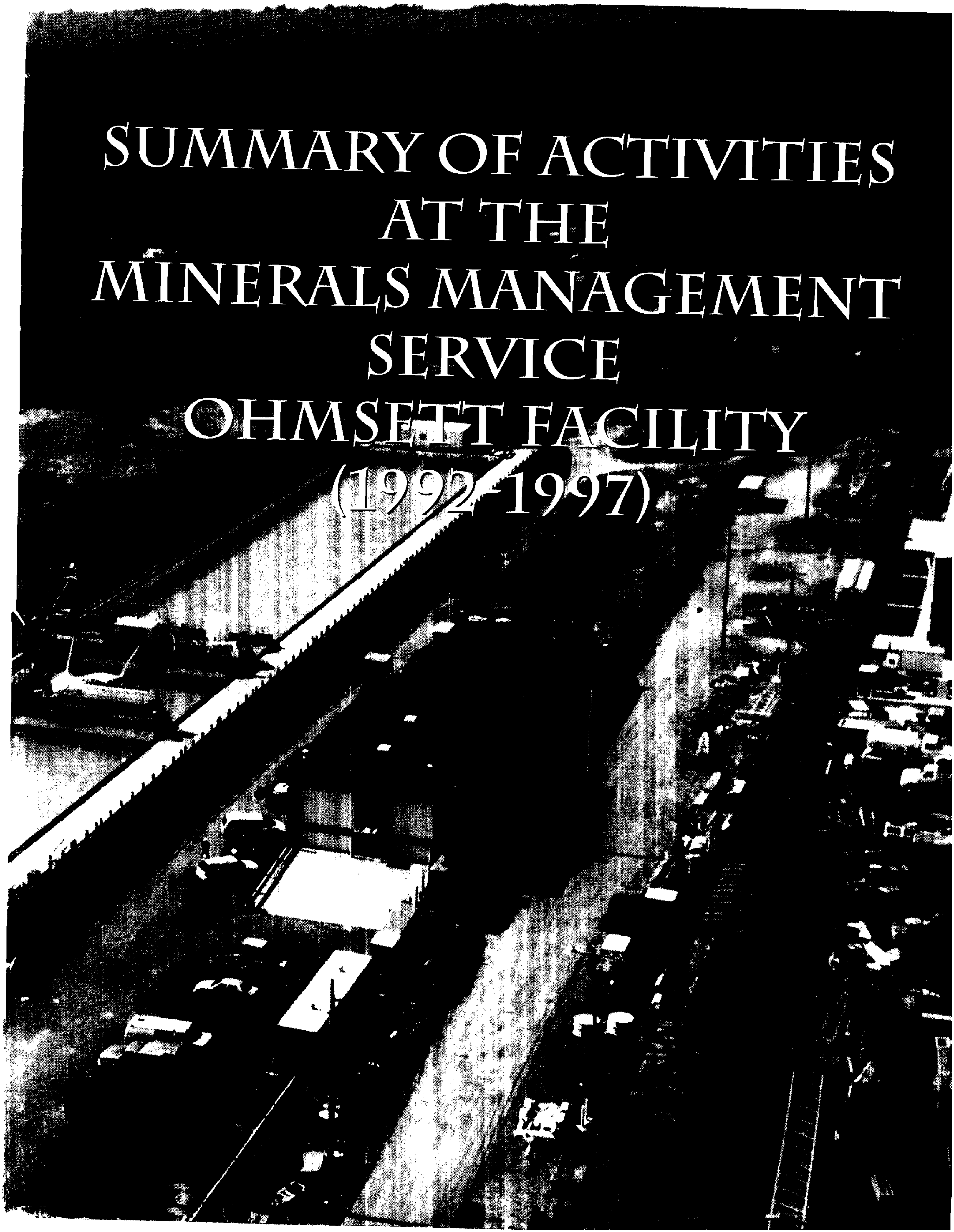
SUMMARY OF ACTIVITIES AT THE MINERALS MANAGEMENT SERVICE OHMSETT FACILITY (1992-1997)



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Summary of Activities
at the
Minerals Management Service

Ohmsett Facility

(1992-1997)

Prepared for

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Table of Contents

Introduction

This summary document is compiled to provide a comprehensive overview of the function and capabilities of the Minerals Management Service (MMS) Ohmsett Facility located in Leonardo, New Jersey; along with a summary of the oil spill countermeasures and cleanup system and equipment testing activities that have been undertaken during the first five years of operation since its reopening by MMS (1992-1997). The purpose of the document is twofold.

First, it is designed as a general information document for managers, technical specialists, spill responders and the general public who have an interest in understanding oil spill response technology, and current progress in improving this technology. To this end, **Sections 1.0 and 2.0** provide a concise but comprehensive overview of the history, capabilities, management, sponsorship and testing and training activities undertaken at the Ohmsett Facility.

Second, it is designed to serve as a reference document for scientists and engineers engaged in oil spill response technology development by providing concise summaries of the individual tests conducted from 1992-1997. These summaries are provided in **Section 3.0** and include test objectives, procedures, and overall results and findings of the containment boom, oil recovery system, temporary storage device, and remote sensing tests that have been undertaken. Important definitions and explanations of test procedures are repeated in individual project summaries so that each summary is easily understood by itself. Enough detail is provided to allow researchers to determine the scope of the testing, and assess the relevance of the tests to their own endeavors. It is not intended that it be a complete reference document for understanding any specific test, and researchers are encouraged to consult the project final reports and related publications cited at the end of each project summary for specific details on the tests. It should also be noted that measurement units and data presentation format differ from summary to summary as the results are provided as originally reported in the project final reports. **Section 4.0** provides a brief synopsis of the tests that were conducted during 1998. Final reports for these tests can be obtained from MMS or the Test Sponsor as completed.

The Ohmsett Facility is available to support a wide range of environmental research and testing activities, as well as training and demonstrations. Funding and imagination are the only limits to the projects that can be planned and undertaken at Ohmsett. MMS stands ready to assist all public and private sector organizations in utilizing the facility. Ohmsett staff are available to work with potential users in developing test plans and submitting requests for use of the facility. This can be accomplished by contacting Mr. Bill Schmidt or Mr. Jim Lane at the following contact points.

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Additional information on the capabilities and activities at Ohmsett can be obtained from the Ohmsett Web Site at http://www.ohmsett.com.

