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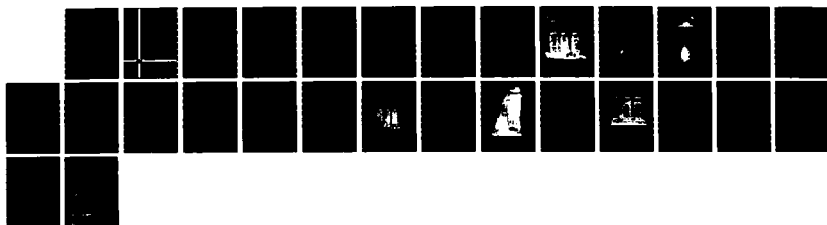
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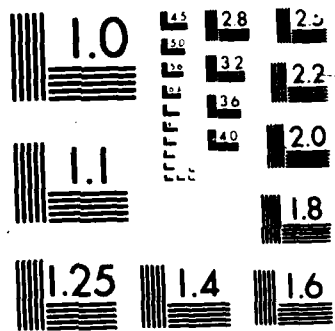
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Report 2435

**EVALUATION OF THE SAREX® 5 GPM
OIL-WATER SEPARATOR, TYPE B**

by
Gregory D. Musa

June 1986

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United States Army

**Belvoir Research, Development & Engineering Center
Fort Belvoir, Virginia 22060-5606**

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19. ABSTRACT (Continue on reverse if necessary and identify by block number) This report covers an investigation conducted to evaluate the operational effectiveness of the Sarex® 5 GPM Oil-Water Separator, Type B. The results of this study indicate that the Sarex® 5 GPM Oil-Water Separator, Type B, is an effective method for the removal of crude oil from feedwater. The Sarex® 5 GPM Oil-Water Separator, Type B, could be operated under field conditions.				
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PREFACE

The investigation covered by this report is an evaluation of the operational effectiveness of Sarex[®] 5 GPM Oil-Water Separator, Type B, during the removal of crude oil from feedwater. Work covered by this report was conducted under Project/Task 1L162733AH20-EW, "Water and Wastewater Management."

The investigation was conducted by Gregory D. Musa, Maurice Pressman, and Janet O. Hall. Engineering technical assistance was provided by Peder B. Pedersen, Staff Sergeant Dennis L. Pathkiller, and James E. Christopher.

Sarex is a registered trade name.



A-1

CONTENTS

Section	Title	Page
	LIST OF ILLUSTRATIONS	iv
	LIST OF TABLES	v
I	INTRODUCTION	1
II	INVESTIGATION	
	1. Equipment	1
	2. General System Description	5
	3. Functional Description	5
	4. Procedure	5
	5. Data Collected	5
III	RESULTS	7
IV	DISCUSSION	
	1. Observations	7
	2. Discussion	7
V	CONCLUSIONS	11
	APPENDIX	
	Detailed Illustrations of the Sarex® 5 GPM Oil-Water Separator, Type B, and Parts List.	13

ILLUSTRATIONS

Figure	Title	Page
1	The Sarex® 5 GPM Oil-Water Separator, Type B.	2
2	Schematic Description of the Sarex® 5 GPM Oil-Water Separator, Type B.	3
3	Handling of Filter Coalescer Element.	4
4	Functional Description of the Sarex® 5 GPM Oil-Water Separator, Type B.	6
A-1	Parts of the Sarex® 5 GPM Oil-Water Separator, Type B.	14
A-2	Side View, Sarex® 5 GPM Oil-Water Separator, Type B.	16
A-3	Rear View, Sarex® 5 GPM Oil-Water Separator, Type B.	18

TABLES

Table	Title	Page
1	Test of Sarex® 5 GPM Oil-Water Separator, Type B	8
2	Input Feedwater Concentration by the Partition-Gravimetric Method	9
3	Total Organic Carbon Content Analysis	10
4	Visual Observation Data	10
A-1	Description of Parts for Figure A-1	15
A-2	Description of Parts for Figure A-2	17
A-3	Description of Parts for Figure A-3	19

EVALUATION OF THE SAREX® 5 GPM OIL-WATER SEPARATOR, TYPE B

I. INTRODUCTION

An efficient and effective oil-water separator device is imperative in certain areas of the world where crude-oil contaminated feedwater is found. The presence of crude oil in the feedwater adversely affects the performance of the reverse osmosis water purification units (ROWPUs) used by the Army and Marines to purify fresh, brackish, and salt water. Both the 600 GPH ROWPU and the 150,000 GPD ROWPU use multi-media and cartridge filters for the removal of suspended solids from the feedwater before they enter the reverse osmosis membranes. Removal of the crude oil, which affixes to the filters, is accomplished by a laborious cleaning process or by replacement of the filters. Crude oil or a derived soluble oil passing the filters and entering the reverse osmosis elements would result in decreased production rate, degradation of the membrane elements, and decreased quality of product water. Thus, satisfactory operation of the ROWPU in this scenario is dependent upon an efficient and effective oil-water separator device. — > to 1.67.18

One such prospective oil-water separator device is the Sarex® 5 GPM Oil-Water Separator, Type B (Figure 1), because of its availability, portability, and standard usage on military watercraft. This oil-water separator is currently used on military and commercial vessels to remove oil from bilge water before the water is discharged overboard. For this reason, the Sarex® 5 GPM Oil-Water Separator, Type B, was chosen for evaluation of operational effectiveness in the removal of crude oil from feedwater.

