PERFORMANCE TESTING OF THE SOVIET OIL/DEBRIS SKIMMER

by

H.W. Lichte
Mason & Hanger-Silas Mason Co., Inc.
Leonardo, New Jersey 07737

Contract No. 68-03-2642

Project Officer

John S. Farlow
Oil and Hazardous Materials Spills Branch
Municipal Environmental Research Laboratory
Edison, New Jersey 08837

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communications link between the researcher and the user community.

This report describes the performance testing of the Soviet Oil/Debris Skimmer under a variety of controlled conditions. Based on these results, a number of operating techniques are of interest to those interested in specifying, using, or testing such equipment. Further information may be obtained through the Oil and Hazardous Materials Spills Branch in Edison, New Jersey.

Francis T. Mayo
Director
Municipal Environmental Research Laboratory
Cincinnati

ABSTRACT

Performance evaluation of a Soviet oil skimmer was conducted at the United States Environmental Protection Agency's Oil and Hazardous Materials Simulated Environmental Test Tank in 1979. The program was sponsored through the Joint U.S.-U.S.S.R. Project on Prevention and Cleanup of Pollution of the Marine Environment from Shipping. The skimmer was provided by the Black Sea Central Planning and Designing Bureau, Odessa. The test program was designed at OHMSETT to evaluate the oil skimming capability of a specially modified Soviet skimmer, Model 2550/4. The self-propelled vessel is 17.7 meters long and weighs 39 metric tons. The 111 kilowatt diesel engine drives a ducted propeller water jet propulsion system. The vessel is capable of five knots forward speed and skims effectively at speeds from zero to two knots.

The unique combination of various weir designs into one system, vessel mobility, the efficient use of energy, a series type oil/water gravity separator, and the propulsion techniques all suggest it to be an effective harbor skimmer. The oil recovery rate of 12.4 cubic meters per hour was confirmed using OHMSETT heavy test oil (1.5 pascal seconds and 0.95 specific gravity) in calm water conditions. Recovery efficiency was 85 percent at 1.5 knots forward speed and throughput efficiency was 90 percent at one knot forward speed. Performance dropped for skimming light oils at faster speeds and higher wave conditions. The skimmer collected 64 percent of the 81.3 cubic meters oil volume encountered during the test program.

This report was submitted by Mason & Hanger-Silas Mason Co., in fulfillment of Contract Number 68-03-2642, Job Order No. 55, with the U.S. Environmental Protection Agency. The test program was completed in July 1979.

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FIGURES

TABLES

LIST OF CONVERSIONS

ENGLISH TO METRIC

centistoke	$meter^2$/second	1.000 E-06
degree Fahrenheit	Celsius	$t_C = (t_F-32)/1.8$
erg	joule	1.000 E-07
foot	meter	3.048 E-01
$foot^2$	$meter^2$	9.290 E-02
foot/minute	meter/second	5.080 E-03
$foot^3$/minute	$meter^3$/second	4.719 E-04
foot-pound-force	joule	1.356 E+00
gallon (U.S. liquid)	$meter^3$	3.785 E-03
gallon (U.S. liquid)/minute	$meter^3$/second	6.309 E-05
horsepower (550 ft lbf/s)	watt	7.457 E+02
inch	meter	2.540 E-02
$inch^2$	$meter^2$	6.452 E-04
knot (international)	meter/second	5.144 E-01
liter	$meter^3$	1.000 E-03
pound force (lbf avoir)	newton	4.448 E+00
pound-mass (lbm avoir)	kilogram	4.535 E-01

ABBREVIATIONS AND SYMBOLS

Abbreviations

CWL	--constructive water line
m	--meter
hp	--horsepower
kW	--kilowatt
km	--kilometer
m^3	--cubic meter
m^3/hr	--cubic meter per hour
rpm	--revolutions per minute
kPa	--kilopascals
psi	--pounds per square inch
mm	--millimeter
cm	--centimeter
dm	--decimeter
Q	--oil distribution rate
t	--slick thickness in skimmer basin
v	--tow speed
RE	--recovery efficiency
TE	--throughput efficiency
ORR	--oil recovery rate
V_{MD}	--main duct velocity
K	--Pitot tube constant
q	--gravity constant
Q_{MD}	--main duct flow
Q_{VD}	--vertical duct flow
A_{MD}	--area of duct
A_{VD}	--area of vertical ducts
V_{VD}	--direct reading of vertical duct velocity
w	--skimmer basin width

Symbols

%	--percent

ACKNOWLEDGMENT

This skimmer test program required innovative solutions to several engineering problems. First was the transportation of the huge skimmer from the U.S.S.R. container ship and its return a month later. Mr. R.A. Ackerman managed this effort, calling on new resources, and in the midst of the New York Harbor tug boat strike. His effective solution incorporated one of the largest U.S. over-the-road mobile cranes, and also tandem lifts of the skimmer, by the U.S. Navy. He also managed to prevent during the test program the subtle concern for interference from the large number of visitors.

The second engineering problem to be solved was communications and transfer of technology. In this regard, the Soviet engineers and technicians were outstanding. Mr. Sergei Nunaparov was responsible for the background work leading to this test program and the excellent Operations Manual. Two Soviet technicians were on site for the month-long test program at OHMSETT. Messrs. Victor Polishchuk and Vladimir Semenov were excellent engineers, communicators, and charming guests. Rarely did the language barrier interfere, but when it did, the mutual understanding of Bernoulli's principles in fluid mechanics was the translator.

The OHMSETT staff contributions made the daily work schedule cost effective and timely. The cooperation of various federal agencies and the U.S. Navy facility, Naval Weapons Station Earle allowed smooth operations.

SECTION 1

INTRODUCTION

Oil and hazardous waste spills on the world's waterways are problems which know no territorial boundary. Under a bi-national agreement, the United States and the Soviet Union tested the latest Russian design for picking up floating oil spills at the Environmental Protection Agency's Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) in Leonardo, New Jersey during June 1979.

The Soviet Oil/Debris skimmer, Model 2550/3 and the newer 2550/4 are seen frequently in the port water areas of the U.S.S.R. At least 120 of the 2550/3 craft have been constructed, and on the order of 50 of the 2550/4 are thought to have been built since 1974. The Model 3 craft is 14.83 m long, has a beam of 4.3 m and a mean draft of just over 1.6 m. The Model 4, 17.4 m long has a more conventional bow which gives it better speed (5 kt vs. 3.8 kt) than the Model 3 and better range and sea-keeping qualities. These craft are designed to collect approximately 12 tons of oil per hour in calm water and to collect one cubic meter of debris per hour.

Oil and debris are initially dumped into a 12 m^3 capacity receiving-settling tank. The oil-water mixture is then pumped into two 11 m^3 capacity gravity separation and storage tanks. Both models can be rigged with containment booms which are extended by tenders during skimming operations. The Model 4 has two hydraulically-actuated doors in the bow which can be opened to give a maximum sweep path of 8 m. In addition to their use as skimmers these craft transport waste waters from ships to treatment or receiving facilities on shore.

The 17.4 m, 43 ton skimmer, shipped from Odessa, U.S.S.R, was tested under the supervision of the Cincinnati Municipal Environmental Research Laboratory's Oil and Hazardous Materials Branch in Edison, New Jersey. The arrangements for the testing were made through the U.S./U.S.S.R. Task Group on Prevention and Cleanup of Pollution of the Marine Environment from Shipping.

The skimmer was lifted into OHMSETT's 20-m wide, 203-m long wave/tow tank to evaluate the effect of such variables as oil type and thickness, wave height and type, and the speed of advance through the water.

OHMSETT provided a controlled, environmentally safe facility for testing the skimmer's effectiveness and rate of oil collection under a variety of different conditions.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

The performance of the Soviet Oil/Debris Skimmer, Model 2550/4, fulfilled design requirements well. The combination of the unique application of various weirs into one system, mobility, the efficient use of energy, the incorporation of series oil/water separation, the propulsion system, and use of high oil/water flow conditions suggest that the skimmer is the best of its class in harbor operations. The actual oil collection performance was near the design specifications and proved better in the heavy oil than in the light, as expected because of entrainment. The high throughput efficiencies in the normal advancing and stationary modes were commendable.

The centrifugal pump used in the gravity separation system was effective in transferring oily water. The second onboard pump, a vortex fire/ballast system had a significantly smaller capacity. Future modifications of the design should address the incorporation of a positive displacement pump somewhere in the circuit. The two-man operation of the vessel was difficult. One was needed on the bow while the second divided his time between the wheel house and pump controls. Skimming oil when under way should include an additional man.

Future testing of the skimmer should address, in more detail, the efficiency of the coke filter system, use of the gill door in the skimming mode, and larger oil volume performance tests requiring significant quantities of oil in the port-side storage.

SECTION 3

DEVICE DESCRIPTION

THE VESSEL

The Soviet Oil/Debris Skimmer (Model 2550/4) tested at OHMSETT (see Appendix A) is a fourth generation design for recovery of floating pollutants, oil, and debris from the water surface. The vessel can navigate offshore and in the roads within limits established by the USSR Register of Shipping. The maximum range is 18.53 km off port with a sea force of 3 and wind force not exceeding 4 in Soviet standards (Reference 1).

The vessel is 17.7 m long, with a constructive water line (CWL) beam of 4.3 m, and a total weight of 39 metric tons. The CWL draft is 1.6 m, and the freeboard is 2.4 m. Hydraulically controlled bow doors provide an adjustable oil slick sweep width up to 8 m. Figure 1 displays the vessel at OHMSETT with the bow doors wide open.

The self-propelled, one-deck vessel is normally operated by two persons: A navigator-engineer and an able-bodied motorman. The crew does not live aboard, but there are provisions for fresh water, wash water, toilet, deck house, change room, heat and navigational aids. The main engine is a diesel rated at 135 HP (100 kW) at 1900 rpm. There is a reversible reductor transmission to drive the 0.54-m diameter ducted-propeller water jet propulsion. Other power takeoffs are used for electricity, air, hydraulic, and pump belt drive systems. The vessel is capable of 5 knots forward speed. Speed during oil collection varies between standing still in a dock area to advancing at 0.5 to 2 knots.

