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Municipal Environmental Research
Laboratory
Cincinnati OH 45268

Research and Development

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# Project Summary

# Performance Testing of Four Skimming Systems

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**A test program (conducted during the 1979 season) evaluated skimmer performance in collecting oil floating on water using several wave conditions, tow speeds, and skimmer operating parameters. Performance tests were conducted at the U.S. Environmental Protection Agency's (EPA) Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) on four commercial oil spill cleanup devices: the Sapiens Sirene* skimming system, the Oil Mop remote skimmer, the Troil/Destroil skimming system, and the Versatile Environment Products Arctic Skimmer.**

**Tests described in this report were sponsored by the OHMSETT Interagency Technical Committee (OITC). The 1979 OITC members were the EPA, U.S. Navy-SUPSALV, U.S. Navy-NAVFAC, U.S. Coast Guard, U.S. Geological Survey, and Environment Canada. A 16-mm film "600 Foot Ocean," produced to summarize the results presented in this report, is available through the EPA, Office of Research and Development, Oil and Hazardous Materials Spills Branch, Edison, New Jersey 08837.**

***This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).***

**Mention of trade names or commercial products does not constitute endorsement or recommendation for use.*

## Introduction

Results and methods used for tests sponsored by the 1979 OITC are presented in this report for the following commercially available spill cleanup equipment: (1) Sapiens Sirene Skimming System, c/o Sapiens, 23-27 Avenue de Neuilly, F75116 Paris, France; (2) Oil Mop Remote Skimmer, Oil Mop Pollution Control, Ltd., Toronto, Canada; (3) Troil/Destroil Skimming System, Hyde Products, Inc., 810 Sharon Drive, Cleveland, Ohio 44145; and (4) Versatile Environment Products Arctic Skimmer, 60 Riverside Drive, North Vancouver, British Columbia, Canada V7H1T4.

Each system was shipped from a foreign country on loan to OHMSETT. Tests were conducted to evaluate (1) best oil collection performance, (2) environmental conditions limiting operation, (3) mechanical problems, and (4) device modifications for improving performance, or operating limits, or both.

In the full report, quantitative performance data to support conclusions in the above areas are presented based on the following parameters calculated from steady state test results.

(1) Throughput Efficiency (TE)—Percentage of oil entering the skimmer that is recovered. This parameter is important for advancing skimmers.

$$TE = \frac{\text{Oil recovered}}{\text{Oil distributed (encounter rate)}} \times 100\%$$

(2) Recovery Efficiency (RE)—Percentage of oil in the fluid recovered by

the skimmer; applies to all devices in this report and is useful for evaluating storage required to contain fluid recovered at a spill.

$$RE = \frac{\text{Oil recovered}}{\text{Total Fluid Recovered}} \times 100\%$$

(3) Oil Recovery Rate (ORR)—Volume of oil recovered per unit time; also applies to all devices in this report and is useful in determining time needed to clean up a spill of known volume.

$$ORR = \frac{\text{Volume oil recovered}}{\text{Unit of time}}$$

Direct comparison of test results should be avoided because all skimmers were operated differently. The Oil Mop remote skimmer and the Versatile Environment Products Arctic skimmer were operated as both stationary and advancing skimmers, whereas the other two were operated as advancing skimmers only.

## Sapiens Sirene Skimmer System

### *Skimmer Description*

The Sapiens Sirene, as tested, is a two-stage oil skimming system composed of five components (Figure 1). The first stage is the oil herding section (side floats); the second is the oil collection section (rear float, hoses, and pump). The five components are:

(1) a 14.5-m-long float of inflated flexible fabric with an increasing boom draft from the forward to aft (right side or wing section);
(2) a 7.5-m-long oil inlet section that includes the narrowing funnel leading into the suction box with a torpedo-like float supporting the oil/water inlet in the center;
(3) another 14.5-m long float of inflated flexible fabric with the boom draft increasing from forward to aft end (left side or wing section);
(4) an aluminum suction box, with floats, that is clamped onto the upper part of the apex of the rear funnel to accept oil collected; and
(5) 20 m of 110-mm hose and two air driven, double-acting diaphragm pumps (162 $m^3$/hr capacity) to remove the collected fluid from the Sirene to the collection barrels.

### *Conclusions*

From July 9-20, 1979, 43 oil recovery performance tests were conducted with the Sapiens Sirene skimmer (Figure 1); 31 tests with a high viscosity oil and 12 with a medium viscosity oil.

### Best Performance—

Consistently, the highest values of RE, TE, and ORR were obtained during tow tests with waves. This result was surprising since waves generally cause poorer performance in oil skimmers.

The tests in high viscosity oil produced better results than the tests in medium viscosity oil. Medium viscosity oil was entrained and lost from the system more easily than the high viscosity oil because of interfacial shear forces.

The best skimmer performance data (highest numerical results) are presented along with accompanying test conditions in Table 1. Because of the skimmer's operating principle, the highest values of TE, ORR, and RE did not occur under the same test conditions. Test oil logistics prevented using enough oil to saturate the system over the entire tow test, thus absolute maximums for ORR and RE were not determined.

