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Equipment to Neutralize Aircraft Fuel Spills

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(AIR FORCE SYSTEMS COMMAND)
TYNDALL AIR FORCE BASE
FLORIDA 32403

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This report describes the selection of types and sizes of equipment for the neutralization of "small" and "other" type fuel spills. Additionally, it deals with the procurement of subject equipment and materials; and, evaluates, on a competitive basis, for application to collection, neutralization, and fabrication of various size fuel spills. Maximum use was made of US Army Mobility Equipment Research and Development Command's in-house facilities to design, assemble, fabricate, and test a pilot model system as described in the report.

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FOREWORD

This report was prepared by Detachment 1 (CEEDO) HQ ADTC (AFSC), Tyndall AFB FL 32403, under Job Order 414N1004. It is based on information contained in US Army Mobility Equipment Research and Development/DRDME-GE Final Letter Report - NEUTRALIZATION OF DOD AIRCRAFT FUEL SPILLS - PHASE II, dated 23 Sep 1977.

This report summarizes work done between Sep 1976 and Sep 1977. Mr Lee R. Munroe, CEEDO/CNE, was the project officer.

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

This technical report has been reviewed and is approved for publication.

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SECTION I

INTRODUCTION

A Military Interdepartmental Purchase Request (MIPR) from the Department of Defense (DOD) Aircraft Ground Fire Suppression and Rescue Systems Program Office (AGFSRSPO), Wright-Patterson Air Force Base, Ohio, was issued to provide for a study concerning the evaluation of alternative methods for neutralization of fuel spills. This study was conducted during the period December 1974 through 30 June 1975 by the Sanitary Sciences Division, Laboratory 2000, United States Army Mobility Equipment Research and Development Command (MERADCOM), Fort Belvoir, Virginia. Details and results of this study are shown in DOD AGFSRSPO Final Report No. DOD AGFSRS 76-2, "A Study to Evaluate the Intensity of and Alternative Methods for Neutralization of DOD Aircraft Fuel Spills - Phase I" by V. J. Cicone, Lt Col/MAS/US Army, and A. P. Graves, 1st Lt/ORD/US Army. This report concluded the following:

a. The frequency of occurrence and the quantity of fuel associated with aircraft fuel spills on military airfields are very significant in both terms of fuel lost and the potential impact upon the environment.

b. Spills in fueling and defueling operations can be considered in either of two categories; namely: "small" (less than four gallons) and "other" (greater than four gallons).

c. Washdown methods for small fuel spills are inefficient in terms of available resources and are unacceptable in terms of environmental impact.

d. Small spills are best neutralized through the use of dry absorbing materials, either granular or mat type products, and with the removal and proper disposal of the resultant fuel saturated material.

e. The standard water flush method is the best approach for the larger or "other" type fuel spills. Sometimes the use of foaming or other fire suppression agents is required with this method. A drainage type or other collection system is needed to gather the spilled fuel and to prevent contamination of the storm sewer system by the spilled fuel.

f. There are no established DOD guidelines for neutralization of fuel waste generated from aircraft ramp services activities. A tentative Environmental Protection Agency (EPA) guideline draft for the air transportation industry has been prepared. Should this draft be adopted, its contents will apply to the DOD to include the problems considered by this study.

SECTION II

DISCUSSION

1. The overall program was designed to be accomplished in two phases. As has been previously stated, the first phase was completed and reported in Final Report DOD AGFSRS 76-2.

a. Objectives of Phase I were as follows:

(1) Define the magnitude of the fuel spill problem in terms of fuel volume, frequency of occurrence, and specific sites of occurrence.

(2) Assemble a list of currently available alternative techniques that may be used to neutralize both the operational hazard and the environmental impact of fuel spills.

(3) Examine the practicality, feasibility, and cost effectiveness of alternatives available for collection, treatment, and/or neutralization of fuel pools resulting from accidental fuel spills at airfields.

(4) Define and examine available physical, physical-chemical, and chemical unit processes, to determine their respective performance characteristics and potential for application in the neutralization of the fuel spills.

b. The performing organization for Phase II was Engineering Division, Energy and Water Resources Laboratory, Mobility Equipment Research and Development Command (MERADCOM), Fort Belvoir VA. Objectives of Phase II were as follows:

(1) Investigation into the application of absorbent materials for fuel recovery.

(2) Procurement of materials and equipment for absorption of small ground spills.

(3) Collection of fuel spills larger than four gallons.

(4) Removal of spilled fuel from the absorbent material.

(5) Separation of the fuel from water waste.

These objectives would most certainly involve comparative tests of the materials and equipment procured.

2. In this, the second phase, the program effort was directed toward the following goals:

a. Proper selection of types and sizes of equipment and materials.

b. Procurement of subject equipment, materials, and evaluation on a competitive basis, regarding application to collection and neutralization of various size fuel spills.

c. Maximum use of in-house facilities to design, assemble, and fabricate a pilot model system.

d. Operational testing sufficient to assure that the fabricated items will fulfill "user requirements."

e. Preparation of assembly drawings and parts lists.

3. During the laboratory part of this work, various types of absorbent materials were tested (see Appendix A) to determine the efficiency of each type on JP-4 fuel spills. Through use of test results, the average absorption capacities in grams of fuel per gram of absorbent were determined to be the following:

a. Vegetable fiber composition pads; 11.2 grams JP-4 per gram of absorbent. This translates to a surface absorption of 0.43 gram JP-4/cm^2 for a 1/4-inch thick pad and a volumetric absorption of 0.6784 gram JP-4/cm^3.

b. Polypropylene composition pads; 3.8 grams JP-4 per gram of absorbent. This translates to a surface absorption of 0.1462 gram JP-4/cm^2 for a 1/4-inch thick pad and a volumetric absorption of 0.2302 gram JP-4/cm^3.

c. Mineral composition granular material; 0.93 gram JP-4 per gram of absorbent. This material could not be translated to surface or volumetric absorption values for obvious reasons, such as physical configurations and voids.

4. A limited funding program was presented to develop a system that could be readily and economically duplicated using commercial equipment where feasible. An arrangement was developed using a three skid concept designed for use on the bed of a 3/4-ton truck. The first skid (see Figures 1, 2, and 3) is used to pick up the small spills (up to four gallons). This skid is provided with three storage cases of sufficient size to be compatible with four-gallon fuel spills. One storage case holds the dry granular material; another, the dry matte material; and the other, the damp matte material. Additionally, a 55-gallon drum, with a manually operated wringer for removal and storage of the liquid and damp material from the saturated mat pads, is mounted on the skid. Most of the granular material collects in the bottom of the 55-gallon drum. The rest of the granular material remains with the damp matte material. The damp mattes can be dried and reused several times. However, on each reuse the absorption capacities are less than they were on the preceding use.

5. The second skid (see Figures 4, 5, and 6) is designed for recovery of fuel spills larger than four gallons. This skid contains a gasoline engine driven, high air volume capacity compressor with air reservoir tank, a 55-gallon vacuum cleaner, and all the necessary safety connections. The spilled fuel, after vacuum pickup, is stored until pumped to the oil/ water separator. The vacuum cleaner is designed to work on any open top 55-gallon drum in order to allow for those cases where spills exceed the 55-gallon vacuum cleaner capacity.