Glossary

ACOE	(U.S. Army) Corps of Engineers
ASTM	American Society of Testing and Materials
CCG	Canadian Coast Guard
CE-TEC	U.S. Army Topographic Engineering Center
CGET	U.S. Coast Guard Evaluation Team
COTR	Contracting Officer's Technical Representative
CRREL	Cold Regions Research and Engineering Laboratory (U.S. Army)
DIP	Dynamic Inclined Plane
DOE	Department of Energy
EIS	Entrainment Inhibitor System
EPA	U.S. Environmental Protection Agency
FSR	Frequency Scanning microwave Radiometer
GER	Geophysical and Environmental Research Corporation
GIS	Geographic Information Systems
Hg	Mercury
IR	Infrared
MIT	Massachusetts Institute of Technology
MMS	Minerals Management Service
MSRC	Marine Spill Response Corporation
MTE	Maximum Throughput Efficiency
NIR	Near Infra-red
NSF	National Strike Force
NVESD	Night Vision and Electronic Sensors Directorate (U.S. Army)
OARS	Oil Aquatic Recovery System
OHMSETT	Oil and Hazardous Materials Simulated Environmental Test Tank
OITC	OHMSETT Interagency Technical Committee
ORE	Oil Recovery Efficiency (ratio of pure oil recovered to the total fluid recovered)
ORR	Oil Recovery Rate (amount of oil recovered per unit time)
OSRP	Oil Spill Research Program
PVC	polyvinyl chloride
R&DC	Research and Development Center (USCG)
RDT&E	Research, Development, Test and Evaluation
RSGISC	Remote Sensing/GIS Center
RSL	Remote Sensing Laboratory
RSTERU	RST Emergency Response Unit
SORS	Spilled Oil Recovery System
TE	Throughput Efficiency (ratio of amount of oil recovered by the system to the amount of oil encountered by the system)
UM	University of Miami
UMFS	Underwater Multichannel Fluorometer System
UNH	University of New Hampshire
URI	University of Rhode Island
USCG	United States Coast Guard
UV	Ultraviolet
VOSS	Vessel of Opportunity Skimming System
WLB	Sea-going Buoy Tender

Units of Measure

C	Centigrade, a measure of temperature
cm	centimeter(s)
cPs	centiPoise, a measure of viscosity (cPs = cSt x oil density)
cSt	centiStokes, a measure of viscosity
F	Fahrenheit, a measure of temperature
ft	foot or feet
g	gram(s)
gal	gallon(s)
gpm	gallons per minute
GHz	Giga Hertz, a measure of frequency
in	inch(es)
kt(s)	knot(s), a measure of speed in nautical miles per hour
hp	horsepower
hr	hour
in	inch
kw	kilowatt
l	liter(s)
lb/ft	pounds per foot
m	meter(s)
µ	micron(s) (10^{-6} meters)
ml	milliliter(s)
mm	millimeter(s)
mph	miles per hour
nm	nanometer(s) (10^{-9} meters)
psi	pounds per square inch
rpm	revolutions per minute
sec	second(s)
T^B	brightness temperature (a measure of microwave radiation)

Section 1.0 Ohmsett Facility Overview 1992-1997

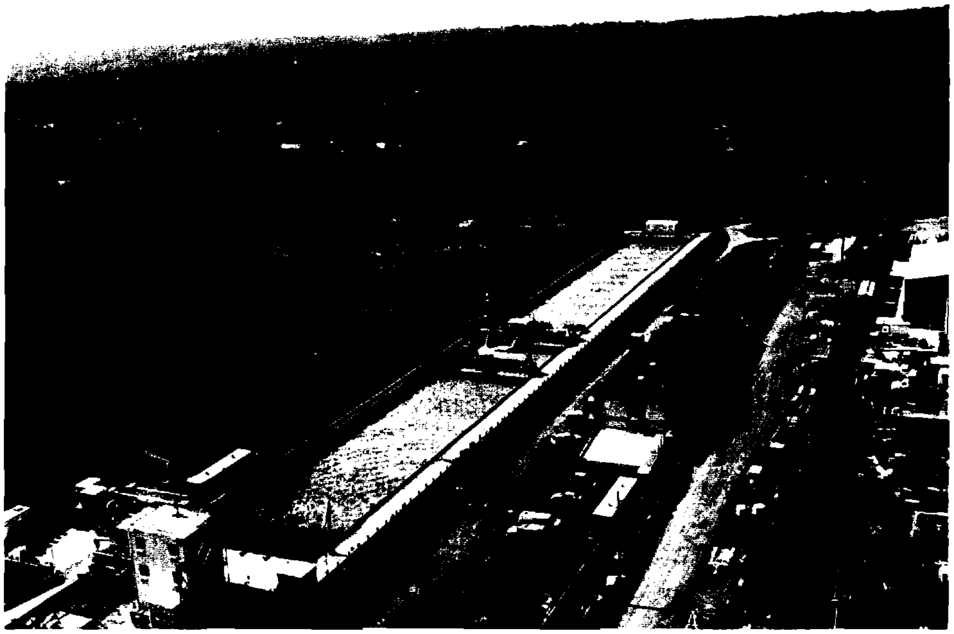


Figure 1.1 Overall View of the Ohmsett Facility at the U.S. Naval Weapons Station Earle in Leonardo, NJ

History, Capabilities, Management, and Sponsorship

The Ohmsett Facility is a unique oil and hazardous chemical spill countermeasures and cleanup test facility located at the U.S. Naval Weapons Station, Earle, Leonardo, New Jersey. The term OHMSETT is an acronym for Oil and Hazardous Materials Simulated Environmental Test Tank. The facility (shown in the photograph in **Figure 1.1**) is situated on the shores of Sandy Hook Bay. It is the only facility in North America that allows for the full-scale testing of oil and chemical spill detection, control and cleanup systems and equipment; in a controlled, simulated at-sea environment. The facility is critical to spill response technology development in the United States. Without Ohmsett, the testing and evaluation of equipment, systems and methodologies would be difficult to accomplish as tests conducted during actual spills cannot be repeated and can interfere with response operations. Conducting test spills at sea involves a rigorous permitting process and is an order of magnitude more expensive than testing at Ohmsett.

History

The Ohmsett Facility was constructed during the early 1970s by the U.S. Environmental Protection Agency, as a joint endeavor with the U.S. Coast Guard. During the period 1974-1987, the facility was used extensively by the Environmental Protection Agency (EPA), Minerals Management Service (MMS), U.S. Coast Guard (USCG), U.S. Navy, and Environment Canada to test a wide range of spill control equipment and systems including oil containment booms, oil skimmers, oil sorbents, dispersants, and in-situ burning techniques. As interest in oil spill response technology waned in the late 1980s, the testing at Ohmsett diminished such that the EPA closed the facility in September 1988 and transferred the buildings and equipment to the Navy.

However, the closure of the facility was not final. In March 1989, just several months after the facility were transferred to the Navy, the supertanker EXXON VALDEZ ran aground on Bligh Reef in Prince William Sound, Alaska, causing the largest oil spill in U.S. history in one of the nation's most environmentally sensitive areas. The difficulties encountered during the subsequent cleanup effort underscored the need for continuing oil spill technology development and the need for the Ohmsett testing capability (which was later formalized and mandated by the Oil Pollution Act of 1990). In April 1990, the Minerals Management Service initiated the restoration of Ohmsett by signing an agreement with the Navy for use of the facility, and placing the Navy's David Taylor Research Center in charge of refurbishment. In addition to MMS funding, financial support for the endeavor was received from the USCG and Environment Canada. Following an extensive renovation process (costing $1.5 million), Ohmsett became operational in July 1992. Because the mission of MMS is focused on regulating offshore oil and gas production, the current testing is limited to oil rather than hazardous materials. Consequently, Ohmsett is now formally known as Ohmsett — The National Oil Spill Response Test Facility. Today the facility is operated as a government owned, contractor operated facility; and is available for testing on a reimbursable basis to government, industry and academia.