No oil was lost because of wave splashover. The cylindrical design of the continuous flotation elements caused the oil and water to be splashed forward, in front of the boom; this was true even at the highest tow speed run in the roughest wave condition. Another reason for lack of splashover was the virtual absence of device heave relative to the water's surface. The great amount of flotation coupled with the concave skirt design, which tends to hold the device to the water's surface, acted to maintain a relatively large, constant freeboard.

### Operating Limits—

Based on quantitative and qualitative test results, the operating limits of the Sirene skimmer appear to depend on the following three items:

(1) Oil entrainment phenomena at tow speeds above 0.75 knot cause oil to escape the skimmer before it can be pumped out. Such losses occurred (1) beneath the points of attachment between the side sections and the rear collection section, (2) beneath the large floats on either side of the oil/water inlet, and (3) out the water outlet located beneath the oil suction box in the aft end of the device.
(2) Limited pump capacity allows oil to build up in front of the oil inlet and, therefore, is subject to entrainment and shedding because of water flow beneath the oil.
(3) Oil cannot flow easily to the oil suction box after it enters the oil inlet. This allows the oil slick to be subjected to water passing below it for a longer period of time, thus increasing shedding and entrainment of oil droplets.

The pumping system did not severely emulsify the collected oil and water. This is evidenced by the similarity between the recovery efficiency samples obtained by allowing gravity to separate the oil and water and those obtained by centrifuging oil/water samples.

TE was not affected by slick thickness whereas RE and ORR were directly dependent.

### Device Modifications—

Device modifications recommended for improving the performance of the Sapiens Sirene system are:

***Table 1.*** *Best Performance - Sapiens Sirene (High and Low Viscosity Oil).*

| *Performance Parameter* | *Highest Value* | *Tow Speed (kt)* | *Wave H x L (m x m)* | *Test No.* |
|---|---|---|---|---|
| *High Viscosity—* | | | | |
| *TE* | *100%* | *0.50* | *0* | *1* |
| *RE* | *71.0%* | *1.25* | *0.6 HC* | *27* |
| *ORR* | *39.7 $m^3$/hr* | *1.0* | *0.6 HC* | *26* |
| *Low Viscosity—* | | | | |
| *TE* | *99%* | *0.75* | *All waves* | *36, 40, 46* |
| *RE* | *66.5%* | *1.25* | *0.7 HC* | *45* |
| *ORR* | *39.8 $m^3$/hr* | *1.25* | *0.5 x 11.6* | *45* |