Onboard storage provides 1.83 m^3 of ballast, 31 m^3 dry compartments, 19.3 m^3 recovered fluids (oil, water), 1.3 m^3 diesel fuel, and 0.23 m^3 hydraulic oil. The deck house is large enough for a sleeper, if required. The engine-room layout is spacious to work in, and the pump room has enough head room for convenient repair work.

THE SKIMMING OPERATION

The skimmer can be operated in both an advancing mode and a stationary mode. The speed and direction of the vessel is controlled by reaction rudders downstream of the propeller duct. The unique stationary mode requires the vessel to manuever its

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1. Operational Manual, Oil/Debris Skimmer (ODS) 2550/4-901-008, USSR Black Sea Central Planning and Designing Bureau, 1979, 63 pp.

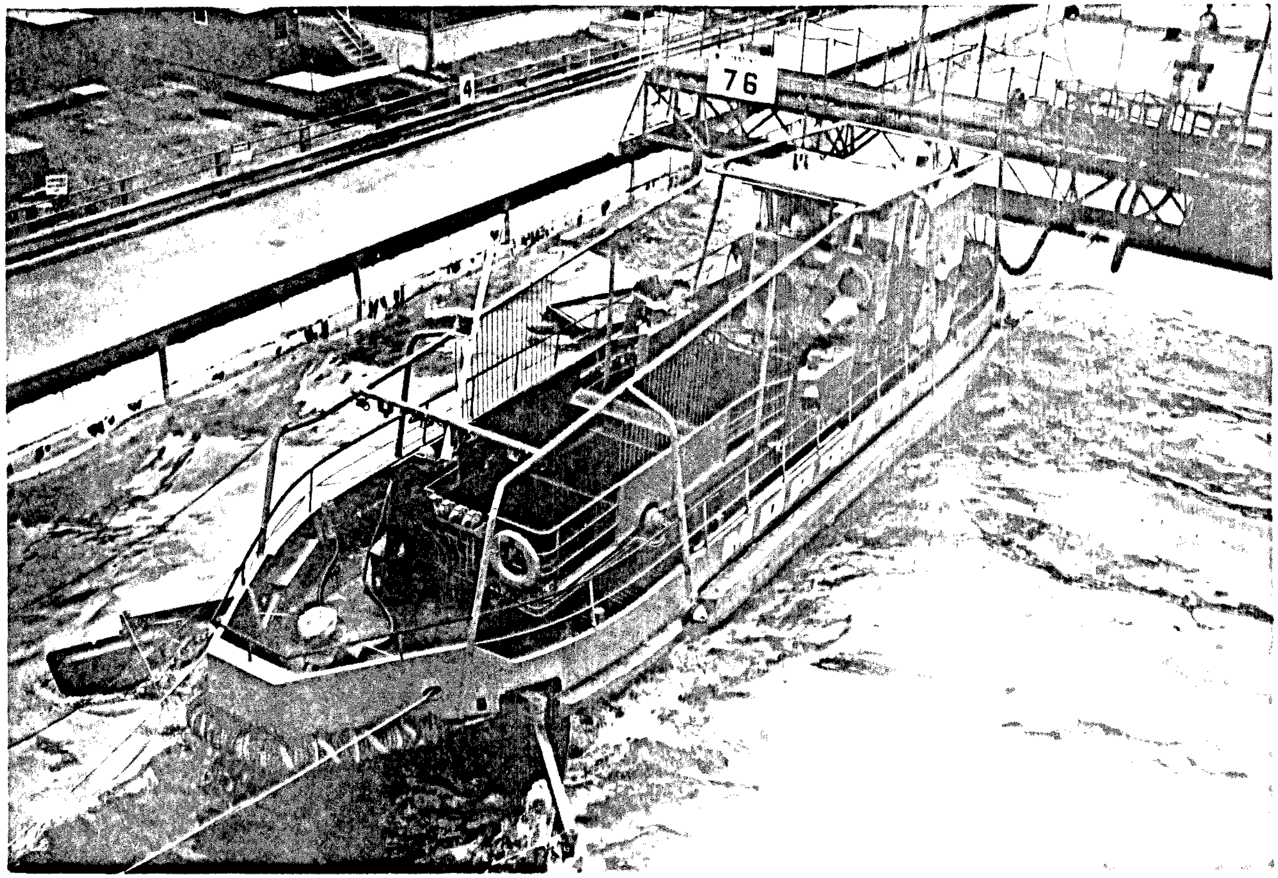

Figure 1. Soviet Oil/Debris skimmer at OHMSETT with the bow doors open.

stern to a dock or piling and close the reaction rudder. The current then caused by the prop wash pushes floating oil around either or both sides of the bow door opening and subsequently is sucked into and over the broad crested weir.

The skimmer operators have various controls and equipment settings to effect the best oil skimming modes. Vessel trim is set using a combination of ballast, bow door opening, and vessel speed. Figure 2 is a cutaway sketch of the integrated system. The debris handling basket and mechanism was not tested at OHMSETT and is not shown in Figure 2, but it is shown clearly in Figure 3. The oil collecting process is best explained qualitatively by describing Figure 4, a representative flow diagram. The overall goal is to transport oil and water through a three stage separation system onboard. While forward speed of the vessel causes oil and water to enter the bow, the major entry force is from suction caused by the ducted propeller intake. As they enter, oil is skimmed using the broad-crested weir. Water flows below the weir through a main duct, out through the propeller duct, and past a pair of reaction rudders. Oil and water passing over the broad-crested weir is trapped in a large basin. If debris is present it will be skimmed with the basket strainer. Once in the basin, water is drawn through a large coke filter, past a tandem pair of adjustable sluice gates, up an annuli, over rectangular weirs, down through annuli, through adjustable valves, and finally into the main propulsion duct mixing with the water from the bow entrance.

Oil is skimmed from the large basin with an adjustable basket strainer over flow weir. It is drawn by suction into the starboard separator tank (9.65 m^3). From there it is drawn into the port-side separator tank, with another 9.65 m^3 capacity. Once these tanks are full of oil, the skimmer must be offloaded. The water passing through the centrifugal pump and eductors is discharged into the midship annulu, joining the water from the large basin.

Quantitatively, the flow area is described in Figure 5, which shows the duct and weir sizes. The centrifugal pump to discharge the port-side separator tank and power the vacuum eductor is rated 115 m^3/hour at 2900 rpm and 372 kPa (54 psi). The vessel's propeller that provides most of the water flow is 544 mm in diameter and has a 503 mm pitch. Revolutions are selectable based on vessel trim, forward speed, and reaction rudder settings up to a maximum of 879 rpm. Flow through the main duct was not stated in the Soviet Skimmer Manual but was measured at OHMSETT between 1400 m^3/hour and 3700 m^3/hour.

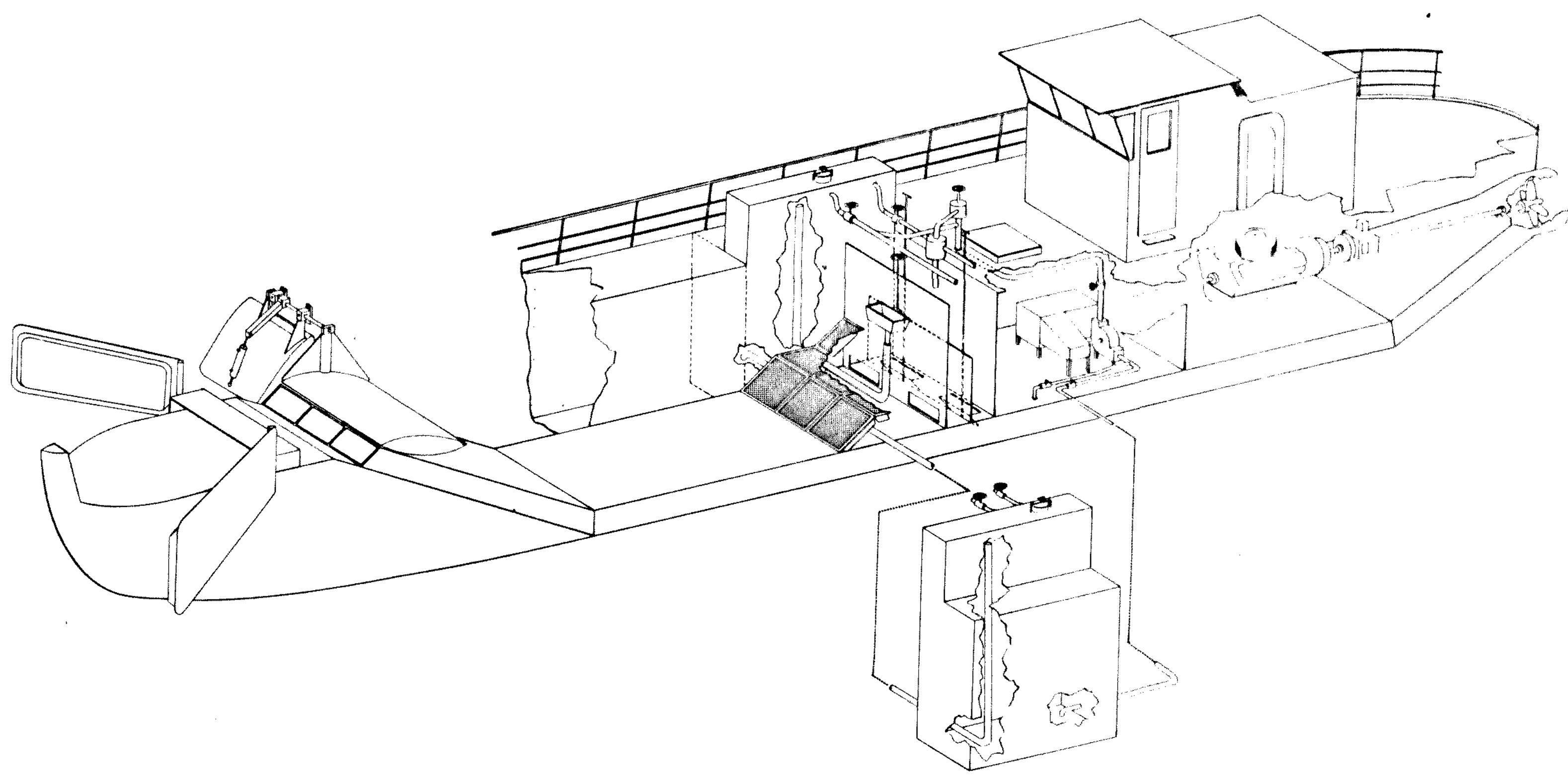

Figure 2. Cutaway sketch of the integrated Soviet Oil/Debris skimmer system.