Capabilities

The primary component of the facility is a pile-supported, above-ground, concrete test tank that is 203 meters (665 feet) long by 20 meters (65 feet) wide and 3.35 meters (11 feet) high. The tank is filled to a depth of 2.4 meters (8 feet) with 2.6 million gallons (U.S.) from Sandy Hook Bay. The general layout of the tank is shown in **Figure 1.2**.

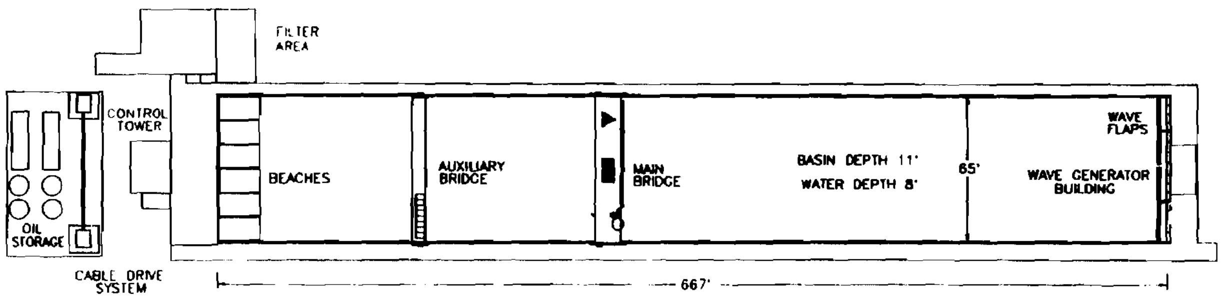


Figure 1.2 General Layout of the Ohmsett Facility

Spanning the tank are three bridges which move back and forth along the length of the tank on rails, driven by two variable speed electric motors. The Main Bridge (towing bridge) moves along the tank towing spill response equipment through the water to simulate actual towing at sea or deployment in a current. The towing bridge is capable of exerting a force of 151 kilonewtons (34,000 pounds), towing equipment at speeds up to 3.3 meters/second (6.5 knots) for at least 40 seconds. Slower speeds yield longer test runs. The towing bridge includes an oil distribution system that allows oil or other test fluids to be deposited on the surface of the water in front of the system being tested to simulate an oil or hazardous material spill at sea. In this way, reproducible thicknesses and volumes of oil can be achieved for multiple test runs at different tow speeds and wave conditions. The towing bridge also includes a built-in skimming barrier for removal of the oil from the tank following testing. The Auxiliary Bridge has an eight section subdivided 2000 gallon tank which is used to store oil recovered by the cleanup equipment being tested. The Auxiliary Bridge also has a skimming boom to aid in cleanup. The Main Bridge and Auxiliary Bridge are shown in **Figure 1.3**. The vacuum bridge is used to vacuum the bottom of the tank, and is also used for advanced oil distribution. The positions of the auxiliary and vacuum bridges can be changed to accommodate the specific test configuration being employed. A fourth bridge, the video bridge, can be affixed between the Main and Auxiliary bridges to support additional instrumentation and video equipment.

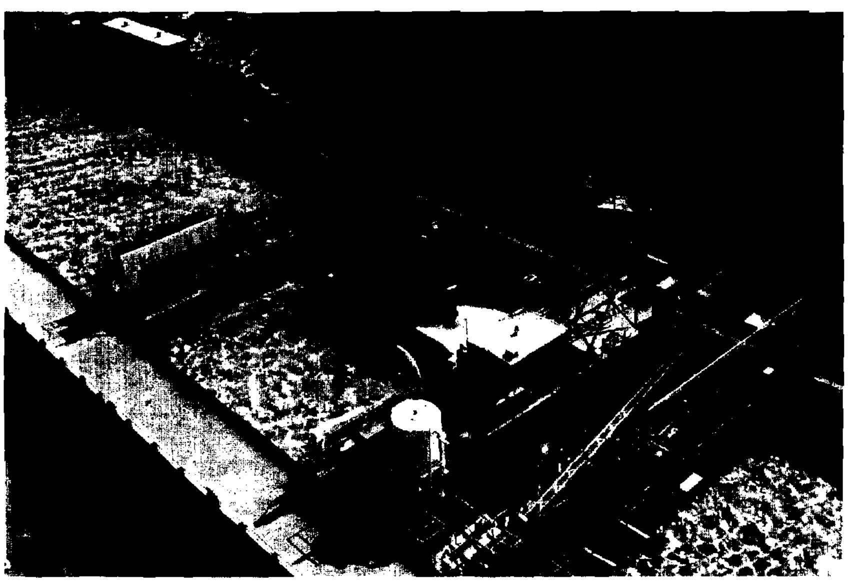


Figure 1.3 View of the Main (Towing) Bridge (foreground) and Auxiliary Bridge (background) spanning the Ohmsett test basin

Test oils are stored in a tank farm consisting of four vertical storage tanks and two horizontal storage tanks, located at the north end of the tank. The total storage capacity in these tanks is 60,000 US gallons. Oil to be used during a test is pumped to another storage tank on the Main Bridge where it is distributed on the water surface using a series of nozzles. At the conclusion of the tests, the oil is removed from the water surface with a skimming boom located beneath the Main Bridge. Remaining oil is swept to the north end of the tank where it is fire-hosed through a sluice gate. The oil is then processed (via settling, heating and centrifuging) to remove dirt, debris and water. The oil is then tested and sent back to the tank farm for storage and reuse, or disposed of in an environmentally approved manner.

Figure 1.4 *Regular (open ocean) waves being generated in the Ohmsett test basin.*

The tank is equipped with a wave-making system comprised of two hydraulically operated wave generators and a wave energy absorbing beach. The system is capable of producing regular waves up to 0.6 meters (2 feet) high and up to 45 meters (147 feet) long to simulate open sea conditions (as shown in **Figure 1.4**), as well as a series of 0.7 meter (2.3 feet) high reflecting complex waves to simulate the water surface of a harbor (harbor chop). The towing, oil distribution and wave generation systems at Ohmsett combine to provide the capability for testing of spill control equipment and systems under a wide range of repeatable conditions and settings. This allows researchers and manufacturers to obtain specific performance data to support development, refinement and efficient operation of spill control systems and equipment.

During testing, the tank is filled with 2.6 million gallons of water. This water is processed through a re-circulation and cleaning system, capable of complete recycling once every 24 hours. The system includes a diatomaceous earth filtering and treatment system. The filter system keeps the water clear to permit the use of a sophisticated underwater photography and video imaging system during testing, and removes residual hydrocarbons from the water after testing. The filtering and treatment system is capable of returning tank water to federal and state water quality standards before discharging.