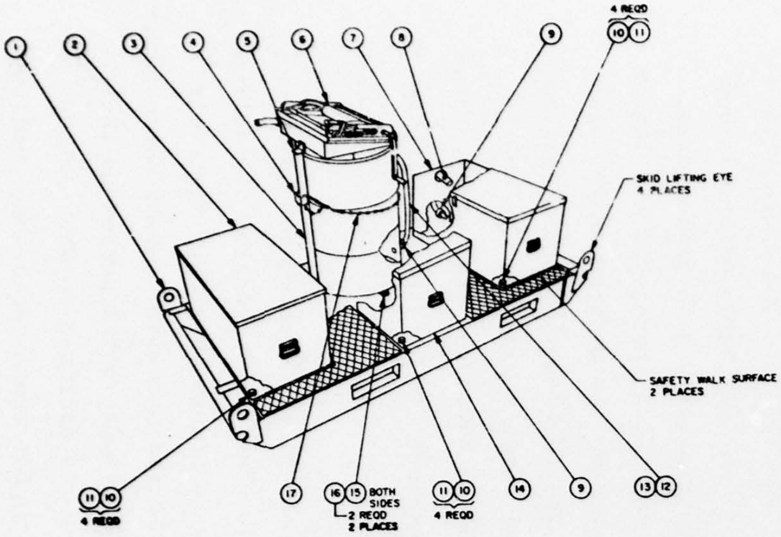

FIGURE 1

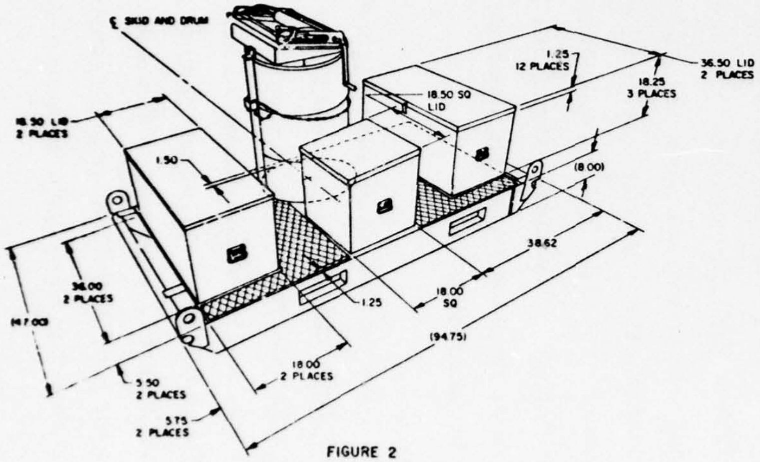

FIGURE 2

PRELIMINARY
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FIND NO	FSCM	DWG SIZE	PART OR IDENTIFYING NO	QTY REQD	NOMENCLATURE OR DESCRIPTION	SPECIFICATION	MATERIAL
17				1	CHAIN DRUM RETAINER GALV 2 25 TWIST LINK		STEEL
16			MS35190-257	4	SCREW, FLAT HD 82°, .164-32 UNC-2A X 1.00 L		
15				2	BAR, .50 X .75 X 1.50 LG		AL ALY
14				1	BOX, HINGED WITH LATCH AND HANDLES, .090 STK (STORAGE)		AL ALY
13				1	CLAMP, LOOP TYPE (HOSE RETAINING)		
12				1	HOSE, LOW PRESSURE, .875 ID (DRUM DRAIN)		RUBBER
11			MS35338-44	12	WASHER LOCK, .250 NOM SIZE		
10			MS90725-3	12	SCREW, CAP, .250-20 UNC-2A X .50 L		
9				2	CLAMP, HOSE		CRES
8				1	HOSE, LOW PRESSURE, .875 ID (WET BOX DRAIN)		RUBBER
7				1	BOX, HINGED WITH LATCH AND HANDLES, .090 STK (WET)		AL ALY
6			WHITE TW 1-8	1	WRINGER WITH HAND CRANK		AL ALY
5				1	WRINGER AND DRUM ADAPTER, .090 STK		AL ALY
4				1	CHANNEL, CHAIN LOCK 3 X 1.42 LBS FT STK		AL ALY
3				1	ANGLE, DRUM SUPPORT 2 X 2 X .25 STK		AL ALY
2				1	BOX, HINGED WITH LATCH AND HANDLES, .090 STK (DRY)		AL ALY
1				1	SKID		AL ALY

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RESEARCH AND DEVELOPMENT COMMAND
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SKID, FUEL SPILLS
DRUM AND WRINGER

SIZE A1 CODE 97403 DWG NO SK 4000.176-01

Figure 1 - Skid, Fuel Spills Drum and Wringer, Preliminary Drawing No SK 4000.178-01

