1	0.2	-	0.0	13	11	Yes	No	1.3	86.0
↓	862	0.2	0.2	0.0	0.0	-	-	-	-	1.0	85.0
Oct. '62	962	0.3	0.0	0.0	0.0	13	17	Yes	Yes	0.8	88.0
Jan. '63	1,008	0.2	0.1	0.0	0.0	<1	<1	-	-	0.8	72.5
↓	1,026	-	-	12.6	3.0	<1	<1	-	-	0.8	71.5
↓	1,620	0.2	0.2	-	0.0	<1	<1	-	-	0.8	79.0
↓	1,638	0.1	0.2	0.0	0.0	-	-	-	-	0.9	79.5
↓	1,692	0.1	0.1	0.0	0.0	<1	<1	-	-	0.9	80.0
Jan. '63	1,701	*	0.6	*	0.0	<1	<1	-	-	1.7	79.5
Mar. '63	1,740	+	-	+	0.0	<1	<1	-	-	1.9	70.5
Mar. '63	1,764	+	0.2	+	0.0	<1	<1	-	-	4.2	72.0
July '63	2,031	0.0	0.0	0.0	0.0	<1	<1	-	-	1.1	86.0
July '63	2,172	0.2	0.1	0.0	0.0	<1	<1	-	-	1.1	90.0
Oct. '63	2,223	#	0.2	#	0.0	<1	1	Yes	Yes	2.5	86.0
Jan. '64	2,223	+	0.9	+	0.0	<1	<1	Yes	Yes	1.2	72.0
Jan. '64	2,229	+	0.1	+	0.0	-	<1	Yes	Yes	1.9	71.0
Jan. '64	2,241	+	0.1	+	0.0	-	1	Yes	No	2.4	70.5

* Indicates injection of 0.1 oz/min of AC Test Dust plus 0.3 gpm of sea water.
\+ Indicates injection of 0.1 oz/min of AC Test Dust plus 0.3 gpm of TWB of the IS.
\# Indicates injection of 0.3 gpm of TWB of the IS, plus 2.5 gal of heavy interfacial microbial slimes.
M indicates 1,000.
Delta P indicates pressure differential.
Note: 1. Inlet values for microbial count indicate the count in JP-4 fuel ahead of injection point. Outlet values indicate actual counts in effluent samples.
2. Hyphens signify that no data were available.

Table VIII. Dynamic Filter/Separator Investigation of F-6, IS, Portable Filter/Separator

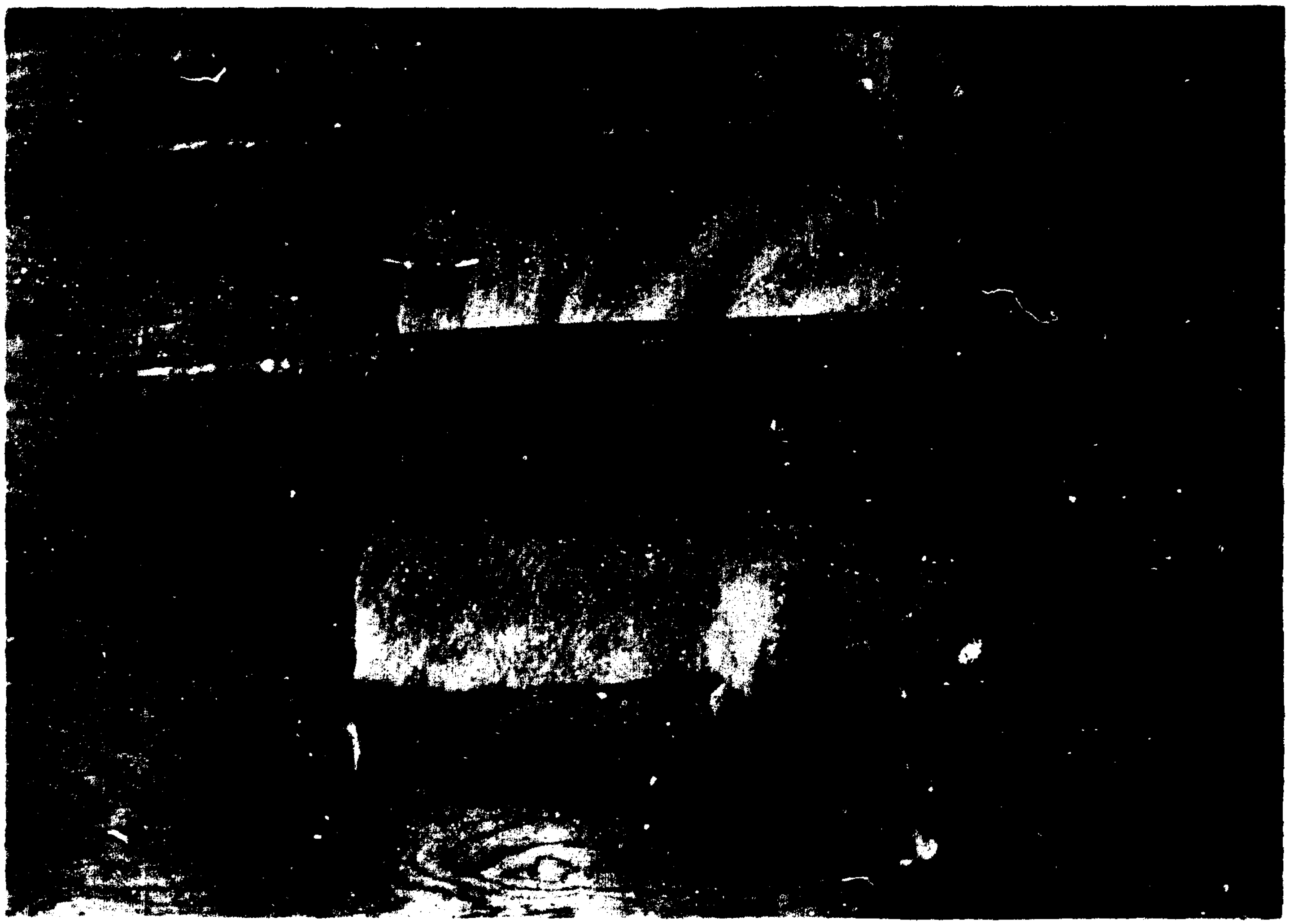
Test Date	Throughput (M gal)	Solids (mg/l) (inlet)	Solids (mg/l) (outlet)	Free Water (mg/l) (inlet)	Free Water (mg/l) (outlet)	Microbial Count (colonies/ml) (inlet)	Microbial Count (colonies/ml) (outlet)	Fungus (inlet)	Fungus (outlet)	Delta P (in. of Hg)	Fuel Temperature (°F)
June '62	18	0.3	0.8	-	5.2	<1	<1	No	Yes	2.8	80.0
June '62	44	0.5	0.5	10.0	5.6	-	-	-	-	2.8	81.0
June '62	90	0.3	0.3	0.0	2.0	<1	<1	No	Yes	2.8	82.0
Aug. '62	144	0.3	0.1	0.0	0.0	<1	<1	No	Yes	2.6	86.0
↓	162	-	-	0.0	0.0	<1	<1	No	No	2.7	86.0
	450	0.2	0.3	-	0.0	<1	<1	Yes	Yes	2.8	88.0
	468	0.0	0.3	1.2	0.0	-	-	-	-	3.1	90.0
Aug. '62	540	0.3	0.2	0.5	0.0	<1	<1	No	Yes	2.8	90.0
Oct. '62	576	0.5	0.3	0.0	0.0	14	17	Yes	Yes	2.8	82.0
↓	584	-	-	0.0	0.0	19	21	Yes	No	2.9	84.0
	864	0.1	0.4	-	0.0	2	10	Yes	Yes	2.8	87.0
	882	0.3	0.6	0.0	0.0	-	-	-	-	2.8	87.0
Oct. '62	962	0.3	0.3	0.0	0.0	3	9	Yes	No	2.8	87.0
Jan. '63	1,008	0.1	0.1	0.0	0.0	<1	<1	-	-	3.0	78.0
↓	1,026	-	-	0.0	0.0	<1	<1	-	-	3.0	79.0
	1,620	0.2	0.2	-	5.5	<1	<1	-	-	2.9	78.0
	1,638	0.3	0.4	0.0	0.0	-	-	-	-	2.9	80.0
	1,692	0.4	0.4	0.0	5.0	<1	<1	-	-	2.9	79.5
Jan. '63	1,701	*	0.6	*	0.6	<1	<1	-	-	3.6	79.5
Mar. '63	1,731	+	-	+	0.0	<1	<1	-	-	3.6	72.5
Mar. '63	1,746	+	0.5	+	0.0	<1	<1	-	-	3.6	74.0
July '63	2,031	0.0	0.0	0.0	0.0	<1	<1	-	-	3.3	82.0
July '63	2,172	0.2	0.2	0.0	0.0	<1	<1	-	-	3.2	84.0
Oct. '63	2,209.5	0.0	0.1	0.0	0.0	<1	<1	No	Yes	3.4	87.0
Oct. '63	2,223	#	0.1	#	0.0	1	<1	Yes	Yes	5.5	87.0
Jan. '64	2,223	+	0.7	+	0.0	1	<1	Yes	No	5.3	72.0
Jan. '64	2,229	+	0.6	+	0.0	-	1	Yes	Yes	6.1	71.0
Jan. '64	2,241	+	0.3	+	0.0	-	<1	Yes	Yes	6.0	71.5

* Indicates injection of 0.1 oz/min of AC Test Dust plus 0.3 gpm sea water.
\+ Indicates injection of 0.1 oz/min of AC Test Dust plus 0.3 gpm TWB of the IS.
\# Indicates injection of 0.3 gpm TWB of the IS, plus 2.5 gal of heavy interfacial microbial slimes.
M indicates 1,000.
Delta P indicates pressure differential.
Note: 1. Inlet values for microbial count indicate count in JP-4 fuel ahead of injection point. Outlet values indicate actual counts in effluent samples.
2. Hyphens signify that no data were available.



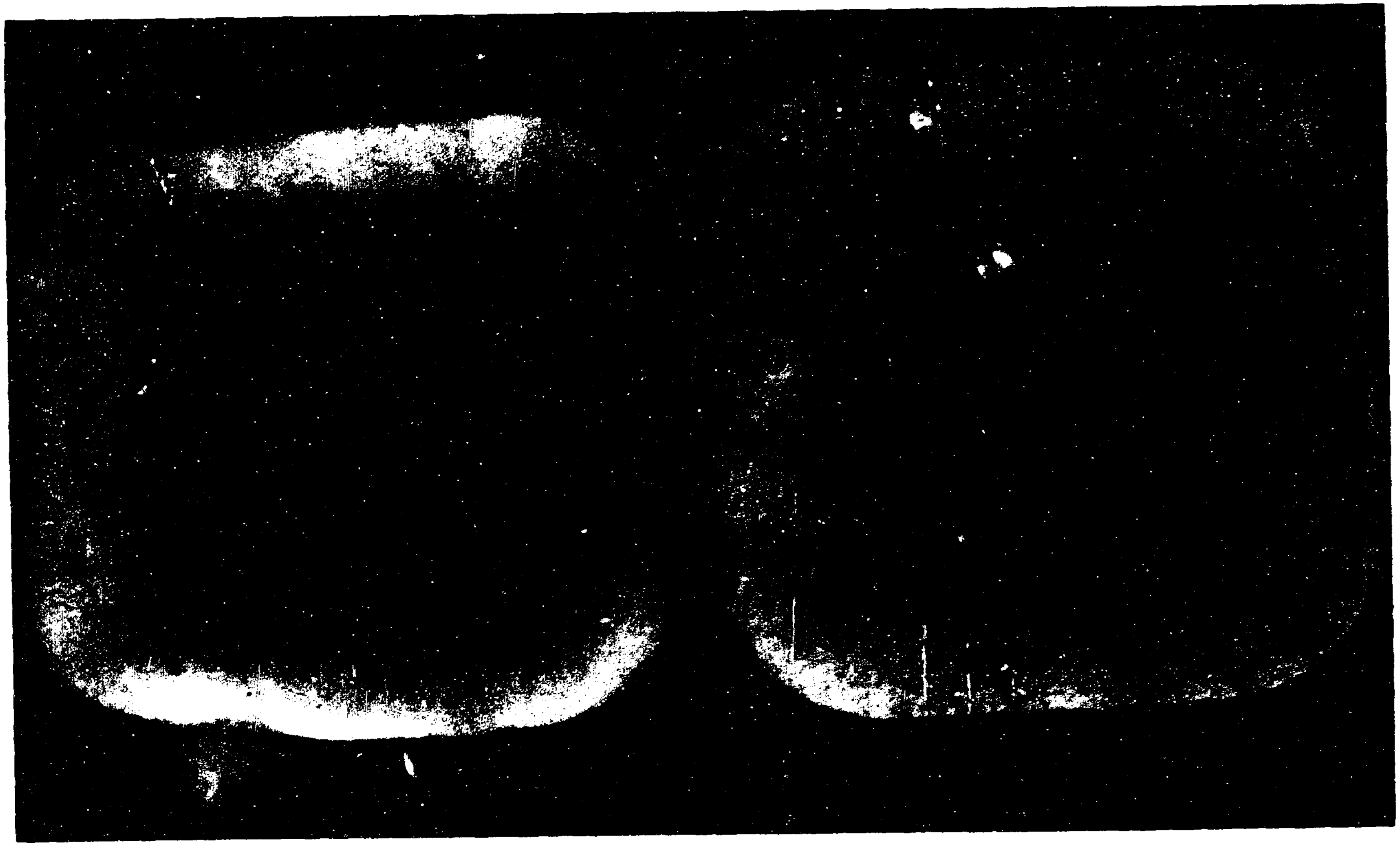
L2356

Fig. 17. Dissected Bowser No. 4737 filter/coalescer element from IS installed filter/separator vessel. Total fuel throughput of 6.6 million gal.



L2357

Fig. 18. Dissected Bowser element from IS, MD filter/separator. Fuel throughput totals 4.4 million gal.

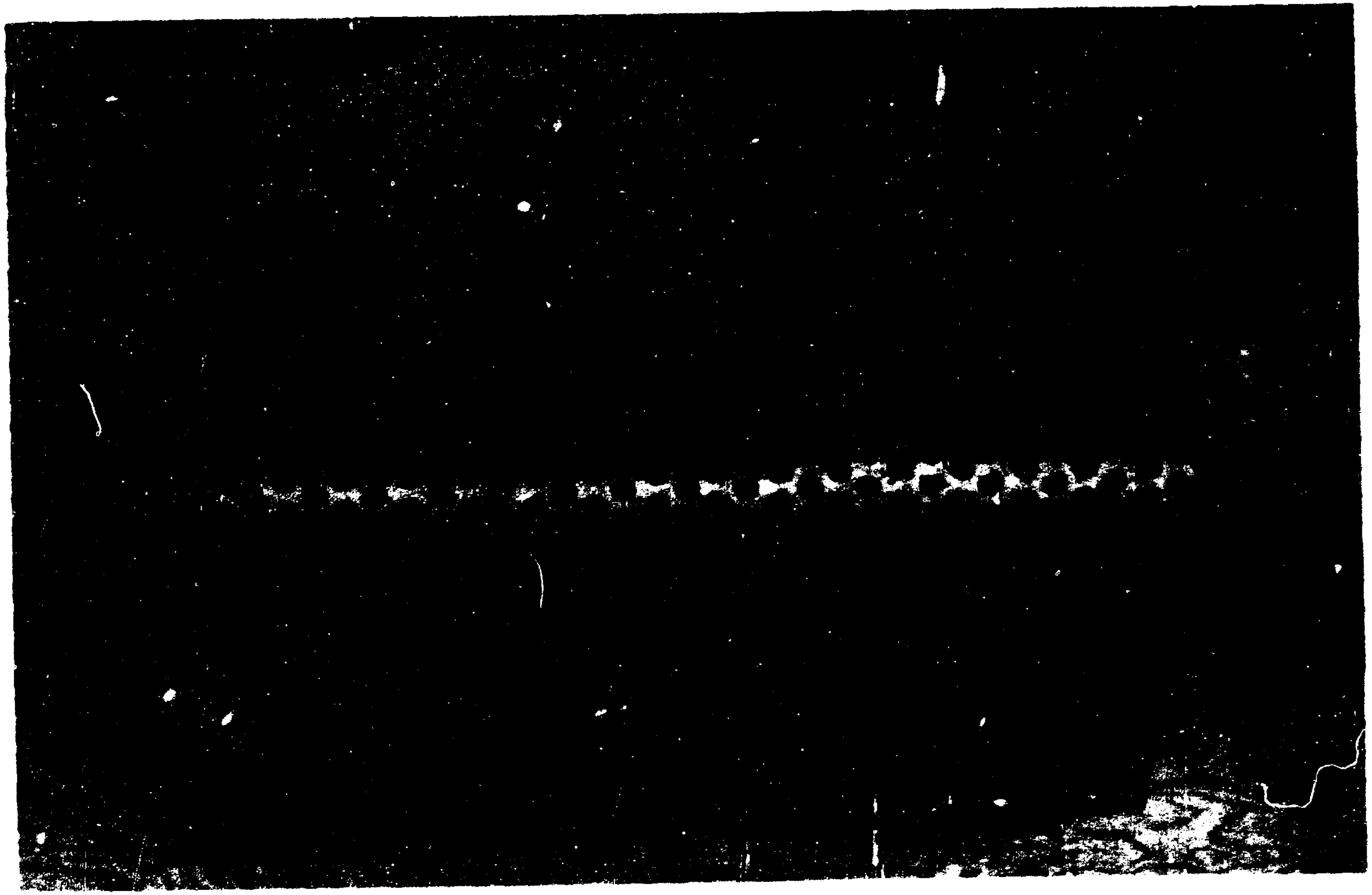


L2343

Fig. 19. Closeup of inner Fiberglas section of Bowser filter/coalescer element in IS system. Note that area of contaminant penetration is confined to center of section.