Testing is controlled from a control station on top of the 3 story tall building located at the north end of the tank. From here, the tests are monitored and the data from various sensors and video cameras collected for synthesis and analysis. Up to 32 data channels are available for sensor input. Sensors include strain gauges, load cells and flow meters used to instrument the equipment tested, as well as oil thickness and environmental sensors. Signal conditioning for voltage, current and frequency sensors is available. Data are processed and stored in the computer in the control station. Computer assisted data analysis programs such as Matlab are available on the computer.

Ancillary support facilities at Ohmsett include an on-site Chemistry Lab and Machine Shop. The Chemistry Lab is capable of determining the physical properties of the various test oils, determining the composition of emulsions that may be used in the tests, and checking the water quality within the tank. All oil properties testing is performed in accordance with American Society of Testing and Materials (ASTM) Standards. The Machine Shop provides a complete range of materials fabrication and welding services to support construction of the test apparatus employed during a specific test.

The Ohmsett Facility is staffed and operated by a team of professionals supplied by the Ohmsett Contractor which is currently MAR Inc. of Rockville, MD. The team includes the following managers, test engineers and technicians:

Program Manager	Mechanical Engineer	Mechanical Technician
Administrator	Instrumentation Technician	Equipment Technician
Technical Writer	Health and Safety Officer	Craftsman/Technician
Test Support Manager	Quality Control Engineer	Chemical Lab Technician
Video Specialist		

A complete description of Ohmsett operating procedures is provided in the document "Standard Operating Procedures for the U.S. Department of Interior, Minerals Management Service Ohmsett Facility" prepared by MAR, Inc. of Rockville, MD, August 1994.

Management

The Minerals Management Service (MMS) has overall responsibility for the operation and maintenance of the Ohmsett. This responsibility was accepted by MMS in 1989 when they undertook the task of re-opening and refurbishing the facility. The responsibility was formalized in April of 1992 with the publication of the Interagency Oil Spill Research and Technology Plan. This plan (mandated by Title VII of the Oil Pollution Act of 1990) assigns MMS the responsibility for operating the facility in cooperation with the other Federal agencies.

The MMS Engineering and Operations Division, located in Herndon, Virginia, provides the overall facility management for Ohmsett, with an MMS Project Officer handling the planning, budgeting, marketing and policy formulation for the facility. Specific MMS management activities include providing expertise in the area of spill control technology, coordinating customer needs with facility capabilities, preparing interagency agreements, coordinating cash flow, participating with clients in the preparation of work orders and test plans, and reviewing test reports. The project officer also serves as the Contracting Officer's Technical Representative (COTR) in supervising the activities of the Ohmsett contractor, MAR, Inc. of Rockville, MD. The contractor handles the day-to-day operation and maintenance of the facility, and carries out the specific test programs in coordination with the federal agency, university or industry client test engineers.

Another group involved in planning the use and funding of the facility is the Ohmsett Interagency Technical Committee (OITC). This ad-hoc advisory committee, organized in 1975, is composed of major users and supporters of the facility. The OITC serves as a focal point to coordinate the research and development activities of those those wishing to use Ohmsett, and to develop a long-range strategy for future enhancement and funding of the facility. The OITC, chaired by an MMS representative, reviews and comments on applications for testing, provides technical guidance on spill cleanup technology and research priorities, provides peer review on test reports, and promotes information exchange and research collaboration among the OITC membership.

Sponsorship

Since its re-opening in 1992, much of the testing undertaken at the Ohmsett Facility has been funded by the federal agencies with responsibility for oil spill research and development as delineated in the Interagency Oil Spill Research and Technology Plan. The Minerals Management Service has supplied most of the funding necessary for basic operation and maintenance of the facility, which averaged approximately $1.2 M per year. The bulk of the funding for actual testing of spill control equipment on a project by project basis has been supplied by the MMS and USCG as part of their ongoing oil spill R&D programs. Additional funding during the period 1992-1997 has come from the U.S. Navy, Environment Canada, the Canadian Coast Guard, U.S. Army Corps of Engineers, Marine Spill Response Corporation, as well as universities and private industry. The funding required for specific tests at Ohmsett by Federal agencies are determined on a project by project basis. The daily use fee at Ohmsett varies according to the requirements of the specific test series. Over the past several years, the average cost to the user has been approximately $3500 per day of tank time.

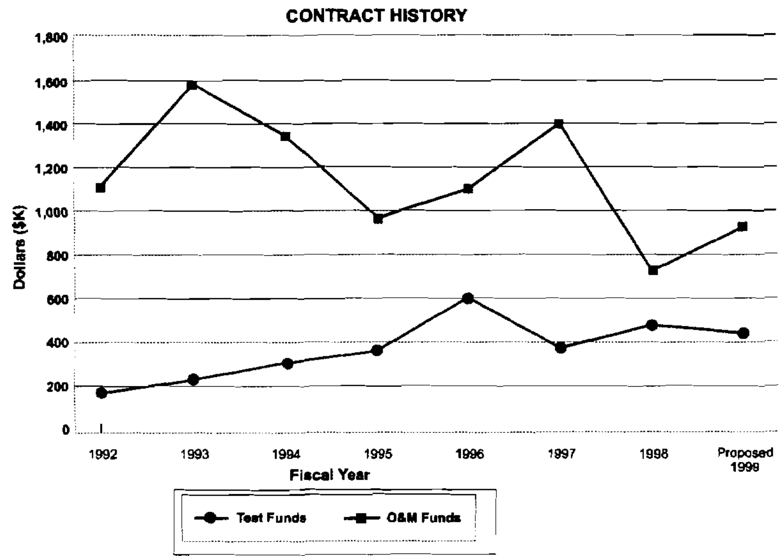


Figure 1.5 Graph Showing the Funding Trends for the Ohmsett Facility for FY 1992-1997

Figure 1.5 provides a funding history for the Ohmsett Facility Center for the period 1992-1997 (Fiscal Years) showing the apportionment of funds between basic operations and maintenance (O&M) and actual testing (project) funds. **Figure 1.6** shows the actual usage of the facility for FY 1992-1997 in actual days of testing, along with the cost per test day. It is significant to note that the cost per test day has dropped considerably as the use of the facility has increased.

Obtaining the necessary funding to operate, maintain and conduct tests at the Ohmsett Facility is an ongoing challenge for MMS and USCG, the two federal agencies designated to provide the bulk of the federal funding for the facility in the Interagency Oil Spill Research & Technology Plan. Federal funds appropriated for this purpose have fallen far short of the levels projected in the Plan. In addition, university and industry usage has not kept pace as the interest and funding for oil spill R&D has declined steadily as the impact of the EXXON VALDEZ spill and the Oil Pollution Act of 1990 diminishes.