II. INVESTIGATION

1. **Equipment.** The unit selected for this investigation, a Sarex® 5 GPM Oil-Water Separator, Type B (Figure 1), was previously used for other studies by a Belvoir Research, Development and Engineering Center contractor. The unit is manufactured by Separation and Recovery Systems, Inc., Irvine, CA. The company also sells other oil-water separators with the following capacities: 5 GPM, 10 GPM, 20 GPM, 60 GPM, 100 GPM, 200 GPM, and 600 GPM. The Sarex® 5 GPM Oil-Water Separator, Type B, is a three-stage coalescer oil-water separator which contains three pressure vessels (Figure 2). The vessels are constructed of carbon steel and are skid mounted. Each vessel is equipped with a cam-bar-secured cover to provide access to the filter elements, an automatic air-eliminator valve to vent air, a sight glass through which to view water clarity and oil level, a manual or automatic oil-discharge valve, a combination water sample/drain valve to either sample or drain water from each vessel, and zinc anodes mounted in the bottom of each vessel to minimize the effects of electrolysis on the tanks. Isolation of the individual stages or pressure vessels is permitted via three manual shut-off valves located in the flow line. The pump motor unit, used concurrently with the oil-water separator, is the Sher-Water, Model SI-251-DC-110 5 GPM pump with a 1,750 rpm motor. The oil-water separator uses the following elements:

- Prefilter primary separator element (MIL-F-52847, Type II, or Sarex® 614-501).
- Dual functional second and third stage coalescer elements (MIL-F-52847, Type III, or Sarex® 611-503) (Figure 3).

A control panel is also included. Pressure gauges indicating the inlet pressure to the prefilter primary separator and the pressure at the discharge side of each of the three vessels complete the system. A 500-gallon tank was used to hold the feedwater, and a high-speed pneumatic stirrer was attached to the tank to ensure thorough mixing of the solution.

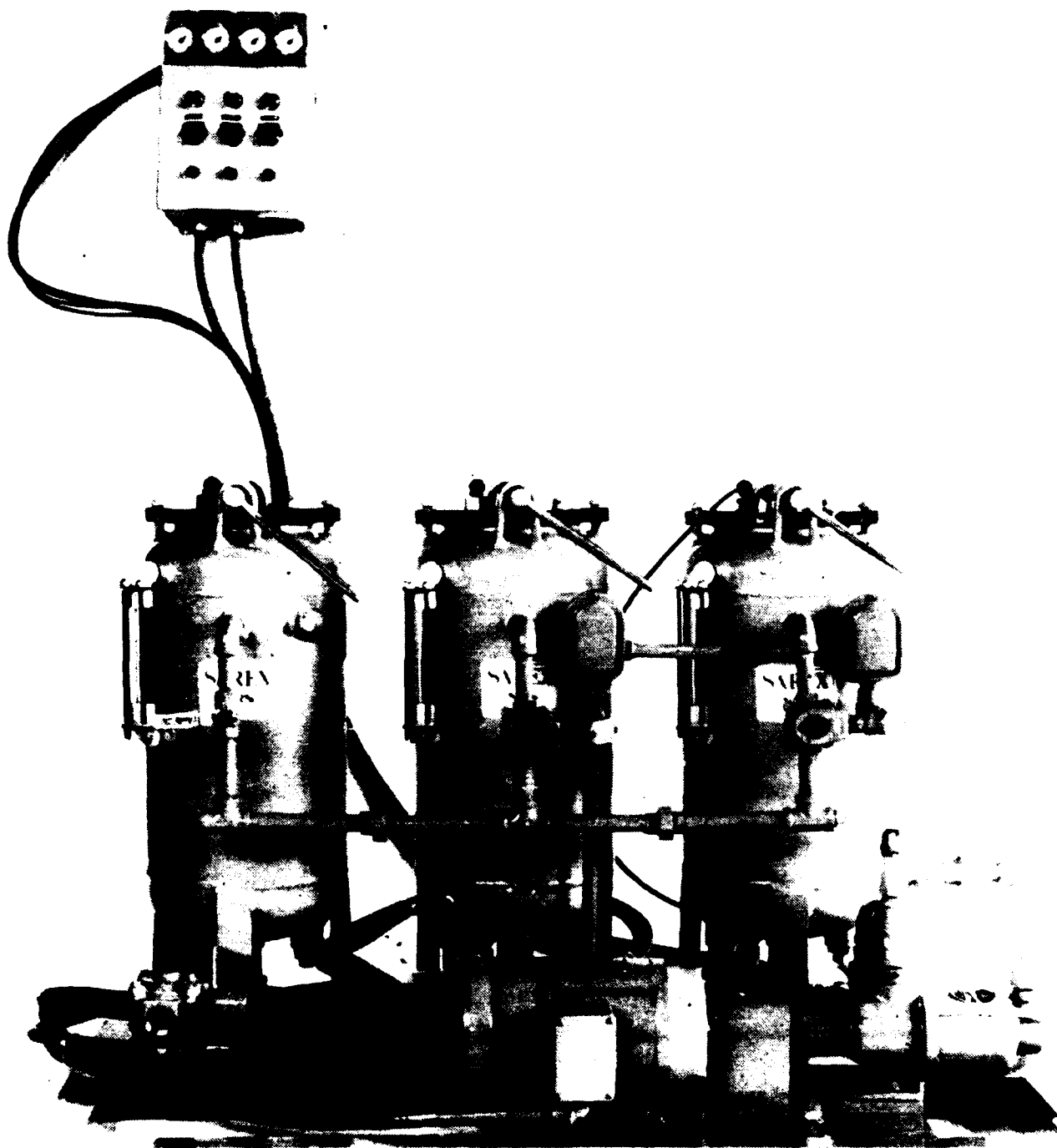


Figure 1. The Sarex® 5 GPM Oil-Water Separator, Type B.