L2347

Fig. 20. Dissected Warner Lewis CC-K3 filter/coalescer element from F-6 filter/separator in IS. Fuel throughput totals 4.4 million gal.

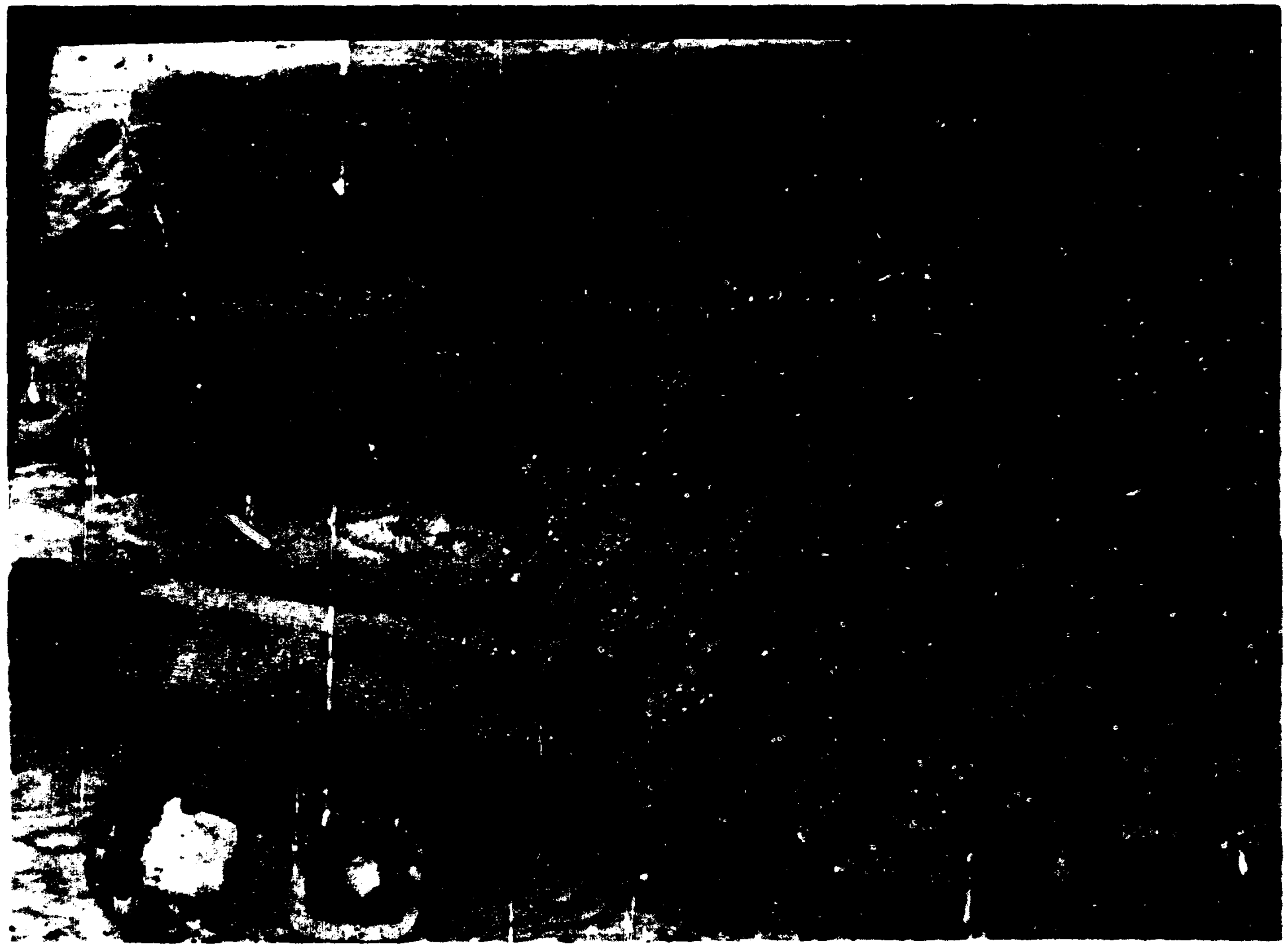


L2352

Fig. 21. Dissected Filters, Inc., filter/coalescer element from IS, MD filter/separator.

L2351

Fig. 22. Dissected Bowser filter/coalescer element from CS, MD filter/separator.



L2348

Fig. 23. Dissected Bowser element from CS installed filter/separator vessel.

L2358

Fig. 24. Closeup showing contaminant deposits in Bowser element in CS, MD filter/separator.

d. Filter/separators are capable of processing microbially contaminated fuel to MIL-F-8901 cleanliness requirements if they are maintained properly and if the fuel is relatively free from surfactants.

e. No deleterious effects were noted in the filter/separator component parts (Figs. 25 through 27).

IV. STATIC 55-GALLON DRUM INVESTIGATION

13. Objectives. The objectives of this investigation were to determine the microbial growth rates and effects on fuel properties of JP-4 and 115/145 Avgas stored in 55-gallon drums and exposed to selected combinations of water types, microbial contaminants, and fuel additives.

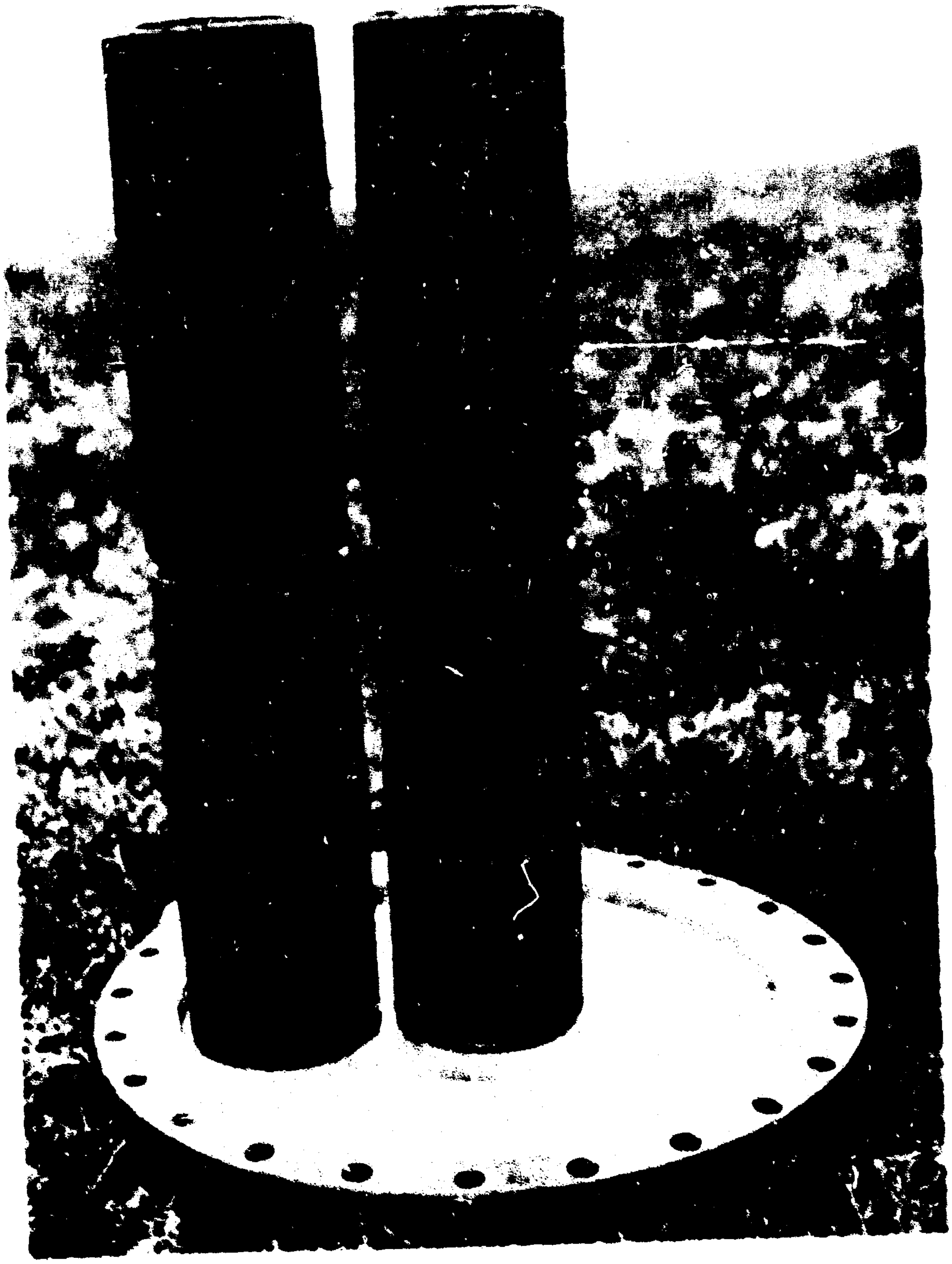
14. Plan. For the static 55-gallon drum investigation, 36 standard steel drums were used. Installation and investigations made are considered here.

a. Installation. Originally, 12 standard 55-gallon steel drums were modified by welding a 6-inch-diameter by 4-inch-long pipe nipple to each drum end, near its outer circumference. A circular section of lucite, 3/4 inch thick and 6 inches in diameter, was used as a transparent flange on each nipple, to permit viewing through the interior of each drum (Fig. 28). The drums were numbered 1 through 12, steam cleaned, aluminum painted, and during May 1962, installed in a horizontal position. In March 1963, the scope of this phase of the investigation was amplified to include 24 additional drums, prepared in the same manner, installed in the same location, and numbered 13 through 36. The drums were filled with various combinations of fuels, inoculum, additives, and water (Appendix I). One-tenth percent of Phillips 55 MB anti-icing compound was added to all JP-4 fuel prior to starting of test.

The inoculum used in drums Nos. 5, 6, 7, 8, 11, and 12 was essentially the same composition as that used to inoculate the JP-4 fuel in the underground storage tank at pumphouse No. 4. Inoculation of these drums was accomplished on 10 May 1962. Of the remaining drums, 13 through 36, those that required contamination by microorganisms, were inoculated by the addition of specific amounts of water bottom from the IS underground storage tank. In addition, those organisms existing in the JP-4 fuel taken from the tank, were present.

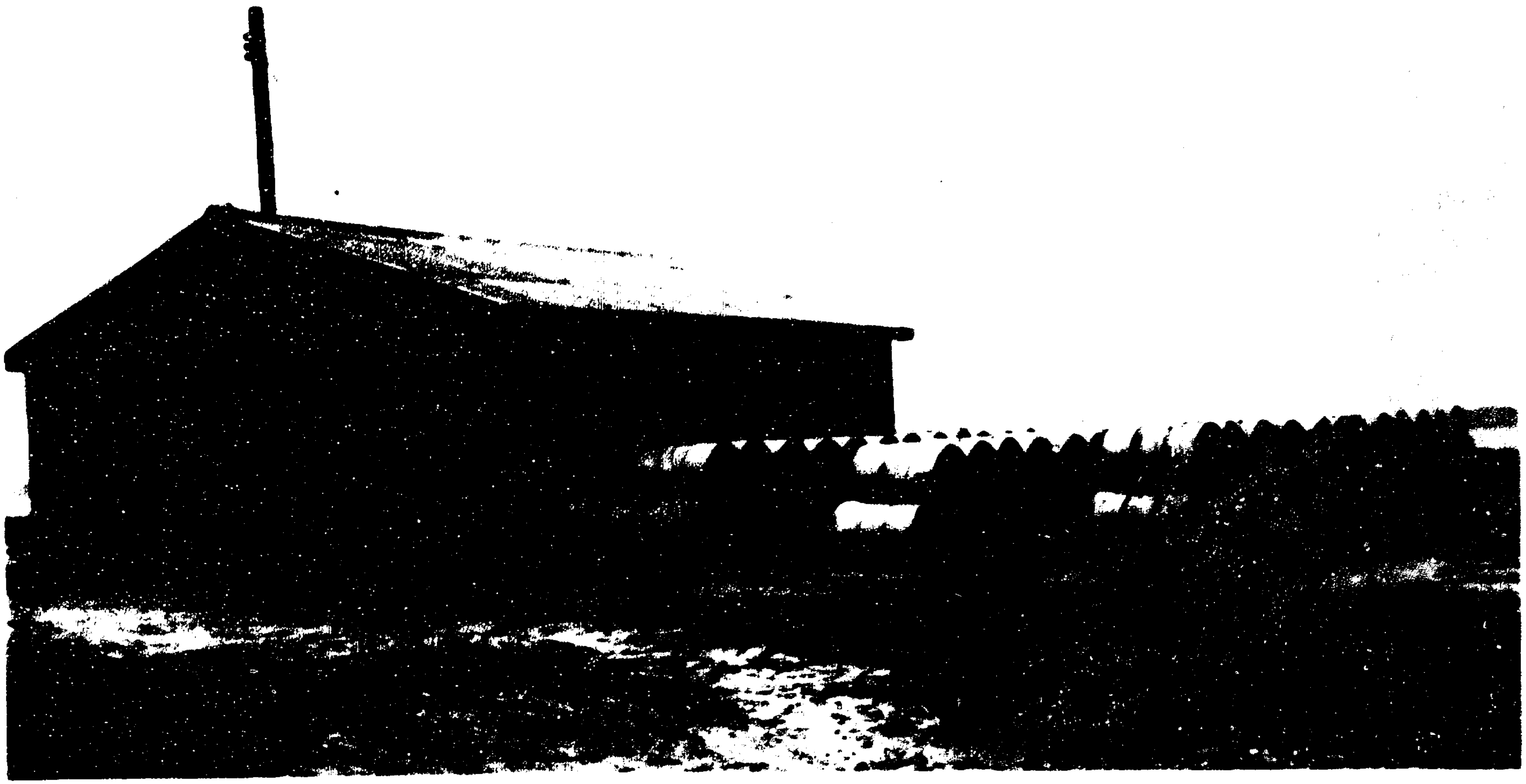
L2342

Fig. 26. Interior of F-6, IS filter/separator vessel. Walls show no evidence of corrosion.