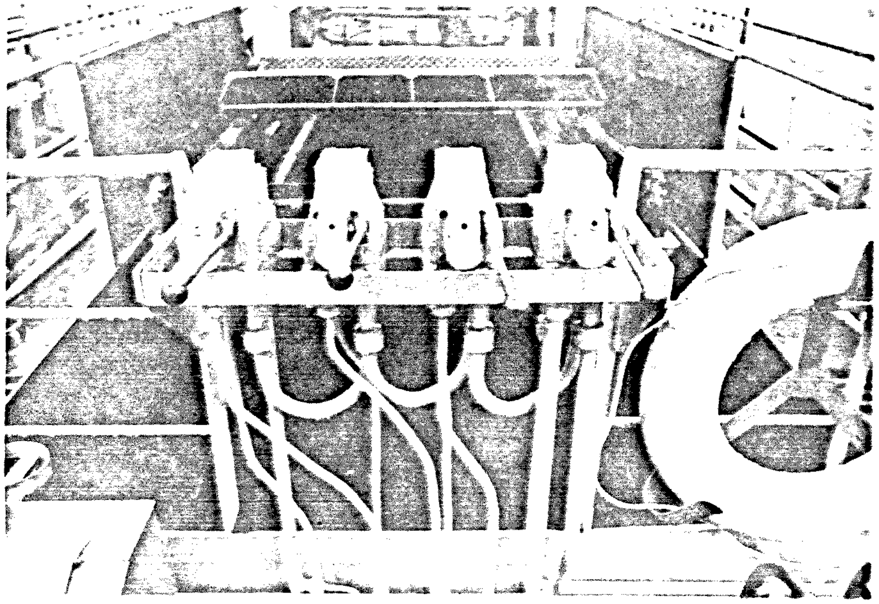

Figure 3a. Debris handling system, view from bow operator's work station.

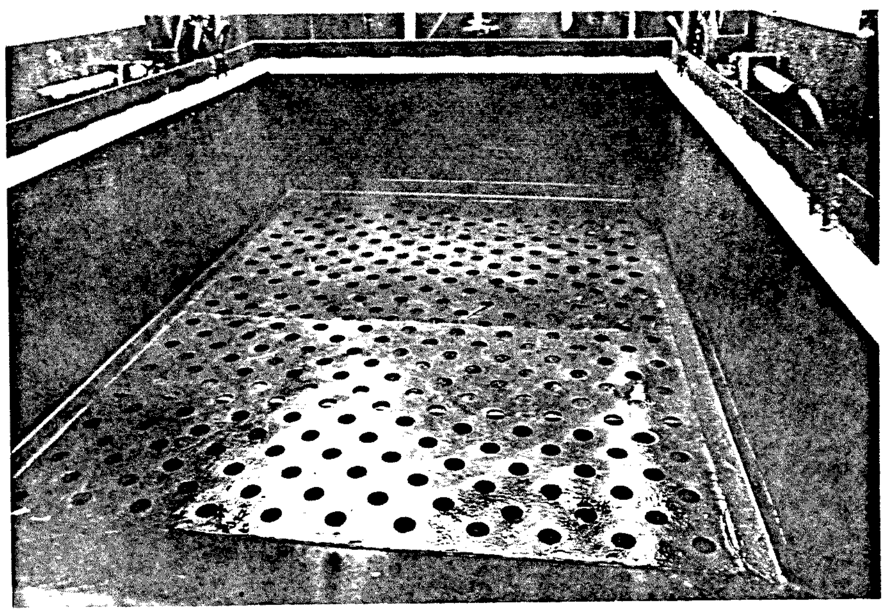

Figure 3b. Debris handling system, close up.

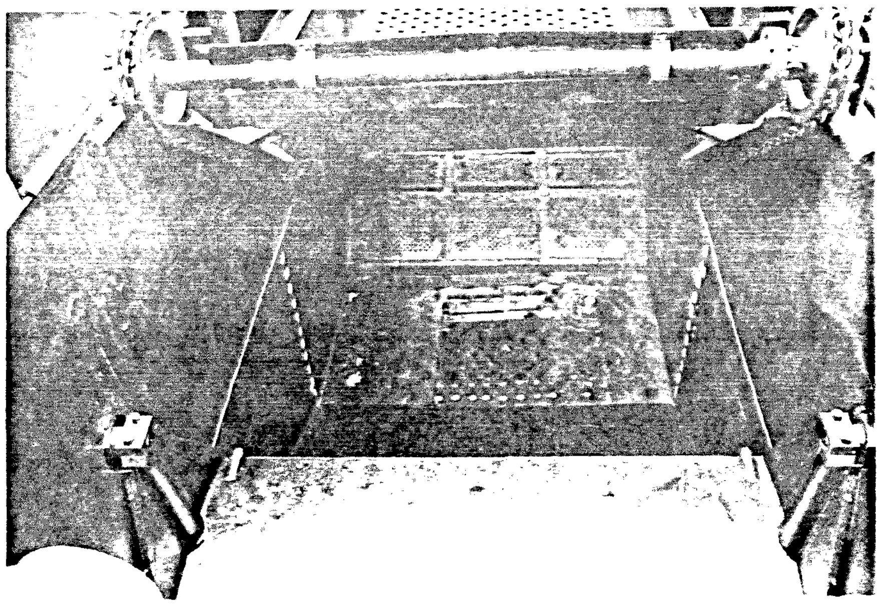

Figure 3c. Debris handling system close up of chain conveyor, empty settling basin, and coke filter entrance.

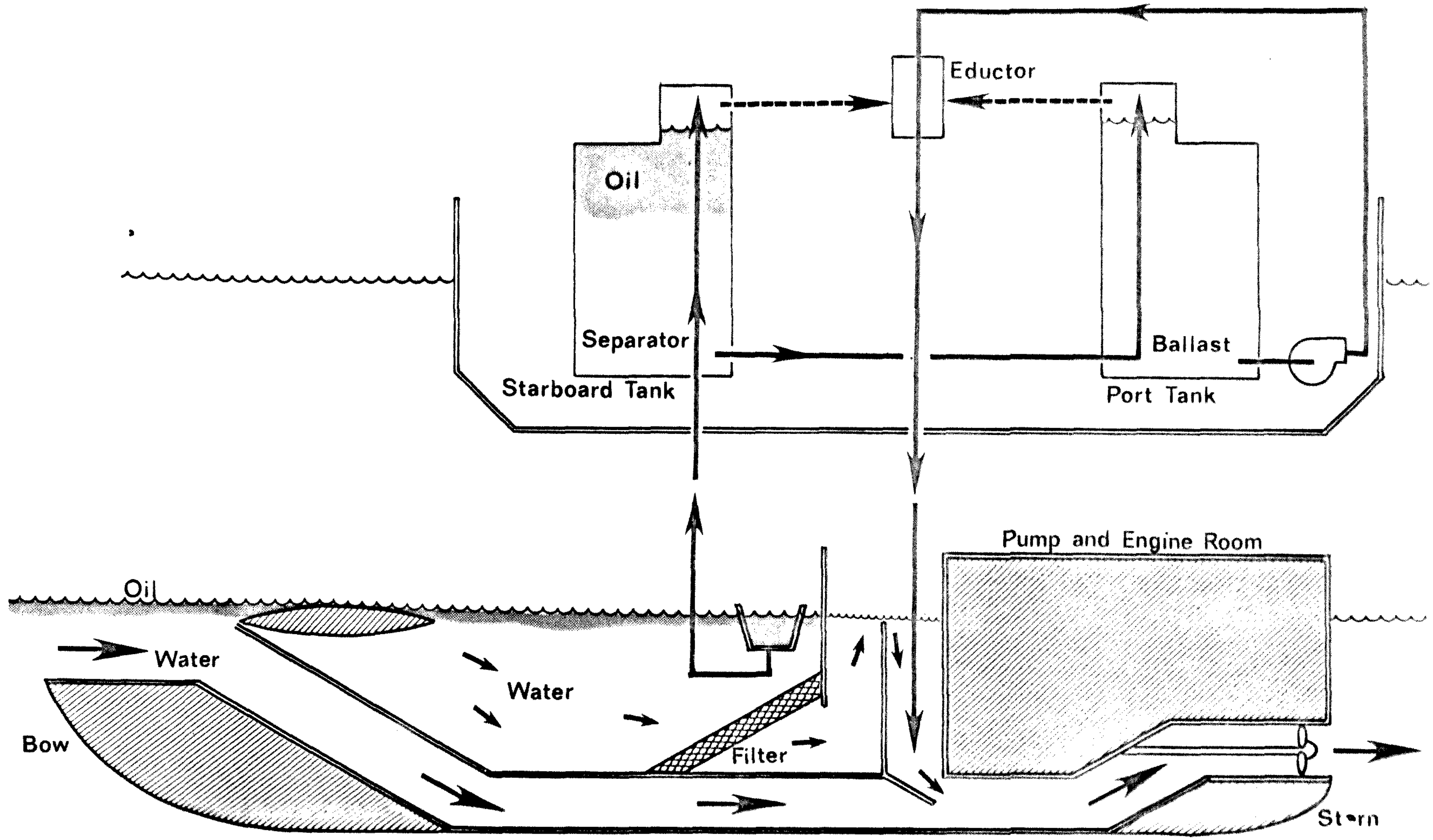

Figure 4. Representative flow diagram of the oil collecting process.