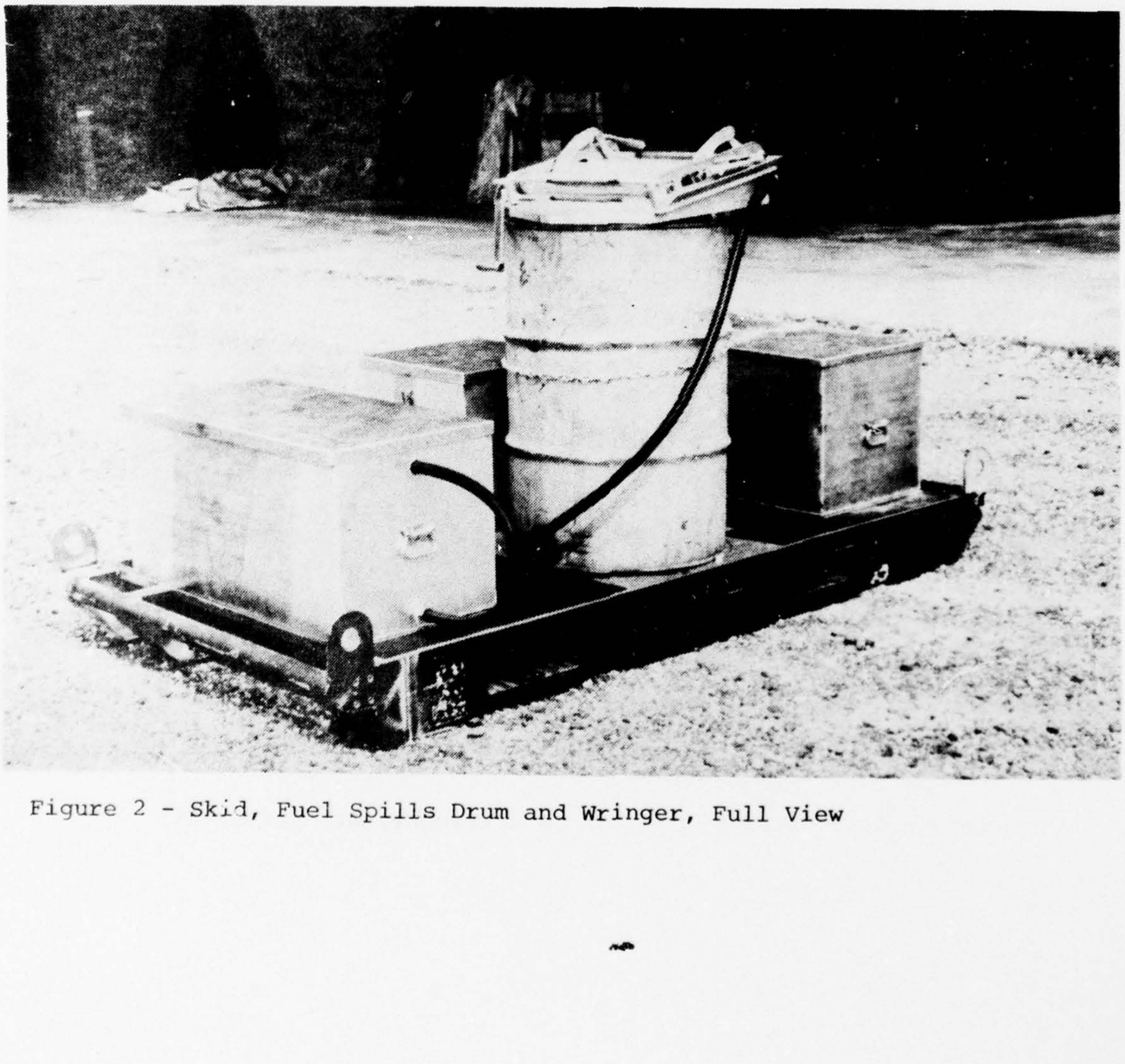

Figure 2 - Skid, Fuel Spills Drum and Wringer, Full View

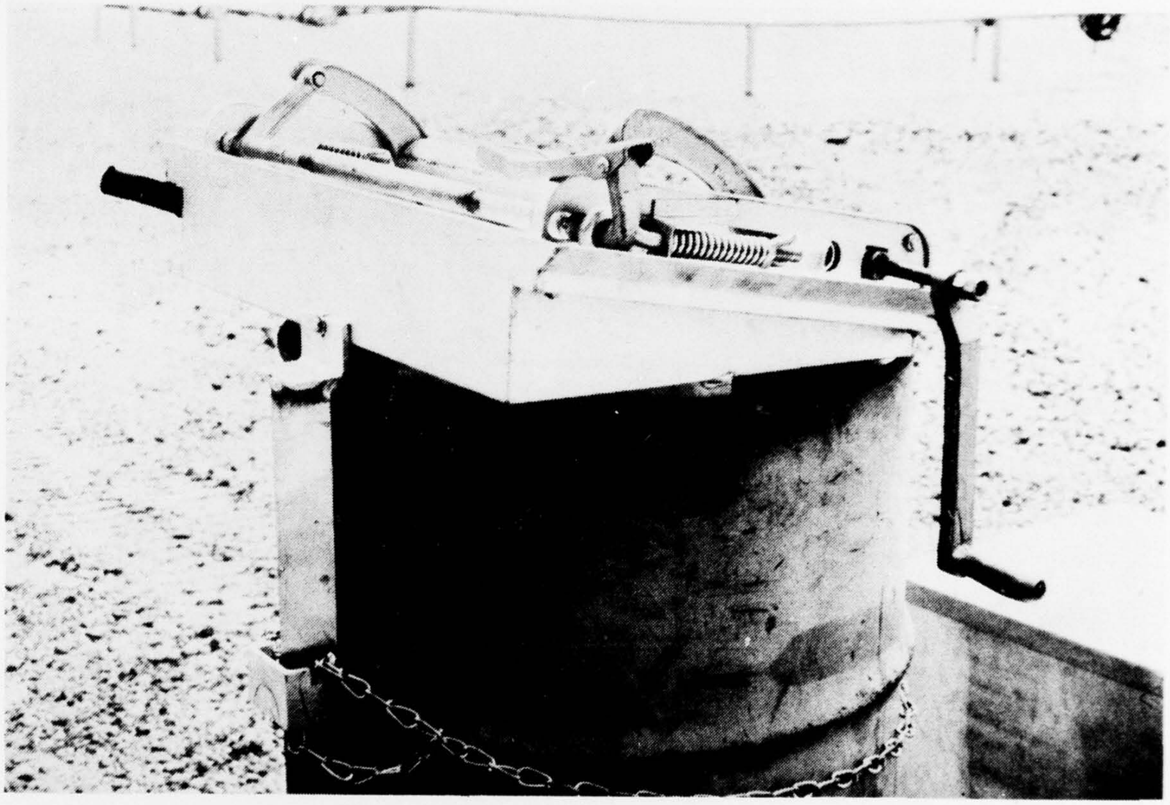

Figure 3 - Skid, Fuel Spills Drum and Wringer, Wringer Detail

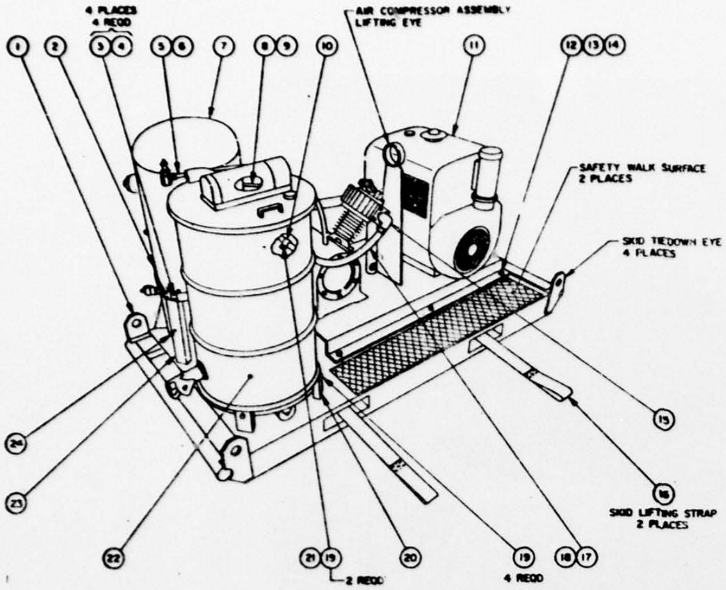

FIGURE 1

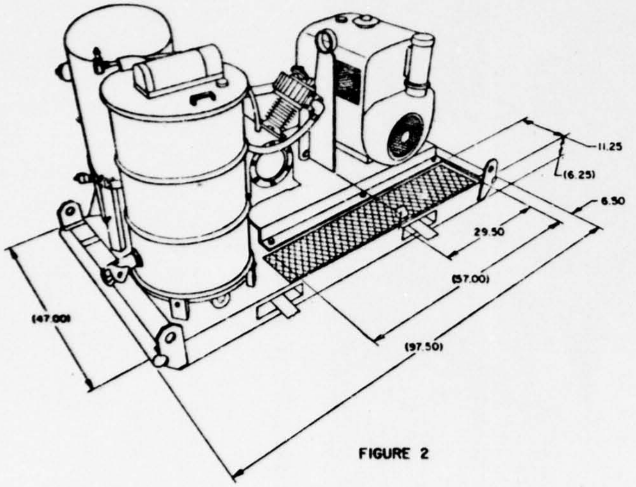

FIGURE 2

PRELIMINARY
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FIND NO	FSCM	DWG SIZE	PART OR IDENTIFYING NO	QTY REQD	NOMENCLATURE OR DESCRIPTION	SPECIFICATION	MATERIAL
24			MS90726-119 MODIFIED	4	SCREW, CAP, .500-20 UNF-2A X 3.00 L WITH SCREW PAD		
23				4	CHANNEL, AIR TANK SUPPORT, WITH GUSSET, 3.00 IN X 1.42 LBS FT X 18.00 L		AL ALY
22	08400		MODEL 55-1-AS	1	VAC-U-MAX, 55 GAL		
21			MS51967-2	2	NUT, PLAIN, .250-20 UNC-2B		
20				4	CHANNEL VACUUM TANK SUPPORT 3.00 IN X 1.42 LB FT X 6.00 IN L		AL ALY
19			MS90725-8	6	SCREW, CAP, .250-20 UNC-2A X 1.00 L		
18				1	BUSHING, PIPE, 2 IN MALE TO 1 1/2 FEMALE GALV		STEEL
17	87373		7010808-24-24-24-50	1	HOSE ASSEMBLY, 1.375 ID X 50.00 L JIC 37° STRAIGHT SWIVEL BOTH ENDS		
16	39428		34035 TYPE 44	2	WEB BELT SLINGS 2.00 WIDTH X 144.00 L, 2400 WORKING LOAD		NYLON
15	87373		2103-24-24	2	ELBOW, 90° MALE PIPE TO MALE JIC 37°, 1 1/2-11 NPT X 1 7/8-12		
14			MS51922-37	6	NUT SELF LOCKING, .500-20 UNF-2B		
13			MS27183-18	6	WASHER, FLAT, .531 BASIC ID		
12			MS90726-114	6	SCREW CAP, .500-20 UNF-2A X 1.75 L		
11	24047 30029		ADR 1014-MOD 5618	1	AIR COMPRESSOR ASSEMBLY, SKID MOUNTED, GED, HAND START, GARDNER DENVER COMPRESSOR MODEL ADR, WISCONSIN MOTOR, AIR COOLED MODEL VH4D, UNLOAD VALVE AND ACCESSORIES BASE MODIFIED WITH LIFTING EYE		
10				1	CLAMP, HOSE SUPPORT, 2.00 WIDE .125 STK		AL ALY
9	87373		0103-8-8	2	ADAPTER STRAIGHT, 1/2 MALE PIPE X 1/2 MALE JIC 37°, 1/2-14 NPT X 3/4-16		
8	87373		R310637-8-8-8-16	1	HOSE ASSEMBLY, .500 ID X 16.00 L, 37° JIC STRAIGHT SWIVEL X ELBOW 45° SWIVEL		
7	04861		68H15	1	TANK AIR WITH 0-300 PSI GAGE, RELIEF VALVE AND DRAIN COCK		
6	87373		0103-4-4	2	ADAPTER STRAIGHT, 1/4 MALE PIPE X 1/4 MALE JIC 37°, 1/4-18 X 7/16-20		
5				1	HOSE ASSEMBLY, .250 ID X 41.00 L, 37° JIC STRAIGHT SWIVEL X ELBOW 90° SWIVEL		
4			MS35338-44	16	WASHER, LOCK, .250 NOM SIZE		
3			MS90725-3	16	SCREW CAP, .250-20 UNC-2A X .500 L		
2				4	CLAMP, BAND AIR TANK, .125 STK 2.00 W		AL ALY
1				1	SKID		AL ALY

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SKID, FUEL SPILLS
VACUUM PICK UP

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Figure 4 - Skid, Fuel Spills Vacuum Pick Up, Preliminary Drawing No. SK 4000, 178-02.