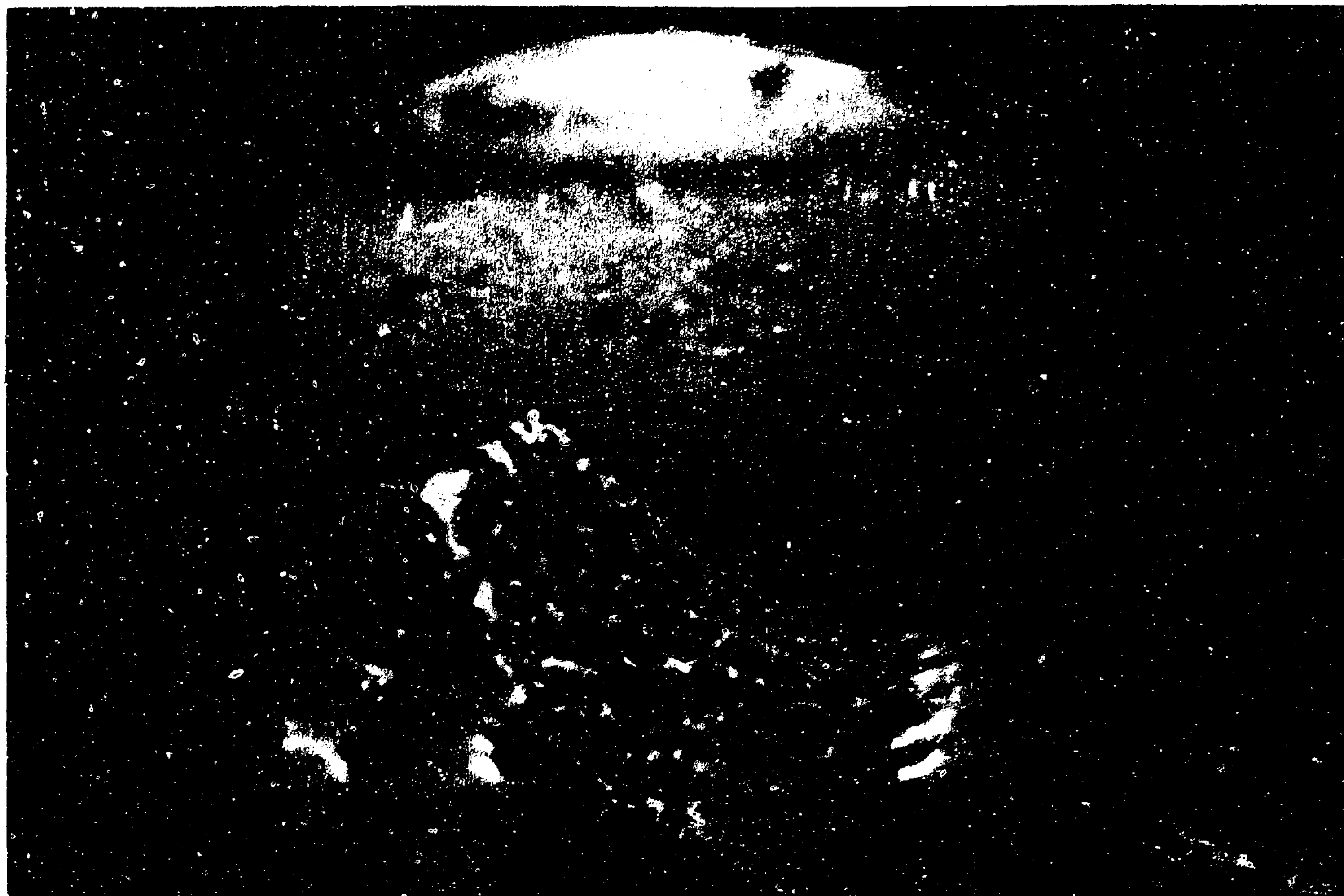
L2340

Fig. 27. Second-stage, pleated paper water barrier elements from F-6, IS filter/separator vessel.



L2273

Fig. 28. Thirty-six, 55-gal drums used in static, aboveground storage tank investigation. Note viewing ports welded to bottom of each drum.



L2379

Fig. 29. Mycelial mat (scum) formation at fuel-water interface viewed through port of drum No. 28.

L2380

Fig. 30. Interfacial microbial growths viewed through port of drum No. 26.

b. Investigation. The interior of each drum, including the fuel, the water bottom, and the fuel-water interface, were visually inspected through the viewing ports at the expiration of 1, 3, 6, 9, 12, and 15 months (Figs. 29 and 30). In addition, the following analyses and tests were performed and recorded on samples at the same time intervals:

(1) Microbiological analyses of samples taken above and below interface.

(2) Copper corrosion tests on fuel samples.

(3) Water separometer tests on the JP-4 fuel only. Tests were run with fuel versus water bottom or with fuel versus distilled water if the drum contained no water bottom.

(4) Determination of interfacial tension, both with JP-4 fuel and Avgas, against water bottoms and distilled water.

(5) Determination of residual anti-icing additive percentage in JP-4 fuel.

15. Results and Discussion. Results shown in Tables IX through XLIV (Appendix J) consist of physiochemical and microbiological data pertinent to the static 55-gallon drum investigation.

a. Physiochemical Analyses. Descriptions of apparatus and procedures for these analyses (Appendices D and F) refer to the water separation index (WSIM); interfacial tension (IFT); hydrogen ion concentration (pH): copper corrosion index (Cu): and anti-icing additive (AIA) percentage. A discussion of the analyses follows:

(1) WSIM. Water retention properties of the fuel were increased (a lower WSIM), by the presence of AIA and rust preventive additives. The presence of water bottoms, however, tended to diminish (increase in WSIM) this effect, because, no doubt, of the solubility of these compounds in water. This effect can be noted by comparing Tables I and III. Microbial growth in the water bottoms, in the fuel, or in both, apparently had little effect on water retention properties.

(2) IFT. These values, throughout the investigations, appeared to follow the same general pattern as the water separometer index, with the chromate-type biocidal additive lowering the interfacial tension the most.

(3) pH. Acidity of the water bottoms increased with increase in total microbial count. This is normally so in areas where acid-forming bacteria are present.

(4) Copper (Cu) Corrosion. All results were negative with copper strips immersed in the fuel. Microorganisms evidently did not produce by-products corrosive to copper.

(5) AIA. These determinations showed a preferential solubility of the AIA in water with a resultant concentration of this material in the water bottoms.

b. Microbiological Analyses. Descriptions of apparatus and procedures for these analyses are given in Appendices E and F.

(1) Total Microbial Count. The bacteriological analysis measures, by a counting procedure, the total number of microorganisms (as colonies) in a milliliter of fuel or water bottom sample. The results show that almost without exception, bacteria were unable to survive and reproduce in the fuel alone (JP-4 and Avgas). However, the data show a rapid increase in bacterial population in the water bottoms from the project beginning to midsummer 1963, after which time a sudden and sharp decrease took place. This pattern, however, follows the normal growth progression as evidenced in typical microbial population curves. Although the fuel drums with inoculated water bottoms showed the highest initial microbial counts, the drums which were not inoculated, but which contained a sea water bottom, developed peak populations almost equal to the inoculated systems. It is evident, therefore, that the sea water used, undiluted or diluted, contained bacteria capable of producing high contamination levels, under optimum conditions, in Military fuel systems. Drums containing sodium chromate, beta-nitro-styrene, and dioxane showed somewhat lower initial counts but thereafter little, biocidal effect.

(2) Fungus Growth. The morphology of fungi is such that their accurate quantitative detection is not possible; consequently, the test results indicate only if fungus growth is or is not present. Analyses of the data indicate fungus growth present in both fuel and water bottoms in most drums with an absence of growth most common in those drums containing Avgas.

16. Conclusions. From data collected during the static drum investigations, the following conclusions are drawn:

a. Bacteria are unable to survive and reproduce in an environment of uncontaminated JP-4 fuel or Avgas.

b. Some types of fungi can exist in the fuel for an indeterminate time.

c. Both bacteria and fungi can grow and flourish in the water bottoms and at the fuel-water interface untii overpopulation produces conditions inimical to continued growth and a sharp reduction in living organisms occurs.

d. The anti-icing and biotoxic additives tried were not found to exert marked biocidal activity under the conditions prevailing and in the concentrations used.

BIBLIOGRAPHY

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Brooks, Donald, compiler, Office of Dept of Defense, Research and Engineering, Government-Industry Symposium, "Contamination of Jet Fuel," held at the Pentagon, 13 and 14 September 1961. The following papers were compiled on 23 October 1961.

Dr. John Krynitsky - "The Water Separometer."

Dr. J. R. Pichtelberger - "Development and Use of the AEL Contaminated Fuel Detector."

Mr. L. L. Stark - "USAERDL's Fuels Decontamination Equipment Development Program."

Dr. Geoffrey Hazzard - "Australian Experience with Trace Impurities in Turbine Fuel."

Shell Oil Company - "Jet Fuel Contaminants and Their Significance."

California Research Corporation - "Fuel Contamination Studies."

Esso Research and Development Company - "Fuel Contamination Studies."

Gulf Research Company - "Development of Microbiological Sludge Inhibitors."

Millipore Filter Corporation, Techniques for Microbiological Analysis, Manual ADM-40, 1961.

APPENDIX A

Exhibit 1

AUTHORITY

RDT & E PROJECT CARD

1. TYPE OF REPORT ☐ NEW ☐ FINAL ☒ REPLACES (No. & Date) 1D643324D59209 1 July 63

REPORT CONTROL SYMBOL CSCRD-1(R3)

3. [redacted] TASK TITLE: FUELS DECONTAMINATION EQUIPMENT (U)

3. SECURITY OF PROJECT: Unclass

4. PROJECT NO.: 1D643324D59209

5.: 6.41.33.24.1

6. REPORT DATE: 1 January 64

7. BASIC FIELD OR SUBJECT: ENGINEERING DEVELOPMENT

8. SUB FIELD OR SUBJECT SUB GROUP:

9. CATEGORY: DT

10a. COGNIZANT AGENCY: AMC-MOCOM

b. DIRECTING AGENCY: MOCOM-ERDL

c. REQUESTING AGENCY:

11a. CONTRACTOR AND/OR GOVERNMENT LABORATORY: USAERDL, Ft Belvoir, Va. Filters, Inc. Milpitas, Calif. Purolator Products, Inc. Rahway, N. J. Warner Lewis Co., Tulsa, Okla.

b. CONTRACT NUMBER: ENG-5110, ENG-5111, ENG-5112

12. PARTICIPATION BY OTHER MILITARY DEPTS. AND OTHER GOVT. AGENCIES:

14. SUPPORTING PROJECTS:

18. EST. COMPLETION DATES

DEV.	Cont
ENGR TEST	Cont
USER TEST	Cont
OPERATIONAL	

15. COORDINATION ACTIONS W/OTHER MILITARY DEPTS. & OTHER GOVT. AGENCIES: SMC, TEC, CDC

16. DATE APPROVED: June 1960

18. PRIORITY:

17. BUDGET CODE: 5600

19. EST. SUPPORT LEVEL

- ☐ UNDER $50,000
- ☐ $50,000 - $100,000
- ☒ $100,000 - $250,000
- ☐ $250,000 - $500,000
- ☐ $500,000 - $1,000,000
- ☐ OVER $1,000,000

20.

21. SPECIAL CODES: 5665.12.756

22. REQUIREMENT AND/OR JUSTIFICATION

The Army is now a major user of aircraft, and the power plants of present-day aircraft require a high degree of fuel cleanliness for satisfactory operation and minimum maintenance. The non-standard commercial fuel decontamination equipment, available does not meet current DOD performance requirements and completely lacks interchangeability of expendable components. Resulting parts replacement, training, operational, and maintenance problems cannot be tolerated, and a standard family of military design filter/separators is required. Fuel cleanliness requirements continue to become more stringent, and a continuous research program is necessary to obtain information to apply as criteria for design and development of advanced high-performance fuel decontamination equipment.

CDOG recognizes the requirement for uncontaminated fuel in the following paragraphs:

1610c(6) POL Distribution which states: "...Increased use of aviation fuels and compression ignition fuels requires improved fuel handling equipment to insure delivery of uncontaminated fuel. There is a need for automatic detection devices which monitor the quality of fuels."

1639f(12) Conversion Kits, Bulk Petroleum Refueler, which states: "... Kits will consist of containers, pumps, manifolding, hose, nozzles, and filter/separators..."

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	1 January 64	1D643324D59209

Memorandum from Chief of Research and Development, Department of the Army dated 7 Oct 57, to Chief of Engineers, Ordnance, and Transportation, and the Quartermaster General, subject: Assignment of Research and Development Responsibility for POL Filter/Separator Units, states: "The Chief of Engineers is assigned Research and Development for all filters and water separators used in bulk distribution of petroleum products. Coordination will be effected with the Department of the Navy and Air Force to insure maximum standardization and interchangeability of components parts..."

23. BRIEF OF PROJECT AND OBJECTIVE

a. Brief:

(1) Objective: To design and develop a group of fuel decontaminating items for maintaining or restoring cleanliness of large quantities of bulk hydrocarbon fuels transported in military systems. The immediate objective is to develop, evaluate, and type classify standard design filter/separators of 15, 50, 300, and 600 gpm flow capacities. These units will have standardized vessel and element details, thereby minimizing procurement, training, operation, maintenance and parts replacement problems which resulted from the former practice of using commercial equipment from numerous sources. A related objective is coordination with DOD users on integration of the development fuels decontamination equipment into current military fixed, portable, and mobile fueling systems, and into systems under development. A long range objective is a comprehensive research study into the mechanics and phenomena of water coalescence, drop formation, and particle retention, to obtain information required as criteria for design and development of improved high performance lightweight fuels decontamination equipment.

(2) Technical Characteristics: See Exhibit "A"

b. Approach: For the fuels decontamination equipment, the technical staff of the U. S. Army Engineer Research and Development Laboratories will perform the necessary engineering research, and design and development work, with such assistance as may be required from the engineering staffs of commercial firms, research organizations, and other Government agencies. Feasibility and design studies will be undertaken to determine optimum design for satisfying overall military requirements. Prototype models will be procured for evaluation. Necessary design modifications will be made, and further evaluation conducted. On satisfactory completion of evaluation, a technical report, and procurement drawings and specifications will be prepared. Type classification action will be completed.

c. Subtasks:

(1) Filter/Separator Research. Includes investigations into the mechanics and phenomena of water coalescence from fuel; water drop formation and migration within coalescing media; fine particle agglomeration and removal; media characteristics which affect coalescibility and filterability; effects of fuel additives;

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and other investigations related to fuel decontamination processes. Effort will be directed toward a capability for a higher flow rate per unit volume of filter/coalescer media. The objective of this program is to apply knowledge gained to the design of still more effective and economical fuel decontamination equipment, which will be smaller and lighter, and which will be able to meet future more difficult decontamination problems.

(2) 15 GPM Filter/Separator, Portable and Mobile (Alum.). Required for use in conjunction with a standard hand-operated barrel pump to provide a system for fueling light liaison planes and helicopters from fuel drums at remote landing strips in the ZI and overseas theaters.

(3) 50 GPM Filter/Separator, Portable and Mobile (Alum.). Required for use in mobile fueling equipment, and in portable fuel dispensing systems.

(4) 300 GPM Filter/Separator, Fixed and Mobile (Steel). Required for use on mobile fueling equipment, on fuel transporters, in aircraft fueling systems, at fuel supply points, and in amphibious assault fuel handling systems.

(5) 600 GPM Filter/Separator, Fixed and Portable (Steel). Required for application in Army Functional Components fueling facilities, in airbase installed fueling systems, and in carrier-installed fueling systems. A standard military design will be developed for this filter/separator, and the three smaller sizes, to eliminate current problems resulting from use of numorous non-interchangeable commercial models of variable configuration and dimensions. Water and solids removal performance must conform to latest DOD specification requirements.

(6) Special Installation Designs for Military Filter/Separators. This item covers a group of activities involving special filter/separator designs for integration into the many and varied DOD fueling systems currently in use or under development.

