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FRAM CORPORATION MODEL OWS-23-FCI-USCG OIL/WATER SEPARATOR

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Army Mobility Equipment Research and Development Center
Fort Belvoir, Virginia

May 1973

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U. S. ARMY MOBILITY EQUIPMENT RESEARCH AND DEVELOPMENT CENTER
FORT BELVOIR, VIRGINIA

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13. ABSTRACT

Based on an evaluation of the test results, degree of conformance to general test goals, and performance relative to the performance of other separators evaluated during the program, this report concludes that:

a. The Fram Corporation Model OWS-23-FCI-USCG oil/water separator should be considered a candidate for further detailed testing to confirm its suitability as a first-generation oil/water separation system for shipboard use.

b. The Fram unit, as tested, was effective only when equipped with the preconditioner.

c. The Fram unit, as tested, was effective only when operated with the diaphragm pump provided by the manufacturer.

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May 1973

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SUMMARY

This report covers the test and evaluation of a Fram Corporation Model OWS-23-FCI-USCG oil/water separator to determine its suitability as a shipboard oil pollution control device.

Based on an evaluation of the test results, degree of conformance to the general test goals, and performance relative to the performance of other separators evaluated during the program, this report concludes that:

a. The Fram Corporation Model OWS-23-FCI-USCG oil/water separator should be considered a candidate for further detailed testing to confirm its suitability as a first-generation oil/water separation system for shipboard use.

b. The Fram unit, as tested, was effective only when equipped with the preconditioner.

c. The Fram unit, as tested, was effective only when operated with the diaphragm pump provided by the manufacturer.

FOREWORD

Authority for the technical evaluation described in this report is contained in a letter from the Chief, Naval Engineering Division, U. S. Coast Guard (USCG), to Commanding Officer, U. S. Army Mobility Equipment Research and Development Center (USAMERDC), dated 29 December 1970, subject: "Oily Water Separators and Monitors; Testing Of"; and reply from Commanding Officer, USAMERDC, to Chief, Naval Engineering Division, USCG, dated 14 January 1971, same subject, stating that the test and evaluation of selected oily water separators and effluent monitors desired by the USCG could be undertaken by the Fuels Handling Equipment Division, Mechanical Technology Department, USAMERDC.

The work was conducted with USCG funds transferred to USAMERDC by Military Interdepartmental Purchase Request (MIPR) No. Z-70099-1-13218.

Tests were conducted in December 1971 in the POL Test Facility, Fort Belvoir, Virginia.

The work was conducted under the overall supervision of T. H. Jefferson, Chief, Fuels Surveillance and Technology Branch, Fuels Handling Equipment Division, USAMERDC; and LCDR Lyman B. Norton, Project Officer, USCG. Initial testing was witnessed by James Murphy and Ralph Terhune, Technical Representatives, Fram Corporation. The following USAMERDC personnel participated in the evaluation program: Edward C. Russell, Senior Project Engineer; Melvin J. Albright, Equipment Specialist; Conrad Korzendorfer, Test Leadman; and Lloyd Johnson and J. C. Young, Test Mechanics.

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FRAM CORPORATION MODEL OWS-23-FCI-USCG