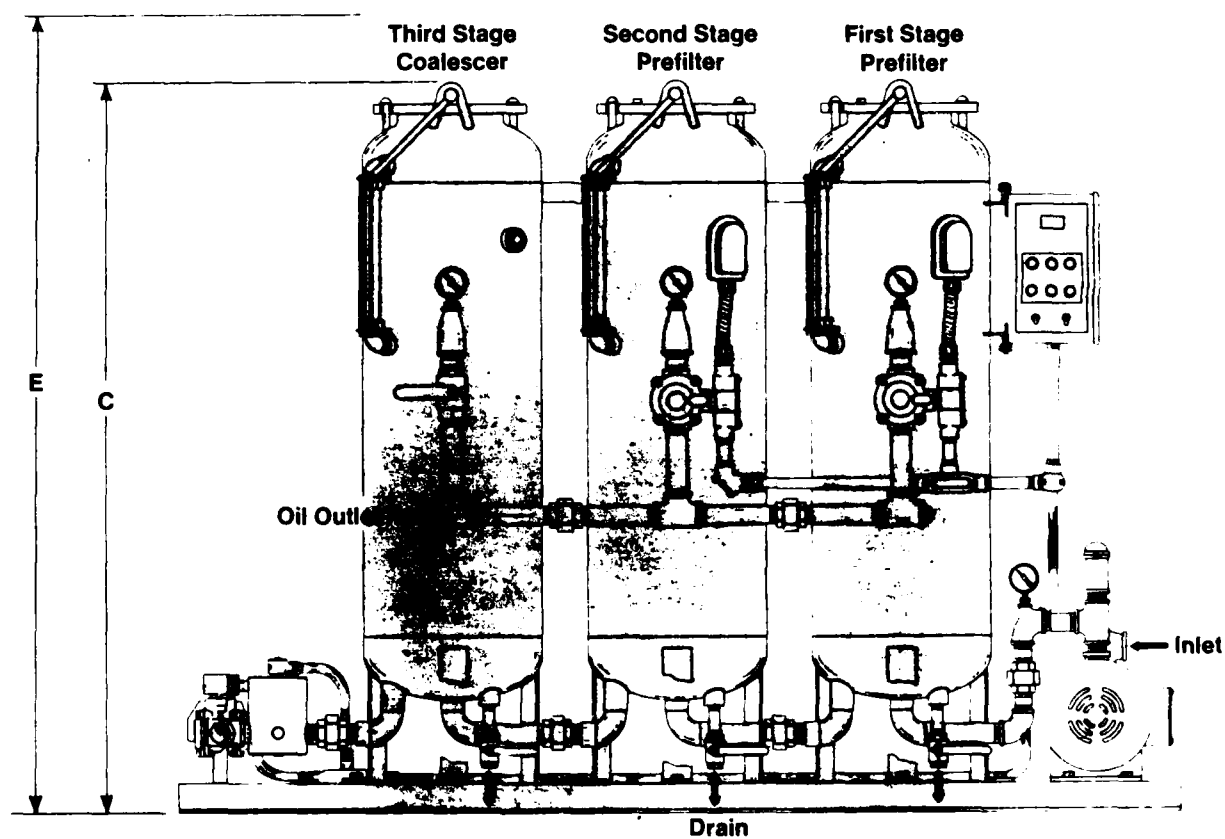
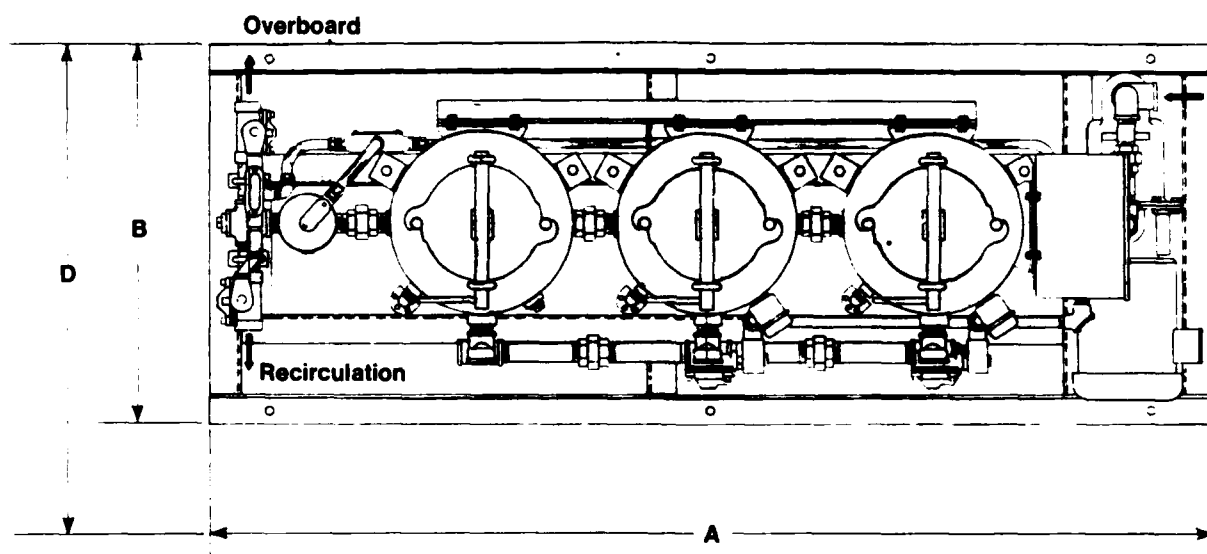


Figure 2. Schematic Description of the Sarex[®] 5 GPM Oil-Water Separator, Type B.