(7) High Performance, Military Design, Filter/Coalescer Element. These elements will possibly employ new principles, or utilize permanent type reuseable media requiring a minimum of operating and maintenance personnel, will be smaller, lighter, and of lower cost than commercial elements, will be adequate for anticipated more stringent performance requirements, and will permit a significant reduction in overall filter/separator size by increasing element flow rates. Will also employ standard materials and fabrication techniques so as to stabilize consistency of quality thereby minimizing quality control problems during quantity production. These filter/coalescer elements are the critical components of a filter/separator, and the degree of effectiveness that can be developed determines the final size, weight, and cost of optimum military design filter/separators.

(8) 15 GPM Filter/Separator, Portable, Discardable (Plastic Case). Required for use in conjunction with a standard hand-operated barrel pump for fueling light liaison planes and helicopters from fuel drums at remote landing

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strips in the ZI and overseas theaters. The unit will be fabricated from low cost lightweight, reinforced plastic materials, will use one standard dimension filter/coalescer element, and to minimize fueling down-time, will be expended as a complete unit when the element becomes contaminant-loaded.

(9) 50 GPM Filter/Separator, Optimum Lightweight Design. This design will take advantage of improvement expected in performance of filter/coalescer elements as a result of research in progress. Will require a lesser number of standard dimension interchangeable elements, so that overall filter/separator size can be reduced. Will be fabricated from lightweight materials, and weight adding automatic controls will be eliminated insofar as practicable. This equipment is required in consonance with the modern concept of warfare employing highly mobile forces and equipment.

(10) 300 GPM Filter/Separator, Optimum Lightweight Design. This design will take advantage of improvement expected in performance of filter/coalescer elements as a result of research in progress. Will require a lesser number of standard dimension interchangeable elements, so that overall filter/separator size can be reduced. Will be fabricated from lightweight materials, and weight adding automatic controls will be eliminated insofar as practicable. This equipment is required in consonance with the modern concept of warfare employing highly mobile forces and equipment.

(11) 600 GPM Filter/Separator, Optimum Lightweight Design. This design will take advantage of improvement expected in performance of filter/coalescer elements as a result of research in progress. Will require a lesser number of standard dimension interchangeable elements, so that overall filter/separator size can be reduced. Will be fabricated from lightweight materials, and weight adding automatic controls will be eliminated insofar as practicable. This equipment is required in consonance with the modern concept of warfare employing highly mobile forces and equipment.

(12) Non-Destructive Quality Control Test For Filter/Coalescer Elements. Facilities and procedures are required for conducting quick and economical quality analyses of each filter/coalescer element that is produced by a manufacturer on a Government contract. Under the current status of the element fabricating technique consistent quality during high volume producting is difficult to attain. Quality varies between manufacturers, and at times, in successive lots from the same manufacturer. Since the elements are the critical components in the fuel decontaminating process, it is essential that each element furnished be of satisfactory quality. The proposed quality control test will be conducted at the manufacturer's plant prior to shipment, will provide a definite indication of quality, and will not impregnate the elements with any material or substance that might adversely affect performance, or interfere with shipping safety.

(13) Filter/Separator, 20 GPM, Lightweight, Horizontal. This unit is required for application on a Transportation Corps developmental fuel transporter where space considerations require horizontal configuration.

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d. Coordinated Test Plan - The test plan will be coordinated with TECOM. Wherever possible joint engineer and service testing will be accomplished so as to reduce the development time to a minimum.

e. Other Information:

(1) Scientific Research. A program will be pursued in co dination with commercial research facilities, in the field of fuels decontaminatio, to develop new parameters which can be applied to design of more effective and conomical equipment, in anticipation of future still more difficult fuel decontamination problems.

(2) References.

(a) Message from Chief Research and Development, dated 7 Oct 57 file CRD/D10519, subject; Assignment of Research and Development Responsibility for POL Filter/Separator Units, to Chiefs of Engineers, Ordnance, Transportation, and the Quartermaster General. This message assigned the subject responsibility to the Chief of Engineers.

(b) Five-year D/A POL Program, FY 1961-FY 1965, which lists development phase schedule and funding for Quality and Quantity Control Equipment.

(c) U. S. Army Materiel RDT&E Command Schedule for FY 1964 and FY 1965, which lists development phase schedule and funding for Quality and Quantity Control Equipment.

(3) Discussion. United States agencies interested in this task, in addition to the Corps of Engineers, include the Supply and Maintenance Command, the Transportation, Ordnance, and Quartermaster segments of the Mobility Command, the Navy and the Air Force. Liaison will be maintained with these agencies and reports on development progress furnished. AE. and NATO nations are also interested in developments under this task, and information is periodically furnished to the appropriate liaison officers.

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Exhibit 2

MEMORANDUM OF UNDERSTANDING

Project BEARS (Bacteriological Effects, Aircraft Refueling Systems)

1. Subject: Microbiological Research Performance Evaluations on Aircraft Fuel Servicing Systems.

2. Objectives: The program objectives are five-fold:

a. To determine the effects of microbiological contamination on the water removal capabilities of filter/separators.

b. To determine the effects of microbiological contamination on the filtering capabilities of filter/separators.

c. To determine the clogging effects of microbiological matter on filter/separators.

d. To determine the physical effects of microbial growths on filter/separator vessels, components, and related equipment.

e. To determine the effects of microbiological contamination on JP-4 and 115/145 Avgas.

3. Scope of Tests: The program will encompass evaluation of microbial effects on fuels and full-scale filter/separators used in JP-4 and 115/145 Avgas service. Comparative tests will be conducted using four Pritchard Hydrant systems. Two of these will utilize JP-4, and the other two, 115/145 Avgas. One system in each pair will be contaminated with microbes; the other will be maintained as a control.

4. Test Procedure (See Attachment 1)*

5. Test Location: Pumphouse Nr. 4 on Runway 01-19 at Kindley Air Force Base, Bermuda (MATS).

6. Duration of Program: Approximately 12 months beginning on or about 1 March 1962.

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* The attachment is not included in this report.

7. Funding: The entire project will be funded under MIPR arrangements between ASD (ASNNSF) and USAERDL (ERDCP), USAF Project 6159, Task 615904.

8. Participating Agencies:

a. Aeronautical Systems Division, Wright-Patterson AFB, Ohio (ASNNSF).

b. U. S. Army Engineer Research and Development Laboratories, Fort Belvoir, Virginia (ERDCP).

c. Naval Research Laboratory, Washington 25, D. C. (Code 6180).

d. Headquarters, U. S. Air Force, Washington 25, D. C. (AFOCE-MU).

e. Headquarters, EASTAF, Military Air Transport Service, McGuire AFB, N. J. (ETMCE).

f. Headquarters, Military Air Transport Service, Scott AFB, Illinois (MAMCE/FS).

g. Headquarters, 1604th Air Base Wing Group, Kindley AFB, Bermuda (WMTL).

9. Agency Responsibilities:

a. The U. S. Army Engineer Research and Development Laboratories (USAERDL), Petroleum Equipment Branch, Fuels Decontamination Section (ERDCP), will be responsible for the following:

(1) Furnishing personnel, both technical and skilled, to implement the program.

(2) Conducting the research investigations.

(3) Furnishing and installing equipment and supplies.

(4) Preparation of final test report, and interim reports as necessary.

(5) Returning the pumphouse and operating storage to its original condition.

b. The Naval Research Laboratory will provide consultant services and fuel analytical capability, i.e., surfactant activity (modified water separometer ratings and KST values).

c. Headquarters, 1604th Air Base Wing (MATS) will supply the following items:

(1) Pumphouse Nr. 4, Runway 01-19, with attached operating storage and fueling outlets.

(2) Fuel necessary to conduct this project will be provided through the Base Fuels Office.

(3) One room of building P-957 will be provided for a laboratory facility. In addition, this building will be provided with the following equipment, furnishings, or both:

(a) A fresh water line. (BEARS will provide materiel, funds, and labor for (a) and

(b) A latrine facility. (b). BCE will provide Trench and technical assistance.)

(c) Four (4) tables (approximate dimensions 36" x 49") (Preferably wooden tops)

(4) One vehicle will be provided for on-base transportation. Group will provide Government licensed vehicle operators. These operators will be licensed at Kindley prior to operating this vehicle.

(5) As additional base support items occur they will be coordinated with the Wing Materiel Officer (WMTL), 1604th Air Base Wing (MATS).

d. Aeronautical Systems Division will technically monitor the overall program.

10. References:

a. MIPR 61-9

b. MIPR 62-

c. Basic ltr USAERDL (ERDCP) Hq MATS (MAMCE/FS), Novem-
ıer 1961, subject: "Microbiological Filter/Separator Research Perform-
ınce Evaluations".

d. 1st Indorsement to above MAMCE/FS to ERDCP dtd 8 Decem-
ıer 1961.

e. ASD presentation to Hq, USAF, "Jet Fuel Contamination,
ntegral Tank Corrosion," Jan 1962 (paper).

11. Coordination:

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JAMES JOHNSON
Captain, USAF
Base Fuels Officer

APPROVED:

LESTER C MESSENGER
Colonel, USAF
Commander

APPENDIX B

PERSONNEL WHO VISITED THE SITE OF INVESTIGATION

In addition to the team and advisory personnel previously mentioned in this report, the following personnel visited Kindley AFB in October 1962 on a formal briefing tour:

Major H. Borgstrom	HQ USAF, Washington, D. C.
Dr. W. M. Bejuki	Prevention of Deterioration Center, Washington, D. C.
Dr. W. P. Iverson	U. S. Army Biological Laboratory, Fort Detrick, Md.
Dr. A. M. Kaplan	U. S. Army Natick Laboratories, Natick, Mass.
Mr. C. W. Karstens	USAERDL, Fort Belvoir, Va.
Mr. F. C. Burk	Atlantic Refining Company, Philadelphia, Pa.
Dr. J. Krynitsky	NRL, Washington, D. C.
Lt. Col. J. B. Montgomery	WPAFB, Ohio
Dr. Sheldon A. London	"
Mr. McRae	"
Mr. E. Suhr	"
Mr. Stevenson	"
Lt. Hager	"
Mr. Reed	"
Mr. Lindner	"
Mr. Churchill	"
Mr. Dickey	"
Mr. Smith	"

Other technical and interested personnel who visited the site at various times during the course of the project were:

Dr. Charles Fifield	Millipore Filter Corporation, Bedford, Mass.
Dr. Sheldon A. London	Aerospace Medical Research Labs., WPAFB, Ohio
Mr. Michael G. Grant	BuWeps, USN, Washington, D. C.
Mr. A. Brad Owens	MATS, EASTAF, Maguire Field, N. J.
Mr. Robert Burnham	Maytag Aircraft Corporation, Boulder, Colo.
Mr. D. d'Ardeloff	Millipore Filter Corporation, Bedford Mass.

APPENDIX C

LABORATORY EQUIPMENT

The laboratory, containing all equipment and apparatus required to conduct the necessary physical, chemical, and bacteriological analyses, is located in an air-conditioned concrete block building (P-957), approximately 1 mile east of the investigative site. The equipment was installed by project team personnel and consisted of the following:

a. Microbiological Equipment

(1) 28-Inch-diameter, electric autoclave

(2) Refrigerator

(3) Oven and incubator

(4) Microscope and counters

(5) Millipore pressure rinse vessels, samplers, monitors, pumps, and media.

(6) Glassware, pipettes, and dilution bottles

(7) Electric water still

b. Physiochemical Apparatus

(1) Millipore Filter Corporation apparatus, for the determination of solids content of fuel samples.

(2) Tensiomat (DuNuoy) for automatic determination of the Interfacial Tension (IFT) of the fuel versus water.

(3) Water Separometer (modified for severity) for determination of the water retention characteristics of the fuel.

(4) Aquameter (Beckman Instruments, Inc.), for the determination of total water content of fuel by the Karl Fischer titration method

(5) Digital analytical balance.

(6) Beckman pH meter.

(7) Copper strip corrosion standards.

(8) Refrigerator and oven-dryer.

(9) Glassware, sample bottles, and chemicals.

Upon completion of the final trip made to collect data, certain of these listed instruments were shipped to SEG at WPAFB, Ohio, and to USAERDL, Fort Belvoir, for future experimental work. The remaining items were retained at Kindley AFB for use of Base POL personnel.

APPENDIX D

SAMPLING PROCEDURES

a. Sampling. Descriptions of sampling procedures and techniques follow.

(1) Underground Storage Tank Investigation. Samples were collected at points outlined in paragraph 6 of the main report, by means of a "thief" sampling device.

(2) Dynamic Filter/Separator Investigation. Samples were taken during this investigation, at points indicated in the diagram shown in Fig. 16. The samples were marked by first designating the system (CS or IS) from which they came and then numerically the day, month, and year taken, then the analysis required, by one of the following initials: M, microbial count (follow this by either an F for fungus or B for bacteria); MP, Millipore; KF, Karl Fischer; WSIM, water separator index; Cu, copper corrosion; IFT, interfacial tension; and A, additive. Then, numerically, the sample number designated was followed by the point in the system where the sample was taken. For example, a sample taken 1 foot from the top of the JP-4 fuel level in the CS tank on 6 June 1962 for a fungus determination would be marked as follows:

CS/6/6/62/MF/1/TT

A similar sample taken 8 July 1962 would be marked:

CS/7/8/62/MF/2/TT

(3) Static Drum Investigation. Samples of fuel were extracted from each of the drums in this investigation by means of a plastic tube siphon actuated by a rubber bulb suction device. After the flow was started, 200 to 300 cc of fuel was run on the ground so as to thoroughly flush the sampling tube of fuel from the preceding drum. The sample bottle was then rinsed with fuel, after which the sample was taken. The same procedure was followed when samples of the water bottom were extracted from each drum, except that a bent copper tube which extended to within 1 inch of the drum bottom was attached to the plastic hose prior to starting the siphoning action.

b. Microbiological Sampling. All microbiological sampling procedures utilized throughout the investigative period were identical to those employed for obtaining the physiochemical samples, herein described, the only exceptions being that sterile sample bottles were used, rinsing was eliminated, and the siphon tube was thoroughly flushed between each sampling.

APPENDIX E

PHYSIOCHEMICAL ANALYTICAL PROCEDURES

Certain physical and chemical properties of fuels reflect their quality and suitability for Military use. To determine the effect, if any, of micro-organisms alone and in the presence of additives and biocides on these properties, analyses were performed by the following procedures:

a. Determination of Water Content. The Karl Fischer analysis method is employed in determining the minute quantities of water which are found in filter/separator effluent samples. The method determines the total water content, a combination of the free water and the water in solution, by direct electrometric titration in methanol with Karl Fischer reagent. This reagent is a mixture of pyridine-sulfur dioxide, iodine, and methanol. The Karl Fischer reagent reacts quantitatively with the water extracted from the fuel by anhydrous methanol. The method is precise, accurate, and rapid and can be conducted with commercially available apparatus such as the Beckman KF-3 Aquameter. The free, or undissolved, water in the fuel is the difference between the total water content, as obtained by the Karl Fischer method, and the dissolved water content at saturation of the fuel at the temperature which prevailed during the test.

b. Determination of Solids Content. The solids content of the test filter/separator effluent stream is determined by filtering a test sample of known volume through a tared Millipore filter. This filter is a thin cellulosic porous membrane having an average pore size of 0.8 micron (0.000032 inch). The filter, with any accumulation of solids from the test fuel, is then washed with a particle-free solvent to remove the residual fuel and dried for 1 hour at 200° F. After cooling to constant weight, the Millipore filter is again weighed, the increase in weight being the solids removed from the test sample. Extreme care is exercised during this analysis to prevent extraneous contamination of the filters from airborne particles, washing solvents, or other sources.

c. Water Separometer Index (WSIM). The water separometer index is a measure of the ability of a hydrocarbon fuel to retain water particles in a more or less permanently dispersed form or stated conversely, the ability of dispersed water particles to coalesce and separate from the fuel by gravity after passage through a standardized wafer of fiberglass filter media. The water separometer apparatus consists of a reservoir tank, pump, flowmeter, coalescing cell, water settling chamber, and a turbidimeter which employs a photoelectric cell and an indicating micro-ammeter scaled from 0 to 100. By means of a long needle hypodermic syringe, 2.0 ml of water (distilled or environmental, depending on the test conditions) are introduced into 2 liters of test fuel at the reservoir outlet pipe. After circulating through the pump and back to the tank for 5 minutes the water is thoroughly dispersed and is then passed through the coalescing cell and turbidimeter at a controlled rate of flow and temperature. Meter readings are then taken at specified time intervals. If the meter is set to show a reading of 100 with clear, clean, dry fuel, the reading after 8 minutes of circulating the water fuel dispersion through the coalescer cell and the turbidimeter is recorded as the separometer index of the fuel. The lower the reading the more water is held by the fuel as a permanently dispersed phase.

d. Interfacial Tension (IFT). The measurement of the apparent interfacial tension which exists between the contacting surfaces of two dissimilar liquids is measured on a Fisher Tensiomat. This semiautomatic instrument employs the DuNuoy principle of operation. A Teflon-coated ring is immersed in one of the liquids to be measured and is pushed through the interface. The force required to do this is a function of the interfacial tension and is indicated on a dial. The Tensiomat contains a motor which applies the force necessary to push the ring through the interface. An electrical contact is broken as soon as the ring breaks through the interface, and an observation of the interfacial tension can be made at the convenience of the operator.

e. Hydrogen Ion Concentration (pH) Determination. The hydrogen ion concentration or pH of the tank and drum water bottoms was determined with a Beckman Zeromatic pH meter. This meter employs a standard calomel-glass electrode, immersed in the sample. Readings are taken from a dial, calibrated to indicate pH directly. Duplicate readings are made for each sample.

f. Copper (Cu) Corrosion Test. This test indicates the presence of corrosive materials in the fuel. In accordance with ASTM Test D-130-56, polished copper strips are immersed in samples of the fuel for 3 hours and are then removed and compared with a set of preserved, color standard strips which indicate the degree of corrosion by a numerical system.