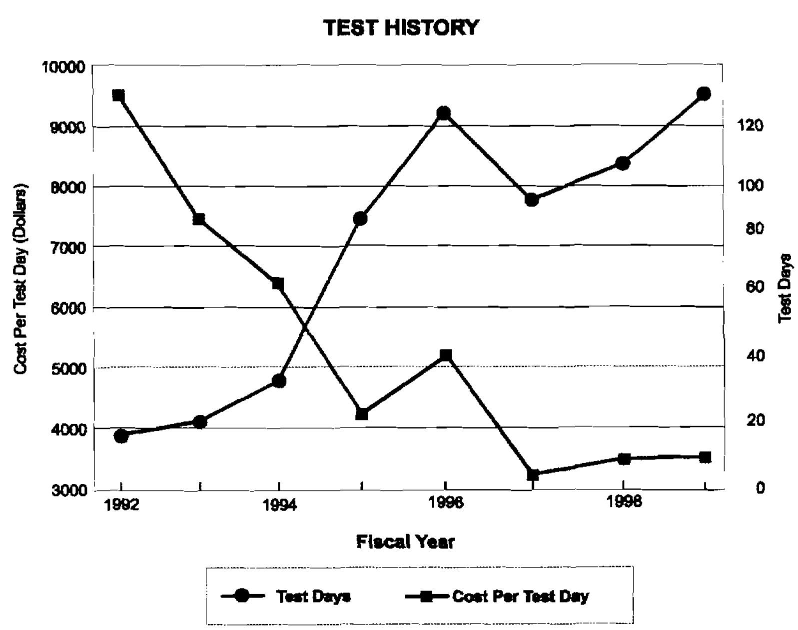


Figure 1.6 Graph Showing Ohmsett Usage and Daily Cost FY 1992-1997

Section 2.0 Testing and Training Activities at the Ohmsett Facility

A wide range of testing and training activities have been conducted at the Ohmsett Facility during the period 1992-1997. The following provides a brief non-technical overview of the nature of the technology tested, the purpose of the tests, and the general test procedure. More detailed descriptions of the test procedures are provided in the individual project test plans and final reports, most of which are available from the agencies and organizations sponsoring the tests. A comprehensive reference for a more detailed description of the technologies used and equipment and systems currently available on the market is the World Catalog of Oil Spill Response Products - 1997/1998, published by World Catalog JV of Annapolis, MD (hereafter referred to as the World Catalog).

Oil Spill Containment Booms

The first response action during an oil spill is often the containment of the oil in the vicinity of the source, or concentration of the oil for mechanical recovery or, where feasible and appropriate, in-situ burning. The standard device used for this purpose is an oil containment boom, generally constructed of a durable, flexible fabric skirt supported by flotation members (for a more complete description of boom design and boom types consult the World Catalog). These containment barriers are tested at the Ohmsett Facility to determine their performance at various current speeds and wave heights, as well as check the overall sea-keeping ability and durability.

The booms are towed from the towing bridge to produce various relative current speeds; and waves are generated by the wave generator. Oil of varying thickness and viscosity is discharged in front of the boom. The ability of the boom to contain the oil at various speeds and wave conditions is recorded using above and under-water video. Important parameters are the First Loss Tow Speed, Gross Loss Tow Speed, Oil Loss Rate, Critical Tow Speed (and failure mode), and Towing Force, which are defined as follows:

- First Loss Tow Speed – the lowest tow speed at which oil droplets (continuously) shed from the boom.
- Gross Loss Tow Speed – the tow speed at which massive continual loss of oil is observed underneath the boom.
- Oil Loss Rate – volume of oil lost from the boom per unit time.
- Critical Tow Speed – the tow speed at which the boom itself mechanically fails, or exhibits one or more performance failure modes (e.g. planing or submerging).
- Tow Force – straight-line tow force on the boom.

Figure 2.1 Tests of a Fast Current Booming System (Pacific Link Multiple Boom System) at Ohmsett.

Wave conformance is also observed visually and wave motion can be quantified using accelerometers mounted on the boom. The booms mechanical response can be measured using load cells, strain gauges, and accelerometers. Water temperature, salinity and meteorological data are also recorded. The complete Ohmsett boom testing procedures have been compiled in a formal draft test protocol entitled "Test Protocol for the Evaluation of Containment Booms With Oil at Ohmsett". This draft protocol has been submitted to the American Society of Testing and Materials (ASTM) F-20 Committee for consideration as an official ASTM Standard.

Containment booms have been available for over 20 years. A major constraint is their ability to contain oil at relative current speeds above 0.75 knots. Above this speed, oil will generally entrain under the boom. Much of the recent testing at Ohmsett has focussed on novel boom designs, which allow containment at faster current speeds. Such a fast-water boom test is depicted in **Figure 2.1** (previous page).

Oil Skimmers

Oil skimmers are devices which remove oil from the surface of the water either by physically skimming, vacuuming, or use of an oleophilic surface. Many different approaches and designs exist as described in the World Catalog. Testing is conducted to determine the skimmers oil recovery efficiency at various current speeds and wave conditions; and with various oil types. Tests can also be conducted to determine the effect of debris and ice on skimming operations. The complete Ohmsett skimmer testing procedures have been compiled into a formal test protocol entitled: Suggested Test Protocol for the Evaluation of Oil Spill Skimmers for the OCS. This test protocol is intended for use with ASTM methods F-631 and F-808.

The standard procedure for skimmer tests is to tow the skimmer from the towing bridge through the oil slick in the test basin, or feed oil into the skimmer opening as it ingests the oil. A specific volume of oil is presented to the skimmer, and the volume of oil actually recovered is measured. Specific parameters measured are the volume of oil and water recovered, the oil recovery rate, recovered oil characteristics (particularly the presence of emulsions), and the entrainment of oil past and underneath the skimmer. Important parameters recorded include First and Gross Loss Tow Speed (as defined previously), and oil recovery performance parameters including Throughput Efficiency, Oil Recovery Efficiency, and Oil Recovery Rate which are defined as follows:

- **Throughput Efficiency** is the ratio of the oil volume recovered to the oil volume encountered by the system.
- **Oil Recovery Efficiency** is the ratio of the volume of pure oil recovered to the total volume of oil/water mixture recovered.
- **Oil Recovery Rate** is the volume of oil recovered per unit time.

Figure 2.2 Tests of the LORI Skimming System at Ohmsett

The variation in the above parameters as a function of oil type and wave conditions is also investigated during skimmer tests. Skimmer designs and configurations can vary significantly based on the oil recovery scheme (e.g. weir, oleophilic surface, or inclined plane) and the deployment mode (e.g. independent deployment in the apex of a boom, mounted on a vessel, or integrated into a vessel). Each variation requires that the test procedures be adapted to provide performance data representative of operational use. Water temperature, salinity and meteorological data are also recorded. A typical skimmer test is shown in **Figure 2.2**.

Like booms, skimmers have been available for some time. Recent tests at Ohmsett have focused on advanced designs which allow skimming at higher current speeds. The Coast Guard has conducted extensive tests of the new Vessel of Opportunity Skimming System (VOSS). This is a boom-skimmer combination deployed from the side of a vessel such that VOSS testing involves measuring both boom and skimmer performance parameters.

Temporary Storage Devices

Figure 2.3 Tests of the Canflex "Sea Slug" at the Ohmsett Facility.