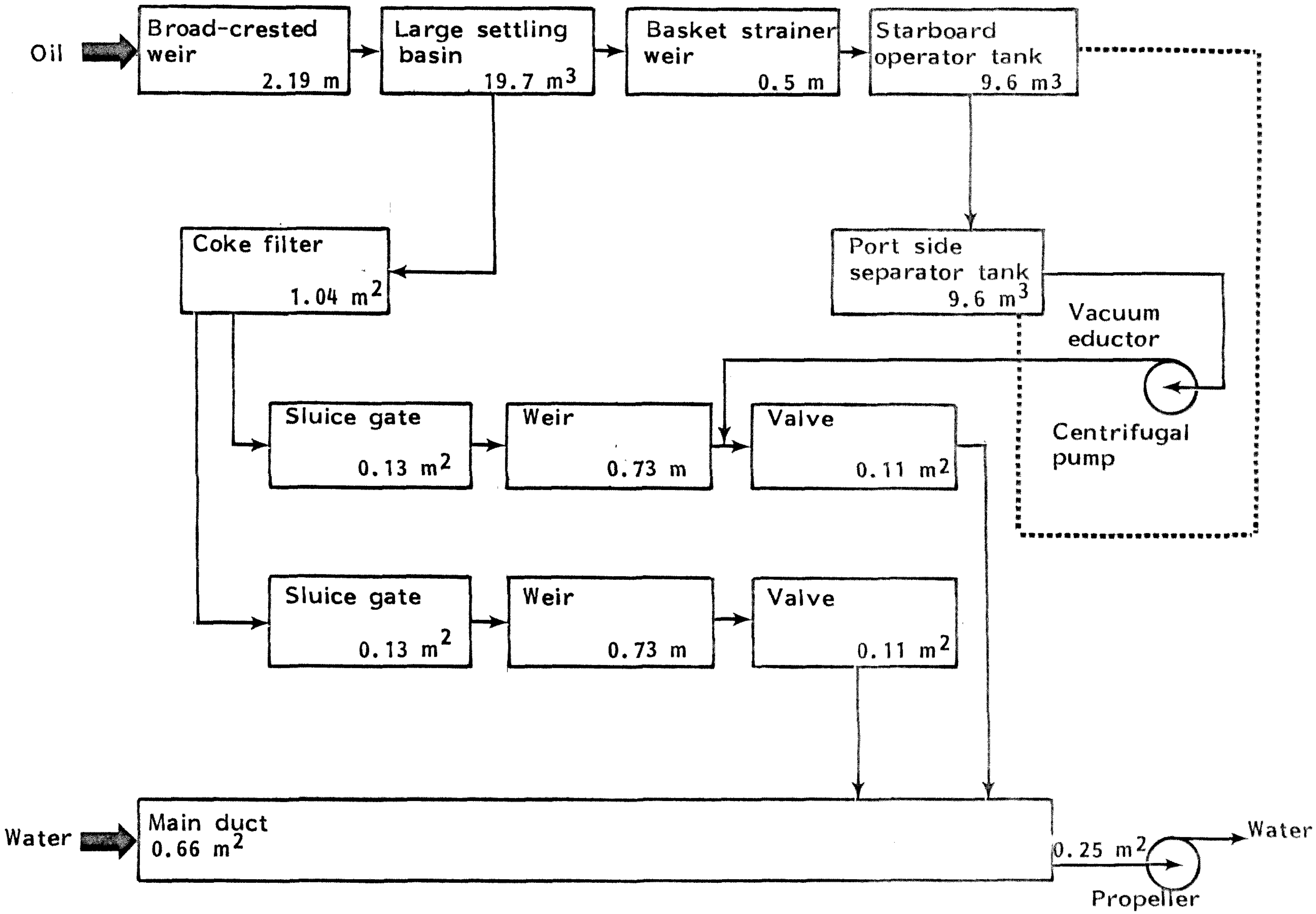

Figure 5. Flow area of the Soviet Oil/Debris skimmer relating the duct and weir size.

SECTION 4

TEST PLAN AND PROCEDURES

TEST PLAN

The test plan was designed to simulate harbor conditions typical of the skimmer's design environment. The USSR designed the system to be both a stationary skimmer not requiring booms and an advancing skimmer useable to 2 knots forward speed and a maximum of 1.5 m wave height. The OHMSETT test plan was in three major sections to investigate the fluid flow, oil skimming in the stationary mode and advancing mode. This skimmer was to be the largest tested, with the deepest draft, and the first to require the propulsion system active during testing (Reference 2).

Heavy and light oil (see Appendix B) tests were required to measure pump and oil/water separation efficiency. The Soviets were interested in the new modification incorporating the coke filter, which necessitated the fluid flow experiments. Calm water and wave conditions (see Appendix C) were selected to observe effects of splash in the broad-crested weir area and the response of the vessel hull reacting to specific wavelengths. Forward test speeds were selected to observe bow-wave interactions, vessel trim, and bow door opening.

The skimmer operator had a wide variety of equipment adjustments for weir height and valve positions but the pump capacities were a direct function of the main engine shaft speed. Fluid flow was controlled by valves between starboard and port oil tanks, and the vacuum eductor output was dependent on this flow. Advancing speed is a function of the opening in the reaction rudders and the engine speed.

The following skimmer settings were considered important to performance results:

Broad-crested weir angle - adjustable between zero and 90°, full open to closed.

Trim ballast tanks - zero to 60 cm, empty to full tanks (1.83 m^3).

Engine speed - idle at 600 rpm to 1800 rpm maximum prudent setting.

Aft valve gate position - full open with 3 intermediate settings to close, controlling water flow through the coke filter.

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2. Lichte, H.W. and M.K. Breslin. Testing Skimmers for Offshore Spilled Oils. In: Proceedings of the 1978 Offshore Technology Conference, Houston, Texas, 1978, pp. 247-254.

Oil collecting weir with basket strainer - depth adjustable to correspond to the oil/water interface in the large basin.

Extensive photo and video coverage was utilized to document qualitative data, vessel response, and dynamic oil/water relations. Underwater and topside 16-mm motion pictures and 35-mm still photography was required. Remote video was important, especially in the instant-replay mode after every test.

Measured data was recorded to calculate throughput and recovery efficiency along with recovery rate.

Flow measurements were taken throughout the skimmer at the request of the Soviets, so as to evaluate several of their developmental improvements in this new model skimmer.

The OHMSETT controlled independent variables were selected based on Soviet estimates of expected performance:

Light and Heavy test oils, slick thickness 1 to 5 mm

Tow speeds from dead in the water to 3 knots advancing.

Water conditions:

Calm
Regular waves (.4 m x 6.95 m, .2 m x 11.6 m, .4 m x 1.52 m)
Harbor chops (.2 m and .7 m)

The skimmer was moored between the OHMSETT main bridge and auxiliary bridge, rigged to allow free vessel response to waves and trim conditions. Oil collected by the skimmer, stored in its starboard tank, was transferred to the auxiliary bridge for measuring. The main bridge oil distribution was 7 m ahead of the skimmer bow doors.

TEST PROCEDURES

Fluid Flow

The first series of tests addressed the flow of water through the skimming system. The Soviets were interested in specific measurements about their new developments in the skimming system and OHMSETT was the only available controlled environment.

The skimmer was towed in calm water the length of OHMSETT. The two Soviet technicians operated the vessel, and three OHMSETT technicians were onboard: one to record data, one camera man, and one to read instrument dials. The OHMSETT Test Engineer divided his observation position among the auxiliary bridge, video bridge, main bridge, and the vessel itself.

The test procedure was to select one specific forward tow speed for a series of engine speeds with the reaction rudders wide open. The ballast level was selected based on the Soviet technicians' judgment for each tow and engine speed. The water mark positions were recorded by observing the vessel pitch or trim early in the test run.

Equipment settings, flow, and pitch of the vessel were recorded in log books and by photo/video film and tape. The broad-crested weir angle was measured observing the forward leading edge in relation to painted index marks on the wall of the large basin. A zero angle corresponds to a horizontal weir or full open. A 90° weir is vertical or fully closed. The ballast level was measured with a dipstick; 600 mm was full and zero was empty. Engine speed was measured with the vessel's tachometer. Vessel trim was measured by decimeter marks painted on the large basin wall forward and aft, designated bow box (dm) and stern box (dm). The horizontal zero position or still water level in the stern was six and in the bow zero. The horizontal distance between bow and stern vertical scales was 4.9 m. The procedure was to keep the bow down, and controlled to ensure an optimum 10-cm deep oil/water skim over the broad crested weir. The aft valve gate position was recorded to evaluate flow through the coke filter; position one was wide open, and to position five was closed.

Water flow in the main duct was calculated using Pitot-tube manometer measurements and the known cross-sectional area. Upwards flow in the vertical annulus duct was calculated using direct velocity measurements from a velocimeter and the known cross-sectional area.

Decimeter bow draft marks were painted on the vessel and bow doors to provide the main bridge operator and Test Director a way to judge vessel trim. If improper trim was developing, the Test Director could slow the tow speed. Decimeter draft marks were also painted on outboard starboard side, fore, aft, and midship to provide observations of pitch.

Skimming Oil--

The trim and fluid flow data gathered in the Flow Test section was incorporated into the oil collection experiments and equipment settings. Performance data was also recorded in the same manner. The Soviet-estimated skimmer design recovery rate was 12 m^3/hour encountering a 1-mm thick slick. The OHMSETT test slick encountering the bow doors was approximately 1-mm thick and 7-m wide. The majority of testing was to be performed in this condition with several tests set aside for higher volumes to evaluate the bow door performance. The test oil was dyed to enhance visual records. Oil loss by the skimmer after it was encountered was recorded using photo/video techniques.

Oil distribution from the main bridge was selected based on the 2.19-m wide skimmer basin and broad-crested weir, the vessel preselected tow speed, a preselected slick thickness, and the expected skimmer oil recovery rate. The main bridge oil distribution pumps were set individually for each test based on the relation:

$$Q = \frac{t\ v\ w}{0.274}$$

Where:

Q = oil distribution rate, m^3/hour
t = slick thickness in skimmer basin, mm
v = tow speed, m/second
w = skimmer basin width (2.19 m)
0.274 = constant for unit conversion

Main bridge observers controlled the slick width using trailing braided polyethylene rope and water jets to ensure, in most tests, that the skimmer bow doors encountered one hundred percent of the slick. One Soviet technician/operator was stationed on the bow to operate the broad-crested weir angle and bow door opening. Vessel ballast was preset for test conditions, based on data from the Fluid Flow experiments. The other Soviet technician/operator would control the engine speed, operate the basket strainer over-flow weir, and adjust water flow values to ensure maximum oil recovery.