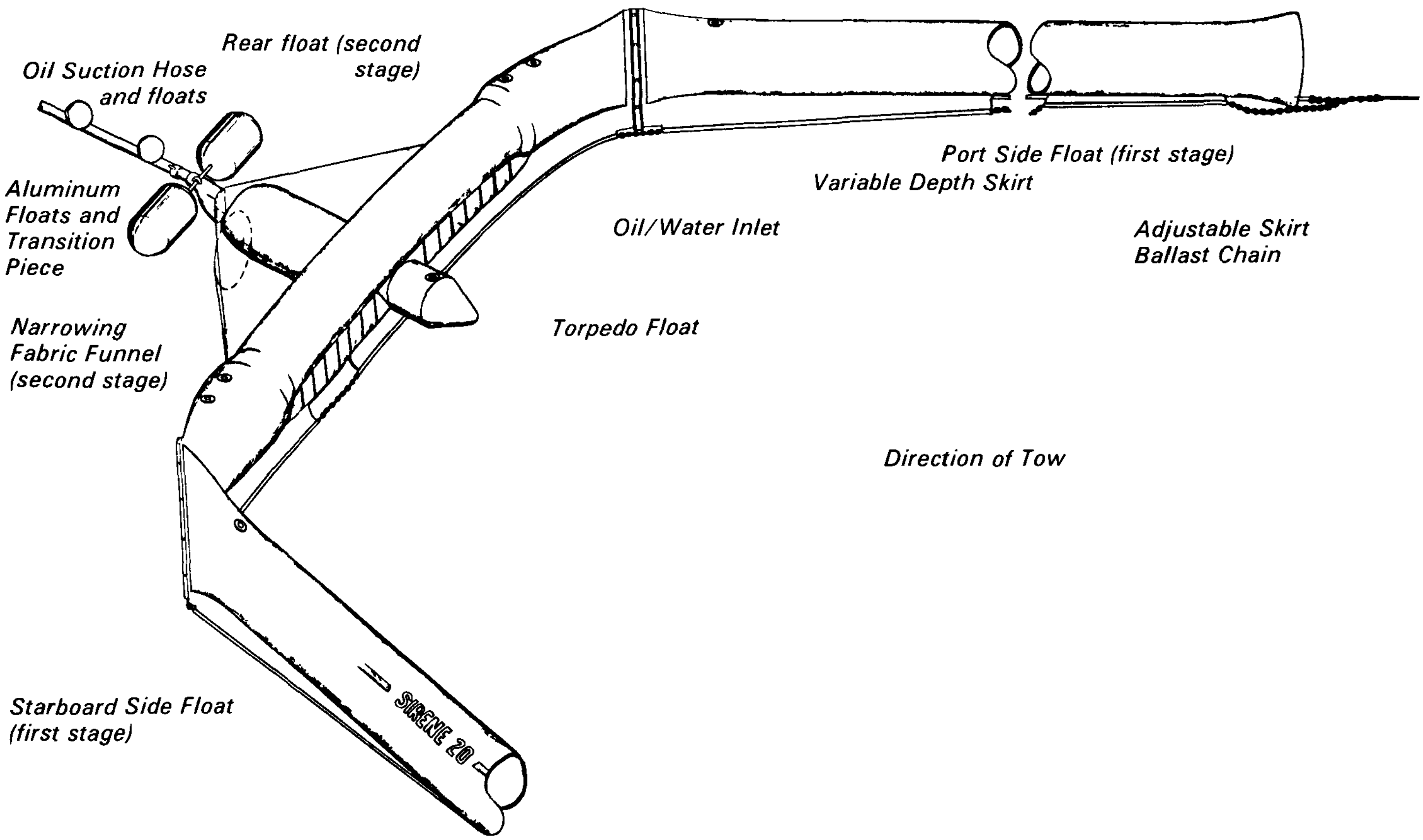


***Figure 1.*** *Sapiens Sirene skimming system.*

(1) Extend the oil inlet across the entire rear section of the device. Eliminate the floats on either side of the oil inlet or place outside the side flotation elements. The oil would travel directly from the side sections into the narrowing funnel behind the oil inlet, thus eliminating the severe angle change that developed at the point where the side sections join the rear section.
(2) Improve the narrowing funnel behind the oil inlet to allow oil to move more easily through it to the oil suction box. If oil could be transported through the funnel area at the same flow rate as the encounter rate, there would be no pool of oil to be subjected to the interfacial shearing forces of the water passing beneath the pool and out the water exit. Longitudinally arranged flotation elements spaced across the funnel would allow oil to pass easily by keeping the fabric above the slick's surface.
(3) Increase the system pumping capacity by improving the arrangement of the two double-acting diaphragm pumps used to transfer the oil/water fluid from the suction box to the collection barrels. The pumps would be 12% more efficient if used independently of each other rather than in a common inlet, common outlet arrangement. A doubling of present pump capacity is recommended.
(4) Replace the center torpedo float on the oil/water inlet with two floats, spaced at one-third and two-thirds the distance across the mouth, to eliminate turbulence generated by the float directly upstream of the oil suction box.

If the recommended modifications or ones that serve the same purpose are incorporated into the system, another test program should be performed at OHMSETT. The system shows promise through its innovations in design and material use.

## Oil Mop Remote Skimmer

### *Skimmer Description*

The Oil Mop remote skimmer model (Figure 2) was fabricated by Oil Mop Pollution Control, Ltd., Toronto, Canada, as a preliminary model of a full-size unit to be used for Arctic oil spill recovery service. The skimmer is designed as an unmanned unit controlled by an umbilical electric cable. The operating principle is that of oil slick sorption onto a bank of polypropylene rope mops, rotating in the vertical plane to produce zero velocity relative to the surface of the water during forward motion of the skimmer.

### *Conclusions*

From August 6-10, 1979, 19 oil pickup performance tests were conducted with the Oil Mop remote skimmer:

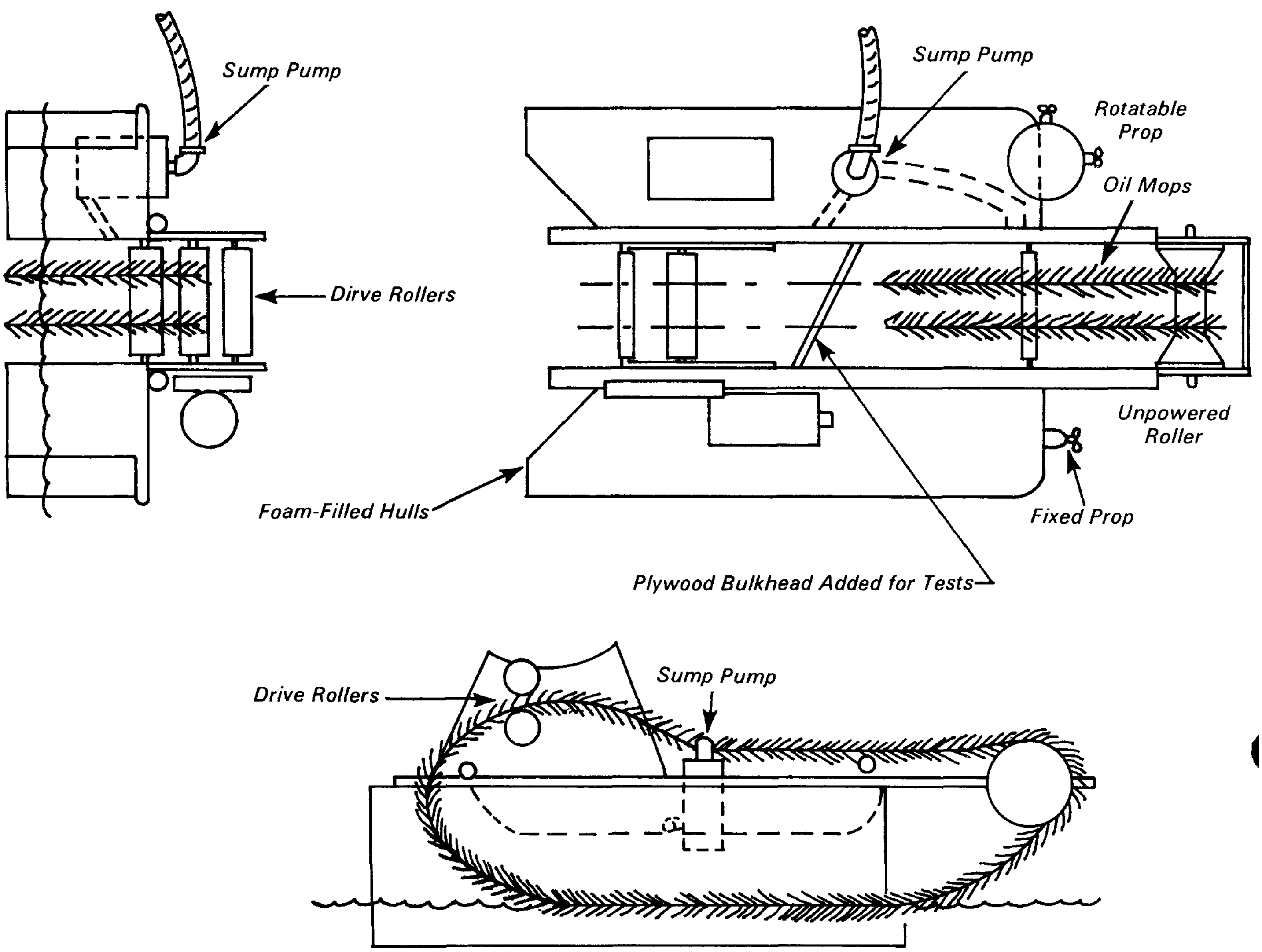


*Figure 2.* *Oil Mop remote skimmer.*

6 with high viscosity oil and 13 with medium viscosity oil.

The primary test objective was to generate design information for future construction of a larger version to be built for Arctic service in Canadian waters. The following test conclusions relate to the design criteria for the larger skimmer:

(1) At least three powered rollers must be provided to prevent slippage of the oil mop, especially when saturated with high viscosity oils.

(2) The mop-to-oil slick contact length and rotational mop speed of the full-scale skimmer should be selected after conducting a series of oil-mop saturation tests with the various viscosity oils expected to be encountered. The oil-mop saturation times can be compared with various values of skimmer length divided by mop speed. Sufficient time was not available during the single test week to determine mop-oil saturation time for the two test oils. In tests with oils of 185 cSt viscosity, however, ORR was unaffected by reducing the mop-to-oil slick contact length from 1.9 m to 1.2 m. ORR performance did fall off rapidly, however, when the contact length was reduced to 0.6 m.

(3) To maximize oil recovery rate, the full-scale skimmer hulls should be open on the sides, if possible, to allow oil to enter from the sides as well as the front. This will increase the ORR by allowing more oil to come in contact with the tops of the oil mops floating above the water surface. The skimmer beam should be maximized to increase the oil-mop surface area being laid down on top of the slick as it enters the front of the skimmer.

(4) A positive displacement type offloading pump is necessary to ensure rapid offloading of collected oil over a wide oil viscosity range.

## Best Performance—

The objective of these tests was to obtain design information for a larger unmanned Oil Mop remote oil skimmer

The highest numerical results obtained in these tests may not be the maximum obtainable with the full-scale Oil Mop skimmer. The highest numerical values of the three performance parameters of TE, RE, and ORR for the present OHMSETT tests are summarized in Table 2.

### Operating Limits—

Based on numerical and qualitative test results, the operating limits for this skimmer appear to depend on two factors: (1) oil mop-to-oil slick contact area and (2) slippage of oil-soaked mops through the squeezing roller assembly.

First factor. During stationary tests with medium viscosity oil, areas of clear water appeared under the point where the oil soaked mops were lifted out of the water at the stern of the skimmer. This indicated that the mops, at least on the side facing the oil slick, were fully saturated with test oil. The ORR performance increased when the entire skimmer hulls were lifted clear of the water by an overhead crane, thereby exposing the tops of the floating oil mop to splashing contact with oil from the sides. In the full-scale device, the ORR can be increased by maximizing the skimmer beam and opening the skimmer hulls along the length of the skimmer to allow oil to splash onto the mops from the sides.