Once oil is recovered from the surface of the water by a skimmer or skimming vessel, it must be stored on-scene for transport to shore or a larger vessel. Two devices developed for this purpose are flexible oil storage bladders (often referred to as dracones) and inflatable oil storage barges. These devices can be tested at Ohmsett to optimize offloading configurations and methods, determine practical pumping rates and storage capacities as a function of oil viscosity, check towing and seakeeping characteristics, and determine the effectiveness of cleaning methods. The pumping, offloading and cleaning tests can be conducted in a static mode in the tank. Towing and seakeeping tests can be conducted using the tow bridge and wave generator in a dynamic mode.

During the period 1992-1997, the Canflex "Sea Slug" Storage Bladder and Lancer Inflatable Barge were tested. Both these systems are now an important part of the spill response inventory of equipment. The Canflex Sea Slug is shown in **Figure 2.3**.

Remote Sensing Tests

Figure 2.4 Test of the Frequency Scanning Radiometer Oil Spill Remote Sensor at Ohmsett.

Conducting effective cleanup operations at sea requires that spill responders be able to locate and map oil slicks on the water, and where possible, locate the thicker portions of the slick to allow for more efficient mechanical recovery or in-situ burning. This is currently accomplished by visual observation from aircraft, but can also be accomplished by the use of remote sensing systems which can map spills during darkness and bad weather. Many of these sensors are still in the developmental stage, and must be tested and calibrated against varying oil types and environmental conditions. The Ohmsett facility allows for testing of these sensors under a range of conditions and with different oil types in a simulated at sea environment. Oil spill remote sensors can be mounted on one of the Ohmsett Bridges (as shown in **Figure 2.4**) or on a tower above the tank. The tank is also large enough such that aircraft can fly over a test oil slick in the tank to check sensor performance. Important test variables that can be varied include oil viscosity and emulsion content, slick thickness, wave conditions, sensor height above the water, and sensor speed over water. During 1992-1997, developmental oil spill remote sensors were tested by the U.S. Coast Guard, Army Corps of Engineers, and the U.S. Navy.

Test Title: **Ohmsett Tests of NOFI VEE-SWEEP 600 AND NOFI 600S OILBOOM**	
Test Date: **August 13, 1992 - October 6, 1992**	
MMS/OHMSETT Work Order #: **01**	

Background and Objective:

The U.S. Coast Guard (USCG) procures oil-spill containment booms for the USCG Vessel of Opportunity Skimming System (CG VOSS). At the time of these tests, the design speed for the VOSS system was 0.75 knots (kts) relative to the water surface, a speed at which many vessels have difficulty transiting and/or holding a desired heading. To overcome this operating deficiency, the USCG is interested in identifying skimming systems that have design speeds in excess of 0.75 kts and are suitable for deployment on vessels of opportunity. The NOFI Vee-Sweep tested was designed to sweep effectively at speeds in excess of 0.75 kts. The OHMSETT tests helped to quantify the Vee-Sweep's operational efficiency at higher speeds.

The tests of the NOFI Vee-Sweep and NOFI 600S Oil boom manufactured by NOFI TROMSϕ A/S of Norway were the first tests conducted at Ohmsett after its reopening in 1992. In addition to providing data on equipment performance, the tests provided a shakedown for the test tank. Lessons learned during these tests helped make future testing more efficient.

The NOFI Vee-Sweep is an ocean oil boom designed for use with an oil skimmer within the apex of the V-shaped boom. Oil is funneled back to the skimmer by the converging sides of the V and concentrated for more efficient skimming. The 60-meter (m) length of the sweep is doubled over to form the V and held in this shape by cross netting at the bottom of the skirt **(Figure 3.1)**.

Figure 3.1 Photograph of the NOFI Vee-Sweep

The NOFI 600S Oilboom is designed to attach to one end of the Vee-Sweep, forming a J-shaped boom. A support boat tows the end of the Oilboom while the skimming vessel tows the other side of the Vee-Sweep.

The test objectives included measurement of:

- Vee-Sweep Critical Tow Speed to determine how fast the Vee-Sweep could be towed before failure occurs, that is, submergence (the boom loses all freeboard), planing (skirt pulls out of the water), substantial splash-over and/or mechanical failure.
- Vee-Sweep and 600S oil loss tow speed to determine First Loss and Gross Loss Tow Speeds,
- Vee-Sweep wave conformance tests to measure how the sweep follows waves, and
- Vee-Sweep Oil Loss rate to determine how much oil is lost at various speeds above the First Loss Tow Speed.

The USCG Research and Development Center (R&DC) provided equipment to be tested and sensor technician services. The tests were conducted by MAR, Inc., under the sponsorship and review of the Minerals Management Service (MMS) and the USCG.

Description of Test Procedures:

The NOFI Vee-Sweep was attached to the Ohmsett Main Bridge as shown in **Figure 3.2**. As the Main Bridge moved along the tank on rails, it towed the Vee-Sweep through the tank.

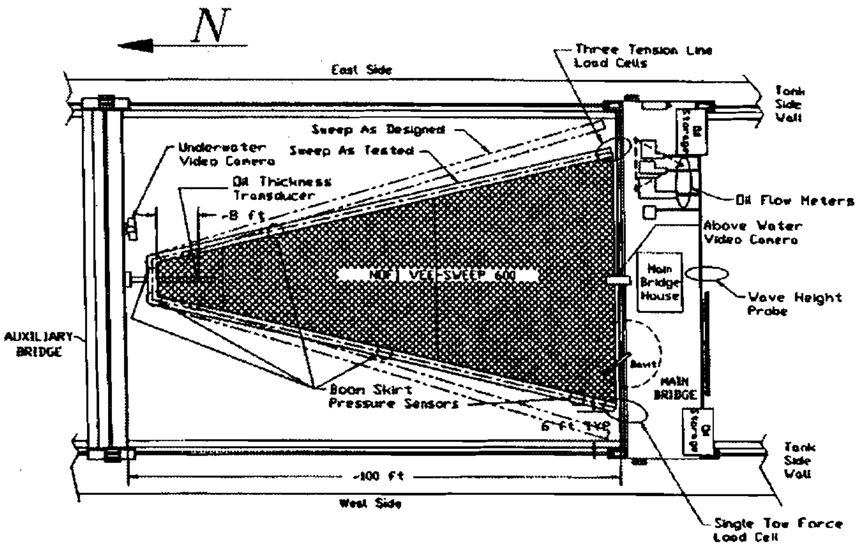


Figure 3.2. Test setup for NOFI Vee-Sweep. (Plan view)

Ohmsett's tank is 2.44 m (8 ft) deep, 20 m (65 ft) wide, and 203 m (665 ft) long. Ohmsett's "Test Protocol for the Evaluation of Oil-Spill Containment Booms" specifies that the space between the tank wall and the boom be 2.5 times the boom's draft and that the tank depth should be four times the boom's draft. The normal NOFI Vee-Sweep configuration has a mouth opening of 19.3 m (64 ft) and a skirt depth of 1.0 m (39.4 in), which violates both protocols. Therefore, the Vee-Sweep had to be reconfigured for the test. The Vee-Sweep's skirt was shortened to 0.7m (27.6 in). The mouth opening was reduced from the designed 19.3 m by rotating the sides of the sweep inward until the ends of the Vee-Sweep at the mouth were about 1.83 m (6 ft) in from the tank walls. This configuration (0.7 m skirt depth and 16.3 m mouth opening) produced a wall clearance of 2.5 times boom draft and a bottom clearance of about 3.5 times boom draft, still less than the bottom clearance specified in the protocol, but closer to the desired clearance.