The recovered oil/water was pumped from the starboard tank to the auxiliary bridge using an OHMSETT double-diaphragm air-operated pump. As a test time saving measure, the skimmer centrifugal offload pump was not used because of its low capacity for pumping 7 m up to the auxiliary bridge measurement tanks.

Most of the tests were performed in triplicate before emptying the starboard tank. This was a labor saving option in that each skimmer tank had a capacity of 9.65 m^3 and each test would use approximately 2.5 m^3 of oil. It was agreed that the three tests arithmetically averaged would smooth out possible errors in otherwise measuring small quantities. Each test duration was timed individually to calculate the total oil volume encountered. The sample barrels on the auxiliary bridge were measured for total fluid quantity, decanted water quantity, mixed for hómogenity, and a sample taken to the Chemistry Lab for measuring oil quantity.

The skimmer, as mentioned earlier, had some new unproven modifications. Each of these was isolated in specific tests to determine its contribution to performance. A wave dampener originally installed in the bow throat was removed during the early heavy oil tests in waves (test no. 47). One repair was required when the flapper valve in the starboard collection tank broke; the discovery came during the offload operation (test no. 39). The outboard doors, coupling dynamic water condition signals to the hydraulically damped broad-crested weir floats, had been enlarged for faster response, but closing them did not visibly change the weir response in waves.

One procedure delayed to the last day of testing in light oil was removing the coke filter panels and observing the change in fluid flow. Last in the exploratory sequence was an experiment with the gill door opened just forward of the propeller in the transition duct between the rectangular main duct and the round propeller duct. The gill door was designed for use in fast forward vessel speeds not associated with oil/debris collection. Based on our experience with skimmer gill doors we convinced the Soviet technicians to open the door partially for several of the tests on the last day.

SECTION 5

TEST RESULTS

Tables 1 through 5 display the test results from the fluid flows, heavy and light oil experiments. The data columns indicate measurements described in the Test Procedures. The following calculations were necessary to arrive at performance estimates:

Oil Distribution Rate, actual

$$\frac{\text{Total oil distribution}}{\text{Time interval}} = \frac{\text{gallons}}{\text{seconds}} \quad x \quad \text{constant} = m^3/\text{second}$$

Where total oil distribution is read from a totalizer meter and time interval read with a stopwatch.

Slick Thickness, actual

$$t = \frac{(Q)(0.274)}{v\ w} = \text{mm}$$

Where: Q = oil distribution rate actual
v = bridge velocity from meter
w = 2.19 m, skimmer dimension

Recovery Efficiency, percent:

$$RE = \frac{\text{quantity of oil recovered by the skimmer}}{\text{Total quantity of fluids recovered (oil \& water)}}$$

Throughput Efficiency, percent:

$$TE = \frac{\text{quantity of oil recovered by the skimmer}}{\text{quantity of oil distributed by the main bridge}}$$

Oil Recovery Rate:

$$ORR = \frac{\text{quantity of oil recovered by the skimmer}}{\text{collection time of the adjustable basket weir}}$$

Main Duct Velocity:

$$V_{MD} = K\sqrt{2gh}$$

Where K = Pitot tube constant, approx. 1.0
g = acceleration due to gravity
h = manometer reading (pressure difference)

Main Duct Flow:

$$Q_{MD} = V_{MD}A_{MD}$$

Where:

V_{MD} = main duct velocity

A_{MD} = area of duct, 0.657 m^2

Vertical Duct Flow:

$$Q_{VD} = V_{VD}A_{VD}$$

Where:

V_{VD} = direct reading of vertical duct velocity
A_{VD} = area of vertical ducts, two, total 0.292 m^2

Waves; height and length

Selected from OHMSETT standard wave charts derived from spectral analysis of a sonic wave probe. The selection is based on wave flap stroke and wave generator rotation speed.

TABLE 1. SOVIET SKIMMER FLUID FLOW TESTS (NO OIL)

Test no.	Tow speed kt	Weir angle deg.	Ballast level mm	Engine speed rpm	Bow box dm	Stern box dm	Main duct flow m^3/s	Vert duct flow m^3/s
1	0.5	55	400	1000	NA	NA	0.41/0.46	0.06/0.18
2	0.5	60	400	1200	2.5	5	0.55/0.62	0.09/0.47
3	0.5	6	550	1400	NA	NA	0.60/0.66	0.50/0.58
4	0.5	60/50	550	1600	2	-5	0.66/0/80	0.44/0.58
5	0.5	45	550	1800	NA	NA	0.78/0.88	0.44/0.58
6	1.0	70	550	1000	3	-5	0.46/0.58	0.51/0.29
7	1.0	65	550	1200	3	-6	0.57/0.60	0.12/0.18
8	1.0	60	550	1400	-3	-5	0.72/0.78	0.12/0.18
9	1.0	65	550	1600	3	-6	0.76/0.76	0.29/0.70
10	1.0	60/50	550	1800	-3/1	-5/4	0.87/0.93	0.18/0.26
11	1.5	70/65	550	1800	4	-5	0.90/0.95	0.29/0.73
12	1.5	65/60	340	1600	3	5	0.78/0.80	0.50/0.53
13	1.5	60	340	1400	3	5	0.72/0.75	0.44/0.44
14	1.5	70	340	1200	3	4.5	0.60/0.64	0.23/0.44
15	1.5	70	340	1000	3	5	0.49/0.57	0.00/0.00
16	2.0	70	50	1000	3.5	-6	0.36/0.41	0.03/0.15
17	2.0	60	50	1200	3/3	5/5.5	0.57/0.62	0.00/0.20
18	2.0	60	50	1400	3	4.5	0.70/0.76	0.00/0.00
19	2.0	65/55	50	1600	3/1.5	5.5/4.5	0.73/0.87	0.00/0.18
19R	2.0	60/55	50	1600	3/2	5.5/5	0.73/0.79	0.09/0.29
20	2.0	50/53	50	1820	NA	NA	0.84/0.90	0.15/0.29
20R	2.0	50/53	50	1800	2/2	5/5.5	0.83/0.92	0.00/0.29
21	2.5	80/80	50	1000	4.5/4.5	6.5/6.5	0.41/0.55	0.00/0.00
21R	2.5	75/75	50	1000	4/4	5/5.5	0.51/0.62	0.00/0.00
22	2.5	70/70	50	1200	4/3.5	-5/5	0.59/0.73	0.00/0.00
23	2.5	70/60	50	1400	3.5/2.5	-5/-5	0.67/0.75	0.00/0.00
24	2.5	60/60	50	1600	2.5/3	4.5/4.5	0.76/0.82	0.00/0.00
25	2.5	65/55	50	1800	3/1.5	5/4	0.80/0.90	0.00/0.06
27	3.0	80	50	1400	NA	NA	0.66/0.93	0.00/0.00
28	3.0	85	50	1600	6/5	8.5/7	0.36/0.79	0.23/0.29
29	3.0	70/75	50	1800	4/4	3.5/3.5	0.93/1.04	0/0

TABLE 2. SOVIET SKIMMER PERFORMANCE RESULTS - CIRCO X HEAVY OIL OF VISCOSITY 700 cst @ 23.0°C

Test no.	Tow speed knots	Oil dist. rate m^3/hr	Slick thick mm	Waves ht x length m x m	Recovery eff. %	Throughput eff. %	Oil rec. rate m^3/hr
30	1.0	10.7	2.66	Calm	81.5	90.5	3.6
31	1.0	10.7	2.66	Calm	81.5	88.7	3.2
32	1.0	10.4	2.60	Calm	81.5	90.6	4.1
33	1.0	21.5	5.36	Calm	61.5	59.0	4.7
34	1.5	37.1	6.16	Calm	61.5	67.1	5.3
35	2.0	50.0	6.23	Calm	61.5	66.8	5.3
36	2.0	0	0.00	Calm	0.0	0.0	0.0
37	2.0	58.3	7.26	0.36x6.95	81.0	25.5	2.8
38	2.0	55.6	6.92	0.36x6.95	81.0	26.7	2.8
39	1.5	47.0	7.81	0.36x6.95	81.0	23.7	2.8
40	2.0	56.2	7.00	Calm	82.3	80.9	10.5
41	2.0	58.1	7.24	Calm	82.3	78.1	9.7
42	2.0	56.9	7.09	Calm	82.3	79.8	12.4
43	0.0	11.8	0.00	Calm	94.4	86.6	6.1
44	2.0	21.2	2.63	0.36x6.95	82.6	58.4	4.6
45	2.0	21.5	2.68	Calm	82.6	58.4	4.6
46	2.0	21.3	2.66	0.36x6.95	82.6	58.0	3.2
47	2.0	11.8	2.64	Calm	82.6	58.0	3.2
48	2.0	28.0	1.01	Calm	79.3	79.6	6.7
49	2.0	28.3	1.27	Calm	79.3	78.8	4.2
50	2.0	28.5	1.02	Calm	79.3	78.4	4.2
51A	2.0	0.0	0.00	0.40x6.95	0.0	0.0	0.0
51B	2.0	28.6	1.28	0.40x6.95	63.8	25.6	1.7
52	2.0	28.5	1.02	0.40x6.95	63.8	25.7	1.5
53	2.0	28.6	1.28	0.40x6.95	63.8	25.6	1.5
54	1.5	21.9	1.01	0.40x6.95	85.9	30.7	1.9
55	1.5	20.4	1.22	0.40x6.95	85.9	32.9	2.4
56	1.5	20.6	0.98	0.40x6.95	85.9	32.8	3.4

(Continued)

TABLE 2. (Continued)