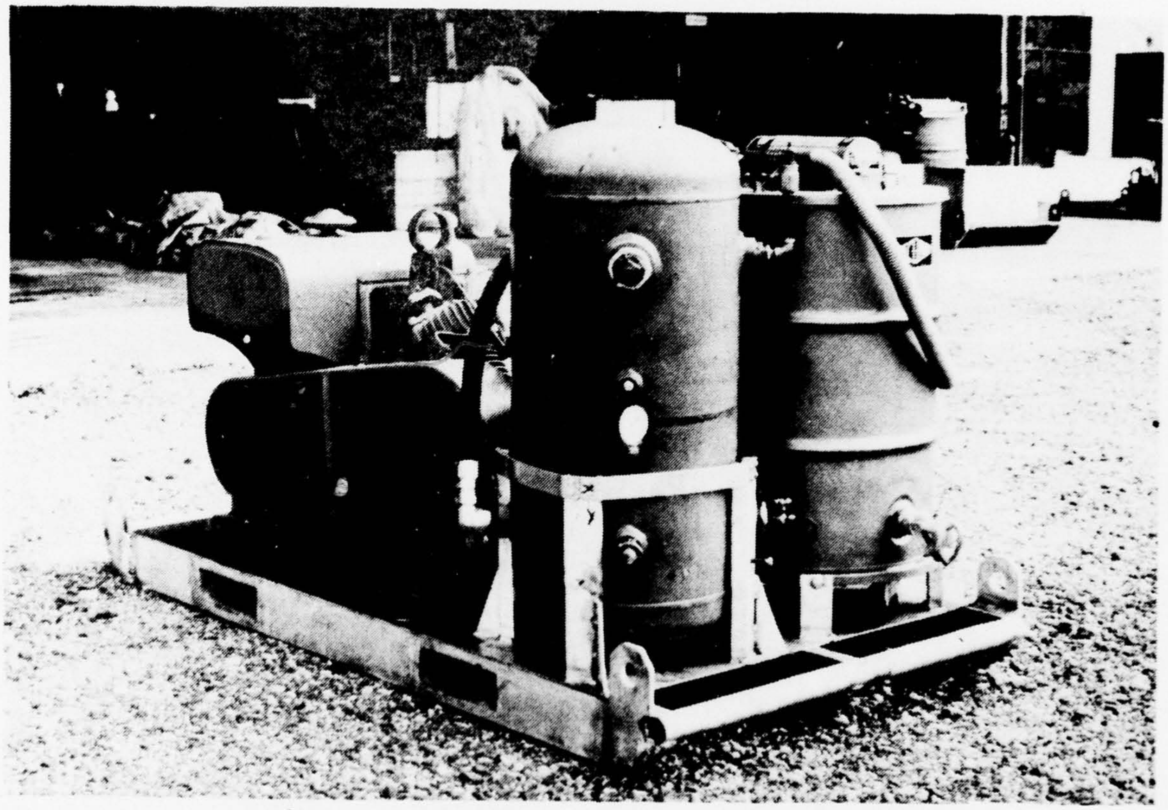


Figure 5 - Skid, Fuel Spills Vacuum Pick Up, Right Side View

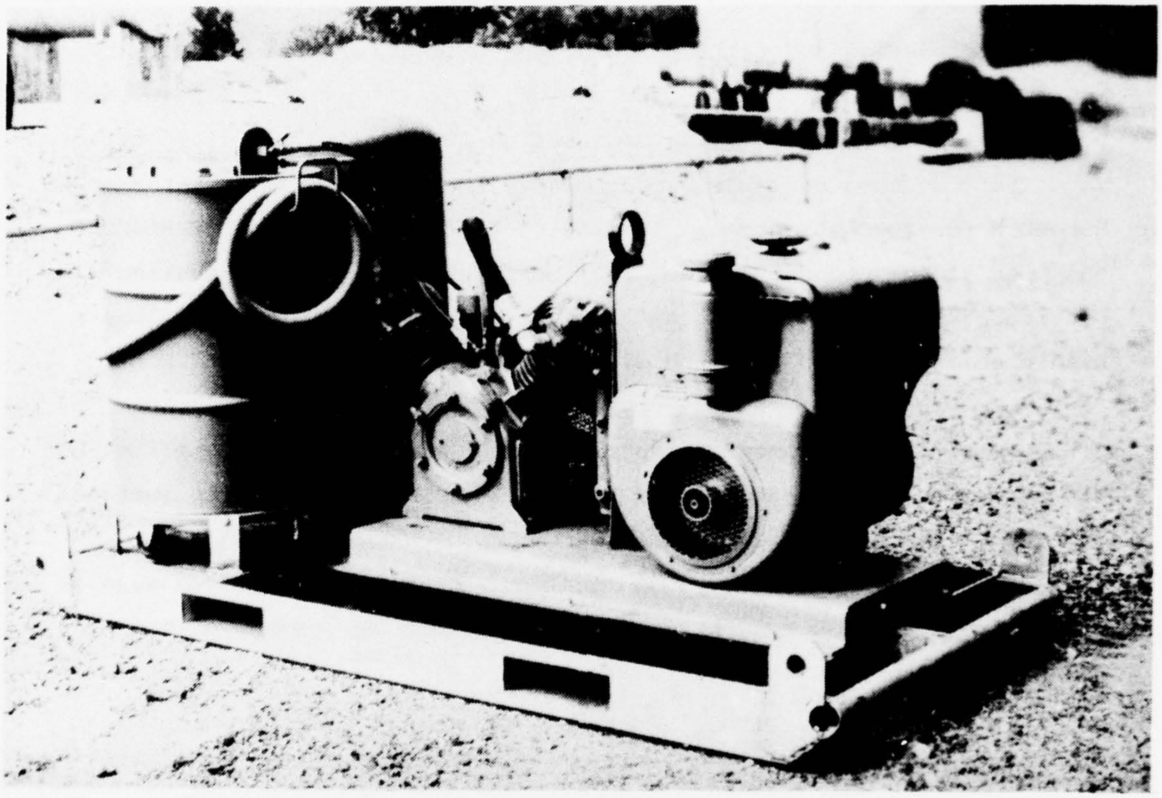


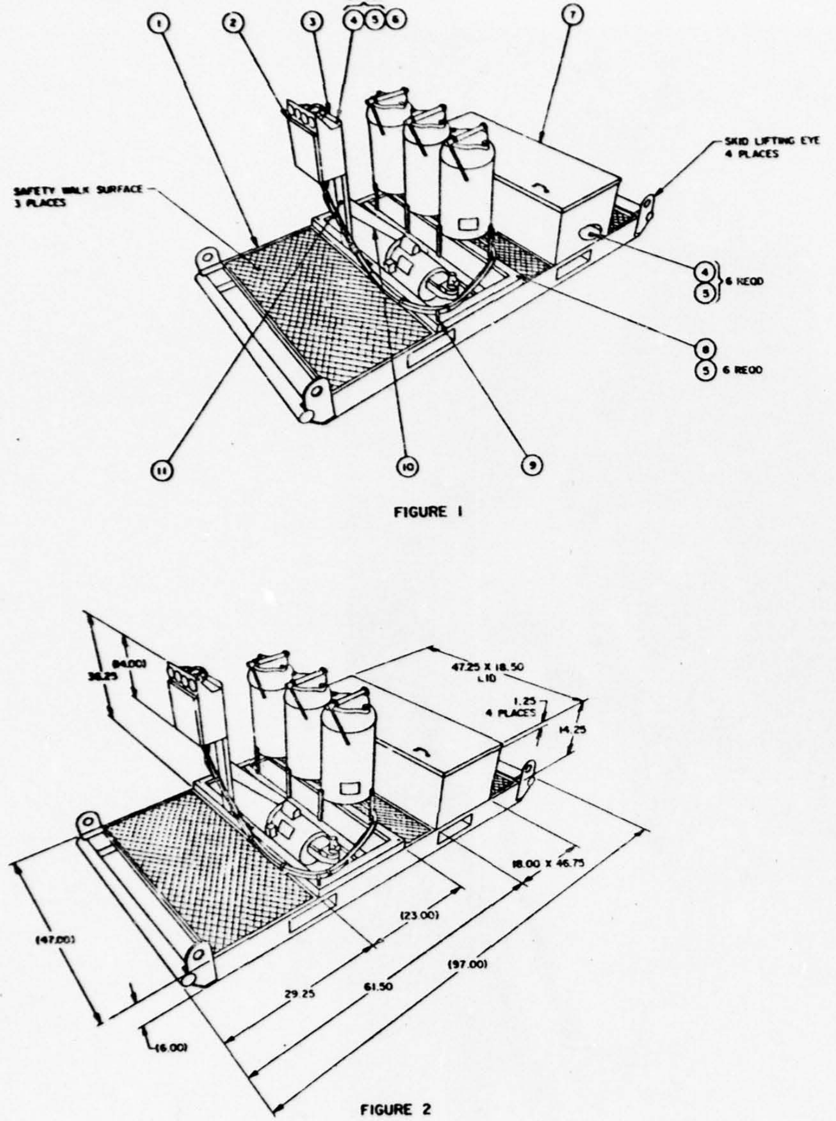
Figure 6 - Skid, Fuel Spills Vacuum Pick Up, Left Side View

6. The third skid (see Figures 7, 8, and 9) contains an oil/water separator unit and a storage chest. The purpose of this unit is to separate the oil/water prior to discharge of water to the sewer system and recovery of the fuel for secondary purposes. Although this skid is of similar size as the other two skids, it is not intended for movement on the vehicle but rather for use at a rear fuel storage area where electrical power can be provided for the electric motor driving the pump.

7. Initial design and fabrication of the skid units were accomplished in-house at MERADCOM. Final fabrication, overall design drawings, and parts lists were done by Value Engineering Company (VECO), Alexandria VA. The completed unit was operationally tested at VECO and returned to MERADCOM for further action. Testing of the final system at MERADCOM has been limited to the "large" fuel spill skid since field testing was considered unnecessary with the "small" fuel spill unit and data has been previously amassed on the oil/water separator (see Appendix B).

8. Because of environmental restrictions, the "large" fuel spill skid was tested against a 10-gallon water spill on a level concrete surface. The vacuum readily sucked up the 10-foot-by-10-foot spill in three minutes using a squeegee type application. Upon being repeated several times, the test required the same amount of time for pickup of the spill.

9. The testing authorities considered electric shielding, insulating boots, flame (spark) arresting equipment, remote shutdown locations, and vapor proofing for the gasoline engine and electric motor as applicable, and discussed these considerations with VECO. Since the spill pick-up operations were in open areas, the length of vacuum pick-up hose permitted a safe distance between the gasoline engine and the spill, the picked-up spill liquid was stored in closed tanks, and the electric motor did not have to operate in the vicinity of the spill, the testers decided, in coordination with VECO, that none of the foregoing devices were essential to the safe operation of this system.