OIL/WATER SEPARATOR

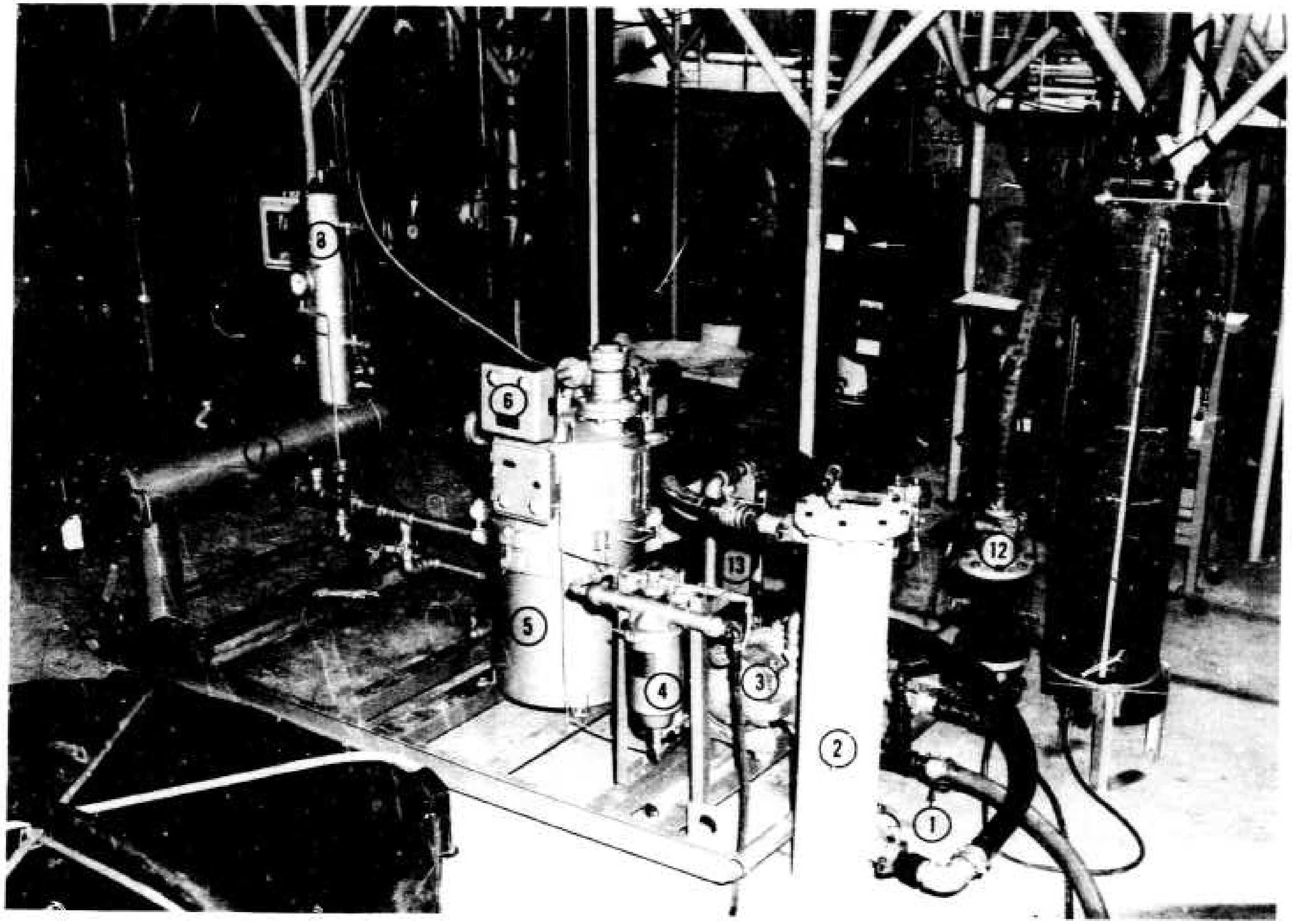
I. INTRODUCTION

1. **Subject.** This report covers tests conducted on a Fram Corporation Model OWS-23-FCI-USCG oil/water separator to determine its suitability as a shipboard oil pollution control device. The quality of the water effluent was of prime importance in the overall evaluation.

2. **Background.** There is a need for oil/water separators as an integral part of certain shipboard systems designed to separate and remove petroleum, fuel, oil, sludge, oil refuse, and oil mixed with wastes (contaminants) from flowing streams of bilge and/or ballast water in piped systems. Harmful quantities of contaminants must be removed from bilge and ballast waters before they are returned to the environment.

Based on a Presolicitation Notice published in the Commerce Business Daily, the U. S. Coast Guard requested firms with pilot or production models of state-of-the-art oil/water separation equipment that met USCG general requirements to submit a Request For Proposal (RFP). The USCG chose certain firms responding to the RFPs to supply off-the-shelf hardware for this test and evaluation program. USAMERDC, acting for the USCG, negotiated R&D Release Agreements with the selected firms to obtain the test items at no cost to the Government. R&D Release Document No. 2349 covering subject oil/water separator was completed with Fram Corporation. (On completion of subject program a second-generation oil/water separator-monitor system was received from Fram Corporation for more detailed test and evaluation. A report on this system will be published at a later date.)