Test no.	Tow speed knots	Oil dist. rate m^3/hr	Slick thick mm	Waves ht x length m x m	Recovery eff. %	Throughput eff. %	Oil rec. rate m^3/hr
57	2.0	87.8	3.94	Calm	83.3	70.3	8.4
58	2.0	94.6	4.24	Calm	83.3	65.3	8.4
59	2.0	0.0	0.00	0.20x11.61	0.0	0.0	0.0
60	1.5	79.3	4.74	0.20x11.61	72.0	36.7	5.1
61	1.5	79.4	4.75	0.20x11.61	72.0	36.6	6.6
62	1.5	81.9	4.90	0.20x11.61	72.0	28.4	5.8
63	1.0	22.6	5.62	0.20x11.61	73.7	56.8	4.8
64	1.0	21.6	5.38	0.20x11.61	73.7	59.4	4.8
65	1.0	21.7	5.41	0.20x11.61	73.7	59.0	5.9
66	2.0	9.1	1.13	Calm	64.8	110.0	3.6
67	2.0	9.1	1.13	Calm	64.8	146.7	6.7
68	2.0	9.1	1.13	Calm	64.8	146.7	6.7
69	1.0	9.1	2.26	0.20x11.61	70.0	38.3	2.1
70	1.0	9.1	2.26	0.20x11.61	70.0	46.0	2.1
71	1.0	9.1	2.26	0.20x11.61	70.0	46.0	1.9
72	1.0	16.1	4.00	0.40x1.52	72.1	64.0	5.1
73	1.0	16.1	4.00	0.40x1.52	72.1	64.0	5.1
74	1.0	15.7	3.92	0.40x1.52	72.1	65.2	4.4
75	2.0	32.3	4.02	0.40x1.52	77.5	58.2	6.3
76	2.0	30.6	3.81	0.40x1.52	77.5	61.4	8.1
77	2.0	30.9	3.85	0.40x1.52	77.5	60.8	5.9
78	1.5	26.1	4.34	0.40x1.52	73.3	51.3	4.9
79	1.5	26.4	4.38	0.40x1.52	73.3	50.9	4.9
80	1.5	26.4	4.38	0.40x1.52	73.3	50.9	5.4
81	1.0	26.7	6.66	0.69 HC	72.0	33.1	4.8
82	1.0	26.7	6.66	0.69 HC	72.0	33.1	5.3
83	1.0	27.0	6.72	0.69 HC	72.0	32.8	6.6
84	2.0	33.2	4.13	0.69 HC	48.9	15.5	3.1
85	2.0	33.0	4.11	0.69 HC	48.9	15.6	2.2

TABLE 3. SOVIET SKIMMER PERFORMANCE RESULTS - CIRCO 4X LIGHT OIL OF VISCOSITY 31 cst @ 22.7°C

Test no.	Tow speed knots	Oil dist. rate m^3/hr	Slick thick mm	Waves ht x length m x m	Recovery eff. %	Throughput eff. %	Oil rec. rate m^3/hr
86	2.0	34.5	4.30	Calm	50.9	79.1	5.1
87	2.0	32.5	4.06	Calm	50.9	83.9	5.1
88	2.0	33.9	4.23	Calm	50.9	80.5	5.1
89	2.5	44.9	4.47	Calm	33.3	45.6	2.9
90	2.5	41.7	4.15	Calm	33.3	49.1	3.1
91	2.5	42.9	4.28	Calm	33.3	47.6	4.1
92	0.0	11.8	0.00	Calm	51.3	101.9	4.1
93	1.0	16.3	4.06	Calm	50.7	88.5	4.3
94	1.0	16.4	4.09	Calm	50.7	87.7	8.6
95	1.0	16.1	4.02	Calm	50.7	89.3	5.4
96	1.0	16.1	4.02	0.20 HC	37.6	52.0	3.0
97	1.0	16.2	4.15	0.20 HC	37.6	51.7	5.0
98	1.0	16.1	.02	0.20 HC	37.6	52.0	5.0
99	2.0	34.1	4.24	0.20 HC	45.9	59.0	5.0
100	2.0	32.4	4.04	0.20HC	45.9	62.0	6.0
101	2.0	32.4	4.04	0.20 HC	45.9	62.0	6.0
102	2.0	145	18.07	Calm	36.4	63.8	4.7
103	2.0	33.5	4.17	0.40x1.52	56.6	73.3	5.7
104	2.0	33.0	4.11	0.40x1.52	56.6	74.3	7.3
105	2.0	33.0	4.11	0.40x1.52	56.6	74.3	6.1
106	1.5	26.1	4.34	0.40x6.95	40.4	30.8	3.2
107	1.5	23.8	3.96	0.40x6.95	40.4	33.7	3.6
108	1.5	24.8	4.11	0.40x6.95	40.4	32.5	3.6
109	2.0	33.6	4.31	0.40x6.95	43.0	29.5	4.2
110	2.0	32.5	4.06	0.40x6.95	43.0	30.5	4.2
111	2.0	48.6	6.06	0.40x6.95	43.0	30.6	3.7
112	1.5	25.3	4.21	0.20x11.61	39.9	26.3	2.7

(Continued)

TABLE 3. (Continued)

Test no.	Tow speed knots	Oil dist. rate m^3/hr	Slick thick mm	Waves ht x length m x m	Recovery eff. %	Throughput eff. %	Oil rec. rate m^3/hr
113	1.5	25.6	4.24	0.20x11.61	39.9	26.1	3.8
114	1.5	25.1	4.17	0.20x11.61	39.9	26.6	2.2
115	2.0	32.4	4.04	0.20x11.61	42.1	35.1	2.8
116	2.0	32.4	4.04	0.20x11.61	42.1	35.1	2.4
117	2.0	32.4	4.04	0.20x11.61	42.1	35.1	2.8
118	1.5	24.9	4.13	0.20x11.61	41.0	47.9	3.6
119	1.5	25.5	4.23	0.20x11.61	41.0	42.1	3.1
120	1.5	24.9	4.13	0.20x11.61	41.0	57.5	3.6
121	1.0	17	4.24	Calm	52.6	81.6	6.4
122	1.0	16.1	4.02	Calm	52.6	86.2	10.4
123	1.0	16.2	4.04	Calm	52.6	85.8	4.9
124	2.0	32.9	4.09	Calm	59.0	85.3	5.3
125	2.0	33.8	4.21	Calm	59.0	83.0	5.3
126	2.0	33.8	4.21	Calm	59.0	83.0	5.3
127	1.0	22.7	5.66	0.69 HC	19.9	8.0	1.2

TABLE 4. SOVIET SKIMMER ADJUSTMENTS - CIRCO X HEAVY OIL VISCOSITY 700 cSt @ 23.0 °C

Test no.	Weir angle deg.	Ballast level mm	Engine speed rpm	Bow box dm	Stern box dm	Main duct flow m^3/s	Vert duct flow m^3/s
30	65/65	500	1300	3.5/3.5	5.5/5.5	0.39/0.49	0.06/0.20
31	60/60	500	1300	2/3	4.5/5	0.44/05.7	0.00/0.15
32	60	500	1600	3	5	0.53/0.69	0.15/0.35
33	60/50	500	1600	3/1.5	5.5/4	0.62/0.69	0.12/0.18
34	60/50	370	1600	2.5	5	0.62/0.69	0.12/0.18
35	35	70	1800	1.5	2.5	0.66/0.80	0.00/0.41
36	70/60	50	1600	3.5/2.5	6/5.5	0.59/0.66	0.09/0.18
37	50/70	50	1450	2/2.5	4.5/5.5	0.62/0.73	0.00/0.18
38	70/57	50	1600	3/3	6/7	0.69/0.78	0.00/0.09
39	50/45	50	1600	2/2	6/6	0.55/0.76	0.03/0.12
40	65/60	50	1600	3/3	5.5/5.5	0.80/0.83	0.12/0.18
41	65/65	50	1600	3.5/3.5	5.5/6	0.84/0.89	0.09/0.15
42	50/70	50	1700/1400	2/4	4/6	0.80/0.95	0.06/0.18
43	60/60	50	1700/1450	2.5/3	5/6	0.59/0.95	0.00/0.12
44	60/60	50	1600	3/3	6/7	1.07/1.10	0.00/0.12
45	60/60	50	1600	3/3	6/7	1.07/1.10	0.00/0.12
46	52/57	50	1850	3/3	6/6	1.04/1.44	0.00/0.00
47	52/57	50	1850	3/3	6/6	1.04/1.44	0.00/0.00
48	65	50	1600/1800	3.5	6.5/4	0.84/0.96	0.06/0.18
49	55/55	50	1450	2.5/3	5.5/6	0.80/0.94	0.00/0.15
50	65/60	50	1300	3.5/3	6/6	0.75/0.93	0.00/0.00
51A	50/50	50	1800	3/3	6/6	1.14/1.17	0.12/0.20
51B	60/65	50	1400/1300	2/3	6/7	0.95/0.99	0.00/0.03
52	60/70	50	1900	3/4	7/7	1.21/1.24	0.00/0.00
53	60/65	50	1900	3/2.5	7/7	1.20/1.24	0.00/0.00
54	45/50	50	1200	2/2	6/6	0.86/0.88	0.00/0.00
55	45/50	50	1200	2/3	6/7	0.86/0.90	0.00/0.00
56	40/60	160	1800/1400	2/3	4/7	0.86/1.09	0.00/0.00
57	65/65	150	1700/1300	3/3	5/5	1.07/1.14	0.00/0.12
58	55/60	160	1600/1450	2/2	4.5/5	1.05/1.13	0.00/0.00

(Continued)

TABLE 4. (Continued)