Second factor. It is essential that future skimmers include three powered rollers instead of two as in the present Oil Mop remote unit. Two rollers are needed to squeeze oil from the saturated rope mop. A third roller, operating against one of the other two rollers, is needed to provide the mop tension to maintain the oil mop rotational speed. By visual observation, in almost all tests with high viscosity oil and in some with medium viscosity oil, slippage of the mops occurred at the two squeezing rollers. This resulted in the mops remaining on the oil slick after they had become fully saturated, reducing the net oil pickup per unit time.

*Table 2. Best Results - OMI Remote (High and Medium Viscosity Oil).*

| Performance Parmeter | Highest Value | Tow Speed (kt) | Waves H x L (m x m) | Slick Thk. (mm) |
|---|---|---|---|---|
| *High Viscosity—* | | | | |
| TE | 30% | 0.5 | 0.3 x 4.2 | 9 |
| RE | 96% | 0.5 | 0 | 6 |
| ORR | 2.6 $m^3$/hr | 1 | 0 | 6 |
| *Medium Viscosity—* | | | | |
| TE | 43% | 0.5 | 0.3 x 4.2 | 9 |
| RE | 93% | 0.5 | 0.2 x 7.0 | 9 |
| ORR | 2.7 $m^3$/hr | 1 | 0 | 9 |

## Troil/Destroil Skimmer System

### Skimmer Description

The Troil/Destroil skimmer system assembled for OHMSETT testing combined the Troilboom Giant 1.5-m boom manufactured by Trelleborg AB, Sweden, and the Destroil Model DS210 skimmer pump manufactured by DESMI A/S, Denmark.

The Troilboom consisted of four 6.4-m sections of a 1.5-m-high collection boom (Figure 3). At the center of the boom is a 3.5-m-wide opening with an additional section of boom attached that provides a pocket to collect the swept oil and contain the floating skimmer pump. The boom panels are supported by curved fiber glass battens that provide a concave boom profile while under tow. The boom is towed by an independent external load line that connects to the battens by individual bridles. This arrangement allows each boom section to conform to waves and maintain a nearly constant waterline.

The Destroil skimmer pump (Figure 4) is a hydraulically-driven screw pump. Oil is recovered as it flows over the central hopper weir into the exposed pump screw. Skimmer flotation is provided by two fixed-position floats and one that is adjusted by remote ballasting with compressed air. The pump is driven by a remote diesel-hydraulic powerpack that provides pump power and air ballast control. The pump discharges through a 127-mm, flexible discharge hose. The screw and hopper have a macerator cutting edge for chopping debris that may enter the pump with the oil.

### Conclusions

The Troil/Destroil skimmer system was tested at OHMSETT August 15-24, 1979. The tests were conducted to measure the recovery performance of the combined boom and skimmer system and observe the interaction of the boom and floating skimmer.

### Best Performance—

Table 3 shows the best skimmer performance for high and low viscosity oils. The skimmer performance parameters RE and ORR were at their highest when the boom preload oil volume was at the test maximum. Because of the high skimmer pump capacity, it was necessary to change the preload charge volume. Tests were conducted with various boomed preload volumes to determine performance changes and guidance for operator control.

### Operating Limits—

The Troil/Destroil skimmer system, as tested, has the following operating limits:

(1) The maximum towing speed at which the Troilboom can retain collected oil, without significant loss, is 1 knot.

(2) The maximum pumping rate of the Destroil skimmer pump is approximately 37.4 $m^3$/hr.

At a boom towing speed of 1 knot, the Troilboom lost oil at a rate of approximately 2.3 $m^3$/hr. when the towing speed was increased to 1.25 knots, the oil loss rate increased to approximately 23 $m^3$/hr. Oil losses were consistently observed to be the result of vortex shedding occurring near the side walls of the skimmer collection pocket.

The Destroil skimmer has an advancing screw pump that increases pumping rate as the viscosity of the pumped mixture increases. The maximum viscosity of the test oil was approximately 925 cSt.

The test series did not determine the pumping capabilities of the skimmer with higher viscosity mixtures. The skimmer pump was capable of ingesting a quantity of floating debris deposited during one of the test runs. The boom and skimmer system showed good wave-following in test waves up to 0.47 m harbor chop. The independent towing bridle allowed the boom to maintain a relatively constant waterline while in the wave.