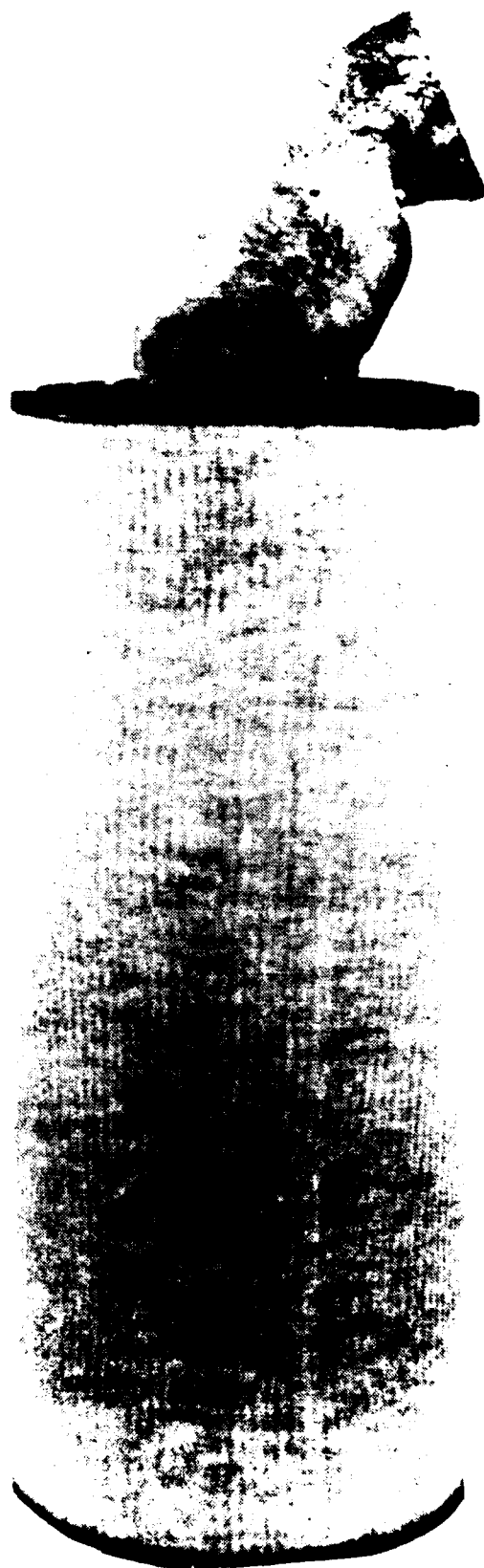


Figure 3. Handling of Filter Coalescer Element.

2. General System Description. The Sarex® 5 GPM Oil-Water Separator, Type B, is a three-stage, coalescent-type device which separates and removes insoluble oil, solids, and entrained air from an oily water mixture. The system does not require chemicals or other additives and can be operated either continuously or intermittently.

3. Functional Description. The principle of coalescence is the basis for the design of the Sarex® 5 GPM Oil-Water Separator, Type B (Figure 4). Oily water is first directed through specially constructed filters. These filters provide both an attaching surface for the miniscule droplets of insoluble oil dispersed in the water and a coalesce with oil droplets. As the oil droplets increase in size, they are pushed off the exterior surface of the filter by fluid flow and, thus, are separated from the water. Separation of the oil from the water occurs because of the difference in the specific gravity of the oil and the water.

Three pressure vessels, or stages, are arranged in series; and the influent, which contains oil, water, and solids, is pumped to this system by a supply pump. In the first stage, or prefilter primary separator, the primary separation and removal of oil from water occurs. The replaceable prefilter element removes both particulate matter and oil from the influent. This removal is accomplished as fluid entering the first stage via the pump flows upward through the hollow core of the prefilter element. The coalescing action occurs within the element as oil drops form on the exterior surface of the element. Fluid flow from the inside to the outside of the element forces the larger oil droplets off the surface of the element. The oil droplets then rise and accumulate at the top of the vessel because of the difference in specific gravity between the oil and the water. Oil is discharged from the first stage when the oil sensor determines the presence of oil and signals the opening of the first-stage, solenoid-operated oil discharge valve and the simultaneous closing of the solenoid-operated water discharge valve. Valves return to their normal position when a sufficient amount of oil is released. The purified effluent exits the bottom of the first stage through the outlet line and enters the second stage separator. The fluid then flows through the filter coalescer element which removes any residual oil not removed in the first stage. The operation of the second stage separator is identical to that of the first stage. Any residual oil in the water will coalesce as it passes through the element and finally accumulates at the top of the second stage. Automatic discharge of the oil occurs when sufficient oil accumulates to activate the oil sensor. The further purified effluent enters the third stage, which functions primarily as a polishing stage from which clean water is discharged via the outlet line. The third stage functions exactly as the previous two stages, but it contains a manually-operated, oil-discharge valve instead of a solenoid-operated valve. A manually-operated valve is used since very little oil is expected to accumulate in stage three.

4. Procedure. A Sarex® 5 GPM Oil-Water Separator, Type B, was refurbished and assembled for operation in this investigation. A three-stage system was employed using the cartridge filters, with the prefilter in the first stage and the skid mounted coalescers in the second and third stages. A 500-gallon tank held the feedwater; and a high-speed, pneumatic stirrer attached to the tank ensured thorough mixing of the solution. The feedwater consisted of 500 gal of tap water and 1,892.5 g of crude oil. Therefore, the crude oil concentration of the feedwater was 1,000 ppm. The contaminated feedwater was fed by gravity to the test unit influent pump. The oil-water separator system was operated for 110 minutes on 4 June 1985. Samples of feedwater and product water were obtained at 5 minute intervals of the test. Product rate, inlet pressure, and the pressure of vessel (stage) 2 were all monitored and data recorded at 15 minute intervals during the test. The feedwater tank was also manually stirred throughout the test with the use of paddles. The test was stopped after 30 minutes, 60 minutes, and 110 minutes, which was the completion of the test. The test was stopped at both the 30 minute and 60 minute marks to add a calculated quantity of tap water and its corresponding calculated quantity of crude oil to maintain the feed concentration at approximately 1,000 ppm.