APPENDIX F

MICROBIOLOGICAL ANALYTICAL PROCEDURES

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a. Analytical Procedures. The microbial activities of the fuel and water phases of each system and of the various drums were determined during the investigation.

(1) Fuel. An 100-ml aliquot of a fuel sample was aseptically taken from a sample bottle and passed through a sterile Millipore field monitor which contained a membrane filter (0.45-micron pore size) with a support pad. Approximately 800 ml of sterile 0.2 percent alkylaryl polyether alcohol (a surface-active agent, Triton X-100) solution was then passed through the monitor to emulsify and remove any residue hydrocarbon fuel from the filter, pad, and monitor. A sterile Millipore filter membrane (0.45-micron pore size) in a Millipore A/H Microanalysis Filter Holder was located in the air pressure line in the flushing assembly (Fig. 9) so as to remove any bacteria and fungus spores from the air used to pressurize the rinse container. This flushing is necessary if microbial growth is to occur on the membrane. One monitor each was prepared in this manner from an individual sample bottle for the total bacterial count and fungus growth determinations. After the rinsing, a metal syringe was used to pull all remaining liquid from the monitor. Next, the contents of an 0.8-ml ampoule of medium was emptied into the back of the monitor to saturate the support pad and thus promote microbial growth on the membrane filter surface during incubation at 30° C. A tryptone glucose extract broth ampoule was used for each total count monitor; and a yeast and mold medium ampoule, for each fungus monitor. After 48 hours' incubation, the total count monitors were examined, and total bacterial counts were made. The fungus growth monitors were examined after 120 hours' incubation, and the determination was made as to the presence or absence of growth on the membrane.

(2) Water Bottoms. The bacterial and fungus growths in the tank and drum water bottoms were determined with essentially the same procedure as that used with the fuels. However, no rinsing of the monitor

was required because no fuel was present. High microbial activity in the water bottom precluded the use of an undiluted aliquot of a water bottom sample and dictated the use of the standard serial dilution technique in preparing samples to be passed through the monitor. Dilutions, which ranged between 1×10^2 and 1×10^9, were prepared from each sample. Usually, only two dilutions of a water bottom sample being tested were prepared; the level of dilution was selected after study of the data from the prior investigative team trip. Each diluted sample (100-ml volume) was aseptically drawn from the dilution bottle and through the monitor by means of a vacuum pump. The addition of the medium to the water bottom sample monitor, temperature, time of incubation, and growth determination were identical to those just described for the fuel samples.

b. Discussion. The Millipore Field Monitor technique was selected for use in the microbiological investigations conducted at Kindley AFB, because it precluded the necessity for installing complete microbiological laboratory facilities in the Project BEARS Laboratory with its limited space. Microbiological analytical procedures could be conducted with this technique using a minimum of laboratory equipment. Furthermore, on the bases of technical data releases, it was purported that a high degree of accuracy and reproducibility is obtained by use of the field monitor.

Several shortcomings were observed in the application of this technique to petroleum microbiology. In this investigation, plans were made to utilize the technique in counting, not only the bacteria, but also the fungi possibly present in the fuel and water bottom samples. During the first phase of the project team investigative trips, discouraging results were obtained in attempting to derive quantitative test data regarding the fungus growth in test samples. Investigation revealed that it was impossible to determine whether a fungus colony observed on the membrane surface in a monitor emanated from a single spore or from merely a fragment of mycelium. This, added to the fact that the fungus growth present invariably tended to merge into several large colonies, prompted a decision to report fungus activity by a visual determination as to whether fungus growth was present or absent in a monitor after the specified incubation period.

Another problem encountered in the use of the Millipore Field Monitor technique was that bacterial counts in the test fuels appeared to be increasing at an unexpected rate, finally reaching a level of 1×10^5/ml, occasionally. This situation prompted the team microbiologist to request and arrange for cooperative and concurrent evaluation tests to be made at Kindley AFB with a view to resolving or reconciling this question of suspect high microbial activity in the fuels under test. Microbiologists from the Millipore Filter Corporation (Dr. Charles W. Fifield); Aerospace Medical Research Labs., WPAFB (Dr. Sheldon A. London); and USAERDL, Project BEARS (Vincent J. Bagdon) participated in the tests. Samples of fuel and water bottoms were taken from the two systems and from various 55-gallon static test drums and analyzed by each of three microbiological procedures: The Millipore Laboratory Test Method (I): the Millipore Field (Monitor) Test Method (II); and the conventional standard spread-plate technique (III). In these simultaneous evaluations the same sample was used in each of the three procedures.

The results of this comparative investigation revealed that: (a) The microbial activity in the fuel was much lower than previously indicated by use of Method II; (b) the results obtained by the Millipore Filter Corporation personnel using Methods I and II were not in conformance with those obtained by Project BEARS and WPAFB personnel using Methods II and III, respectively. The Millipore Filter Corporation personnel were unable to report any microbial activity in either the fuel or water bottom samples; (c) the results obtained by WPAFB and Project BEARS personnel correlated closely; occasionally, however, WPAFB personnel found more bacteria in the samples than did the Project BEARS personnel (by as much as 80-fold), viz., fuel samples from Drums Nos. 35 and 36, and water bottom samples from Drums Nos. 19, 32, and 34; and (d) Method II in its present form, particularly utilizing the Flash-O-Lens with its 5X magnification for total counts is an unreliable procedure for determining the microbial activity in fuel. However, this method is satisfactory for total bacterial counts of water bottom samples.

The lack of microbiological laboratory facilities for Project BEARS at Kindley AFB obviated an early discovery of the shortcoming in the Millipore Field Monitor technique. This fallibility, later deemed responsible for the misleading interpretations in total bacterial counts on the incubated fuel monitors, manifested itself in the appearance of artifacts, which were mistaken for bacterial colonies on the monitor membrane. In this technique, malachite green is used as a differential negative stain to increase visual contrast of bacterial colonies on the filter membrane for total count determinations. The colonies remain unstained (white) while the background takes up a light green color. Critical microbiological examination and culturing of representative fuel monitors returned to USAERDL on several different occasions for further study revealed that all of the white spots on stained fuel monitor membranes were indeed of bacterial origin. Then, too, during the October 1962 project team trip to Kindley AFB, the consensus of all microbiologists attending a formal briefing on Project BEARS was obtained. It was unanimously agreed that the white spots appearing on stained fuel monitor membranes were bacterial colonies per se; the Flash-O-Lens was used in these observations. The possible occurrence of these artifacts (white spots, on stained membranes, not of bacterial origin) is not mentioned in Millipore technical publication ADM-40, Techniques for Microbiological Analysis, which describes in detail on pages 16 and 17 the field monitor method in question. Suspicions as to the true nature of many of the white spots were confirmed during the last days of the July 1963 project team trip to Kindley AFB when a newly requisitioned wide-angle binocular stereoscopic microscope (magnification: 10 X to 80 X) finally arrived and enabled a critical examination of many incubated and stained fuel monitors. Frequently, globules of undissolved surfactant, Triton X-100, were discovered to be centered in many of the white spots. The aforementioned comparative evaluation of the three microbiological analytical procedures ensued during the next project team trip to Kindley AFB. Although the findings which resulted from this cooperative endeavor indicated that the field monitor technique did not accurately reflect the true microbial activity in the fuel, practical considerations dictated the continued use of the method for the remainder of the program, particularly because a stereoscopic microscope was available to examine the stained monitor filter membranes critically for the presence of Triton X-100 globules. On the bases of the data derived during this evaluation program, the Project Steering Committee amended all Project BEARS data to reflect the realistic and accurate bacterial count of less than one per ml of fuel instead of the original spurious high counts in the laboratory data. It should be noted here that no question was ever raised as to the validity of the total counts in the water bottom samples.

c. Observations. Experiences gained during progress of the Project BEARS program indicate that the field monitor technique as described in Millipore technical publication ADM-40 is not suitable for enumerating the total count of microorganisms in fuel samples under field conditions. This is because of the frequent occurrence of artifacts which are not readily identifiable without the aid of a stereoscopic microscope. Without this microscope it would be advisable to use the conventional standards spread-plate techniques.

The microbiological analyses of water-bottom samples indicate that the use of the Millipore Field Monitor technique is satisfactory.

APPENDIX G

MICROORGANISMS

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A listing of some of the representative genera of microorganisms which comprised the inoculum used in the Project BEARS program has been presented in paragraph 6 of the main report. Approximately 2,400 field monitors were used in the microbiological analyses during the program; some of them were returned to USAERDL. In addition, during several of the investigative team trips to Kindley AFB, various fuel and water-bottom samples were streaked onto several selected media contained in petri dishes. These were taken back to USAERDL. Laboratory studies are in progress on the isolation and identification of the microorganisms found in contaminated fuel systems pertinent to the Project; the monitors and petri dish cultures returned to the USAERDL were the bases for these studies.

The physiological and biochemical characteristics of approximately 100 bacterial isolates are being studied in an attempt to identify them specifically. A majority of these isolates are gram-negative rods and appear to be of the genus Pseudomonas. Many of the other isolates have been tentatively identified as forms belonging to the genera Aerobacter, Bacillus, Alkaligenes, and Micrococcus.

Over 450 fungus cultures were obtained during the program. Duplicates were eliminated. As expected, many of the fungus isolates are species of the ubiquitous genus Cladosporium. Many of the other isolates have been tentatively identified as forms belonging to the genera Penicillium, Aspergillus, Fusarium, Pullularia, Cephalosporium, and Alternaria. A few actinomycetes and several different red, orange, black, and white yeast and yeast-like organisms were isolated.

A report will be prepared covering this investigative phase of the Project BEARS program, when this work has been completed.

APPENDIX H

JP-4 STORAGE TANK RESTORATION

A final Project BEARS requirement was restoration of the test site to its original condition prior to returning the facilities to Kindley AFB for tactical use. The restoration plan included draining, inspecting, cleaning, and coating, if necessary, the four 50,000-gallon storage tanks in the Pumphouse No. 4 system.

The tank cleaning task was included as part of a contract with a contractor to inspect and clean all the Pritchard System storage tanks on the base. The BEARS CS (Control System) and IS (Inoculated System) 50,000-gallon underground JP-4 storage tanks were inspected during the week of 22 June 1964, after project completion. The slight degree of corrosion found in the CS tank was similar to that found in fourteen identical operational fuel storage tanks examined during the same period, even though a saline water bottom was present in the CS tank. However, the IS tank revealed extremelv severe corrosion over its entire interior surface with no apparent difference in degree on the surfaces below the fuel level, above the fuel, and in the water bottom area. In addition, the connecting fuel lines contained corrosion products in the form of stalactites approximately 1 inch in length (Figs. 31 and 32). The corrosion on the tank surfaces was in the form of incrustations and scale (Fig. 33). Laboratory analyses determined that these corrosion products contained microorganisms, but no sulfides or other corrosive biological byproducts could be detected.

In view of the greater degree of corrosion in the only tank at Kindley Air Base which had been inoculated, it is concluded that microbially infected water bottoms appear capable of accelerating corrosion on the interior surfaces of unprotected steel storage tanks.

L7861
Fig. 31. Plug valve body with connecting fuel line upstream of pump in IS. Note corrosion stalactites hanging in pipe.

L7860
Fig. 32. Upstream side of IS valve plug showing extent of corrosion on steel surface.

L7862

Fig. 33. Dome of pump riser in IS storage tank. Note severe corrosion in dome area. Other areas have been scraped.

APPENDIX I

CONTENTS OF DRUMS USED IN THE STATIC DRUM INVESTIGATION

The listing of combinations of fuels, inoculi, additives, and waters, with which the drums were filled follows:

Drum No. 1	40 gal of JP-4.
Drum No. 2	40 gal of 115/145 Avgas.
Drum No. 3	32 gal of JP-4 fuel and 8 gal of sea water.
Drum No. 4	32 gal of 115/145 Avgas and 8 gal of sea water.
Drum No. 5	32 gal of JP-4 fuel, 8 gal of sea water, and 100 ml of inoculum.
Drum No. 6	32 gal of 115/145 Avgas, 8 gal of sea water, and 100 cc of inoculum.
Drum No. 7	32 gal of JP-4 fuel, 1.6 gal of sea water, 6.4 gal of distilled water, and 100 cc of inoculum.
Drum No. 8	32 gal of 115/145 Avgas, 1.6 gal of sea water, 6.4 gal of distilled water, and 100 cc of inoculum.
Drum No. 9	32 gal of JP-4 fuel, 1.6 gal of sea water, 6.4 gal of distilled water (no inoculum).
Drum No. 10	32 gal of 115/145 Avgas, 1.6 gal of sea water, 6.4 gal of distilled water (no inoculum).
Drum No. 11	32 gal of JP-4 fuel, 1.6 gal of sea water, 6.4 gal of distilled water, 100 cc of inoculum, and 608 gms (2.0 percent) of potassium dichromate.
Drum No. 12	32 gal of 115/145 Avgas, 1.6 gal of sea water, 6.4 gal of distilled water, 100 cc of inoculum, and 608 gms (2.0 percent) of potassium dichromate.

Drum No. 13	40 gal of IS (inoculated system) JP-4 fuel.
Drum No. 14	32 gal of IS JP-4 fuel + 8 gal of IS water bottom.
Drum No. 15	40 gal of IS JP-4 fuel + 6.9 gms of Santolene C.
Drum No. 16	32 gal of IS JP-4 fuel + 5.52 gms of Santolene C + 8 gal of IS water bottom.
Drum No. 17	40 gal of IS JP-4 fuel + 8.64 gms of Dupont RP-2.
Drum No. 18	32 gal of IS JP-4 fuel + 6.9 gms of Dupont RP-2 + 8 gal of IS water bottom.
Drum No. 19	32 gal of IS JP-4 fuel + 5.52 gms of Santolene C + 8 gal of IS water bottom + 11.0 gms of beta-nitro-styrene (32 lb/ 1,000 bbl or 0.01 percent).
Drum No. 20	32 gal of IS JP-4 fuel + 5.52 gms of Santolene C + 8 gal of IS water bottom + 22.0 gms of beta-nitro-styrene (64 lb/ 1,000 bbl or 0.02 percent).
Drum No. 21	32 gal of IS JP-4 fuel + 5.52 gms of Santolene C + 8 gal of IS water bottom + 44.0 gms of beta-nitro-styrene (128 lb/ 1,000 bbl or 0.04 percent).
Drum No. 22	32 gal of IS JP-4 fuel + 5.52 gms of Santolene C + 8 gal of IS water bottom + 31.75 gms of sodium chromate (0.1 percent water bottom by weight).
Drum No. 23	32 gal of IS JP-4 fuel + 5.52 gms of Santolene C + 8 gal of IS water bottom + 158.76 gms of sodium chromate (0.5 percent water bottom by weight).
Drum No. 24	32 gal of IS JP-4 fuel + 5.52 gms of Santolene C + 8 gal of IS water bottom + 635.04 gms of sodium chromate (2.0 percent water bottom by weight).
Drum No. 25	32 gal of IS JP-4 fuel + 5.52 gms of Santolene C + 8 gal of IS water bottom + 11.0 gms of 6-acetoxy-2, 4-dimethyl-M-dioxane (0.01 percent).