A DESMI-250 oil skimmer was used in some of the oil loss tests. During oil recovery operations, the skimmer operates in front of the sweep apex, removing oil that the sweep has collected. No attempt was made to collect or analyze test data for the recovery capabilities of the DESMI-250 skimmer. The purpose of including the skimmer was to test the NOFI Vee-Sweep under conditions that resembled actual oil skimming operations.

Vee-Sweep Critical Tow Speed Tests:

Critical Tow Speed is defined as that speed at which the boom being towed experiences large changes in freeboard or draft, rendering it ineffective in containing oil. The Vee-Sweep was towed in calm water and four wave conditions without oil present. Three of the wave conditions represented regular waves of a single frequency; the fourth represented a harbor chop condition. The tow began at 0.5 kts, and speed was increased until the Critical Tow Speed was reached. Critical Tow Speed was determined by visual observation. Results of the Critical Tow Speed tests were also used to determine the Tow Force on the Vee-Sweep versus speed.

Vee-Sweep Oil Loss Tow Speed Tests:

First LossTow Speed and Gross Loss Tow Speed were determined visually. First LossTow Speed is the speed at which droplets of oil first begin to escape under the sweep; Gross Loss Tow Speed is the speed at which large amounts of oil begin to be lost from under the sweep. Determination of both oil loss tow speeds was subjective based on observations using an underwater camera.

Tests were conducted with and without the DESMI-250 oil skimmer present and operating. The Vee-Sweep was towed in calm water and various wave conditions using varying pre-loads of oil, and two oils of different viscosities. The pre-load is the amount of oil in the boom prior to beginning the test. Pre-load amounts varied for the heavier oil.

Vee-Sweep Wave Conformance Tests:

Wave Conformance Tests determine the motion of the boom when subjected to waves. The Vee-Sweep was towed in various wave conditions (generated by the Ohmsett wavemaker) without oil present to determine its dynamic response to waves. Pressure sensors mounted at the bottom of the boom skirt measured changes in local skirt depth. The tests were conducted at the First Loss Tow Speed (without a skimmer) as determined during the oil loss test described above. Each test run was made over the maximum possible length of the tank.

Vee-Sweep Oil Loss Rate Tests:

To quantify the steady state Oil Loss Rate, oil must be supplied to the boom as oil is lost underneath. In the Oil Loss Rate tests, the Vee-Sweep was pre-loaded, and then accelerated to slightly above First Loss Tow Speed while oil was continuously added in front of the sweep. The run continued the length of the test tank, and the elapsed time was recorded. All oil lost underneath the Vee-Sweep was skimmed from the water surface and collected in a calibrated settling tank. The Oil Loss Rate of the Vee-Sweep was computed from the amount of oil recovered in the settling tank. Due to time constraints, only three Oil Loss Rate tests were conducted, one without continuous distribution of oil throughout the test.

600S Oilboom Oil Loss Tow Speed Tests:

For the NOFI 600S Oilboom, only First Loss and Gross Loss Tow Speeds were measured. The 60 m long NOFI 600S Oilboom was towed in a U-shaped configuration. The initial mouth opening of 16.8 m was reduced to 14 m due to wake effects. Tests were conducted with and without the boom's feather net attached. The oil loss test series included calm water, 2.5-sec regular (sea) waves and harbor chop.

Summary of Results:

The final report theorizes that the flow velocity under the Vee-Sweep may have been higher than in the open ocean because the skirt depth was closer to the tank bottom than recommended. The observed Critical Tow Speed, First Loss Tow Speed, and Gross Loss Tow Speed in the tank are likely to be slightly lower than would occur in the open ocean because of this higher flow velocity under the sweep.

Vee-Sweep Critical Tow Speed:

The mode of failure at Critical Tow Speed was submergence of the boom apex in all cases. The Vee-Sweep remained stable up to the point of apex submergence. The measured Critical Tow Speed for full submergence was 3.4 to 3.6 kts in calm water and small regular waves. The Critical Tow Speed was 2.4 kts in harbor chop conditions. Waves of 1.6-sec period caused significant splashover at the apex well before the Critical Tow Speed was reached but did not reduce the critical speed.

Vee-Sweep Tow Force:

None of the wave conditions generated during the tests had a significant effect on the tow force. The maximum averaged, total tow force in the direction of travel for the Vee-Sweep under the conditions tested was 8,540 pounds (lbs), which occurred at a speed of 3.5 kts for both calm conditions and 1.6-sec waves.

Vee-Sweep Oil Loss Tow Speed Tests:

First Loss and Gross Loss Tow Speeds were lower for the less viscous oil than for the more viscous oil (Table 3.1). For the more viscous oil, First and Gross Loss Tow Speeds varied with changing wave conditions. (Table 3.2).

Note: First Loss Tow Speed and Gross Loss Tow Speed can vary with the amount of oil pre-loaded into the sweep apex. Pre-load tests were included in later Ohmsett tests to determine the amount of oil that should be placed into the apex of the boom before towing begins for oil loss tow speed tests.

Test Oil	SUNDEX 8600T		Hydrocal 300	
Wave Condition	First Loss Speed	Gross Loss Speed	First Loss Speed	Gross Loss Speed
Calm	1.4	1.8	1.1	1.4
4.6 sec Regular	1.4	1.6	—	—
2.5 sec Regular	1.5	1.7	—	—
1.6 sec Regular	1.3	1.65	—	—

Table 3.1. Oil Loss Tow Speeds with Different Viscosity Oils (100 gallon pre-load; all speeds in knots)

	No Skimmer in Sweep		Skimmer Operating	
Wave Condition	First Loss Speed	Gross Loss Speed	First Loss Speed	Gross Loss Speed
Calm	1.25	1.6	1.2	1.55
1.6 sec Regular	1.0	1.35	1.2	1.35

Table 3.2. Oil Loss Tow Speeds with Higher Viscosity Oil with and without a Skimmer (900 gallon pre-load; all speeds in knots; SUNDEX 8600T used)

Vee-Sweep Wave Conformance Tests:

Results of the wave conformance tests showed that the relative motion of the boom in the vertical ranged from 34 to 92 percent of the significant wave height. In general, the Vee-Sweep followed the waves very well.

Vee-Sweep Oil Loss Rates:

The Oil Loss Rate Tests were complicated by the inability to match the oil discharge rate into the boom with the Oil Loss Rate underneath. Resolving this problem would have required extensive additional testing. The limited data gathered were inconclusive.