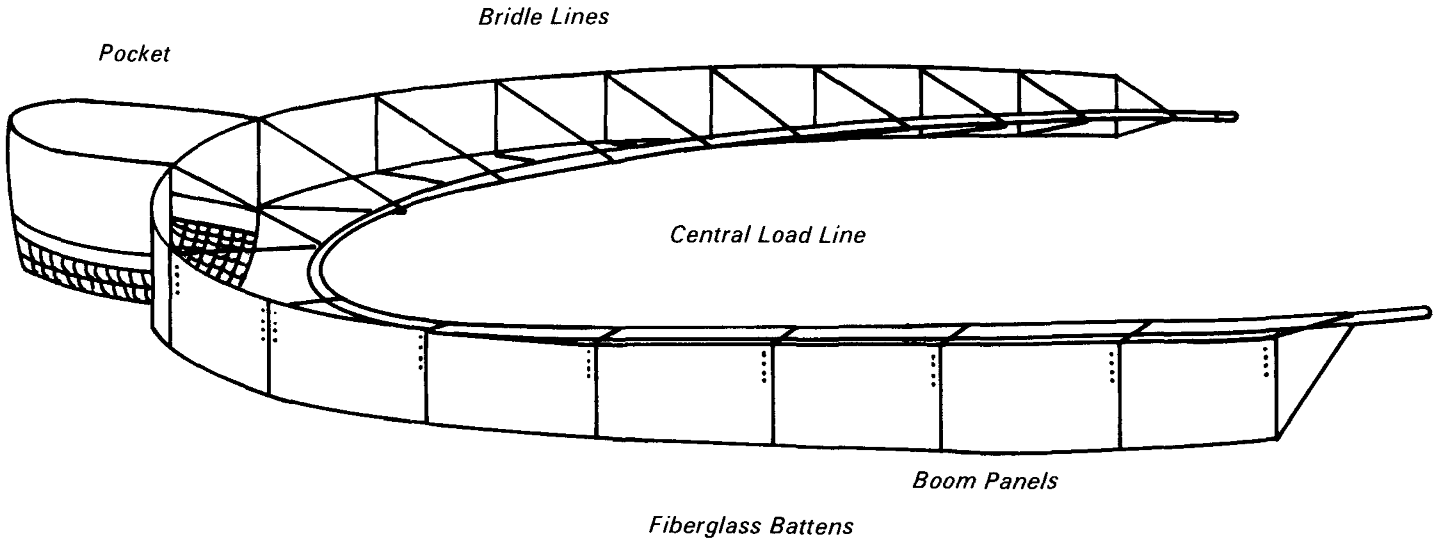


**Figure 3.** *Troilboom illustration.*

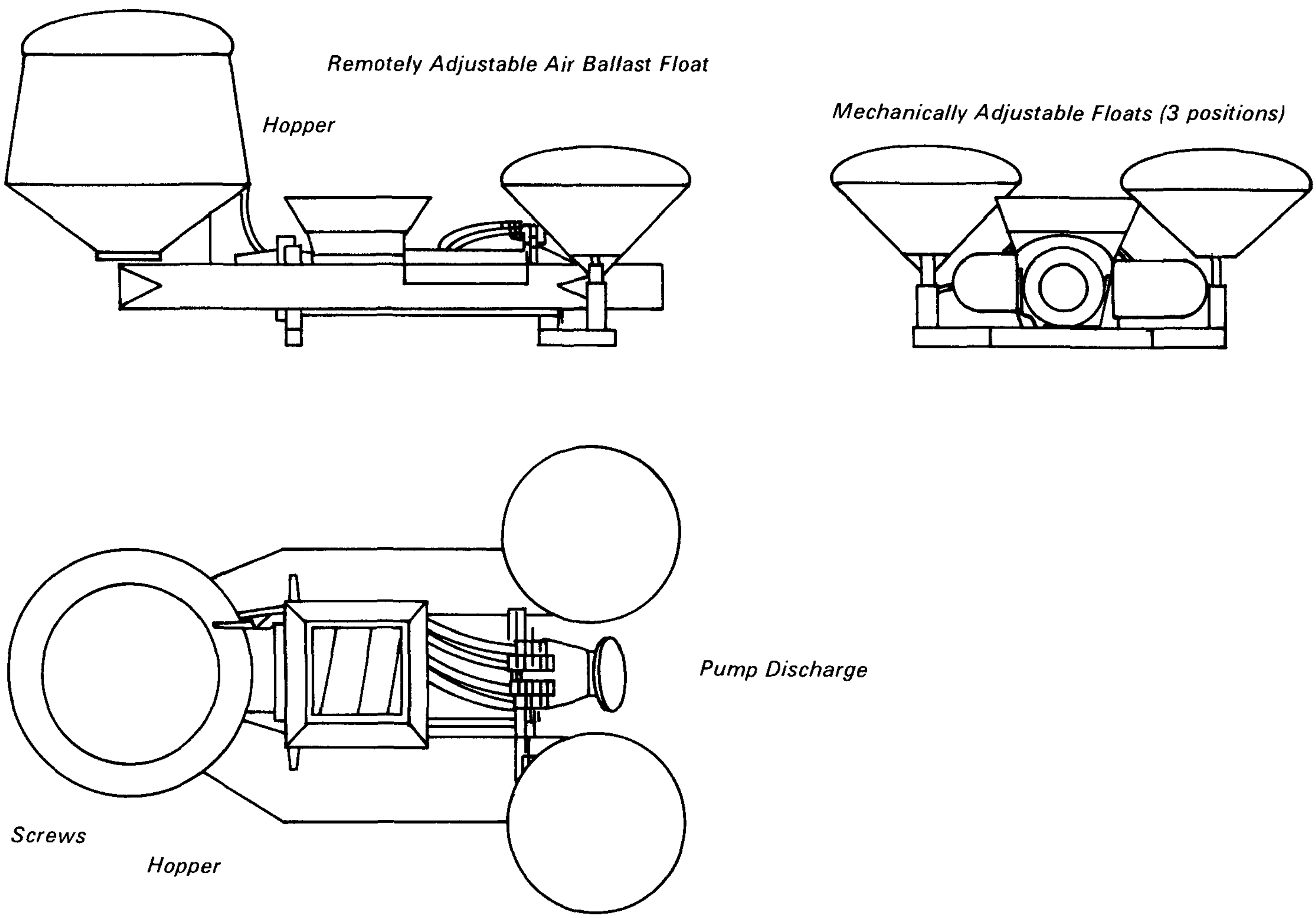


**Figure 4.** *Destroil skimmer pump.*

## *Recommendations*

The Troil/Destroil skimmer system, as tested, should be used at speeds not exceeding 1 knot. The device can be used in moderate waves without significant performance reduction. Once rigged, a single operator can control the recovery operation by adjusting pumping rate and skimmer height. Skimmer performance for RE and ORR can be increased if the operator allows a precharge oil volume to remain in the skimmer pocket while operating the pump. At least 3.8 $m^3$ is necessary to provide an appropriate precharge volume in the boom pocket for good performance.

The ORR of the skimmer is limited by the pump capacity. A larger pump with about three times the pumping capacity should be considered for the Troil/Destroil skimmer system. The boom and skimmer must be able to survive a variety of weather and towing conditions. Towing bridles and boom stiffener battens should be made stronger so that the boom can survive greater towing loads. The bridle attachment points should be redesigned to provide for quick rigging adjustments to allow a proper boom towing attitude.

# Versatile Environment Products Arctic Skimmer

## *Skimmer Description*

The Versatile Environment Products Arctic Skimmer (Figure 5) is a non-self-propelled advancing weir skimmer with an adsorbent rotating belt. The skimmer is equipped with a hydraulic power pack that powers the collection belt mechanism, the oil offloading pump, and a water pump for ballasting and powering the water jet booms. The skimmer can be operated with the power pack and control station onboard the skimmer, or with the power pack removed, the skimmer can be remotely controlled by means of a 27.4-m umbilical hose bundle.