5. Data Collected. Visual observations of the water samples were made and recorded. In the laboratory, the Partition-Gravimetric Method (Standard Methods for the Examination of Water and Wastewater, p. 46.) was used

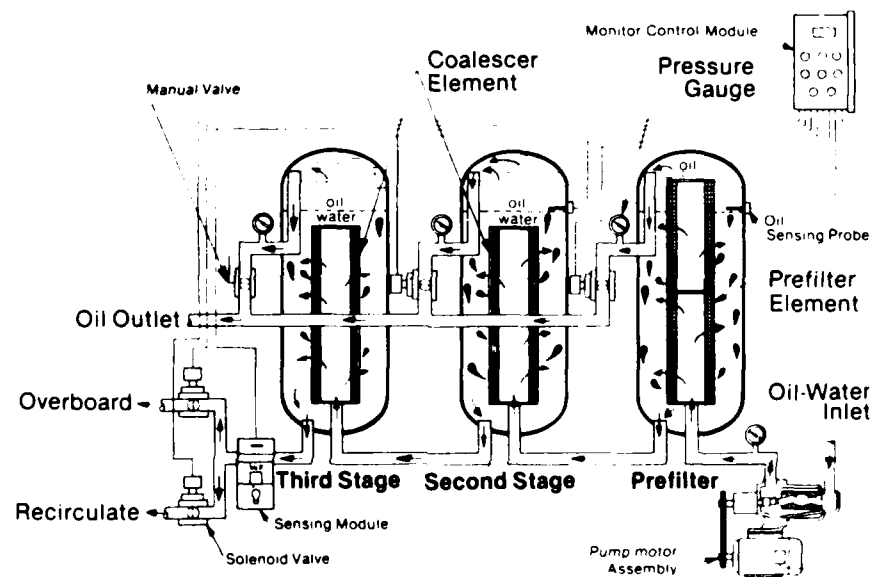


Figure 4. Functional Description of the Sarex[®] 5 GPM Oil-Water Separator, Type B.

to determine analytically the concentration of oil in the sample. The product water was analyzed with a Total Organic Carbon Model 700 analyzer to determine the organic carbon content.

III. RESULTS

The data and results obtained during the investigation of the Sarex® 5 GPM Oil-Water Separator, Type B, are given in Tables 1, 2, 3, and 4 beginning on the next page. Table 1 indicates the performance of the Oil-Water Separator with product rate, inlet pressure, and pressure of vessel 2 data included. Table 2 provides the results of the input feedwater concentration by the Partition-Gravimetric Method. Table 3 gives the total of both organic and inorganic carbon content of the tap water, prefilter water, and product water. Table 4 provides visual observation data on both the feedwater and the product water samples.

IV. DISCUSSION

1. Observations.

- a. The subject separator system can be easily operated by one technician.
- b. It provides a constant and reliable source of product water. The results of the data in Table 1 show that the product rate only varied from 3.9 to 4.8 gpm throughout the 110 minute test.
- c. The inlet pressure and the pressure of Vessel 2 were also maintained at near constant pressures throughout the test. The inlet pressure fluctuated from 47 to 55 psi, and Vessel 2 pressure varied from 37 to 40 psi.
- d. An increase in the inlet pressure resulted in increased product rate, while the pressure of Vessel 2 was not affected by these variations in inlet pressure.

2. Discussion. The oil-water separator is easily operable and provides a constant source of product water as Table 1 indicates. To determine the effectiveness of the oil-water separator, an input, or a feedwater oil contamination concentration, and an output, or a product water concentration, were needed for comparison. An analytical, input-feed concentration was provided by the Partition-Gravimetric Method. Table 2 shows the feed concentration of Sample 1 was 631.8 mg/L, the feed concentration of Sample 2 was 855.8 mg/L, and the feed concentration of Sample 3 was 254.8 mg/L. Therefore, the concentration of oil contamination in the feedwater varied from approximately 250 parts per million (ppm) to 850 ppm. However, this data indicates that the input-feed concentration was not a constant 1,000 ppm as suggested earlier in the "procedure" section of this report. This discrepancy was due to the difficulty of suspending the crude oil uniformly in the feedwater. Oil has an inherent tendency to rise to the top of the feed tank; and the feed-tank water was stirred manually, contributing to the variation of the input-feed concentration. Therefore, the predicted 1,000 ppm input-feed concentration was only a theoretical value which actually varied considerably under empirical conditions. Table 3 indicates the total organic carbon content of the tap water, the prefilter water, and the product water. The total organic carbon content of the tap water was 3.55 ppm, the prefilter water was 6.72 ppm, and the product water was 5.80 ppm. Therefore, the total organic carbon content of the product water was approximately 2 ppm greater than the noncontaminated tap water. In addition, this data confirms the hypothesis that the first stage, or prefilter, removes most of the oil from the water. The total organic carbon content of the water after passing through the prefilter element was 6.72 ppm, as stated earlier. The following two stages lower the total organic carbon content of the feedwater 0.92 ppm to a value of 5.80 ppm.

TABLE 1**Test of Sarex® 5 GPM Oil-Water Separator, Type B**

DATE	TIME (hours)	PRODUCT RATE (gpm)	INLET (psi)	VESSEL 2 (psi)	TEST STATUS
6/4/85	1015	-	-	-	Start Test
6/4/85	1025	3.9 gpm	47 psi	40 psi	-
6/4/85	1040	4.2 gpm	48 psi	39 psi	-
6/4/85	1045	-	-	-	Stop Test
6/4/85	1100	-	-	-	Start Test
6/4/85	1100	4.2 gpm	49 psi	37 psi	-
6/4/85	1115	3.9 gpm	51 psi	39 psi	-
6/4/85	1130	4.2 gpm	52 psi	38 psi	-
6/4/85	1130	-	-	-	Stop Test
6/4/85	1320	-	-	-	Start Test
6/4/85	1335	4.5 gpm	54 psi	39 psi	-
6/4/85	1350	4.5 gpm	54 psi	38 psi	-
6/4/85	1405	4.8 gpm	55 psi	38 psi	-
6/4/85	1410	-	-	-	Stop Test

TABLE 2

**Input Feedwater Concentration (mg/L Oil and Grease)
by the Partition--Gravimetric Method**

Feedwater Sample No. 1 at 1025 (hours)

850 ml sample starting volume

77.878 g 250 ml Distilling Flask & Oil/Grease

77.341 g 250 ml Distilling Flask

.537 g Oil/Grease

$$\frac{.537 \text{ g}}{.850 \text{ L}} \times \frac{1000 \text{ mg}}{1 \text{ g}} = \frac{631.8 \text{ mg oil/grease}}{\text{L sample}}$$