3. **Description and Function.** The Fram Corporation Model OWS-23-FCI-USCG oil/water separator is a multi-stage skid-mounted system with a nominal flow rate of 23 gpm. The test unit (shown in the figure) came equipped with a 1½-inch, double-diaphragm pneumatic supply pump with a rated flow of 20 gpm. The pump discharge is directed to an inclined-plate gravity separator designed to separate and remove the free and unemulsified oil from the flowing stream of water. The gravity separator is equipped with an automatic interface control to remove the free oil that accumulates in the oil chamber. The effluent from the gravity separation stage passes to a final emulsion-breaking (coalescence) stage. A vertical sump is attached to this stage to contain the separated free oil. It is provided with an oil-water level sight gauge and manual drain and air-vent valves. The unit is equipped with pressure gauges, sampling valves,



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View of Fram Oil/Water Separator. (1) Inlet from suction tank, (2) pre-conditioner, (3) double-diaphragm pump, (4) air filter and controls, (5) gravity separator, (6) interface control, (7) coalescer section, (8) oil sump, (9) cleanup filter/separator, (10) fluorescence detector, (11) pressurized tank for oil injection, (12) turbidity meter pickup head, and (13) rate of flow indicator.

and piping and valving for bypassing or recirculating. It is also provided with an air-supply filter and a rate-of-flow indicator. Early in the test series the manufacturer added a preconditioner stage to the system between the supply pump discharge and the gravity separation stage. Its purpose was to remove particulate matter from the influent stream and to act as a precoalescer.

II. EVALUATION TESTS AND RESULTS

4. **Test Facilities.** The evaluation tests were conducted in the USAMERDC Fuel Filter/Separator Test Facility in a test loop designed to accommodate the Fram Corporation oil/water separator. The test loop was composed of 500-gallon and 1500-gallon rubber tanks that served as test water reservoirs and supply pump suction tanks. Rubber hose of appropriate size with quick-disconnect couplings was used to connect the reservoirs, through a manifold, to the supply pump and to the test 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. Other Flowrators, or a calibrated, pressurized (5 psig) reservoir tank, were used to meter precise amounts of contaminant oil into the test water at the suction side of the supply pump. In-line isokinetic sampling probes were located at 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 was calibrated using known amounts of various oils in water and installed in the test loop downstream from the test separator to give a continuous indication of effluent water quality. An in-line ultraviolet absorption device was also installed in parallel with the turbidity meter. A modified military standard fuel filter/separator was connected to the discharge end of the test loop to remove residual contaminants from the test water before returning it to a slop tank, suction tank, or storm sewer. The test loop was piped and valved to permit tests to be performed on a once-through, single-pass basis, or on a recirculating basis.

5. **Test Fluid and Test Contaminant.**

a. **Test Fluid.** Prefiltered fresh water from the Fort Belvoir utility system was used. The water contains less than 1 mg/l of solids, surface tension of not less than 65 dynes/cm at 75° F, and a pH value between 5 and 8.

b. **Test Contaminant.** The test contaminant was Contaminant Oil, Fuel Oil, Diesel, No. 2, VV-F-800.

6. **Oil-In-Water Analysis Procedures.** The ability to accurately measure the quantity of oil in water in the laboratory or on-line in a flowing system is vital to the evaluation of performance and efficiency of oil/water separation equipment. The lack of accurate, reliable instruments and procedures created the most difficult problem encountered in the entire oil/water separator test and evaluation program. Normally, editorial comment and subjectivity are outside the scope of a technical report. The writer feels justified, however, in addressing both of these areas in this report. First, the current state of the art covering oil-in-water detection and measurement is inadequate for today's requirements. This equipment is essential for the control of oil/water separation systems and the measure of oil pollution levels in water. In addition, it is essential that accurate, precise, reliable laboratory procedures be developed as a standard and for evaluation and calibration of all other instruments and techniques. Second, because of the low reliability of certain quantitative values obtained for oil in water during this program, certain of our conclusions, at least in part, are subjective. Every effort will be made to identify these data and conclusions in the report so the reader will be aware of the subjective areas.

The various on-line instruments and analytical laboratory procedures used in evaluating oil/water separators are listed below with a brief discussion of their use in the program and the problems encountered with each.

a. **Fluorescence Detector.** This is an on-line monitor that operates off of the side stream from the separator effluent water discharge line. Detection of oil in water is based on measurement of the amount of visible light (fluorescence) emitted when the flowing stream is irradiated with ultraviolet (U.V.) light. The instrument must be precalibrated for each specific oil. This device was found to be sensitive to flow rate and oil particle size at high concentrations (100 ppm), and slightly sensitive to particulate matter, air bubbles, detergents, water salinity, and water soluble components that may be extracted from the oils. The effect of these uncontrollable variables on the accuracy of the device made the values obtained from it questionable.