Drum No. 26 — 32 gal of IS JP-4 fuel + 5.52 gms of Santolene C + 8 gal of IS water bottom + 55.0 gms of 6-acetoxy-2, 4-dimethyl-M-dioxane (0.05 percent).

Drum No. 27 — 32 gal of IS JP-4 fuel + 5.52 gms of Santolene C + 8 gal of IS water bottom + 111.0 gms of 6-acetoxy-2, 4-dimethyl-M-dioxane (0.1 percent).

Drum No. 28 — 32 gal of IS JP-4 fuel + 5.52 gms of Santolene C + 8 gal of IS water bottom + 605.6 cc of Phillips 55 MB (2.0 percent water bottom by volume).

Drum No. 29 — 32 gal of IS JP-4 fuel + 5.52 gms of Santolene C + 8 gal of IS water bottom + 1.514 liters of Phillips 55 MB (5.0 percent water bottom by volume).

Drum No. 30 — 32 gal of IS JP-4 fuel + 5.52 gms of Santolene C + 8 gal of IS water bottom + 4.542 liters of Phillips 55 MB (15 percent of water bottom by volume).

Drum No. 31 — 32 gal of IS JP-4 fuel + 5.52 gms of Santolene C + 8 gal of IS water bottom + 7.57 liters of Phillips 55 MB (25 percent of water bottom by volume).

Drum No. 32 — 32 gal of IS JP-4 fuel + 5.52 gms of Santolene C + 8 gal of IS water bottom + 90 gm (1 ppm) of sodium (petroleum) sulfonate.

Drum No. 33 — 32 gal of IS JP-4 fuel + 5.52 gms of Santolene C + 8 gal of IS water bottom + 1.8 gms (20.0 ppm) of sodium (petroleum) naphthanate.

Drum No. 34 — 32 gal of Kindley AFB (Maytag) JP-4 fuel + 5.52 gms of Santolene C + 1.6 gal of sea water + 6.4 gal of distilled water.

Drum No. 35 — 40 gal of Kindley AFB (Maytag) JP-4 fuel + 6.9 gms of Santolene C.

Drum No. 36 — 40 gal of Kindley AFB (Maytag) JP-4 fuel.

APPENDIX J

STATIC DRUM DATA

Table IX. Static Drum Investigation, Drum No. 1

Analysis Date	WSIM JP-4 Fuel vs:		IFT (dynes/cm) JP-4 Fuel vs:		Microbial Count (colonies/ml)		Fungus		Cu Corrosion	pH	Anti-Icing Additive (%)	
	Distilled Water	TWB	Distilled Water	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB
June '62	79	n. a.	35.1	n. a.	<1	n. a.	Yes	n. a.	Neg		-	n. a.
Aug. '62	82	n. a.	35.9	n. a.	<1	n. a.	Yes	n. a.	Neg		-	n. a.
Oct. '62	87	n. a.	32.6	n. a.	<1	n. a.	Yes	n. a.	Neg		0.1	n. a.
Jan. '63	76	n. a.	31.3	n. a.	<1	n. a.	Yes	n. a.	Neg		-	n. a.
Mar. '63	75	n. a.	29.9	n. a.	<1	n. a.	Yes	n. a.	Neg		-	n. a.
June '63	77	n. a.	29.7	n. a.	<1	n. a.	-	n. a.	Neg		-	n. a.
July '63	82	n. a.	28.1	n. a.	<1	n. a.	Yes	n. a.	1a		0.04	n. a.
Oct. '63	-	n. a.	27.2	n. a.	<1	n. a.	Yes	n. a.	-		-	-
Jan. '64			25.1		<1	n. a.	No	n. a.	-		-	-

Note: 1. On 10 May 1962, 40 gal of fuel, treated with 0.1 percent anti-icing additive, was introduced into the drum.
2. The 1a value for copper corrosion designates an ASTM standard.
3. n. a. signifies not applicable.
4. Hyphens signify that no data were available.
5. Blank spaces indicate that no data were taken.

Table X. Static Drum Investigation, Drum No. 2

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) Avgas	Microbial Count (colonies/ml) TWB	Fungus Avgas	Fungus TWB	Cu Corrosion Avgas	pH TWB	Anti-Icing Additive (%) Avgas	Anti-Icing Additive (%) TWB
June '62			29.8	n.a.	<1	n.a.	No	n.a.	Neg			
Aug. '62			32.2	n.a.	<1	n.a.	Yes	n.a.	Neg			
Oct. '62			34.1	n.a.	<1	n.a.	Yes	n.a.	Neg			
Jan. '63			33.3	n.a.	<1	n.a.	No	n.a.	Neg			
Mar. '63			32.2	n.a.	<1	n.a.	No	n.a.	Neg			
June '63			33.1	n.a.	<1	n.a.	No	n.a.	Neg			
July '63			34.8	n.a.	-	n.a.	-	n.a.	-			
Oct. '63												
Jan. '64												

Note:
1. On 10 May 1962, 40 gal of 115/145 Avgas was introduced into the drum.
2. n.a. signifies not applicable.
3. Hyphens signify that no data were available.
4. Blank spaces indicate that no data were taken.

Table XI. Static Drum Investigation, Drum No. 3

Analysis Date	WSIM JP-4 Fuel vs:		IFT (dynes/cm) JP-4 Fuel vs:		Microbial Count (colonies/ml)		Fungus		Cu Corrosion	pH	Anti-Icing Additive (%)	
	Distilled Water	TWB	Distilled Water	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB
June '62	95	99	39.6	34.1	< 1	134	Yes	No	Neg	-	-	-
Aug. '62	99	99	37.8	29.5	< 1	5.9×10^3	Yes	No	Neg	-	-	-
Oct. '62	98	98	36.0	35.3	< 1	4.8×10^5	Yes	Yes	Neg	5.9	0.04	>0.14
Jan. '63	-	100	-	31.7	< 1	2.5×10^6	Yes	Yes	Neg	-	-	-
Mar. '63	-	100	-	34.2	-	-	-	-	Neg	-	-	-
June '63	-	-	-	33.8	<1	2.9×10^8	Yes	-	Neg	5.0	-	-
July '63	-	-	-	34.8	-	-	-	-	-	5.60	0.04	-
Oct. '63	-	-	-	32.7	<1	3.5×10^2	Yes	No	-	6.15	-	-
Jan. '64	-	98	-	32.4	<1	720	No	Yes	-	6.0	-	-

Note: 1. On 10 May 1962, 32 gal of JP-4 fuel, treated with 0.1 percent anti-icing additive and 8 gal of sea water were introduced into the drum.

2. Hyphens signify that no data were available.

Table XII. Static Drum Investigation, Drum No. 4

Analysis Date	WSIM JP-4 Fuel vs:		IFT (dynes/cm) JP-4 Fuel vs:		Microbial Count (colonies/ml)		Fungus		Cu Corrosion	pH	Anti-Icing Additive (%)	
	Distilled Water	TWB	Distilled Water	TWB	Avgas	TWB	Avgas	TWB	Avgas	TWB	Avgas	TWB
June '62			33.5	-	<1	-	No	-	Neg	-		
Aug. '62			41.8	38.2	<1	3.7×10^4	No	No	Neg	-		
Oct. '62			39.7	37.1	<1	1.8×10^6	Yes	Yes	Neg	4.9		
Jan. '63			-	39.9	<1	5.5×10^6	Yes	Yes	Neg	-		
Mar. '63			-	36.8	-	-	-	-	Neg	-		
June '63			-	36.9	<1	2.1×10^8	Yes	-	Neg	4.4		
July '63			-	38.2	-	-	Yes	-	Neg	5.05		
Oct. '63			-	-	<1	-	Yes	-	-	5.70		
Jan. '64						400		Yes				

Note: 1. On 10 May 1962, 32 gal of 115/145 Avgas and 8 gal of sea water were introduced into the drum.
2. Hyphens signify that no data were available.
3. Blank spaces indicate that no data were taken.

Table XIII. Static Drum Investigation, Drum No. 5

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) JP-4 Fuel	Microbial Count (colonies/ml) TWB	Fungus JP-4 Fuel	Fungus TWB	Cu Corrosion JP-4 Fuel	pH TWB	Anti-Icing Additive (%) JP-4 Fuel	Anti-Icing Additive (%) TWB
June '62	99	99	40.6	35.9	<1	59	Yes	Yes	Neg	-	-	-
Aug. '62	99	99	39.2	37.6	<1	5.2×10^3	Yes	Yes	Neg	-	-	-
Oct. '62	99	100	38.9	37.1	<1	2.0×10^6	Yes	Yes	Neg	5.8	0.04	>0.14
Jan. '63	-	100	-	34.3	<1	2.0×10^6	Yes	Yes	Neg	-	-	-
Mar. '63	-	99	-	36.9	-	-	-	-	Neg	-	-	-
June '63	-	-	-	32.8	<1	9.0×10^7	Yes	-	Neg	5.2	-	-
July '63	-	-	-	35.7	-	-	-	-	-	5.55	0.04	-
Oct. '63	-	-	-	36.0	<1	1.1×10^3	No	Yes	-	6.20	-	-
Jan. '64	-	93	-	22.0	<1	430	Yes	Yes	-	6.1	-	-

Note: 1. On 10 May 1962, 32 gal of JP-4 fuel, treated with 0.1 percent anti-icing additive, 8 gal of sea water, and 100 ml of inoculum were introduced into the drum.
2. Hyphens signify that no data were available.

Table XIV. Static Drum Investigation, Drum No. 6

Analysis Date	WSIM JP-4 Fuel vs:		IFT (dynes/cm) JP-4 Fuel vs:		Microbial Count (colonies/ml)		Fungus		Cu Corrosion	pH	Anti-Icing Additive (%)	
	Distilled Water	TWB	Distilled Water	TWB	Avgas	TWB	Avgas	TWB	Avgas	TWB	Avgas	TWB
June '62			33.7	-	<1	-	No	-	Neg	-		
Aug. '62			41.2	39.5	<1	1.8×10^4	Yes	Yes	Neg	-		
Oct. '62			40.8	38.2	<1	2.0×10^6	Yes	No	Neg	4.8		
Jan. '63			-	40.7	<1	4.8×10^6	Yes	Yes	Neg	-		
Mar. '63			-	36.9	-	-	-	-	Neg	-		
June '63			-	36.7	<1	3.0×10^8	Yes	-	Neg	4.4		
July '63			-	40.7	-	-	-	-	-	5.00		
Oct. '63			-	-	<1	-	Yes	-	-	5.80		
Jan. '64						640		No				

Note: 1. On 10 May 1962, 32 gal of Avgas, 8 gal of sea water, and 100 ml of inoculum were introduced into the drum.

2. Hyphens signify that no data were available.

3. Blank spaces indicate that no data were taken.

Table XV. Static Drum Investigation, Drum No. 7

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) JP-4 Fuel	Microbial Count (colonies/ml) TWB	Fungus JP-4 Fuel	Fungus TWB	Cu Corrosion JP-4 Fuel	pH TWB	Anti-Icing Additive (%) JP-4 Fuel	Anti-Icing Additive (%) TWB
June '62	98	100	36.8	36.1	<1	400	Yes	Yes	Neg	-	-	-
Aug. '62	98	100	37.3	35.7	<1	7.1×10^4	Yes	Yes	Neg	-	-	-
Oct. '62	97	97	35.8	34.0	<1	3.4×10^6	Yes	Yes	Neg	5.3	0.04	> 0.14
Jan. '63	-	100	-	31.7	<1	2.7×10^6	Yes	Yes	Neg	-	-	-
Mar. '63	-	98	-	30.3	<1	8.0×10^8	Yes	Yes	Neg	-	-	-
June '63	-	-	-	33.6	<1	1.3×10^8	Yes	-	Neg	5.0	-	-
July '63	-	-	-	34.4	-	-	-	-	-	4.80	0.04	-
Oct. '63	-	-	-	35.2	<1	1.09×10^3	Yes	Yes	-	5.80	-	-
Jan. '64	-	96	-	31.1	<1	880	Yes	Yes	-	5.6	-	-

Note: 1. On 10 May 1962, 32 gal of JP-4 fuel, treated with 0.1 percent anti-icing additive, 1.6 gal of sea water, 6.4 gal of distilled water, and 100 ml of inoculum were introduced into the drum.
2. Hyphens signify that no data were available.

Table XVI. Static Drum Investigation, Drum No. 8

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water		IFT (dynes/cm) JP-4 Fuel vs: Distilled Water		Microbial Count (colonies/ml)		Fungus		Cu Corrosion	pH	Anti-Icing Additive (%)	
	Distilled Water	TWB	Distilled Water	TWB	Avgas	TWB	Avgas	TWB	Avgas	TWB	Avgas	TWB
June '62			34.3	-	<1	-	No	-	Neg	-		
Aug. '62			41.0	37.3	<1	6.5×10^4	No	Yes	Neg	-		
Oct. '62			41.4	38.7	<1	2.3×10^6	Yes	Yes	Neg	4.9		
Jan. '63			-	38.4	<1	5.8×10^6	Yes	No	Neg	-		
Mar. '63			-	38.0	<1	1.7×10^9	No	Yes	Neg	-		
June '63			-	37.1	<1	2.7×10^8	Yes	-	Neg	4.5		
July '63			-	37.7	-	-	-	-	-	4.50		
Oct. '63			-	-	<1	-	No	-	-	5.70		
Jan. '64						620		Yes				

Note:
1. On 10 May 1962, 32 gal of 115/145 Avgas, 1.6 gal of sea water, 6.4 gal of distilled water, and 100 ml of inoculum were introduced into the drum.
2. Hyphens signify that no data were available.
3. Blank spaces indicate that no data were taken.

Table XVII. Static Drum Investigation, Drum No. 9

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) JP-4 Fuel	Microbial Count (colonies/ml) TWB	Fungus JP-4 Fuel	Fungus TWB	Cu Corrosion JP-4 Fuel	pH TWB	Anti-Icing Additive (%) JP-4 Fuel	Anti-Icing Additive (%) TWB
June '62	95	99	38.6	33.5	< 1	168	Yes	Yes	Neg	-	-	-
Aug. '62	99	100	40.1	37.1	< 1	2.5×10^4	Yes	Yes	Neg	-	-	-
Oct. '62	99	99	37.7	37.6	< 1	1.7×10^6	Yes	Yes	Neg	5.2	0.04	> 0.14
Jan. '63	-	96	-	34.2	< 1	1.5×10^6	Yes	Yes	Neg	-	-	-
Mar. '63	-	100	-	36.0	-	-	-	-	Neg	-	-	-
June '63	-	-	-	34.3	< 1	2.0×10^8	Yes	-	Neg	5.0	-	-
July '63	-	-	-	33.8	-	-	-	-	-	5.40	0.04	
Oct. '63	-	-	-	35.9	<1	2.6×10^2	No	Yes	-	5.50	-	-
Jan. '64						660		Yes				

Note: 1. On 10 May 1962, 32 gal of JP-4 fuel, treated with 0.1 percent anti-icing additive, 1.6 gal of sea water, and 6.4 gal of distilled water were introduced into the drum.
2. Hyphens signify that no data were available.
3. Blank spaces indicate that no data were taken.