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FIND NO	[illegible]	DWG SIZE	PART OR IDENTIFYING NO	QTY REQD	NOMENCLATURE OR DESCRIPTION	SPECIFICATION	MATERIAL
11				1	SUPPORT, CHANNEL 3 IN. X 4.1 LBS FT STK		STEEL
10				1	GUSSET PLATE, .250 STK		STEEL
9				3	CLAMP, CABLE RETAINING, .281 MTG HOLE		
8			MS90725-17	6	SCREW CAP, .250-20 UNC-2A X 2.75 L		
7				1	BOX, .090 STK HINGED LID WITH LATCHES AND HANDLES		AL ALY
6			MS35649-2252	4	NUT PLAIN, .250-20 UNC-2B		
5			MS35338-44	16	WASHER LOCK, .250 NOM SIZE		
4			MS90725-3	10	SCREW CAP, .250-20 UNC-2A X .50 L		
3				1	MOUNTING PLATE, .1196 STK		STEEL
2	53910			1	SEPARATOR OIL WATER 5 GPM WITH SPARE PARTS AND FILTERS		
1				1	SKID		AL ALY

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SKID, FUEL SPILLS
WATER, OIL SEPARATOR

A1 97403 SK 4000.178-03

Figure 7 - Skid, Fuel Spills Water, Oil Separator, Preliminary Drawing No. 4000.178-03

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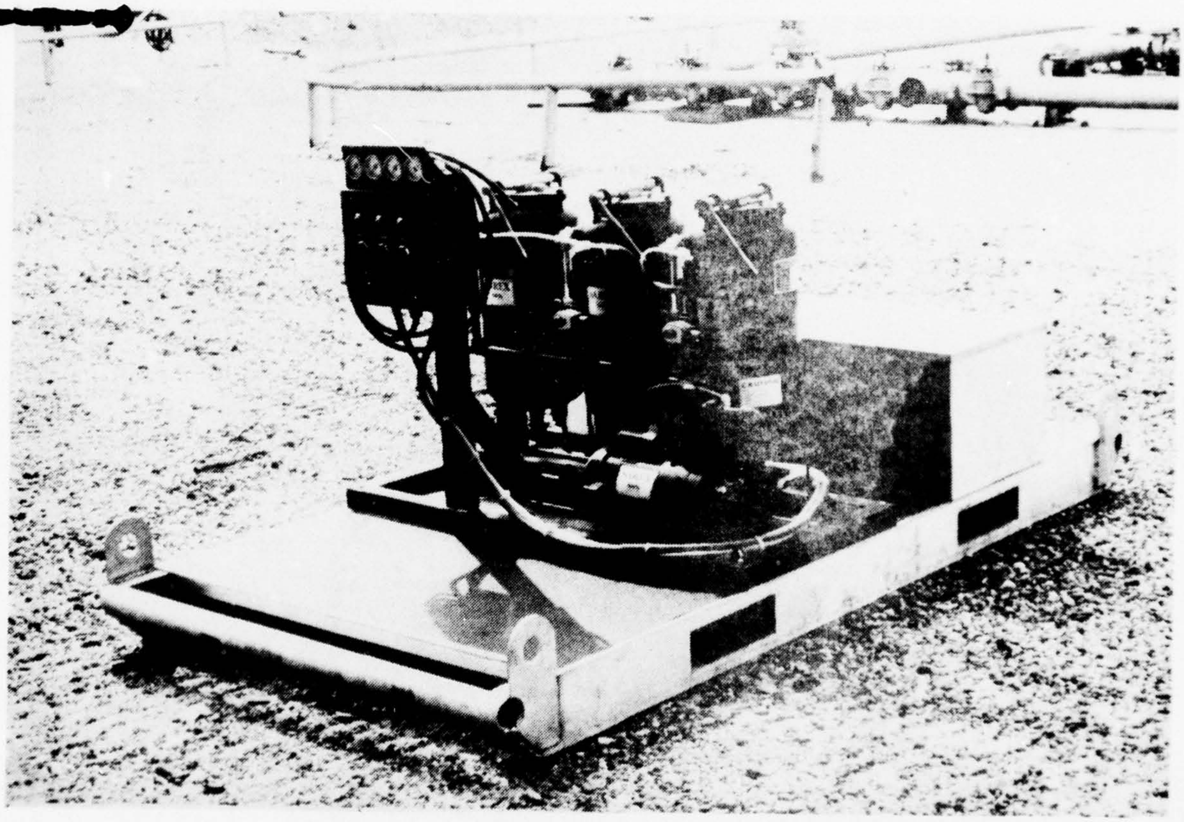

Figure 8 - Skid, Fuel Spills Water, Oil Separator, Front View

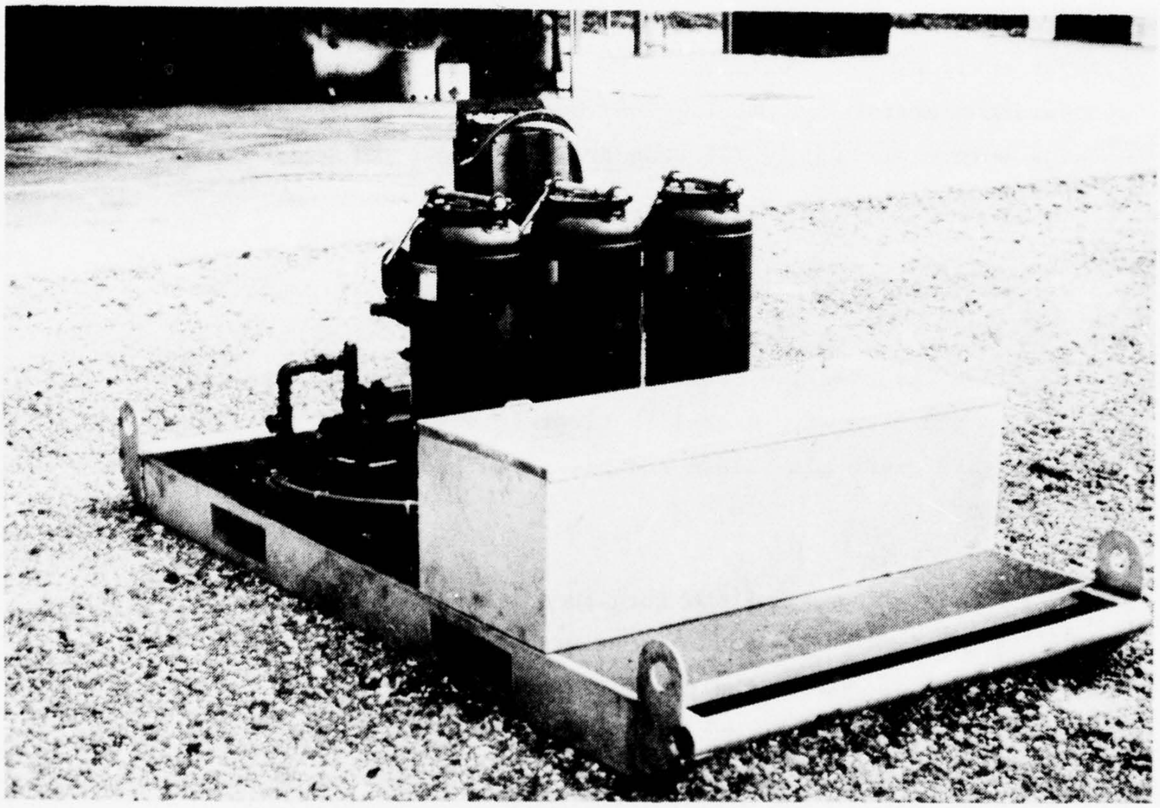

Figure 9 - Skid, Fuel Spills Water, Oil Separator, Rear View

SECTION III

CONCLUSIONS AND RECOMMENDATIONS

1. The system, as designed and tested for the recovery of aircraft fuel spills, performed satisfactorily. The system permits recovery of the fuel from runways and refueling areas, separation of the fuel from residual water, and release of the water to the drainage system without environmental pollution. The system can be assembled from standard commercial equipment. The vacuum system on the skid requires a large volume air supply (35 standard cubic feet per minute) for effective operation.

2. Recommendations for improvement of this system are as follows:

   a. That the gasoline engine driven, high air volume capacity compressor be replaced with a smaller electric start compressor which provides sufficient air volume and pressure to operate the air driven vacuum unit.

   b. That each skid unit be furnished with a lunette-eye type drawbar and mounted on a pneumatic-tired, four wheel frame for towing. This reasoning is due to the time element required to remove and replace the "small" skid on the truck with the "other" spill skid when unexpected large spills occur.

APPENDIX A

TEST PROCEDURES AND DATA FOR FUEL ABSORBENCY DETERMINATIONS

Investigations were made with JP-4 fuel on a laboratory bench scale basis using granular or matte absorbent pad materials.