b. **Ultraviolet Energy Absorption Monitor.** This is an on-line monitor that operates off of the side stream from the separator effluent water discharge line. (This device was installed in parallel with the device described in paragraph 6a and was operated simultaneously.) Monitoring of oil concentration in a flowing stream is based on the reduction in transmitted U. V. energy caused by absorption of U. V. energy by oil. The instrument must be precalibrated for each specific oil. Many other things may also block transmission of U. V. energy, such as particulate matter, air bubbles, detergents, or any water soluble component that may be extracted from the oil. Values obtained from this device were also suspect.

c. **Turbidity Meter.** This on-line, full-flow, continuous monitor was also installed in parallel with devices mentioned in paragraphs 6a and 6b. The instrument must also be precalibrated for each specific oil. It measures turbidity as the ratio of scattered light to transmitted light. This device also reacts to particulate matter and air bubbles, as well as the turbidity caused by water extractable components found in certain oils. However, since this is a full-flow device and is familiar to the test personnel, it proved useful as an indicator of relative oil concentration (anomalies) in the test loop. The meter readings reported in the test results are not to be considered absolute values.

d. **Infrared (I.R.) Spectrophotometry.** This is a standard laboratory procedure used to measure the amount of oil in water in a bottled ("grab") sample. Calibration curves must be prepared for each specific oil. In this procedure, the oil is extracted from the oil-water sample with carbon tetrachloride solvent. The sample-solvent mixture is thoroughly mixed using an ultrasonic bath or mechanical shaker, the solvent-oil phase is separated from the water phase, and a small sample of the oil-solvent mixture is introduced into the I. R. Spectrophotometer. The reading obtained using the calibration curve for the particular oil is proportional to the amount of oil in the original sample. While this is a precise procedure, the accuracy is dependent primarily on the efficiency of the solvent extraction step. Early in the program, we learned from the chemistry laboratory (USAMERDC's Materials Research Support Division) doing our sample analyses that their solvent extraction efficiency was varying from 28 percent to 90 percent, depending on the original oil concentration. In addition, the procedure is time consuming—six to eight samples per day, on the average. The values obtained using this procedure were questionable.

e. **Total Carbon Analysis.** This procedure is based on the measurement of total organic carbon in an oil-water sample. Here, too, calibration curves must be prepared for each specific oil. Two representative 20-microliter samples are required for analysis. The first sample is introduced into the instrument and completely oxidized. The gas obtained is passed into a gas phase I. R. absorption cell tuned to one of the CO_2 absorption peaks. The reading thus obtained is a measure of total carbon. The second sample is introduced into a separate sample port in the instrument, and the amount of total inorganic carbon is determined.

The difference between total carbon and total inorganic carbon is total organic carbon (TOC), such as oil. The major problems with the TOC procedure were getting representative samples of the oil-water bottled sample for injection and the possible presence of other unknown organic carbon compounds in the sample that would give a false indication of the amount of oil present. For these reasons, the TOC procedure was discontinued.

f. **Crystal Microbalance.** The crystal microbalance is based on the correlation between the change in beat frequency in one of two crystals initially vibrating at the same beat frequency when a known amount of oil is placed on one of the crystals. In the laboratory, the oil was extracted from a bottled oil-water sample using reagent grade dichloromethane solvent. The oil-water-solvent mixture was shaken on a mechanical shaker to assure complete solvent extraction. A 2-microliter sample was withdrawn from the solvent phase and placed on the sample crystal. After 3 minutes all the solvent was found to have evaporated, and a reading was taken from a self-contained meter or an external frequency counter. This final beat frequency was proportional to the mass of the oil residue remaining. Using this procedure and solvent-water samples containing known amounts of each oil to be used, calibration (working) curves were prepared for each specific oil. Here, again, solvent extraction efficiency was a variable. It was also learned that the amount of residual oil remaining on the sample crystal after solvent evaporation was a function of the volatility of the oil. For example, in preparing the calibration curve for Navy Distillate, recovery was 62 percent; 48 percent for No. 2 Diesel Fuel; and only 4 percent for JP-5 turbine fuel. Because of the low recovery of JP-5, the procedure was not used with any oil more volatile than No. 2 Diesel Fuel. By exercising great care in preparation of calibration curves and good operator technique, the operator found that the standard deviation of reproducibility was about 2 percent. It is recommended that at least two readings be taken on each sample to minimize or eliminate spurious readings. Because of the high degree of reproducibility and the relative speed of analysis, the crystal microbalance, along with readings from one or more of the on-line instruments discussed above, was relied on for quantitative data throughout the test and evaluation program. (Technical Report 2057, entitled "Evaluation of a Crystal Microbalance for Determination of Oil in Water," dated May 1973, has been prepared by Dr. James V. Mengenhauser, Fuels Handling Equipment Division, USAMERDC, Fort Belvoir, Virginia.)