Feedwater Sample No. 2 at 1030 (hours)

770 ml sample starting volume

77.915 g 250 ml Distilling Flask & Oil/Grease

77.256 g 250 ml Distilling Flask

.659 g Oil/Grease

$$\frac{.659 \text{ g}}{.770 \text{ g}} \times \frac{1000 \text{ mg}}{1 \text{ g}} = \frac{855.8 \text{ mg oil/grease}}{\text{L sample}}$$

Feedwater Sample No. 3 at 1035 (hours)

840 ml sample starting volume

106.324 g 250 ml Distilling Flask & Oil/Grease

106.110 g 250 ml Distilling Flask

.214 g Oil/Grease

$$\frac{.214 \text{ g}}{.840 \text{ L}} \times \frac{1000 \text{ mg}}{1 \text{ g}} = \frac{254.8 \text{ mg oil/grease}}{\text{L sample}}$$

TABLE 3**Total Organic Carbon Content Analysis
5 June 1985**

Sample	Total Organic Carbon Content	Total Inorganic Carbon Content
Tap Water	-	11.14 ppm
Tap Water	3.55 ppm	-
Prefilter Water	-	12.58 ppm
Prefilter Water	6.72 ppm	-
Product Water	-	12.16 ppm
Product Water	5.80 ppm	-

TABLE 4**Visual Observation Data**

Feedwater	Brown, murky water, heavy amount of suspended large brown particles, large amount of oily residue on top of jar, very strong oil odor.
Product Water	Clear, colorless water, slight amount of suspended particles, no detectable oil or other odor.

The visual observations (Table 4) further confirmed the effectiveness of the separator system. The product water showed no visual indication of oil contamination. It did not contain a sheen. A rule of thumb for oil contamination is that a visible sheen occurs at 13 to 15 ppm of the oil-contamination level. Furthermore, the product water did not contain any detectable odors. In contrast, the feedwater had obvious visual signs of oil contamination and a strong, highly detectable petroleum odor. In summary, the oil-water separator provided a product water with a concentration of 5.80 ppm of total organic carbon content (an increase of 2.25 ppm over the baseline) from an input feedwater concentration between 250 to 850 ppm of oil concentration.

V. CONCLUSIONS

The results of this investigation indicate that the Sarex® 5 GPM Oil-Water Separator, Type B, is a viable method for the purification of oil-contaminated water. This oil-water separator would make an effective and efficient pretreatment unit which would remove the crude oil contamination from feedwater prior to processing with the ROWPUs. During operation where the surf action is vigorous, a strainer of sufficient mesh, or another pretreatment for suspended solids such as the cyclone separator, would be required to prevent sand from clogging the filters. In conclusion, the Sarex® 5 GPM Oil-Water Separator, Type B, could be deployed as an effective separator of oil and water in any area where the presence of oil in water is anticipated.

APPENDIX

DETAILED ILLUSTRATIONS OF THE SAREX® 5 GPM OIL-WATER SEPARATOR, TYPE B, AND PARTS LIST.