## *Conclusions*

The Versatile Environment Products Arctic Skimmer was tested at OHMSETT October 15-23, 1979. This skimmer is an air-transportable, remotely controlled version incorporating the original Bennett oil collection principle. The Arctic Skimmer is a prototype version developed for Environment Canada and intended for cold-weather use.

The objectives of the Arctic Skimmer tests were to observe the operator control and mechanical performance. Skimmer performance was measured over several tank test conditions to gain operator control experience that would maximize skimmer performance, and the following conclusions were determined from the test series:

(1) The skimmer can be controlled from either onboard with the power pack mounted on the skimmer or remotely with the power pack removed and connected to the skimmer through the hydraulic control lines. The several adjustable skimmer settings can be preset for remote skimmer operation.

(2) The water jet nozzles can effectively concentrate and sweep oil into the skimmer at speeds from 1 knot to 4 knots in both calm and wave conditions.

(3) The settings of the three adjustable skimmer doors are critical for maximum performance at each speed. A graph of skimmer door settings was developed from performance tests.

### Best Performance—

Table 4 lists the best skimmer performance for high and low viscosity oils. In addition to regular towing tests with a 3-mm slick, several tests were performed to establish the maximum ORR of the skimmer. In these tests, at least 25.0-mm thickness of oil was presented to the skimmer and the skimmer then adjusted for maximum recovery rate.

***Table 3.*** *Peak Performance - Troil/Destroil Skimmer System (High and Low Viscosity Oil).*

| *Performance Parameter* | *Highest Value* | *Tow Speed (kt)* | *Boom Preload ($m^3$)* | *Waves H x L (m x m)* |
|---|---|---|---|---|
| *High Viscosity—* | | | | |
| *RE* | *93%* | *0.75* | *3.8* | *0.26 x 4.2* |
| *ORR* | *20.9 $m^3$/hr* | *0.75* | *3.8* | *0.26 x 4.2* |
| *Low Viscosity—* | | | | |
| *RE* | *91%* | *0.75* | *3.8* | *calm* |
| *ORR* | *23.7 $m^3$/hr* | *0.75* | *3.8* | *calm* |

