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Project Summary

Performance Testing of the Soviet Oil/Debris Skimmer

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The oil skimming capability of a specially modified Soviet oil/debris skimmer was investigated at the U.S. Environmental Protection Agency's Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) in 1979. The self-propelled vessel is 17.7 m long and weighs 39 metric tons. The 111-kw diesel engine drives a ducted propeller, water jet propulsion system. The vessel is capable of 5 knots forward speed and skims effectively at speeds of 0 to 1.0 m/sec.

The unique combination of various weir designs into one system, vessel mobility, the efficient use of energy, a series-type of oil/water gravity separator, and the propulsion techniques all suggest that this model is an effective harbor skimmer. The oil recovery rate of 12.4 m^3/hr was confirmed using high-viscosity test oil (1.5 pascal seconds and 0.95 specific gravity) in calm water conditions. Recovery efficiency was 85 percent at 0.77 m/sec forward speed, and throughput efficiency was 90 percent at 0.51 m/sec forward speed. Performance dropped when low-viscosity oils were skimmed at faster speeds and higher wave conditions. The skimmer collected 64 percent of the 81.3-m^3 oil volume encountered during the test program.

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).

Introduction

Performance evaluation of a Soviet oil skimmer was conducted at the U.S. 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 test program was designed at OHMSETT to evaluate the oil skimming capability of a specially modified Soviet skimmer, Model 2550/4, which was provided by the Black Sea Central Planning and Designing Bureau (Odessa).

The Soviet oil/debris skimmer tested at OHMSETT 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 U.S.S.R. Register of Shipping. The maximum range is 18.53 km off port with a sea force of 3 and wind force not exceeding Soviet standards of 4.

The self-propelled vessel is 17.7 m long, with a constructive water line (CWL) beam of 4.3m and a total weight of 39 metric tons. The CWL draft is 1.6 m, and the freeboard is 2.4 m. The 111-kw diesel engine drives a ducted propeller, water jet propulsion system. The vessel is capable of 2.6 m/sec forward speed and skims effectively at speeds of 0 to 1.0 m/sec. Hydraulically controlled bow doors provide an adjustable oil slick sweep width up to 8 m. Figure 1 shows the vessel at OHMSETT with the bow doors wide open, and Figure 2 illustrates the flow pattern through the vessel.

The skimmer can be operated in both an advancing 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 maneuver its 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 sucks it into and over the broad-crested weir.

The test was designed to simulate harbor conditions typical of the skimmer's design environment. The U.S.S.R. designed the system both as a stationary skimmer not requiring booms and as an advancing skimmer usable at forward speeds up to 1.0 m/sec and at a maximum wave height of 1.5 m. The OHMSETT test plan therefore included three major phases: (1) investigation of the fluid flow, (2) oil skimming in the stationary mode, and (3) oil skimming in the advancing mode. This skimmer was the largest ever tested at OHMSETT, had the deepest draft, and was the first to require an active propulsion system during testing.

High- and low-viscosity oil tests were required to measure the pump and oil/water separation efficiency. Because the Soviets were interested in the new modification incorporating the coke filter, fluid flow experiments were also needed. Calm water and wave conditions were selected to observe the effects of splash in the broad-crested weir area and the resonance of the vessel hull reacting to wave length. Forward test speeds were selected to observe bow/wave interactions, vessel trim, and bow door opening.

The skimmer had some new unproven modifications. Each of these was isolated in specific tests to determine its contribution to performance.

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, though 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 imply a reasonably progressive increase in flow at speeds of 0 to 1.0 m/sec. Beginning with the experiments conducted at 1.3 m/sec, the degree of linearity becomes confusing. The manometer readings to measure the main duct flow were steady in the calm water tests, but they were erratic at high speeds and wave conditions. Reading error was more likely to occur because of the 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 low-viscosity oil test series revealed clogging problems with the Pitot tube. The direct-reading, four-cone velometer in the vertical duct was valuable in the early testing, but it soon became apparent that the flow in that area was not increasing as expected, and the meter registered in the lower 10 percent of the scale. The stainless steel cones were well protected, but bearings and the electrical connections soon became corroded from the salt water.