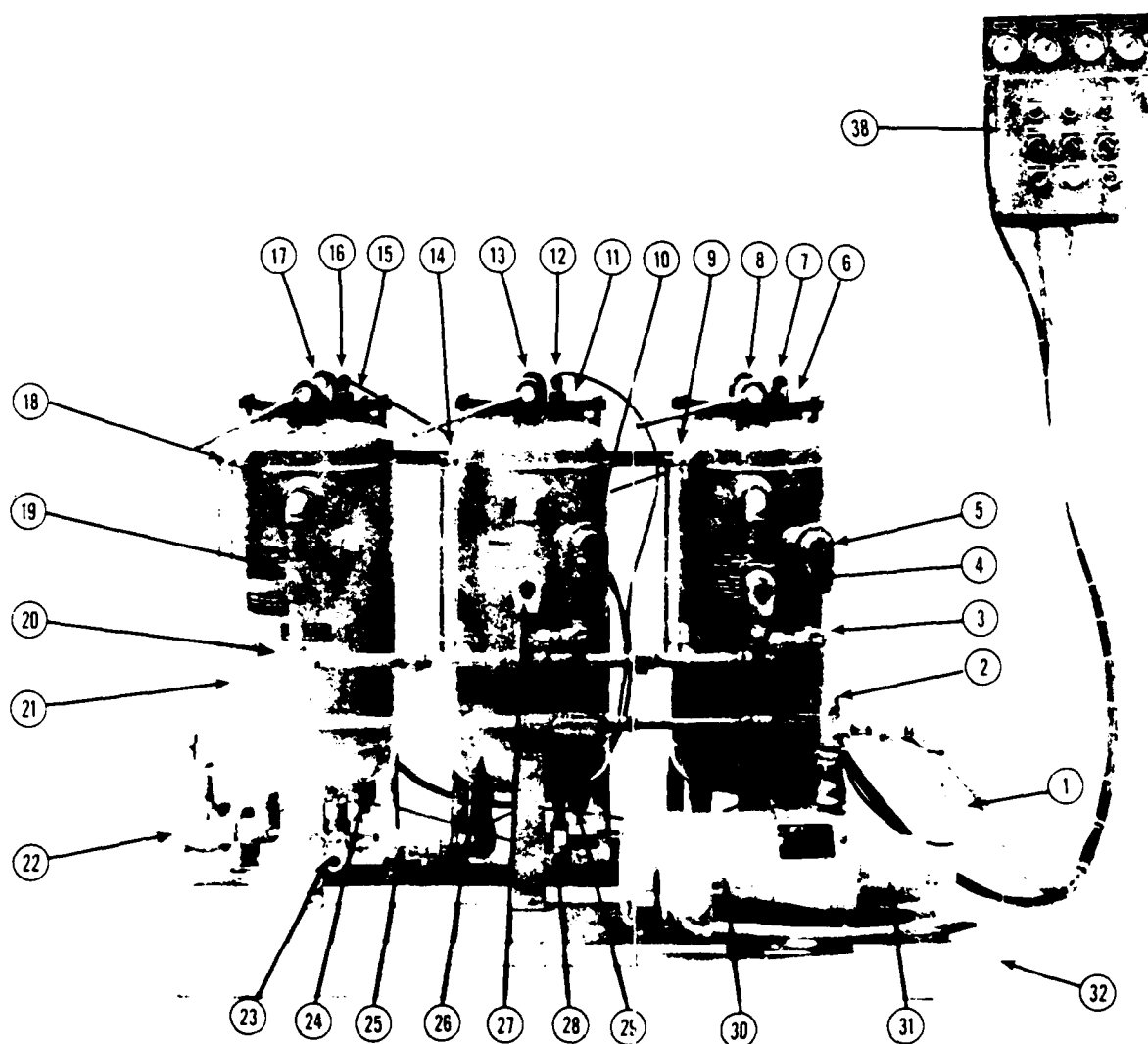


Figure A-1. Sarex® 5 GPM Oil-Water Separator, Type B.

TABLE A-1
Description of Parts for Figure A-1

Figure Number	SRS Part Number	Name
1	952-4	Pump Inlet
2	952-2	Pressure Relief Valve
3	071-2	Prefilter Primary Separator
4	934-7	Solenoid Operated Oil Discharge Valve - Prefilter Primary Separator
5	392	Sensor - Prefilter Primary Separator
6	080	Cover - Prefilter Primary Separator
7	306	Automatic Air Eliminator Valve - Prefilter Primary Separator
8	081	Cam Bar - Prefilter Primary Separator
9	423-1	Sight Glass - Prefilter Primary Separator
10	392	Sensor - Second Stage Separator
11	080	Cover - Second Stage Separator
12	306	Automatic Air Eliminator Valve - Second Stage Separator
13	081	Cam Bar - Second Stage Separator
14	423-1	Sight Glass - Second Stage Separator
15	080	Cover - Third Stage Separator
16	306	Automatic Air Eliminator Valve - Third Stage Separator
17	081	Cam Bar - Third Stage Separator
18	423-1	Sight Glass - Third Stage Separator
19	934-8	Manual Oil Discharge Valve - Third Stage Separator
20	---	Oil Discharge Line
21	071-2	Third Stage Separator
22	928-15	Solenoid Operated Water Discharge Valve
23	928-14	Water Sample/Drain Valve - Third Stage Separator
24	928-23	Anode - Third Stage Separator
25	928-13	Intervessel Shutoff Valve
26	071-2	Second Stage Separator
27	934-7	Solenoid Operated Oil Discharge Valve - Second Stage Separator
28	928-14	Water Sample/Drain Valve - Second Stage Separator
29	928-23	Anode - Second Stage Separator
30	952-1	Motor
31	952-1	Supply Pump
32	929	Skid
38	937	Control Panel