Test no.	Weir angle deg.	Ballast level mm	Engine speed rpm	Bow box dm	Stern box dm	Main duct flow m3/s	Vert duct flow m3/s
59	40/80	160	800/1950	2/5	5/7	0.15/1.30	0.00/0.23
60	45/60	160	1300	1/4	7/9	0.55/0.60	0.03/0.18
61	55/65	160	1000	1/6	5/9	0.49/0.55	0.09/0.18
62	40/60	320	1550	0/5	5/10	0.33/0.84	0.03/0.18
63	50.65	450	1300/1200	1/5	4/8	0.41/0.55	0.06/0.15
64	45/60	410	1300/1200	1/5	4/10	0.33/0.46	0.00/0.18
65	45/55	410	1000/1100	1/5	4/7	0.36/0.49	0.09/0.18
66	55/50	70	1400	2/2	5/5	0.36/0.39	0.00/0.00
67	60/60	70	1400	3/2.5	5.5/5.5	0.51/0.60	0.00/0.06
68	60/60	70	1400	2.5/2.5	5/5.5	0.36/0.44	0.00/0.03
69	45/55	400	1400/1100	0/5	3/9	0.46/0.72	0.03/0.18
70	50/60	400	1000	1/5	4/8	0.29/0.51	0.06/0.15
71	50/60	420	1000	1/5	4/8	0.33/0.62	0.06/0.12
72	55/60	410	1200/1300	2/5	5/7	0.21/0.36	0.00/0.03
73	55/60	410	1200	2/5	5/7	0.15/0.36	0.00/0.06
74	55/60	410	1200	2/5	5/7	0.15/0.36	0.03/0.09
75	65/70	70	1700	3/4	6/7	0.87/1.06	0.29/0.18
76	65/65	70	1500/1700	2/4	5/7	0.82/0.98	0.06/0.12
77	65/70	70	1650	3/5	6/7	0.88/0.97	0.06/0.15
78	50/55	160	1350	1/4	4/8	0.55/0.67	0.03/0.15
79	55/60	160	1400/1600	1/4	5/8	0.57/0.67	0.03/0.12
80	55/55	160	1400	1/4	4/8	0.60/0.70	0.06/0.20
81	30/45	160	1300/1200	1/4	4/9	0.57/0.80	0.06/0.35
82	40/50	160	1100/800	1/4	4/10	0.57/0.76	0.12/0.41
83	60/70	290	1200	1/5	4/10	0.84/0.00	0.15/0.41
84	60/70	80	1800	1/5	4/9	0.73/1.09	0.06/0.35
85	65/70	40	1900	1/5	6/9	0.87/1.23	0.23/0.35

TABLE 5. SOVIET SKIMMER ADJUSTMENTS - CIRCO X LIGHT OIL VISCOSITY 31 cSt @ 22.7°C

Test no.	Weir angle deg.	Ballast level mm	Engine speed rpm	Bow box dm	Stern box dm	Main duct flow m^3/s	Vert duct flow m^3/s
86	65/60	60	1400	3/2.5	5.5/5.5	0.70/0.86	0.00/0.03
87	60/55	60	1400	3/2.5	6/5.5	0.75/0.80	0.00/0.03
88	65/55	60	1400	3/2.5	5.5/5	0.70/0.80	0.00/0.03
89	65/70	60	1800/1900	3.5/3.5	5.5/5.5	0.95/1.09	0.00/0.06
90	65/60	60	1900	3.5/3	5.5/5	0.93/1.01	0.00/0.09
91	70/65	40	1800	4/3.5	5.5/5	1.04/1.09	0.00/0.00
92	50/60	40	1300/1400	2.5/3	5/5.5	1.40/1.52	0.00/0.12
93	60/55	420	1300/1400	2.5/2.5	5/5.5	0.25/0.44	0.00/0.03
94	55/55	420	1400	2.5/2.5	5/5.5	0.00/0.00	0.03/0.09
95	60/55	420	1400	2.5/2	5.5/5	0.00/0.00	0.00/0.06
96	50-55/60	300	1250/1000	1/3-1/4	4.5/6-5/6	0.29/0.46	0.00/0.09
97	50-55/60	300	1150/1000	1/3-2/4	5/6-5/6	0.00/0.36	0.00/0.03
98	53/51	300	1000/900	1/3-1/3	5/6-5/6	0.25/0.39	0.00/0.03
99	65/60	70	1550	2/5-2/4	5/8-4/7	0.78/0.80	0.00/0.06
100	70-55/60	70	1400	3/5-2/4	4/7-5/8	0.90/1.05	0.00/0.06
101	65/65	70	1350/1400	3/4-3/5	6/7-5/7	0.95/1.02	0.00/0.06
102	70/65	60	1400/1500	4/3.5	6.5/6	1.02/1.04	0.00/0.03
103	65/70	50	1550/1600	3/5-3/4	5/8-5/8	0.90/1.06	0.03/0.09
104	60/50	50	1550	3/4-3/5	5/7-6/8	0.95/1.04	0.03/0.06
105	65/50	50	1550	3/5-3/5	5/8-6/8	0.99/1.08	0.03/0.09
106	52/60	50	1200/1050	1/4-1/4.5	5/8-5.5/8	0.00/0.93	0.03/0.06
107	50/55-60	50	1100	1/4-1/3	5/9-5/9	0.00/0.89	0.01/0.03
108	52/60	50	1050	1/4-1/4	5/8-4/7	0.00/0.88	0.03/0.06
109	52/60	50	1500/1550	1/5-1/5	5/8-5/8	0.69/1.15	0.01/0.03
110	45/52	50	1600/1500	1/4-1/4	5/8-5/8	0.00/1.12	0.00/0.03
111	50/57	50	1500	1/3.5-1/4	5/8-5/8	0.25/1.06	0.00/0.06

(Continued)

TABLE 5. (Continued)

Test no.	Weir angle deg.	Ballast level mm	Engine speed rpm	Bow box dm	Stern box dm	Main duct flow m^3/s	Vert duct flow m^3/s
112	40/55	50	1000	1/4-1/5	4/8-4/8	0.21/0.83	N/A
113	40/52	50	1000	1/3-1/4	4/7-4/8	0.00/0.76	N/A
114	47/60	50	1000	1/5-1/5	4/9-4/9	0.25/0.80	N/A
115	62/760	50	1800/1900	3/5-1/5	5/9-5/9	0.73/1.18	N/A
116	57/70	50	1700/1650	1/5-1/5	5/10-5/10	0.66/1.19	N/A
117	55/70	50	1700	3/5-1/5	5/9-5/9	0.72/1.19	N/A
118	47/62	50	1500	2/5-1/5	4/8-5/9	0.57/0.80	N/A
119	52/62	50	1450	1/5-1/5	4/9-5/9	0.62/0.90	N/A
120	45/60	50	1500	1/4-1/5	5/8-5/9	0.57/0.88	N/A
121	55/55	450	1650	2.5/2.5	5+/5.5	0.00/0.25	0.06/0.12
122	55/55	450	1550/1625	2.5/2.5	5.5/5+	0.00/0.15	0.03/0.09
123	55-50/55	450	1600/1550	2.5/2	5+/5	0.00/0.00	0.03/0.09
124	65/55	50	1550	3/2	5.5/5	0.57/0.70	0.00/0.09
125	60/65	50	1500	3/3	5.5/5.5	0.59/0.69	0.00/0.09
126	60/65	50	1600/1550	2.5/2	5/5	0.66/0.78	0.00/0.06
127	52/60	50	1300/1400	1/4-1/5	5/8-5/8	0.33/0.90	0.00/0.09

SECTION 6

DISCUSSION OF RESULTS

FLUID FLOW

Fluid flow measurements in the main duct were of specific interest to the Soviets. They provided the opportunity to measure and confirm calculations in a large test tank. Empirical calculations, while straightforward in this application, nevertheless depend on friction factors, degree of laminar flow, geometry, physical properties of the fluid, propeller efficiency, and synergistic factors difficult to measure. The results displayed in Table 1 for tests 1 through 29 imply a reasonably progressive increase in flow up through the two knot region. Beginning at the 2.5 knot experiments the degree of linearity becomes confusing. The manometer readings to measure the main duct flow were steady in the calm water tests but were erratic at high speeds and wave conditions. There was more opportunity for reading error due to pitch and roll of the vessel, and turbulence in the main duct. Variations in the differences of the two columns over several seconds was not uncommon. The later stages of the light oil test series revealed problems with the Pitot tube clogging up. The direct-reading four-cone velocimeter in the vertical duct was valuable in the early testing, but it soon became apparent that the flow in that area was not to be increased as expected, and the meter registered in the lower ten percent of the scale. The stainless steel cones were well protected but bearings and the electrical connections soon became corroded from the salt water.

The test results indicate that the vessel trim from the bow/stern box dm varied due to ballast, engine speed, and tow speed. The skimmer operator was continuously attempting to keep the bow down and a 10 cm skim depth over the broad crested weir. The bow, if too low, would cause the vessel to dive dangerously and the bow doors to submerge completely. The bow, if too high, would cause the vessel to rise thus causing encountered oil to flow under the weir into the main duct and be lost out the propeller tunnel.

The gate positions, while always recorded, were not changed often during the test program. The broad-crested weir angle, a function of operator control and turbulence from waves, proved tedious to interpret. The goal was to keep the leading edge 10 cm below the water line, which was a function of ballast and vessel speed.

SKIMMING OIL

The heavy oil tests distributed a grand total of 41.6 m^3 during the six days. The skimmer collected a net quantity of 66% combining all test conditions. A summary of the fifty seven tests displayed in Table 2 showed good performance. Recovery efficiency averaged 66% through all test conditions, dropping to a low of 48% in a .69 m harbor chop advancing at 2 knots. The best RE (85%) was in calm water at 1½ knots, a slight drop off to 83% at 2 knots. The stationary operating mode of the skimmer was outstanding with an RE of 94%, using its reaction rudders and sucking oil on the water surface from 4 m away.

Throughput efficiency best performance was 90% in calm water at 1 knot, dropping to 80% at 2 knots. Best performance in waves (.36 x 6.95 m) produced 77% at 2 knots, dropping to 15% at 2 knots with a 0.7 harbor chop. Throughput efficiency while remaining dead in the water and collecting the available surrounding oil pool was 86%. Maximum recovery rate as designed in the skimmer was verified to be 12.4 m^3/hr.

The light oil tests distributed a grand total of 39.7 m^3 during the four test days. The skimmer collected a net quantity of 61%, combining all test conditions. A summary of the forty two tests displayed in Table 3 showed good performance for the light oil.

Recovery efficiency averaged 44% through the tow tests, dropping to a low of 19% in the worst condition a 0.69 m harbor chop at one knot. The best RE (59%) was in calm water at 2 knots, dropping slightly to 56% in waves (.4 x 1.52 m). The stationary test RE with the skimmer dead in the calm water while using its reaction rudders to push the oil from around the vessel and sucking oil was 51%.

Throughput efficiency best performance was 89% in the advancing mode in calm water at one knot. The performance dropped to 85% at 2 knots in calm water, and 74% with regular waves (.4 x 1.52 m). Throughput efficiency when dead in the water was nearly 100%. The best maximum recovery rate was 8.64 m^3/hour advancing at one knot in calm water.