Table XVIII. Static Drum Investigation, Drum No. 10

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) Avgas	Microbial Count (colonies/ml) TWB	Fungus Avgas	Fungus TWB	Cu Corrosion Avgas	pH TWB	Anti-Icing Additive (%) Avgas	Anti-Icing Additive (%) TWB
June '62			34.3	-	< 1	-	No	-	Neg	-		
Aug. '62			40.4	36.5	< 1	7.1×10^4	No	Yes	Neg	-		
Oct. '62			40.1	36.5	< 1	1.3×10^6	No	Yes	Neg	5.0		
Jan. '63			-	38.8	< 1	5.5×10^6	No	No	Neg	-		
Mar. '63			-	38.5	-	-	-	-	Neg	-		
June '63			-	37.5	< 1	2.4×10^8	No	-	Neg	4.6		
July '63			-	40.8	-	-	-	-	-	4.85		
Oct. '63			-	-	< 1	-	No	-	-	5.60		
Jan. '64						890		Yes				

Note: 1. On 10 May 1962, 32 gal of 115/145 Avgas, 1.6 gal of sea water, and 6.4 gal of distilled water were introduced into the drum.
2. Hyphens signify that no data were available.
3. Blank spaces indicate that no data were taken.

Table XIX. Static Drum Investigation, Drum No. 11

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) JP-4 Fuel	Microbial Count (colonies/ml) TWB	Fungus JP-4 Fuel	Fungus TWB	Cu Corrosion JP-4 Fuel	pH TWB	Anti-Icing Additive (%) JP-4 Fuel	Anti-Icing Additive (%) TWB
June '62	99	99	38.5	32.8	<1	163	Yes	Yes	Neg	-	-	-
Aug. '62	99	99	39.1	31.7	<1	5.3×10^5	Yes	Yes	Neg	-	-	-
Oct. '62	99	98	37.6	28.7	<1	1.2×10^6	Yes	No	Neg	6.2	0.04	>0.14
Jan. '63	-	97	-	30.6	<1	1.7×10^6	Yes	Yes	Neg	-	-	-
Mar. '63	-	99	-	27.4	<1	1.2×10^9	No	No	Neg	-	-	-
June '63	-	-	-	30.4	<1	8.0×10^7	No	-	Neg	6.1	-	-
July '63	-	-	-	29.9	-	-	-	-	-	6.40	0.04	
Oct. '63	-	-	-	30.6	<1	2.1×10^2	No	No	-	6.35	-	-
Jan. '64		94		28.8		510		Yes		6.30		

Note:
1. On 10 May 1962, 32 gal of JP-4 fuel, treated with 0.1 percent anti-icing additive, 1.6 gal of sea water, 100 ml of inoculum, 6.4 gal of distilled water, and 2.0 percent potassium dichromate were introduced into the drum.
2. The percentage of potassium dichromate is in relation to the amount of water bottom, by weight, and was 1.89 percent in October 1962.
3. Hyphens signify that no data were available.
4. Blank spaces indicate that no data were taken.

Table XX. Static Drum Investigation, Drum No. 12

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) Avgas	Microbial Count (colonies/ml) TWB	Fungus Avgas	Fungus TWB	Cu Corrosion Avgas	pH TWB	Anti-Icing Additive (%) Avgas	Anti-Icing Additive (%) TWB
June '62			34.5	-	<1	-	No	-	Neg	-		
Aug. '62			38.1	33.9	<1	6.6×10^4	No	Yes	Neg	-		
Oct. '62			37.7	35.7	<1	1.2×10^6	No	No	Neg	6.0		
Jan. '63			-	34.9	<1	4.2×10^6	Yes	Yes	Neg	-		
Mar. '63			-	36.4	-	-	-	-	Neg	-		
June '63			-	35.1	<1	3.2×10^8	Yes	-	Neg	6.0		
July '63			-	34.5	-	-	-	-	-	6.40		
Oct. '63			-	-	<1	-	No	-	-	6.40		
Jan. '64						410		No				

Note: 1. On 10 May 1962, 32 gal of 115/145 Avgas, 1.6 gal of sea water, 6.4 gal of distilled water, 100 ml of inoculum, and 2.0 percent of potassium dichromate were introduced into the drum.
2. The percentage of potassium dichromate is in relation to amount of water bottom, by weight, and was 1.9 percent in October 1962.
3. Hyphens signify that no data were available.
4. Blank spaces indicate that no data were taken.

Table XXI. Static Drum Investigation, Drum No. 13

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) JP-4 Fuel	Microbial Count (colonies/ml) TWB	Fungus JP-4 Fuel	Fungus TWB	Cu Corrosion JP-4 Fuel	pH TWB	Anti-Icing Additive (%) JP-4 Fuel	Anti-Icing Additive (%) TWB
Mar. '63	98	n. a.	37.0	n. a.	<1	n. a.	-	n. a.	Neg	-	-	n. a.
June '63	98	n. a.	34.0	n. a.	<1	n. a.	-	n. a.	Neg	-	-	n. a.
July '63	-	n. a.	29.2	n. a.	-	n. a.	-	n. a.	1a	-	0.04	n. a.
Oct. '63	91	n. a.	28.6	n. a.	<1	n. a.	Yes	n. a.	-	-	-	n. a.
Jan. '64	-	n. a.	27.2	n. a.	<1		No	n. a.				

Note:
1. During the week of 10 March 1963, 40 gal of IS JP-4 fuel was introduced into the drum.
2. The 1a value for copper corrosion designates an ASTM standard.
3. n. a. signifies not applicable.
4. Hyphens signify that no data were available.
5. Blank spaces indicate that no data were taken.

Table XXII. Static Drum Investigation, Drum No. 14

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) JP-4 Fuel	Microbial Count (colonies/ml) TWB	Fungus JP-4 Fuel	Fungus TWB	Cu Corrosion JP-4 Fuel	pH TWB	Anti-Icing Additive (%) JP-4 Fuel	Anti-Icing Additive (%) TWB
Mar. '63	-	100	-	27.0	<1	2.6×10^7	-	-	Neg		-	-
June '63	-	97	-	29.2	<1	1.2×10^8	-	-	Neg	4.2	-	-
July '63	-	-	-	30.9	-	-	-	-	-	5.00	0.04	-
Oct. '63	-	-	-	30.2	<1	9.3×10^2	Yes	Yes	-	5.90	-	-
Jan. '64				30.9	<1	990	Yes	Yes	-	5.6	-	-

Note: 1. During the week of 10 March 1963, 32 gal of IS JP-4 fuel and 8 gal of IS water bottom were introduced into the drum.
2. Hyphens signify that no data were available.
3. Blank spaces indicate that no data were taken.

Table XXIII. Static Drum Investigation, Drum No. 15

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) JP-4 Fuel	Microbial Count (colonies/ml) TWB	Fungus JP-4 Fuel	Fungus TWB	Cu Corrosion JP-4 Fuel	pH TWB	Anti-Icing Additive (%) JP-4 Fuel	Anti-Icing Additive (%) TWB
Mar. '63	52 & 67	n. a.	33.5	n. a.	<1	n. a.	-	n. a.	Neg	-	-	-
June '63	58	n. a.	28.2	n. a.	<1	n. a.	-	n. a.	Neg	-	-	-
July '63	-	n. a.	23.8	n. a.	-	n. a.	-	n. a.	-	-	0.04	-
Oct. '63	64	n. a.	23.3	n. a.	<1	n. a.	Yes	n. a.	-	-	-	-
Jan. '64			22.7									

Note:
1. During the week of 10 March 1963, 40 gal of IS JP-4 fuel and 6.9 g of Santolene C were introduced into the drum.
2. n. a. signifies not applicable.
3. Hyphens signify that no data were available.
4. Blank spaces indicate that no data were taken.

Table XXIV. Static Drum Investigation, Drum No. 16

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) JP-4 Fuel	Microbial Count (colonies/ml) TWB	Fungus JP-4 Fuel	Fungus TWB	Cu Corrosion JP-4 Fuel	pH TWB	Anti-Icing Additive (%) JP-4 Fuel	Anti-Icing Additive (%) TWB
Mar. '63	-	-	-	-	<1	1.7×10^9	-	-	-	-	-	-
June '63	-	64	-	31.9	<1	2.9×10^8	-	-	Neg	4.4	-	-
July '63	-	-	-	33.3	-	-	-	-	1a	5.15	0.04	-
Oct. '63	-	-	-	33.2	<1	1.9×10^3	Yes	Yes	-	5.90	-	-
Jan. '64	-	-	-	33.7	<1	910	Yes	Yes	-	5.8	-	-

Note: 1. During the week of 10 March 1963, 32 gal of IS JP-4 fuel, 8 gal of IS water bottom, and 5.52 g of Santolene C were introduced into the drum.
2. The 1a value for copper corrosion designates an ASTM standard.
3. Hyphens signify that no data were available.

Table XXV. Static Drum Investigation, Drum No. 17

Analysis Date	WSIM JP-4 Fuel vs:		IFT (dynes/cm) JP-4 Fuel vs:		Microbial Count (colonies/ml)		Fungus		Cu Corrosion	pH	Anti-Icing Additive (%)	
	Distilled Water	TWB	Distilled Water	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB
Mar. '63	56	n. a.	23.0	n. a.	<1	n. a.	-	n. a.	Neg	-	-	n. a.
June '63	43	n. a.	22.7	n. a.	<1	n. a.	-	n. a.	Neg	-	-	n. a.
July '63	-	n. a.	22.0	n. a.	-	n. a.	-	n. a.	1b	-	0.04	n. a.
Oct. '63	-	n. a.	22.1	n. a.	<1	n. a.	Yes	n. a.	-	-	-	n. a.
Jan. '64			22.1									

Note: 1. During the week of 10 March 1963, 40 gal of IS JP-4 fuel and 8.64 g of Dupont RP-2 were introduced into the drum.
2. The 1b value for copper corrosion designates an ASTM standard.
3. n. a. signifies not applicable.
4. Hyphens signify that no data were available.
5. Blank spaces indicate that no data were taken.

Table XXVI. Static Drum Investigation, Drum No. 18

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) JP-4 Fuel	Microbial Count (colonies/ml) TWB	Fungus JP-4 Fuel	Fungus TWB	Cu Corrosion JP-4 Fuel	pH TWB	Anti-Icing Additive (%) JP-4 Fuel	Anti-Icing Additive (%) TWB
Mar. '63	-	45	-	21.6	<1	6.9×10^7	-	-	Neg	-	-	-
June '63	-	45	-	27.4	<1	2.6×10^8	-	-	Neg	4.6	-	-
July '63	-	-	-	28.2	-	-	-	-	-	4.80	0.04	-
Oct. '63	-	84	-	25.9	<1	6.9×10^2	Yes	Yes	-	5.65	-	-
Jan. '64		22		28.2		780		Yes		5.8		

Note: 1. During the week of 10 March 1963, 32 gal of IS JP-4 fuel, 6.9 g of Dupont RP-2, and 8 gal of IS water bottom were introduced into the drum.
2. Hyphens signify that no data were available.
3. Blank spaces indicate that no data were taken.

Table XXVII. Static Drum Investigation, Drum No. 19

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) JP-4 Fuel	Microbial Count (colonies/ml) TWB	Fungus JP-4 Fuel	Fungus TWB	Cu Corrosion JP-4 Fuel	pH TWB	Anti-Icing Additive (%) JP-4 Fuel	Anti-Icing Additive (%) TWB
Mar. '63	-	-	-	-	<1	1.9×10^{8}	-	-	-	-	-	-
June '63	-	78	-	28.4	<1	1.2×10^{8}	-	-	Neg	4.8	-	-
July '63	-	-	-	-	-	-	-	-	-	5.10	-	-
Oct. '63	-	-	-	32.8	<1	1.6×10^{3}	No	Yes	-	5.70	-	-
Jan. '64		58		30.4	<1	2,110	Yes	Yes	-	5.6	-	-

Note:
1. During the week of 10 March 1963, 32 gal of IS JP-4 fuel, 8 gal of IS water bottom, 5.52 g of Santolene C, and 11.0 g of beta-nitro-styrene (32 lb/1,000 bbl or 0.01 percent) were introduced into the drum.
2. Hyphens signify that no data were available.
3. Blank spaces indicate that no data were taken.

Table XXVIII. Static Drum Investigation. Drum No. 20

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) JP-4 Fuel	Microbial Count (colonies/ml) TWB	Fungus JP-4 Fuel	Fungus TWB	Cu Corrosion JP-4 Fuel	pH TWB	Anti-Icing Additive (%) JP-4 Fuel	Anti-Icing Additive (%) TWB
Mar. '63	-	-	-	-	<1	3.3×10^8	-	-	-	-	-	-
June '63	-	78	-	27.3	<1	2.7×10^8	-	-	Neg	4.6	-	-
July '63	-	-	-	-	-	-	-	-	-	5.25	-	-
Oct. '63	-	-	-	-	<1	9.6×10^2	No	No	-	6.10	-	-
Jan. '64				29.4		2,400		Yes		5.9		

Note: 1. During the week of 10 March 1963, 32 gal of IS JP-4 fuel, 8 gal of IS water bottom, 5.52 g of Santolene C, and 22.0 g of beta-nitro-styrene (64 lb/1,000 bbl or 0.02 percent) were introduced into the drum.
2. Hyphens signify that no data were available.
3. Blank spaces indicate that no data were taken.

Table XXIX. Static Drum Investigation, Drum No. 21

Analysis Date	WSIM JP-4 Fuel vs:		IFT (dynes/cm) JP-4 Fuel vs:		Microbial Count (colonies/ml)		Fungus		Cu Corrosion	pH	Anti-Icing Additive (%)	
	Distilled Water	TWB	Distilled Water	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB
Mar. '63	-	-	-	-	<1	2.6×10^8	-	-	-	-	-	-
June '63	-	65	-	27.5	<1	1.6×10^8	-	-	Neg	4.7	-	-
July '63	-	-	-	-	-	-	-	-	1b	5.30	-	-
Oct. '63	-	-	-	-	<1	3.0×10^3	Yes	Yes	-	5.60	-	-
Jan. '64				29.1		2,560		Yes		5.90		

Note: 1. During the week of 10 March 1963, 32 gal of IS JP-4 fuel, 8 gal of IS water bottom, 5.52 g of Santolene C, and 44.0 g of beta-nitro-styrene (128 lb/1,000 bbl or 0.04 percent) were introduced into the drum.
2. The 1b value for copper corrosion designates an ASTM standard.
3. Hyphens signify that no data were available.
4. Blank spaces indicate that no data were taken.

Table XXX. Static Drum Investigation, Drum No. 22

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ ml) JP-4 Fuel	Microbial Count (colonies/ ml) TWB	Fungus JP-4 Fuel	Fungus TWB	Cu Corrosion JP-4 Fuel	pH TWB	Anti-Icing Additive (%) JP-4 Fuel	Anti-Icing Additive (%) TWB
Mar. '63	-	-	-	-	<1	1.5×10^8	-	-	-	-	-	-
June '63	-	72 & 75	-	24.0	<1	4.6×10^8	-	-	Neg	6.9	-	-
July '63	-	-	-	-	-	-	-	-	-	7.60	-	-
Oct. '63	-	73	-	27.0	<1	4.9×10^2	Yes	No	-	7.00	-	-
Jan. '64				26.1	<1	450	Yes	Yes		7.2		

Note: 1. During the week of 10 March 1963, 32 gal of IS JP-4 fuel, 8 gal of IS water bottom, 5.52 g of Santolene C, and 31.75 g of sodium chromate (0.1 percent water bottom by weight) were introduced into the drum.

2. Hyphens signify that no data were available.

3. Blank spaces indicate that no data were taken.

Table XXXI. Static Drum Investigation, Drum No. 23

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) JP-4 Fuel	Microbial Count (colonies/ml) TWB	Fungus JP-4 Fuel	Fungus TWB	Cu Corrosion JP-4 Fuel	pH TWB	Anti-Icing Additive (%) JP-4 Fuel	Anti-Icing Additive (%) TWB
Mar. '63	-	-	-	-	<1	7.5×10^7	-	-	-	-	-	-
June '63	-	78	-	21.9	<1	1.3×10^8	-	-	Neg	6.7	-	-
July '63	-	-	-	-	-	-	-	-	-	8.10	-	-
Oct. '63	-	-	-	-	<1	6.5×10^2	No	No	-	7.80	-	-
Jan. '64				22.3		250		Yes		7.9		

Note: 1. During the week of 10 March 1963, 32 gal of IS JP-4 fuel, 5.52 g of Santolene C, 8 gal of IS water bottom, and 158.76 g of sodium chromate (0.5 percent water bottom by weight) were introduced into the drum.