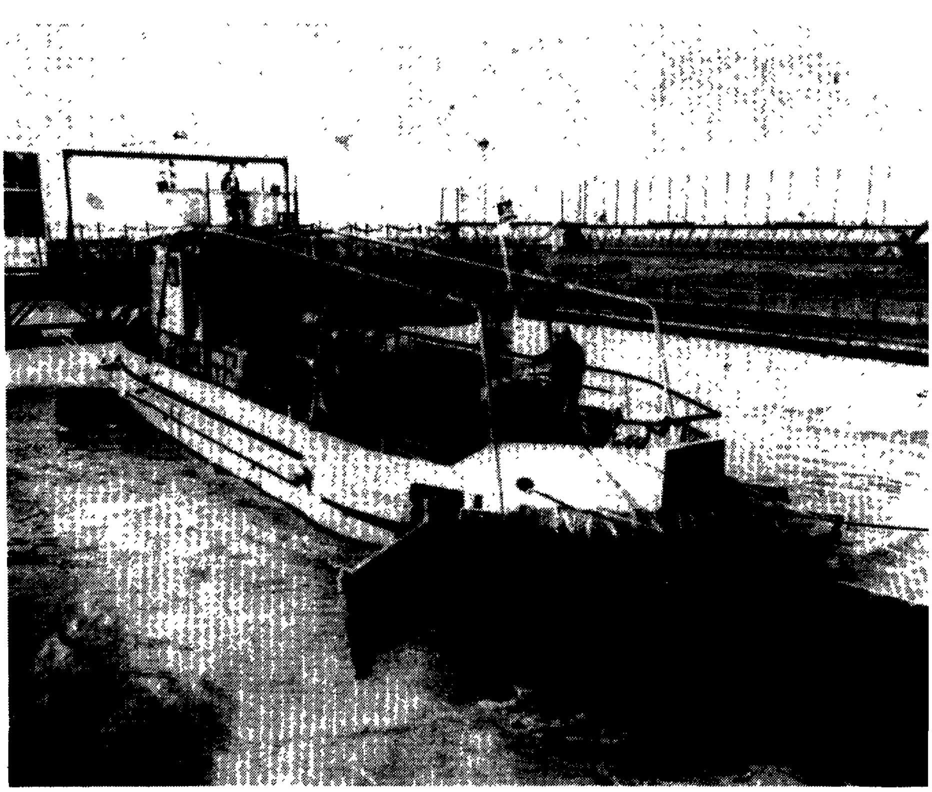

Figure 1. *Soviet skimmer as tested at OHMSETT.*

The test results indicate that the tri of the oil collection box varied as a resu of ballast, engine speed, and tow spee The skimmer operator continuousl attempted to keep the bow down and 10-cm skim depth over the broac crested weir. If the bow sank too lov the vessel would dive dangerously an the bow doors would submerge com pletely. If the bow rose too high, th vessel would rise and cause encountere oil to flow under the weir into the mai duct and be lost out the propeller tunne

The gate positions, though alway recorded, were not changed ofte during the test program. The broac crested weir angle, a function operator control and turbulence fro waves, proved tedious to interpret. Th goal was to keep the leading edge 10 c below the water line, which was function of ballast and vessel speed.

Skimming Oil

The high-viscosity oil tests distribute a grand total of 41.6 m^3 of oil during th 6 test days. A summary of the 57 tes shows good performance. Recove efficiency (RE) averaged 66 perce through all test conditions, dropping to low of 48 percent in a 0.69-m harb