The first determinations were made with 1/4-inch thick absorbent pads cut in 2-inch by 2-inch squares (26 cm 2). The squares were weighed dry and placed in a 3-inch diameter petri dish with cover. A weighed volume of JP-4 fuel greater than the maximum absorption capacity of the matte material was added to the dish and the cover replaced. The pad was kept under the fuel surface for 30 seconds and then held by tweezers on the open fuel layer and allowed to drain for 20, 30, or 45 seconds depending on test. The saturated drained pad was then transferred to another dry petri dish with cover and reweighed. The absorption capability of the pad was determined by weight and by surface area. The test data is presented below in Table A-1.

TABLE A-1. ABSORPTION OF JP-4 BY DRY MATTE MATERIAL

Sample No	Wt Dry Matte (gms)	Wt JP-4 Before Absorption (gms)	Wt JP-4 Absorbed (gms)	Absorption Capacity $\frac{\text{gms JP-4}}{\text{gms Matte}}$	Surface Absorption $\frac{\text{gms JP-4}}{\text{cm 2}}$	Drain Time Sec
1	1.576	25.115	14.730	9.346	0.5665	20
2	1.591	17.404	14.642	9.203	0.5631	20
3	1.423	24.833	14.168	9.956	0.5449	20
4	1.564	34.270	14.887	9.519	0.5726	20
5	1.470	29.383	13.773	9.369	0.5297	20
6	1.389	37.301	14.947	10.761	0.579	30
7	1.445	25.567	16.998	11.763	0.659	30

TABLE A-1. ABSORPTION OF JP-4 BY DRY MATTE MATERIAL (CONTINUED)

Sample No	Wt Dry Matte (gms)	Wt JP-4 Before Absorption (gms)	Wt JP-4 Absorbed (gms)	Absorption Capacity gms JP-4 / gms Matte	Surface Absorption gms JP-4 / cm 2	Drain Time Sec
8	1.480	36.957	15.582	10.528	0.604	30
9	1.310	21.034	13.311	10.101	0.516	30
10	1.246	34.496	13.067	10.487	0.506	30
11	1.543	32.343	14.237	9.227	0.552	45
12	1.307	29.628	13.908	10.641	0.539	45
13	1.498	37.508	15.264	10.190	0.591	45
14	1.296	23.362	14.328	11.056	0.555	20
15	0.869	25.003	11.724	13.491	0.454	20
16	1.150	22.407	13.989	12.164	0.542	20
17	1.101	41.957	13.865	12.593	0.533	30
18	1.107	27.827	13.446	12.146	0.517	30
19	0.982	33.288	12.513	12.742	0.481	30
20	0.998	20.526	12.937	12.999	0.498	45
21	0.737	24.251	11.190	15.183	0.430	45
22	1.001	27.595	13.584	13.570	0.522	45
23	3.847	43.762	14.853	3.861	0.571	20
24	3.883	28.749	14.382	3.704	0.553	20
25	3.808	31.201	14.518	3.813	0.558	20

The last three tests shown in Table A-1 were conducted using a polypropylene type matte. This gave considerably less absorption capability even though the surface absorption rate was the same.

With an average absorption of 0.5 gm JP-4/sq cm, it would require a minimum of 32 ft^2 to pick up a four-gallon spill.

A series of tests were made on granular absorbent material using JP-4 as the agent. The same arrangement of weighing and petri dishes was used except that the granular material was held on a mesh screen for liquid saturation and drainage before weighing. The test data is presented in Table A-2.

TABLE A-2. ABSORPTION OF JP-4 BY DRY GRANULAR MATERIAL

Sample No	Wt Granular Material gms	Wt JP-4 Before Absorption gms	Wt JP-4 Absorbent gms	Absorption Capacity gms/gm	Drain Time Sec
26	4.842	20.976	4.148	0.857	20
27	4.725	24.402	5.110	1.081	20
28	5.024	19.599	5.014	0.998	20
29	5.070	54.883	5.838	1.152	30
30	4.889	48.646	5.959	1.833	30
31	5.095	42.034	6.237	1.224	30
32	5.612	21.295	5.980	1.066	45
33	5.464	28.694	6.402	1.172	45
34	7.054	31.537	8.033	1.139	45
35	7.371	26.261	4.577	0.621	20
36	5.466	21.138	3.893	0.712	20
37	6.599	20.361	4.572	0.693	20
38	6.132	15.593	4.228	0.689	30
39	6.463	27.976	4.285	0.663	30
40	6.310	23.470	4.173	0.661	30
41	6.283	19.120	4.091	0.651	45
42	5.160	14.574	3.680	0.713	45
43	6.689	23.509	4.755	0.711	45

From the above data it would require 10.5 kilograms (23 lbs) of absorbent to pick up a 15.14 liter (four-gallon) spill (estimated 25 lbs or 11.3 kg).

APPENDIX B

STUDY TO DETERMINE FEASIBILITY OF USING A COALESCENCE-TYPE OIL-WATER SEPARATOR TO REMOVE JP-4 FUEL FROM WATER

1. INTRODUCTION.

a. Subject. This report covers tests conducted to determine the feasibility of using a five (5) GPM, coalescence-type oil-water separator to separate and remove various concentrations of JP-4 fuel from JP-4 - water mixtures. The quality of the effluent water was of prime importance in the overall evaluation.

b. Background. There is a need to develop techniques and equipment for use at military airfield fueling/defueling points to clean up accidental/incidental fuel spills that occur as a result of normal operations. It is essential that these spills be dealt with as quickly as possible as they may present a fire hazard when washed into sanitary or storm sewers, or have an adverse ecological impact when the fuels reach rivers, streams, ground water, etc. This type of pollution is prohibited by various Federal and State laws and regulations, as well as military regulations.

c. Description and Function of the Oil-Water Separator. The oil-water separator used in this study is a two-stage coalescence-type device with a prefilter stage manufactured by Separation and Recovery Systems, Inc. (SRS) to meet the requirements of Military Specifications MIL-S-52846 and MIL-S-52851 (ME). The separator consists of three skid-mounted 10-inch diameter by 32-inch high pressure vessels connected in series. Overall dimensions of the skid-mounted system are 62.5 inches long by 16.5 inches wide by 34 inches high. Approximate dry weight is

250 pounds (Figure B-1). The separator was equipped with a one-inch double diaphragm air-operated supply pump. A one-inch pipe in the first stage directs the influent through (inside to outside) a 6-inch diameter by 14-inch long expendable pre-filter/precoalescer element to remove and retain particulate matter from the influent and to separate and remove essentially all non-dispersed oil. The effluent from the prefilter stage is then directed through two coalescer stages connected in series containing 6-inch diameter by 11-inch long expendable coalescer elements. These stages coalesce the fine, dispersed oil droplets into oil drops large enough to separate from the water phase by gravity. The oil thus separated accumulates in an oil sump at the top of each of the three vessels where it is drained off periodically. Each vessel is equipped with a glass sight gage to show the oil level in the sumps. The prefilter and first coalescer stage are equipped with a capacitance-type probe that senses the oil-water interface and controls the automatic oil-discharge cycle. The final coalescer stage acts as a polishing stage and provides redundancy if there is gross failure in the first two stages. The vessels are also fitted with automatic air eliminators in their removable heads, pressure gages, and sampling valves between all stages.

2. EVALUATION TEST AND RESULTS.

a. Test Facilities. The evaluation tests were conducted in the USAMERDC Fuel Filter/Separator Test Facility in a test loop designed to accommodate the 5-GPM oil-water separator (Figure B-2). The test loop was composed of a 1,500-gallon collapsible rubber tank that serves as a reservoir for the test oil-water mixtures and system supply pump suction tank. Rubber hose of appropriate size with quick-disconnect couplings was used to connect the reservoir to the supply pump and then to the oil-water separator. A Fischer and Porter variable area-type flowrator, periodically calibrated, was installed in the test loop downstream from the test separator to indicate system flow rate in gallons per minute. Inline isokinetic sampling probes were located at