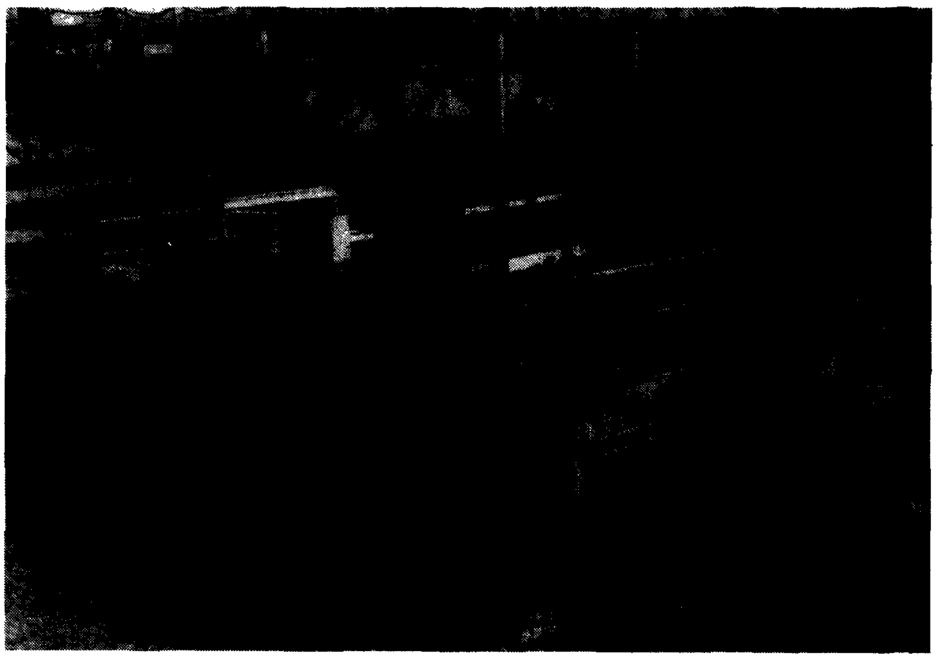

***Figure 5.*** *Versatile Environment Products Arctic skimmer as tested at OHMSETT.*



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## Operating Limits—

Each of the performance parameters can be maximized by the operator as follows:

1. To maintain high throughput efficiency, the skimmer should be operated at speeds not greater than 2 kt. The maximum safe skimming speed in calm water is 5 kt.
2. To maintain high recovery efficiency, a thick oil layer should be maintained at the collection belt. The belt should be raised to be even with the oil/water interface.
3. The oil recovery rate of the skimmer is limited by the maximum pumping rate of the skimmer pump. The actual rate will vary with the viscosity and discharge hose requirements. Maximum pumping rates observed for the 8-mm discharge hose with 4.5-m head was 23.6 $m^3$/hr.

The Arctic skimmer was tested in waves 0.18-m high by 9.4-m long. The maximum height of wave in which the skimmer can perform is about 0.3-m height, which is about the maximum depth of the bow door. As the skimmer is able to respond to longer period waves, the actual height of the wave can increase if the relative wave height at the skimmer mouth remains near 0.3 m.

**Table 4.** *Peak Performance - Versatile Environment Products Arctic Skimmer (High and Low Viscosity Oil).*

| *Performance Parameter* | *Highest Value* | *Tow Speed (kt)* | *Waves H x L (m x m)* | *Slick Thk. (mm)* |
|---|---|---|---|---|
| *High Viscosity—* | | | | |
| *TE* | *96.3%* | *2* | *calm* | *3.4* |
| *RE* | *85.0%* | *0* | *calm* | *25.0* |
| *ORR* | *20 $m^3$/hr* | *0* | *calm* | *25.0* |
| *Low Viscosity—* | | | | |
| *TE* | *99.4%* | *1* | *calm* | *2.8* |
| *RE* | *97.4%* | *0* | *calm* | *25.0* |
| *ORR* | *19.4 $m^3$/hr* | *0* | *calm* | *25.0* |

## *Recommendations*

(1) The Arctic skimmer is intended to be transported partially disassembled. The skimmer could arrive with the belt mechanism removed and lowered, flotation collars removed, and additional equipment stored within the skimmer. Clear rigging, reassembly, and system check-out procedures should be fixed on the skimmer to facilitate quick deployment.

(2) The skimmer operating manual should be updated to include optimal skimmer door settings, belt speed, and pump control calibration curves.

(3) An auxiliary cooler should be provided for the hydraulic reservoir for extended operation in warm weather.

(4) The rigging for the water jet sweep booms should be simplified to allow quick adjustment from the skimmer.

(5) The squeeze belt collection sump could be enlarged to contain belt splashover at high speed.

(6) The adjustment screws for the aft and middle gill door should be modified to make readjustment quicker.

The full report was submitted in fulfillment of Contract No. 68-03-2642 by Mason & Hanger-Silas Mason Co., Inc., Leonardo, New Jersey 07737, under the sponsorship of the U.S. Environmental Protection Agency. Technical direction and evaluation of the Oil Mop Remote skimmer and the Versatile Environment Products Arctic Skimmer were subcontracted to PA Engineering, Corte Madera, California.

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***Richard A. Griffiths** is the EPA Project Officer (see below).*
*The complete report, entitled "Performance Testing of Four Skimming Systems," (Order No. PB 82-101 353; Cost $9.50, subject to change) will be available only from:*
*National Technical Information Service*
*5285 Port Royal Road*
*Springfield, VA 22161*
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*The EPA Project Officer can be contacted at:*
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