As may be seen from the foregoing discussion of oil-in-water analysis instruments and procedures, each has some serious shortcoming. However, after we accumulated some experience, visual examination of the effluent samples along with results obtained from some of the on-line instruments and the crystal microbalance permitted us to make a reasonable evaluation of the relative performance of the oil/water separators included in the program.

7. **Test Criteria.** The following test criteria were selected to determine the ability of oil/water separators to separate and remove various oils and mixtures of oil from fresh and salt waters within the general constraints found aboard a U.S. Coast Guard vessel. The following tests and test sequence were designed to be made progressively more difficult for use as screening tests. Each separator was tested only to the point where its performance grossly failed to meet the general program goals, or it was judged worthy of further testing. The separators passing the initial screening tests were set aside for

more rigorous testing after all the separators in the program had been screened. Thus, not all the separators in the test program underwent the complete series of tests.

The test criteria were:

a. Effluent water quality while injecting various percentages of contaminant oil in fresh water. The program goal was no visible sheen of oil on the effluent water.

b. The effect of the addition of detergents, air bubbles, and particulate matter on effluent water quality during the above oil separation tests. The program goal was no visible sheen of oil on the effluent water.

c. Replace the manufacturer's supply pump with a high-speed centrifugal pump, if not so equipped initially, to determine the separator's ability to separate the resulting mechanical emulsions using selected contaminant oils and oil injection rates. The program goal was no visible sheen of oil on the effluent water regardless of supply pump type.

d. Assessment of system power requirements (hydraulic, electrical, air, etc.) and sensitivity to power fluctuations. The program goal was minimum power requirement and no effects from power variations of 10 percent.

e. Estimate of ratio of oil/water separation system space requirement and weight versus throughput capacity. The program goal was low weight versus capacity ratio and space requirements to meet shipboard limitations.

f. Assessment of system reliability, maintainability, operating cost, first cost, and overall suitability for shipboard use.

8. Test Results. The tests shown in the table were run using various contaminants and prefiltered fresh water. Where available, data on the amount of oil in the effluent water obtained by other analytical methods have been reported as received. (Please refer to Section II, paragraph 6 for a discussion of the various analytical methods used.) The results of the tests are as follows.

No. 2 Diesel Fuel Injection (New)

Time (Min)	Total Flow (gpm)	Oil Inj (%)	Diff Press (psig)	Flu Det (ppm)	TOC (rpm)	Turbidity (JTU)
0	23		0.5			0.6
14	23	4.5	1.0	171	17	10.0
24	23	9.0	1.0	> 300	29	33.0
27	23	Oil Off				
No. 2 Diesel Fuel Injection (Used) Pre-Conditioner Installed						
0	23.0	4.6	0	39		1.0
14	22.5		0	117	11	3.2
35	22.5	9.2	1	165	15	5.5
37	22.5	Oil Off	1			
44	22.5		0			1.0
Diaphragm Pump Replaced with 20-gpm Centrifugal Pump						
0	23					
5	23	10.0	1			>500

The first series of tests were run on the Fram unit without the preconditioner installed. The monitors and analytical procedure, as well as visual examination of effluent samples, indicated unsatisfactory performance. The bottled samples had poor optical clarity with a visible sheen of oil on top of the water. The Fram representative agreed that testing should be suspended until a preconditioner could be sent from their plant.

The second series of tests were run after installation of the preconditioner between the supply pump discharge and the gravity separator section. All the indicators utilized showed a satisfactory effluent water quality.

The final test was run to determine the effectiveness of the Fram unit when the diaphragm pump was replaced with a centrifugal pump. When 10 percent No. 2 diesel fuel was injected, the effluent water quality, by visual examination and turbidity meter, degraded in less than 5 minutes.

III. CONCLUSIONS

9. **Conclusions.** Based on an evaluation of the test results, degree of conformance to the general program goals, and performance relative to the performance of other separators evaluated during the program, it is concluded that:

a. The Fram Corporation Model OWS-23-FCI-USCG oil/water separator should be considered a candidate for further detailed testing to determine its suitability as a first-generation oil/water separation system for shipboard use.

b. The Fram unit, as tested, was effective only when equipped with the preconditioner.

c. The Fram unit, as tested, was effective only when operated with the diaphragm pump provided by the manufacturer.