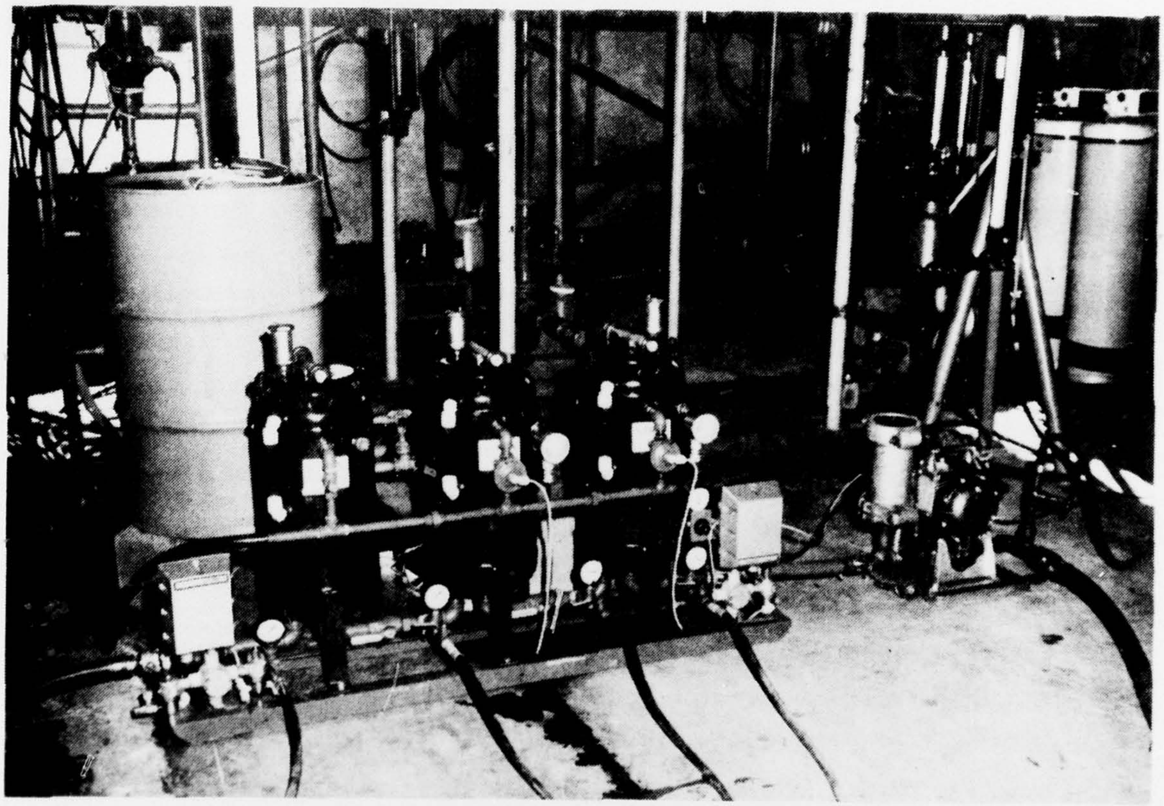

Figure B-1 - Five Gallons Per Minute Oil-Water Separator

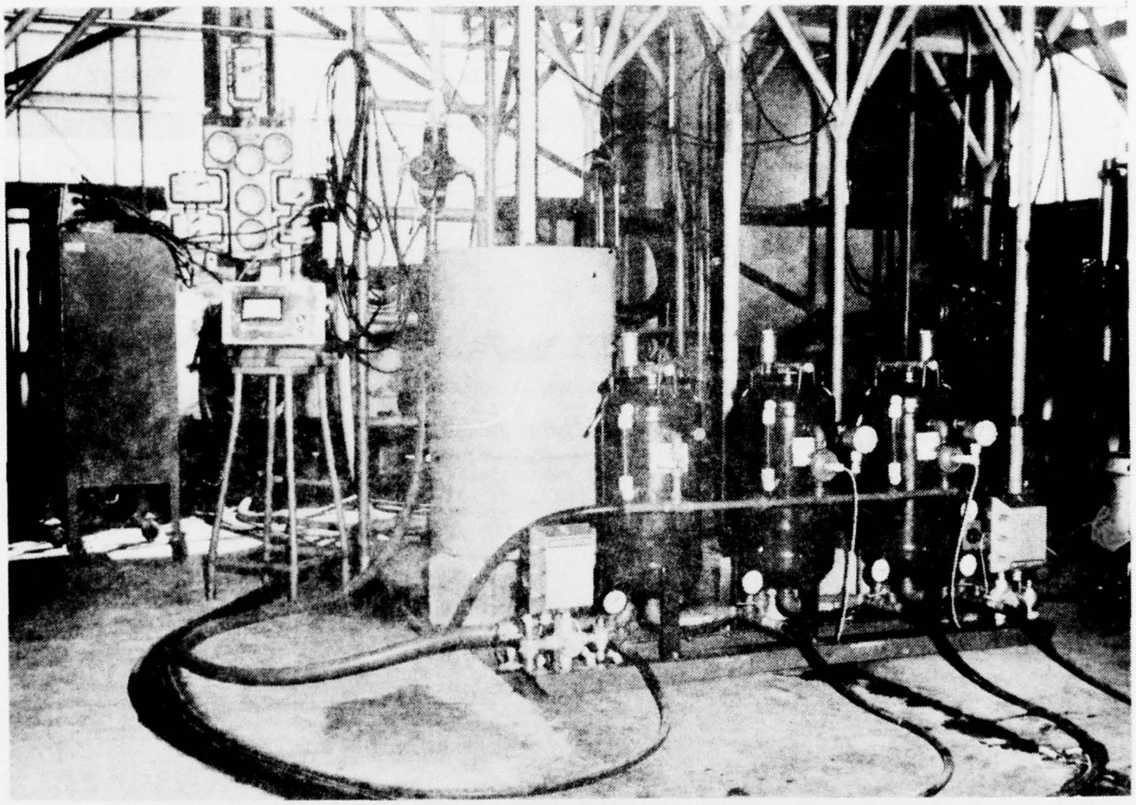

Figure B-2 - Oil-Water Separtator Test Loop various points in the test loop to gather bottled samples for laboratory analysis. Conventional in-line temperature and pressure instrumentation was used for control of test conditions and to provide test data. A turbidity meter designed to monitor the turbidity of a transparent liquid on a continuous, full-flow basis, previously calibrated using known amounts of oil in water, was installed in the test loops downstream from the test separator to give a continuous, real-time indication of effluent water quality. All test water and oil-water mixtures were directed to a slop tank during the tests for later processing to remove any residual oil before pumping the water to a sewer.

b. Test Water and Contaminant Oil.

(1) Test Water. The test water was prefiltered water from the Fort Belvoir Utility System. The water contains less than 1 milligram per liter of solids and has a surface tension of not less than 65 dynes/centimeter at $75^{\circ}F$ and a pH value between 5 and 8. The temperature varied between $48^{\circ}F$ and $51^{\circ}F$.

(2) Contaminant Oil. Aviation Turbine Fuel, Grade JP-4, conforming to MIL-T-5624, was used for all tests. Test fuel was obtained from Davison U.S. Army Airfield, Fort Belvoir, Virginia.

c. Oil-in-Water Analysis Procedures. The on-line instrument and laboratory procedures used during the test program are listed below with a brief discussion of their use in the program.

(1) Turbidity Meter. This is an on-line, full-flow, continuous monitor which was installed in the test loop as mentioned in paragraph 2a. The instrument must be precalibrated for each specific oil. It measures turbidity as the ratio of scattered light to transmitted light. It also reacts to particulate matter and air bubbles. However, since

it is a full-flow, real-time device and a device familiar to the test personnel, it has proved very useful as an indicator of relative free or dispersed oil concentration in the test loop. The meter readings reported in the test results are not to be considered absolute values.

(2) Pyrographic Analyzer. The pyrographic analyzer is an instrument which was designed and developed under a USAMERDC contract for direct analysis of both free and dissolved organic materials in a water matrix. The operation of the pyrographic instrument involves injection of an untreated water sample containing organic materials of interest into a pyrolysis chamber, pyrolysis of organic composition in the presence of water, separation of the resulting pyrolytic fragments using gas chromatography, detection of eluted fractions by means of a hydrogen flame ionization detector, conversion of the generated analog signal into digital form, and transfer of the data to a teletype where it is printed and punched into a paper tape. The paper tapes containing the data are fed into a time-sharing computer via an acoustic coupler and voice-grade telephone. Computer programs containing previously established calibration patterns and constants for specific materials such as petroleum fuels and lubricants are used to solve a series of simultaneous equations for the unknown concentration of organic material represented by the pyrograms developed from the injected sample or samples. This technique was employed during this program primarily to measure the level of dissolved JP-4 in the effluent water samples from the various tests.

d. Test Criteria and Test Methods.

(1) Test Criteria. The criteria for the preparation and processing of the various mixtures of JP-4 and water are as follows:

(a) The mixtures would result from the hosing-down of an area where varying amounts of JP-4 had been spilled.

(b) The resulting mixture was collected in a container for processing.

(c) Three or four hours elapsed between collection and processing to permit settling of debris and particulate matter.

(d) The processed water would be satisfactory for discharge into a storm or sanitary sewer from a point of view of safety (no fire hazard), and water quality (no visible sheen of oil).