Oil quantities in the port side storage tank, vertical annuli, and main duct were too low to measure in both the heavy and light oil test phases. The mechanical adjustments available to the skimmer operator during the oil tests were selected based on experience from the fluid flow tests. Tables 4 and 5 display those recorded during the oil tests.

Photographs, motion pictures, and video tape recorded several oil loss sources. The major losses occurred in advancing tests when oil would be driven under the broad-crested weir into the main duct and were quite apparent discharging out the propeller duct. This was less obvious at slow speeds and in calm water than at high speeds and in waves. The bow doors did not significantly cause oil loss at any of their selectable angles. This was surprising in that they were not articulated in the vertical plane.

Oil loss was not apparent in the stationary tests. The large quantity of oil stagnant in front of the skimmer would soon be reduced to a sheen. The suction was great enough to cause a vortex originating at the oil surface several meters out from the bow that then would run horizontally into the mouth of the skimmer.

APPENDIX A

OHMSETT TEST FACILITY

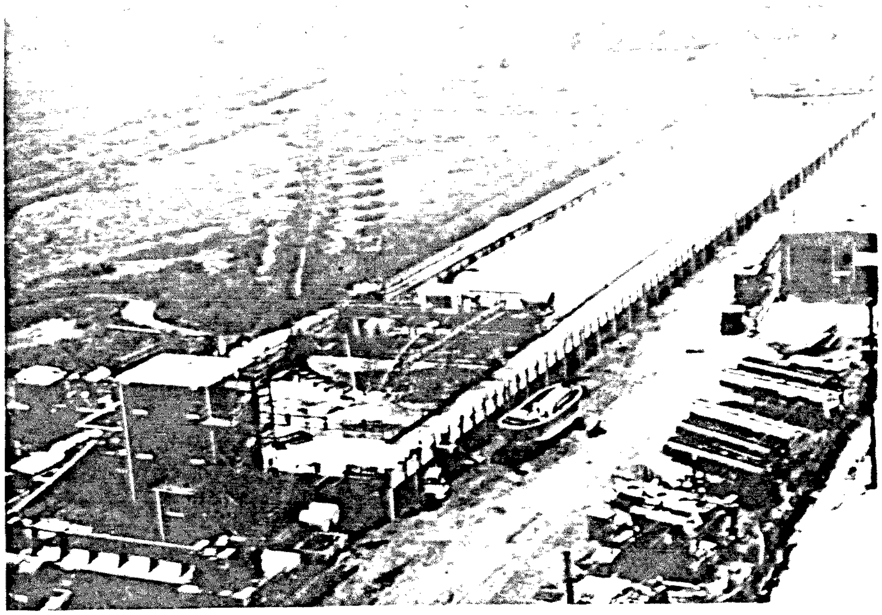

Figure A-1. OHMSETT Test Facility.

GENERAL

The U.S. Environmental Protection Agency is operating an Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) located in Leonardo, New Jersey (Figure A-1). This facility provides an environmentally safe place to conduct testing and development of devices and techniques for the control of oil and hazardous material spills.

The primary feature of the facility is a pile-supported, concrete tank with a water surface 203 meters long by 20 meters wide and with a water depth of 2.4 meters. The tank can be filled with fresh or salt water. The tank is spanned by a bridge capable of exerting a force up to 151 kilonewtons, towing floating equipment at speeds to 3 meters/second for at least 45 seconds. Slower speeds yield longer test runs. The towing bridge is equipped to lay oil or hazardous materials on the surface of the water several meters ahead of the device being tested, so that reproducible thicknesses and widths of the test fluids can be achieved with minimum interference by wind.

The principal systems of the tank include a wave generator and beach, and a filter system. The wave generator and adsorber beach have capabilities of producing regular waves to 0.7 meter high and to 28.0 meters long, as well as a series of 1.2 meters high reflecting, complex waves meant to simulate the water surface of a harbor or the sea. The tank water is clarified by recirculation through a 0.13 cubic meter/second diatomaceous earth filter system to permit full use of a sophisticated underwater photography and video imagery system, and to remove the hydrocarbons that enter the tank water as a result of testing. The towing bridge has a built-in skimming barrier which can move oil onto the North end of the tank for cleanup and recycling.

When the tank must be emptied for maintenance purposes, the entire water volume, or 9842 cubic meters is filtered and treated until it meets all applicable State and Federal water quality standards before being discharged. Additional specialized treatment may be used whenever hazardous materials are used for tests. One such device is a trailer-mounted carbon treatment unit for removing organic materials from the water.

Testing at the facility is served from a 650 square meters building adjacent to the tank. This building houses offices, a quality control laboratory (which is very important since test fluids and tank water are both recycled), a small machine shop, and an equipment preparation area.

This government-owned, contractor-operated facility is available for testing purposes on a cost-reimbursable basis. The operating contractor, Mason & Hanger-Silas Mason Co., Inc., provides a permanent staff of eighteen multi-disciplinary personnel. The U.S. Environmental Protection Agency provides expertise in the area of spill control technology, and overall project direction.

For additional information, contact: Richard A. Griffiths, OHMSETT Project Officer, U.S. Environmental Protection Agency, Research and Development, MERL, Edison, New Jersey 08837, 201-321-6629.

APPENDIX B

OHMSETT TEST OILS

Test oils used during this test program were obtained from the Sun Oil Company and are designated as Circo Light and Circo X Heavy. These oils are continually reprocessed by OHMSETT to remove water and sediment that becomes entrained during test operations. As a result, certain documented physical properties do change over time and use and need to be monitored. These properties and changes are detailed in the following tables.

Since oil temperature upon distribution to the water surface quickly equilibrates to tank water temperature, it is necessary to detail water temperature throughout the program. Generally, this ranged from 21.1 to 23.9°C.

Interfacial tension (IFT) and surface tension were determined at 22.8°C with tank water salinity at 8.6 ppt. Samples were collected from the oil distribution holding tanks just prior to discharge onto the tank water surface during testing, and after the oil collected from the tank surface by the test device had been de-watered by the vacuum distillation unit ("after VDU").

TABLE B-1. OIL PHYSICAL PROPERTIES SOVIET OIL/DEBRIS SKIMMER

Oil type	Date sampled	Viscosity cSt @ °C	Specific gravity	Surface tension dynes/cm	Interfacial tension dynes/cm	% Water & sediment
Heavy	5 June	850 @21.1	0.935	35	11	0
Heavy	7 June	700 @22.2	0.9335	35	12	0
Heavy	7 June	850 @21.6	0.935	36	11	0
Heavy	8 June	725 @23.8	0.935	36	11	0
Heavy	11 June	650 @23.3	0.935	36	10	0
Heavy	12 June	900 @22.3	0.937	36	13	0
Heavy	13 June	1100 @21.7	0.9375	37	12	0
Heavy	14 June	750 @22.8	0.937	42	13	0
Heavy	15 June	770 @22.2	0.9365	36	14	0
Heavy	18 June	650 @23.9	0.936	36	13	0
Heavy	19 June	750 @22.7	0.937	37	9	0
Heavy	20 June	725 @23.8	0.937	37	11	0
Heavy	21 June	350 @23.8	0.938	37	10	0
Heavy	22 June	510 @23.8	0.935	37	10	0
Light	25 June	29 @22.7	0.909	35	6	0
Light	26 June	33 @22.7	0.91	34	5	0
Light	27 June	30 @24.4	0.909	35	5	0
Light	28 June	31 @23.3	0.909	35	6	0

APPENDIX C

OHMSETT WAVES - JO 55

The following waves were used during this test project.

REGULAR WAVES

Stroke (mm)	CPM	Significant Height (1/3) (m)	Wave Length (m)	Wave Period (sec)
114	26	0.36	8.3	---
152	15.	0.2	24.2	---
38	43	0.4	3	---
152	20	0.41	14	---

HARBOR CHOP

Stroke (mm)	CPM	Significant height (1/3) (cm)
152	20	0.69
38	50	0.2

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Performance Testing of the Soviet Oil/Debris Skimmer		5. REPORT DATE 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) H. W. Lichte		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Mason & Hanger-Silas Mason Co., Inc. P.O. Box 117 Leonardo, NJ 07737		10. PROGRAM ELEMENT NO. 1NE826 11. CONTRACT/GRANT NO. 68-03-2642
12. SPONSORING AGENCY NAME AND ADDRESS Municipal Environmental Research Laboratory Office of Research and Development U.S. Environmental Protection Agency Cincinnati, OH 45268		13. TYPE OF REPORT AND PERIOD COVERED Final 14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES

John S. Farlow, Project Officer (201-321-6631)

16. ABSTRACT

Performance evaluation of a Soviet oil skimmer was conducted at the United States Environmental Protection Agency's Oil and Hazardous Materials Simulated Environmental Test Tank in 1979. The skimmer was provided by the Black Sea Central Planning and Designing Bureau, Odessa. The test program was designed at OHMSETT to evaluate the oil skimming capability of a specially modified Soviet skimmer, Model 2550/4. The self-propelled vessel is 17.7 meters long and weighs 39 metric tons. The 111 kilowatt diesel engine drives a ducted propeller water jet propulsion system. The vessel is capable of five knots forward speed and skims effectively at speeds from zero to two knots.

The unique combination of various weir designs into one system, vessel mobility, the efficient use of energy, a series type oil/water gravity separator, and the propulsion techniques all suggest it to be an effective harbor skimmer. The oil recovery rate of 12.4 cubic meters per hour was confirmed using OHMSETT heavy test oil (1.5 pascal seconds and 0.95 specific gravity) in calm water conditions. Recovery efficiency was 85 percent at 1.5 knots forward speed and throughput efficiency was 90 percent at one knot forward speed. Performance dropped for skimming light oils at faster speeds and higher wave conditions. The skimmer collected 64 percent of the 81.3 cubic meters oil volume encountered during the test program.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Performance Tests Skimmers Water Pollution Oils	Spilled Oil Cleanup Protected Waters Coastal Waters	

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* UNCLASSIFIED	21. NO. OF PAGES 41
	20. SECURITY CLASS *(This page)* UNCLASSIFIED	22. PRICE

EPA Form 2220-1 (9-73)