2. Hyphens signify that no data were available.

3. Blank spaces indicate that no data were taken.

Table XXXII. Static Drum Investigation, Drum No. 24

Analysis Date	WSIM JP-4 Fuel vs:		IFT (dynes/cm) JP-4 Fuel vs:		Microbial Court (colonies/ml)		Fungus		Cu Corrosion	pH	Anti-Icing Additive (%)	
	Distilled Water	TWB	Distilled Water	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB
Mar. '63	-	-	-	-	<1	1.8×10^8	-	-	-	-	-	-
June '63	-	65 & 70	-	20.9	<1	1.1×10^8	-	-	Neg	6.6	-	-
July '63	-	-	-	-	-	-	-	-	1b	8.50	-	-
Oct. '63	-	-	-	-	<1	4.9×10^2	No	No	-	7.90	-	-
Jan. '64				19.4		260		Yes		7.90		

Note: 1. During the week of 10 March 1963, 32 gal of IS JP-4 fuel, 5.52 g of Santolene C, 8 gal of IS water bottom, and 635.04 g of sodium chromate (2.0 percent water bottom by weight) were introduced into the drum.
2. The 1b value for copper corrosion designates an ASTM standard.
3. Hyphens signify that no data were available.
4. Blank spaces indicate that no data were taken.

Table XXXIII. Static Drum Investigation, Drum No. 25

Analysis Date	WSIM JP-4 Fuel vs:		IFT (dynes/cm) JP-4 Fuel vs:		Microbial Count (colonies/ml)		Fungus		Cu Corrosion	pH	Anti-Icing Additive (%)	
	Distilled Water	TWB	Distilled Water	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB
Mar. '63	-	-	-	-	<1	1.3×10^8	-	-	-	-	-	-
June '63	-	79	-	32.7	<1	8.4×10^7	-	-	Neg	4.6	-	-
July '63	-	-	-	-	-	-	-	-	-	5.30	-	-
Oct. '63	-	73	-	32.8	<1	1.3×10^3	No	Yes	-	6.20	-	-
Jan. '64				29.9	<1	1.5×10^3	Yes	No		6.10		

Note: 1. During the week of 10 March 1963, 32 gal of IS JP-4 fuel, 5.52 g of Santolene C, 8 gal of IS water bottom, and 11.0 g of 6-acetoxy-2, 4-dimethyl-M-dioxane (0.01 percent) were introduced into the drum.

2. Hyphens signify that no data were available.

3. Blank spaces indicate that no data were taken.

Table XXXIV. Static Drum Investigation, Drum No. 26

Analysis Date	WSIM JP-4 Fuel vs:		IFT (dynes/cm) JP-4 Fuel vs:		Microbial Count (colonies/ml)		Fungus		Cu Corrosion	pH	Anti-Icing Additive (%)	
	Distilled Water	TWB	Distilled Water	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB
Mar. '63	-	-	-	-	<1	6.3×10^7	-	-	-	-	-	-
June '63	-	53 & 60	-	31.8	<1	8.0×10^7	-	-	Neg	4.7	-	-
July '63	-	-	-	-	-	-	-	-	-	5.60	-	-
Oct. '63	-	-	-	-	<1	4.1×10^2	No	Yes	-	6.15	-	-
Jan. '64		47		32.0		330		No		6.0		

Note:
1. During the week of 10 March 1963, 32 gal of IS JP-4 fuel, 5.52 g of Santolene C, 8 gal of IS water bottom, 55.0 g of 6-acetoxy-2, 4-dimethyl-M-dioxane (0.05 percent) were introduced into the drum.
2. Hyphens signify that no data were available.
3. Blank spaces indicate that no data were taken.

Table XXXV. Static Drum Investigation, Drum No. 27

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) JP-4 Fuel	Microbial Count (colonies/ml) TWB	Fungus JP-4 Fuel	Fungus TWB	Cu Corrosion JP-4 Fuel	pH TWB	Anti-Icing Additive (%) JP-4 Fuel	Anti-Icing Additive (%) TWB
Mar. '63	-	-	-	-	<1	3.3×10^7	-	-	-	-	-	-
June '63	-	73	-	28.5	<1	1.1×10^7	-	-	Neg	4.5	-	-
July '63	-	-	-	-	-	-	-	-	1b	5.45	-	-
Oct. '63	-	-	-	-	<1	1.6×10^2	Yes	No	-	5.80	-	-
Jan. '64				28.6		200		Yes		6.1		

Note: 1. During the week of 10 March 1963, 32 gal of IS JP-4 fuel, 5.52 g of Santolene C, 8 gal of IS water bottom, and 111.0 g of 6-acetoxy-2, 4-dimethyl-M-dioxane (0.1 percent) were introduced into the drum.
2. The 1b value for copper corrosion designates an ASTM standard.
3. Hyphens signify that no data were available.
4. Blank spaces indicate that no data were taken.

Table XXXVI. Static Drum Investigation, Drum No. 28

Analysis Date	WSIM JP-4 Fuel vs:		IFT (dynes/cm) JP-4 Fuel vs:		Microbial Count (colonies/ml)		Fungus		Cu Corrosion	pH	Anti-Icing Additive (%)	
	Distilled Water	TWB	Distilled Water	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB
Mar. '63	-	69	-	26.8	<1	4.7×10^8	-	-	Neg	-	0.04	-
June '63	-	57	-	28.8	<1	1.2×10^8	-	-	Neg	4.9	0.04	6.0
July '63	-	46	-	30.3	<1	1.6×10^8	-	-	-	5.45	0.04	6.0
Oct. '63	-	55	-	31.8	1	8.5×10^2	Yes	Yes	-	5.70	-	-
Jan. '64				29.9	1	1,580	Yes	Yes		6.0		

Note: 1. On 18 March 1963, 32 gal of IS JP-4 fuel, 5.52 g of Santolene C, 8 gal of IS water bottom, and 605.6 ml of Phillips 55 MB (2.0 percent water bottom by volume) were introduced into the drum.
2. Hyphens signify that no data were available.
3. Blank spaces indicate that no data were taken.

Table XXXVII. Static Drum Investigation, Drum No. 29

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) JP-4 Fuel	Microbial Count (colonies/ml) TWB	Fungus JP-4 Fuel	Fungus TWB	Cu Corrosion JP-4 Fuel	pH TWB	Anti-Icing Additive (%) JP-4 Fuel	Anti-Icing Additive (%) TWB
Mar. '63	-	63	-	26.9	<1	8.6×10^8	-	-	Neg	-	0.04	-
June '63	-	62	-	28.3	<1	1.9×10^8	-	-	Neg	4.6	0.04	8.0
July '63	-	-	-	27.4	<1	1.6×10^8	-	-	-	5.60	0.05	8.0
Oct. '63	-	-	-	-	<1	7.5×10^2	Yes	Yes	-	6.00	-	-
Jan. '64		96		28.6	<1	1,020	Yes	Yes		6.0		

Note: 1. On 18 March 1963, 32 gal of IS JP-4 fuel, 5.52 g of Santolene C, 8 gal of IS water bottom, and 1.514 liters of Phillips 55 MB (5.0 percent water bottom by volume) were introduced into the drum.

2. Hyphens signify that no data were available.

3. Blank spaces indicate that no data were taken.

Table XXXVIII. Static Drum Investigation, Drum No. 30

Analysis Date	WSIM JP-4 Fuel vs:		IFT (dynes/cm) JP-4 Fuel vs:		Microbial Count (colonies/ml)		Fungus		Cu Corrosion	pH	Anti-Icing Additive (%)	
	Distilled Water	TWB	Distilled Water	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB
Mar. '63	-	61	-	24.3	<1	7.9×10^8	-	-	Neg	-	0.06	-
June '63	-	63	-	26.2	<1	1.3×10^8	-	-	Neg	4.7	0.10	18.0
July '63	-	-	-	28.7	<1	1.6×10^8	-	-	-	5.65	0.08	16.3
Oct. '63	-	-	-	-	<1	2.7×10^2	Yes	Yes	-	5.90	-	-
Jan. '64				28.5	<1	890	Yes	Yes		6.0		

Note: 1. On 18 March 1963, 32 gal of IS JP-4 fuel, 5.52 g of Santolene C, 8 gal of IS water bottom, and 4.542 liters of Phillips 55 MB (15 percent water bottom by volume) were introduced into the drum.
2. Hyphens signify that no data were available.
3. Blank spaces indicate that no data were taken.

Table XXXIX. Static Drum Investigation, Drum No. 31

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) JP-4 Fuel	Microbial Count (colonies/ml) TWB	Fungus JP-4 Fuel	Fungus TWB	Cu Corrosion JP-4 Fuel	pH TWB	Anti-Icing Additive (%) JP-4 Fuel	Anti-Icing Additive (%) TWB
Mar. '63	-	77	-	20.7	<1	2.1×10^9	-	-	Neg	-	0.11	-
June '63	-	72	-	21.9	<1	7.0×10^7	-	-	Neg	4.7	0.15	30.0
July '63	-	-	-	23.3	<1	3.2×10^8	-	-	1b	5.70	0.14	30.0
Oct. '63	-	90	-	26.3	<1	3.8×10^2	Yes	Yes	-	5.90	-	-
Jan. '64		96		25.6	<1	170	Yes	Yes		6.0		

Note:
1. On 18 March 1963, 32 gal of IS JP-4 fuel, 5.52 g of Santolene C, 8 gal of IS water bottom, and 7.57 liters of Phillips 55 MB (25 percent water bottom by volume) were introduced into the drum.
2. The 1b value for copper corrosion designates an ASTM standard.
3. Hyphens signify that no data were available.
4. Blank spaces indicate that no data were taken.

Table XL. Static Drum Investigation, Drum No. 32

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) JP-4 Fuel	Microbial Count (colonies/ml) TWB	Fungus JP-4 Fuel	Fungus TWB	Cu Corrosion JP-4 Fuel	pH TWB	Anti-Icing Additive (%) JP-4 Fuel	Anti-Icing Additive (%) TWB
Mar. '63	-	48 & 56	-	25.9	<1	1.8×10^9	-	-	Neg	-	-	-
June '63	-	44	-	27.2	<1	1.1×10^8	-	-	Neg	4.6	-	-
July '63	-	73	-	27.7	<1	1.1×10^8	-	-	1b	5.60	0.04	-
Oct. '63	-	76	-	32.1	<1	1.3×10^3	No	Yes	-	6.00	-	-
Jan. '64				31.5	<1	1,350	Yes	Yes		6.1		

Note: 1. On 18 March 1963, 32 gal of IS JP-4 fuel, 5.52 g of Santolene C, 8 gal of IS water bottom, and 90 mg (1 ppm) of sulfonate were introduced into the drum.
2. The 1b value for copper corrosion designates an ASTM standard.
3. Hyphens signify that no data were available.
4. Blank spaces indicate that no data were taken.

Table XLI. Static Drum Investigation, Drum No. 33

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) JP-4 Fuel	Microbial Count (colonies/ml) TWB	Fungus JP-4 Fuel	Fungus TWB	Cu Corrosion JP-4 Fuel	pH TWB	Anti-Icing Additive (%) JP-4 Fuel	Anti-Icing Additive (%) TWB
Mar. '63	-	63	-	27.7	<1	2.6×10^9	-	-	Neg	-	-	-
June '63	-	55	-	27.4	<1	1.8×10^8	-	-	Neg	4.5	-	-
July '63	-	67	-	27.8	<1	1.1×10^8	-	-	1b	5.40	0.04	-
Oct. '63	-	57	-	29.1	<1	2.2×10^3	Yes	Yes	-	5.90	-	-
Jan. '64				32.0	<1	1,300	Yes	Yes		6.1		

Note:
1. On 18 March 1963, 32 gal of IS JP-4 fuel, 5.52 g of Santolene C, 8 gal of IS water bottom, and 1.8 g (20.0 ppm) of naphthanate were introduced into the drum.
2. The 1b value for copper corrosion designates an ASTM standard.
3. Hyphens signify that no data were available.
4. Blank spaces indicate that no data were taken.

Table XLII. Static Drum Investigation, Drum No. 34

Analysis Date	WSIM JP-4 Fuel vs:		IFT (dynes/cm) JP-4 Fuel vs:		Microbial Count (colonies/ml)		Fungus		Cu Corrosion	pH	Anti-Icing Additive (%)	
	Distilled Water	TWB	Distilled Water	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB
Mar. '63	-	68	-	22.9	<1	8.0×10^8	-	-	Neg	-	-	-
June '63	-	59	-	33.4	<1	2.1×10^8	-	-	Neg	4.9	-	-
July '63	-	-	-	33.5	7	1.3×10^8	-	-	Neg	5.25	0.04	-
Oct. '63	-	56	-	30.6	<1	1.5×10^3	Yes	Yes	-	6.00	-	-
Jan. '64				33.6	<1	1,660	Yes	Yes		5.8		

Note: 1. During the week of 10 March 1963, 32 gal of Kindley AFB (Maytag) JP-4 fuel, 5.52 g of Santolene C, 1.6 gal of sea water, and 6.4 gal of distilled water were introduced into the drum.
2. Hyphens signify that no data were available.
3. Blank spaces indicate that no data were taken.

Table XLIII. Static Drum Investigation, Drum No. 35

Analysis Date	WSIM JP-4 Fuel vs: Distilled Water	WSIM JP-4 Fuel vs: TWB	IFT (dynes/cm) JP-4 Fuel vs: Distilled Water	IFT (dynes/cm) JP-4 Fuel vs: TWB	Microbial Count (colonies/ml) JP-4 Fuel	Microbial Count (colonies/ml) TWB	Fungus JP-4 Fuel	Fungus TWB	Cu Corrosion JP-4 Fuel	pH TWB	Anti-Icing Additive (%) JP-4 Fuel	Anti-Icing Additive (%) TWB
Mar. '63	57	n. a.	31.4	n. a.	<1	n. a.	-	n. a.	Neg	-	-	n. a.
June '63	58	n. a.	31.5	n. a.	<1	n. a.	-	n. a.	Neg	-	0.06	n. a.
July '63	65	n. a.	29.8	n. a.	2	n. a.	-	n. a.	1b	-	0.06	n. a.
Oct. '63	-	n. a.	29.6	n. a.	25	n. a.	Yes	n. a.	-	-	-	n. a.
Jan. '64	48		29.2		2		Yes					

Note:
1. During the week of 10 March 1963, 40 gal of Kindley AFB (Maytag) JP-4 fuel and 6.9 g of Santolene C were introduced into the drum.
2. The 1b value for copper corrosion designates an ASTM standard.
3. n. a. signifies not applicable.
4. Hyphens signify that no data were available.
5. Blank spaces indicate that no data were taken.

Table XLIV. Static Drum Investigation, Drum No. 36

Analysis Date	WSIM JP-4 Fuel vs:		IFT (dynes/cm) JP-4 Fuel vs:		Microbial Count (colonies/ml)		Fungus		Cu Corrosion	pH	Anti-Icing Additive (%)	
	Distilled Water	TWB	Distilled Water	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB	JP-4 Fuel	TWB
Mar. '63	77	n. a.	37. 6	n. a.	<1	n. a.	-	n. a.	Neg	-	-	n. a.
June '63	74	n. a.	31. 6	n. a.	<1	n. a.	-	n. a.	Neg	-	-	n. a.
July '63	77	n. a.	28. 7	n. a.	4	n. a.	-	n. a.	1a	-	0. 05	n. a.
Oct. '63	78	n. a.	27. 5	n. a.	20	n. a.	No	n. a.	-	-	-	n. a.
Jan. '64			26. 2		<1		Yes					

Note:
1. During the week of 10 March 1963, 40 gal of Kindley AFB (Maytag) JP-4 fuel were introduced into the drum.
2. The 1a value for copper corrosion designates an ASTM standard.
3. n. a. signifies not applicable.
4. Hyphens signify that no data were available.
5. Blank spaces indicate that no data were taken.

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