(2) Test Methods. Test conditions were simulated as closely as possible to meet the criteria established in paragraph 2d. The 1500-gallon tank was filled with enough prefiltered tap water to cover the discharge outlet in the side of the tank about six inches from the bottom. A selected amount of JP-4 was then dumped into the tank. A water hose was then used to thoroughly mix the fuel and water and to bring the total volume of the mixture to 1000 gallons. The contents of the tank were then processed through the oil-water separation system. Approximately three to four hours elapsed from the start of mixing until the mixture was completely processed. Using this technique, the separator was required to process water containing very little fuel (a few parts per million) at the bottom of the tank, to 100 percent fuel at the very top.

e. Test Results. The results of the tests are as follows:

(1) One Percent (10 Gallons) JP-4. The oil-water separator, under the test conditions, was capable of separating and removing JP-4 from water to a satisfactory level to meet safety and water quality requirements (Table B-1). It is believed that the slight increase in free oil shown by the turbidity meter and the dissolved oil shown by pyrographic analysis on the last samples on this and subsequent tests

TABLE B-1. ONE PERCENT JP-4

Time (min)	Flow Rate (GPM)	System Press. Drop (PSIG)	Water Temp. (°F)	Turbidity (PPM-Free Oil)	Pyrolysis (PPM-Dissolved Oil)
0	5	5.0	48	1.9	
10	5	5.0	49	1.8	
20	5	5.5	49	1.6	
30	5	5.5	49	1.5	4±1
45	5	6.0	49.5	1.5	
60	5	6.0	49.5	1.5	5±1
75	5	6.5	49.5	1.5	
90	5	6.5	49.5	1.5	4±1
105	5	7.0	49.5	1.5	
120	5	7.5	49.5	1.5	4±2
130	5	8.0	50	1.5	
140	5	8.0	50	1.5	
150	5	8.5	50	1.5	4±2
165	5	8.5	50	1.5	
180	5	8.5	50	1.6	5±1
185	5	6.0	50	3.4	7±1

were a result of the presence of 100 percent fuel in the separator and the resulting automatic oil discharge cycle at the time the readings and samples were taken.

(2) Two percent (20 Gallons) JP-4. The oil-water separator, under the test conditions, was capable of separating and removing JP-4 from water to a satisfactory level to meet safety and water quality requirements (Table B-2).

(3) Five Percent (50 Gallons) JP-4. The oil-water separator, under the test conditions, was capable of separating and removing JP-4 from water to a satisfactory level to meet safety and water quality requirements (Table B-3).

(4) Ten Percent (100 Gallons) JP-4. The oil-water separator, under the test conditions, was capable of separating and removing JP-4 from water to a satisfactory level to meet safety and water quality requirements (Table B-4).

(5) Twenty Percent (200 Gallons) JP-4. The oil-water separator, under the test conditions, was capable of separating and removing JP-4 from water to a satisfactory level to meet the safety and water quality requirements (Table B-5). The drop in pressure differential across the separator system reported on line 5 is the result of replacing the coalescer element in the second stage (first coalescer stage) of the system. Biological growth or "surfactant slime" generated as a result of the fuel-water contact is believed responsible for the element plugging that made the change necessary. This is a common phenomenon in fuel tanks and storage tanks when water is present, and points up the critical need to keep turbine fuels dry and free of water bottoms.

(6) General. A review of the test data shows that during the series of tests the free oil content of the effluent water as measured

TABLE B-2. TWO PERCENT JP-4

Time (min)	Flow Rate (GPM)	System Press. Drop (PSIG)	Water Temp. (^{o}F)	Turbidity (PPM-Free Oil)	Pyrolysis (PPM-Dissolved Oil)
0	5	9.5	50	1.5	
10	5	8.0	50	1.3	
20	5	8.5	50	1.3	
30	5	9.0	50	1.3	8±2
45	5	9.0	50	1.3	
60	5	9.5	50	1.3	9±2
75	5	10.0	50	1.3	
90	5	10.5	50	1.3	9±2
105	5	11.0	50	1.3	
120	5	11.5	50	1.3	8±2
130	5	13.5	50	1.3	
140	5	13.5	50	1.3	
150	5	14.0	50	1.3	9±2
165	5	14.0	50	1.3	
180	5	12.0	50	1.4	14±4
183	5	6.0	50	1.4	8±2

TABLE B-3. FIVE PERCENT JP-4

Time (min)	Flow Rate (GPM)	System Press. Drop (PSIG)	Water Temp. (°F)	Turbidity (PPM-Free Oil)	Pyrolysis (PPM-Dissolved Oil)
0	5	12.5	49.5	1.3	
10	5	13.5	49.5	1.3	
20	5	13.5	49.5	1.3	
30	5	14.0	49.5	1.3	15±5
45	5	14.0	49.5	1.3	
60	5	14.5	49.5	1.3	12±4
75	5	15.5	49.5	1.3	
90	5	15.5	50	1.3	14±4
105	5	15.5	50	1.3	
120	5	16.0	50	1.3	11±4
130	5	16.5	50	1.3	
140	5	16.5	50	1.3	
150	5	17.0	50	1.3	15±4
165	5	17.5	50	1.3	
180	5	18.0	50	1.3	12±4
185	5	15.5	50	3.4	22±5
190	5	8.0	50	2.2	27±5

TABLE B-4. 10 PERCENT JP-4

Time (min)	Flow Rate (GPM)	System Press. Drop (PSIG)	Water Temp. (^{o}F)	Turbidity (PPM-Free Oil)	Pyrolysis (PPM-Dissolved Oil)
0	5	21	49.5	1.3	
10	5	22	49.5	1.2	
20	5	22	49.5	1.2	
30	5	22	49.5	1.2	31±6
45	5	23	49.5	1.2	
60	5	23	49.5	1.2	33±7
75	5	23	49.5	1.2	
90	5	24	49.5	1.2	24±5
105	5	24	49.5	1.2	
120	5	24	49.5	1.2	26±5
135	5	26	49.5	1.3	
150	5	26	49.5	1.3	30±6
165	5	26	49.5	1.4	
180	5	26	49.5	1.4	32±8
190	5	22	49.5	3.3	29±6
200	5	18	49.5	3.5	32±6
205	3.5	7	49.5	3.5	

TABLE B-5. 20 PERCENT JP-4

Time (min)	Flow Rate (GPM)	System Press. Drop (PSIG)	Water Temp. (^{o}F)	Turbidity (PPM-Free Oil)	Pyrolysis (PPM-Dissolved Oil)
0	5	31	50	2.2	
10	5	32	50	1.3	
20	5	32	50	1.2	
30	5	33	50	1.2	70±8
40	5	4	50	1.5	
50	5	4	50	1.5	
60	5	4	50	1.5	68±7
75	5	4	50	1.5	
90	5	5	50	1.6	79±9
105	5	5	50	1.7	
120	5	5	50.5	1.7	83±9
135	5	5	50.5	1.8	
140	5	4	50.5	3.2	71±7
150	5	4	50.5	3.4	87±11
160	5	4	51	3.3	121±16

by the turbidity meter never exceeded 3.5 ppm with an average of approximately 1.5 ppm. This was confirmed by visual examination of the bottled samples for clarity and irridescent appearance or visible sheen. However, pyrographic analysis shows increasing levels of petroleum derived soluble materials in the effluent water as the JP-4 concentration increased. Our past experience has shown that considerable amounts (21 ppm to 230 ppm) of water soluble organic material may be extracted from various fuels and lubricants after as little as four hours contact time. In some cases, the levels can increase substantially with time (300-600 ppm after 42 days). Limited experimental work has also shown that the water soluble materials present as a result of contact with petroleum products may contain high levels of such toxic materials as phenols, cresols, and other aromatic and polycyclic compounds. Thus the persistent discharge of waters containing sublethal quantities of these materials could have a long-term ecological effect on the receiving water. The standard error calculated by the computer on the data measured by the pyrographic analyzer (at least two runs on each sample) averaged approximately 25 percent. Normally, the standard error is closer to 10 percent when the instrument has been precalibrated for a particular fuel as it was in the case of the JP-4. It was postulated that the cause of this higher than usual error was the presence of water-soluble fuel system icing inhibitor (FSII) or corrosion inhibitor (HITEC E-515) in the fuel. An analysis of the test JP-4 found 4.2 pounds per 1000 barrels of corrosion inhibitor present, and one analysis reported no FSII present, while another measured .008 percent (80 ppm) of FSII. It is more probable that molecular modification of the hydrocarbons by biological oxidation as discussed in paragraph 2e(5) was responsible for formation of additional water soluble materials not present when calibration patterns and coefficients were established. The average standard error on those samples analyzed from the mixture containing 20 percent JP-4 (Table B-5) is 10.6 percent and is considered more normal.

3. CONCLUSIONS. Based on an evaluation of the test results and degree of conformance to the program criteria, it is concluded that:

a. The separation and removal of JP-4 fuel from fresh water to a satisfactory level to meet safety and water quality requirements using a coalescence-type oil-water separator is feasible.

b. While no solids removal tests were included in this series of tests, experience indicates that any system designed to process fuel spills will require provisions for handling large amounts of debris and particulate matter such as a settling tank, strainers, prefilters, etc., ahead of the coalescing stages.

c. Fuel-water mixtures should be processed as quickly as practicable to minimize the amount of potentially harmful water soluble organic material that can be transferred from the fuel to the water phase. Haste may also preclude or minimize the development of biological growth or "surfactant slimes" which in themselves cause a serious element plugging problem, and the byproducts of this development process can also contribute to the pollution problem.

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