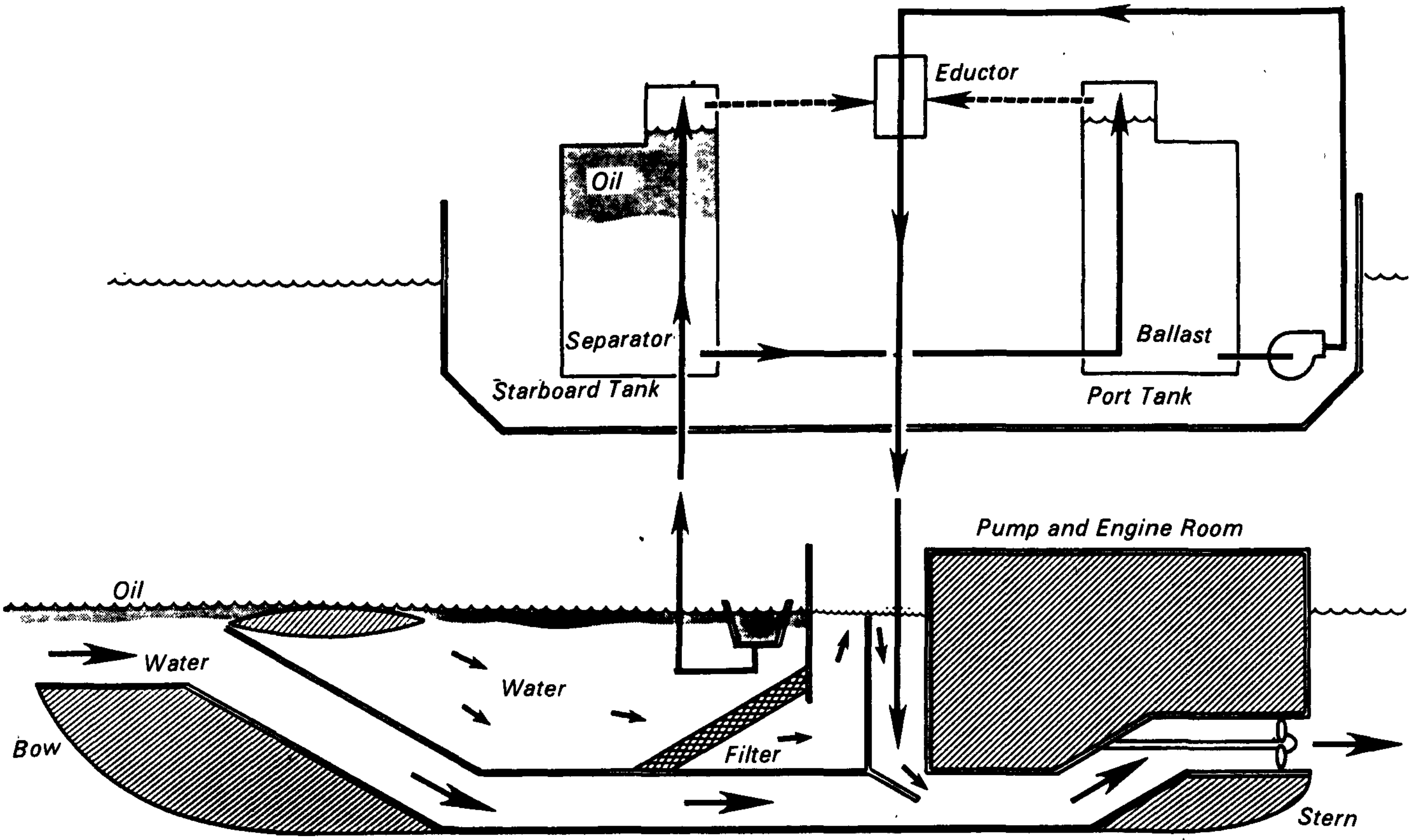

Figure 2. *Soviet skimmer flow diagram.*

chop at a forward speed of 1.0 m/sec. The best RE (85 percent) was in calm water at 0.77 m/sec; this figure dropped slightly to 83 percent at 1.0 m/sec. The stationary operating mode of the skimmer was outstanding, with an RE of 94 percent. In this mode, the vessel used reaction rudders and sucked oil on the water surface from 4 m away.

The best performance for throughput efficiency (TE) was 90 percent in calm water at 0.51 m/sec, a figure that dropped to 80 percent at 1.0 m/sec. Best performance in waves (0.36 x 6.95 m) produced a 77-percent TE at 1.0 m/sec, which dropped to 15 percent at 1.0 m/sec with a 0.7 harbor chop. TE during stationary collection of the available surrounding oil pool was 86 percent. Maximum recovery rate as designed in the skimmer was verified to be 12.4 m^3/hr.

The low-viscosity oil tests distributed a grand total of 39.7 m^3 of oil during the 4 test days. The skimmer collected an average of 61 percent of the distributed oil for all test conditions. A summary of the 42 tests shows good performance for the low-viscosity oil.

Recovery efficiency for low-viscosity oils averaged 44 percent through the tow tests, dropping to a low of 19 percent under the worst condition, a 0.69-m harbor chop at 0.51 m/sec. The best RE (59 percent) was in calm water at 1.0 m/sec; this figure dropped slightly to 56 percent in waves (0.4 × 1.52 m). The stationary test RE was 51 percent in calm water, with the oil being pushed around the vessel by the reaction rudders and sucked in.

The best throughput efficiency was 89 percent in the advancing mode in calm water at 0.51 m/sec. Performance dropped to 85 percent at 1.0 m/sec in calm water, and 74 percent with regular waves (0.4 × 1.52 m). Throughput efficiency in the stationary mode was nearly 100 percent. The best maximum recovery rate was 8.64 m^3/hr when advancing at 0.51 m/sec in calm water.

Oil quantities in the port side storage tank, vertical annuli, and main duct were too low to measure in both the high- and low-viscosity 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.

Photographs, motion pictures, and video tape recorded several oil loss sources. The major losses occurred in advancing tests when oil was driven under the broad-crested weir into the main duct and was 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 cause significant oil loss an any of their selectable angles. This fact 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 was quickly reduced to a sheen. The suction was great enough to cause a vortex originating at the oil surface several meters out from the bow and running horizontally into the mouth of the skimmer.

Conclusions and Recommendations

The Soviet oil/debris skimmer, Model 2550/4, performed well, according to its design requirements. The combination of a unique application of various weirs into one system, its mobility, the efficient use of energy, the incorporation of series oil/water separation, the propulsion system, and the 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 design specification and proved better in the high-viscosity oil than in the low-viscosity oil, 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 because one man was needed on the bow, and another was needed to divide his time between the wheel house and the pump controls. An additional man is needed for skimming oil in the advancing mode.

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

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***John S. Farlow** is the EPA Project Officer (see below).*
The complete report, entitled "Performance Testing of the Soviet Oil/Debris Skimmer," (Order No. PB 81-244 790; Cost: $6.50, subject to change) will be available only from:
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