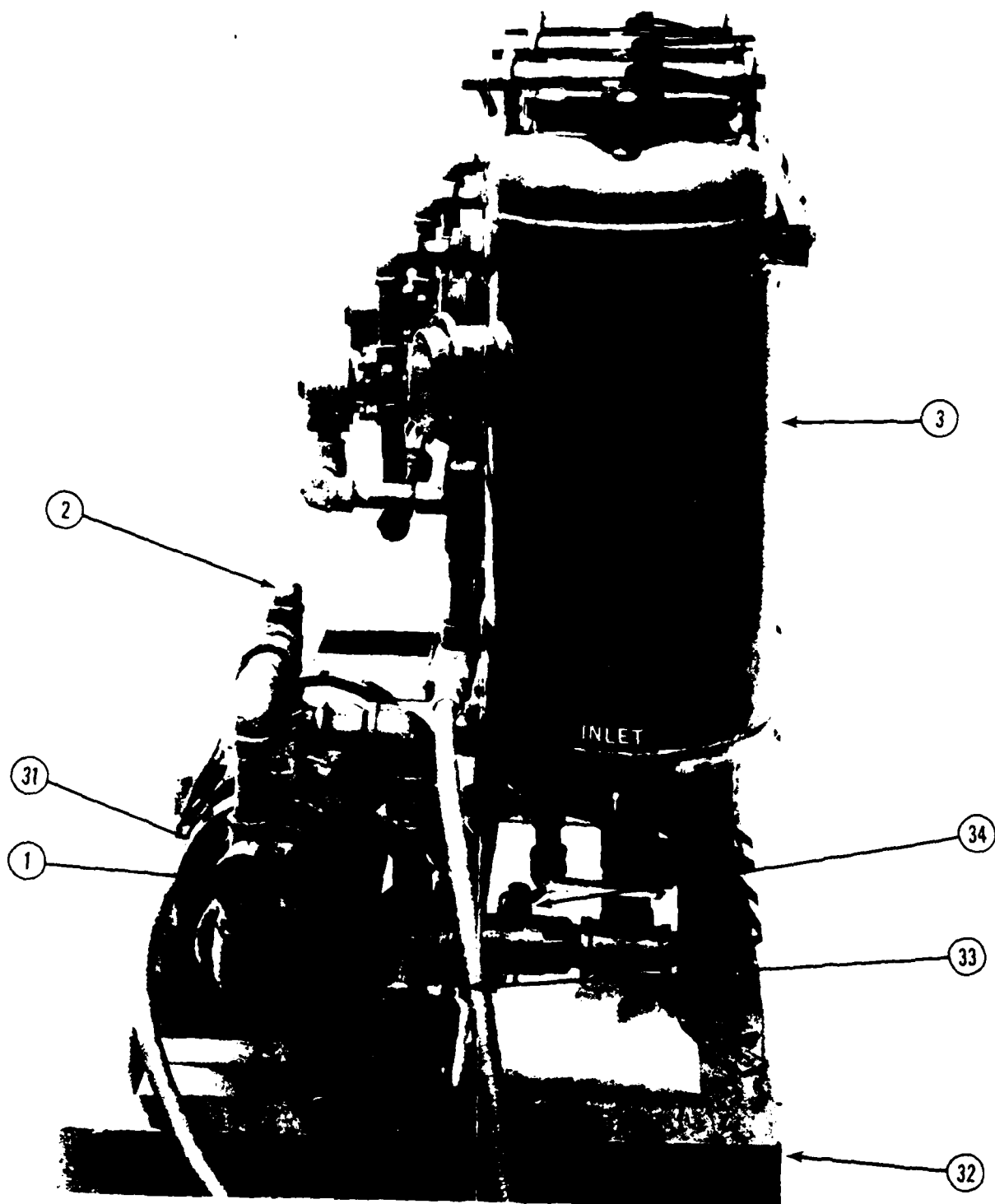
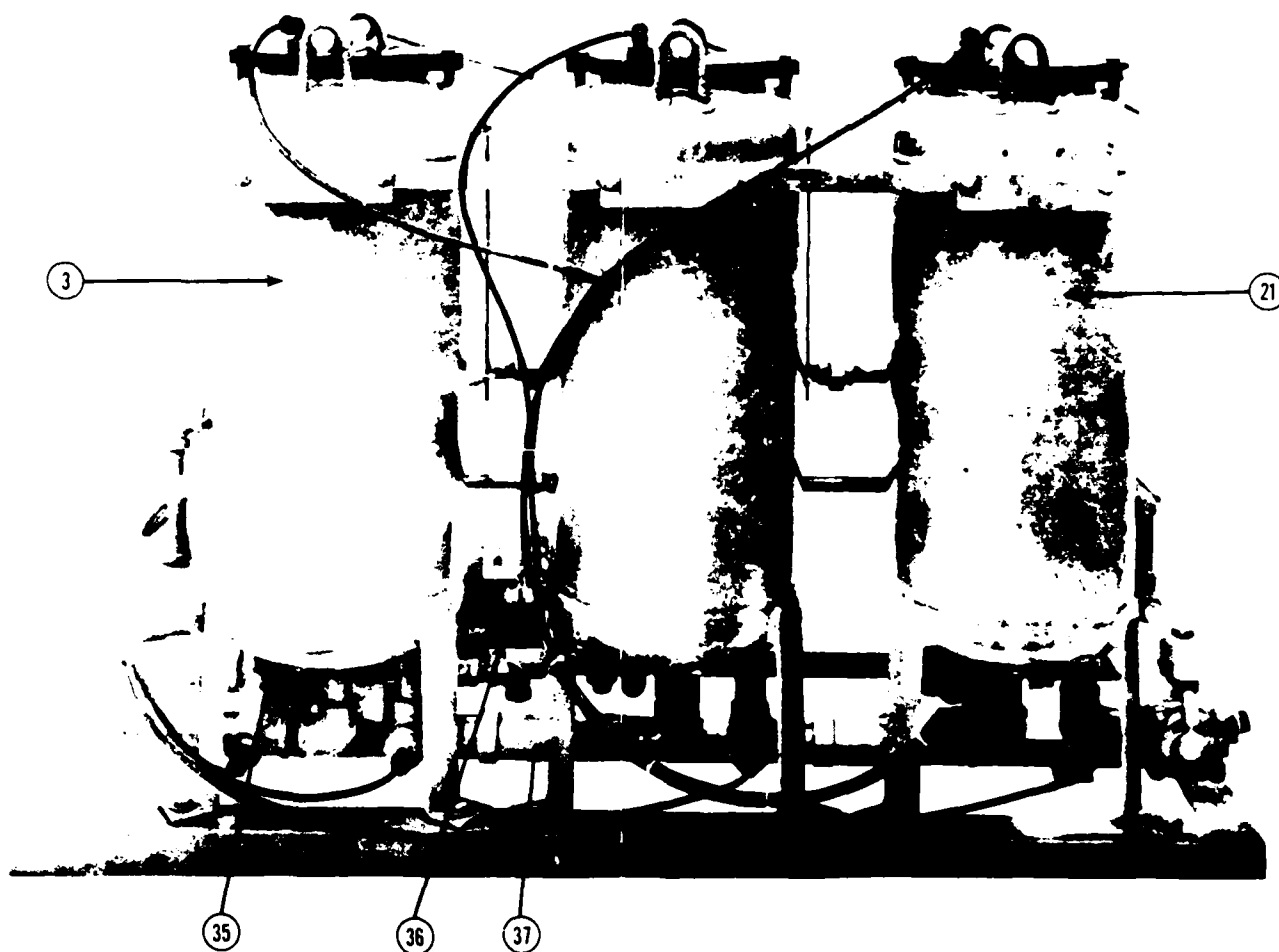


Figure A-2. Side View, Sarex® 5 GPM
Oil-Water Separator, Type B.

TABLE A-2**Description of Parts for Figure A-2**

Figure Number	SRS Part Number	Name
1	952-4	Pump Inlet
2	952-2	Pressure Relief Valve
3	071-2	Prefilter Primary Separator
31	952-1	Supply Pump
32	929	Skid
33	952-3	Manual Shutoff Valve - Pump Discharge
34	928-13	Manual Shutoff Valve - Prefilter Primary Separator Inlet



**Figure A-3. Rear View, Sarex® 5 GPM
Oil-Water Separator, Type B.**

TABLE A-3**Description of Parts for Figure A-3**

Figure Number	SRS Part Number	Name
3	071-2	Prefilter Primary Separator
21	071-2	Third Stage Separator
35	928-23	Anode - Prefilter Primary Separator
36	928-14	Water Sample/Drain Valve - Prefilter Primary Separator
37	928-13	Intervessel Shutoff Valve

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