600S Oilboom Oil Loss Tow Speed Tests:

A 300-gallon pre-load was used. Results (Table 3.3) show that the bottom netting appears to have little effect in calm water but does increase First and Gross Loss Tow Speeds in wave conditions. First Loss Tow Speeds between 1.0 and 1.3 kts were obtained; Gross Loss Tow Speeds varied between 1.25 and 1.6 kts.

	NOFI 600S with Feather Net			***NOFI 600S without Feather Net***		
Wave Condition	**Viscosity (cSt)**	**First Loss Speed (knots)**	**Gross Loss Speed (knots)**	**Viscosity (cSt)**	**First Loss Speed (knots)**	**Gross Loss Speed (knots)**
Calm	870	1.25	1.4	1050	1.2	1.4
4.5 sec Regular	870	1.3	1.6	1050	1.2	1.4
Harbor Chop	630	1.25	1.5	1050	1.0	1.25

Table 3.3 Summary of NOFI 600S Gross Oil Loss Tow Speed.

Summary of Findings:

The Vee-Sweep and 600S Oilboom both towed in a very stable manner up to the Critical Tow Speed. The sweep had substantial reserve buoyancy and the apex sank gradually as the tow speed was increased. The shape of the sweep was constant throughout the speed range. The oil loss tests demonstrated that the NOFI Vee-Sweep could contain and concentrate oil at speeds above 1 knot, which was a significant improvement over the VOSS limit of 0.75 kts.

Final Report References:

Goodwin, M.J., D.S. DeVitis, R.L. Custer, D.L. Backer, S.L. Cunneff and E.F. McClave, 1993. Ohmsett TESTS OF NOFI VEE-SWEEP 600 AND NOFI 600S OILBOOM. Report No. OHM-93-001, Minerals Management Service Contract No. 14-35-0001-30544. Prepared by MAR, Incorporated, 6110 Executive Boulevard, Suite 410, Rockville, MD 20852, 30 pp. + app.

Related Publications:

Bitting, K.R. and J. Vicedomine, 1993. NOFI Oil Vee-Sweep and Extension Boom Test at Ohmsett. Proceedings of the Sixteenth Arctic and Marine Oil Spill Program Technical Seminar, Environment Canada, Ottawa, Canada, pp. 393-408.

Eisenberg, K.C., J.F. Etxegoien and D.A. Furey, 1995. At-Sea Evaluation of the Coast Guard VOSS, NOFI-V and FIOCS Oil Recovery Systems. U.S. Coast Guard Research and Development Center Report CG-D-19-96, 1082 Shennecossett Road, Groton, CT 06340-6096, 167 pp.

Test Title: **Ohmsett Tests of RST EMERGENCY RESPONSE UNIT**	
Test Date: **October 16, 1992 – October 27, 1992**	
MMS/OHMSETT Work Order #: **02**	

Background and Objective:

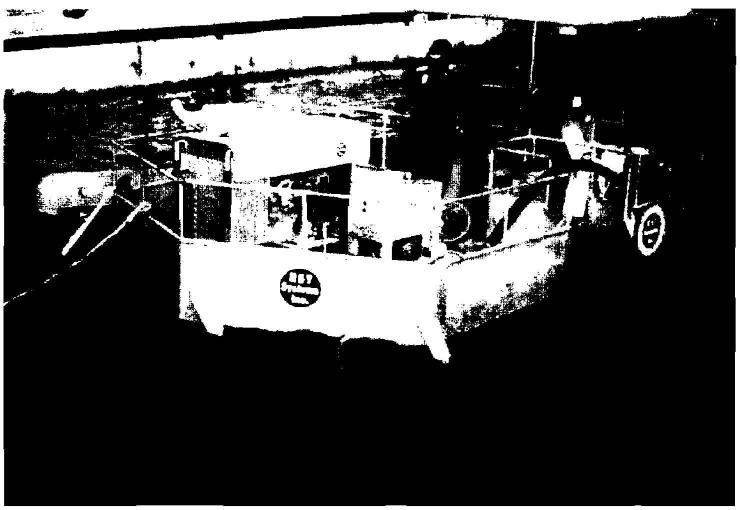


Figure 3.3 The RSTERU in the Ohmsett Basin.

The U.S. Coast Guard tests oil spill cleanup equipment for possible inclusion in the equipment inventory of the National Strike Force. The gravity separation device incorporated into the RST Emergency Response Unit (RSTERU), was identified as having potential applications in Coast Guard oil spill response operations. Key factors to be tested in determining efficiency and effectiveness of such devices are Oil Recovery Rate and flow rate.

The RSTERU is a 7.3 m (24 ft) long, self-propelled vessel incorporating a skimming system, a gravity oil/water separation system, and storage for approximately 8 m^3 (2,100 gal) of recovered oil in a free-flooding section of the hull. The RSTERU can store and transport the oil it has recovered, or the recovered oil can be offloaded to a storage vessel or to a towed storage device such as a floating bladder after oil collection has ceased. With sufficient offload pumping capacity and a storage vessel, the RSTERU could be used to offload oil while it is still collecting oil, *i.e.*, as a steady-state recovery device. The objective of this testing was to evaluate the oil/water separation capabilities of the RSTERU when operated as a steady-state recovery device. Effectiveness as a skimming device was not tested. It is pictured in **Figure 3.3** and described in more detail in **Figures 3.4** and **3.5**. Oil is channeled to the weir skimmer intake by flat wings extending from the sides of the vessel. The oil is then pumped to the oil/water separator. The water leaving the separator moves downward, eventually being discharged to the sea through the discharge opening; the oil leaving the separator moves upward, eventually reaching the level of the offload pump intake.

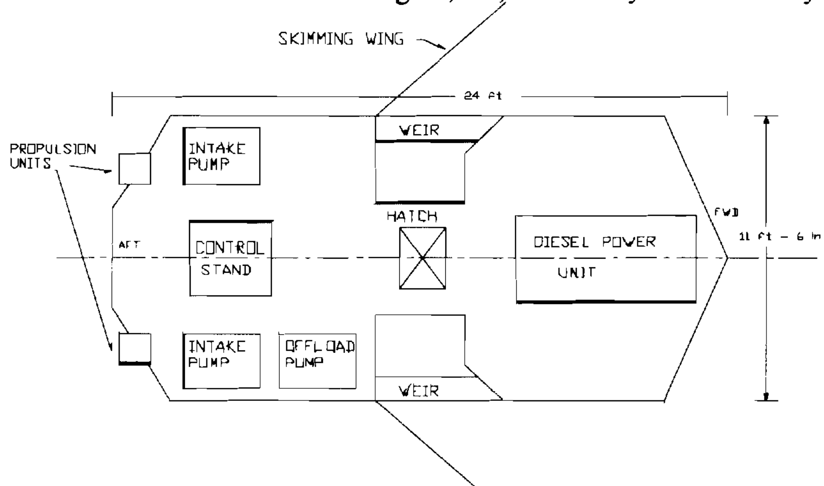
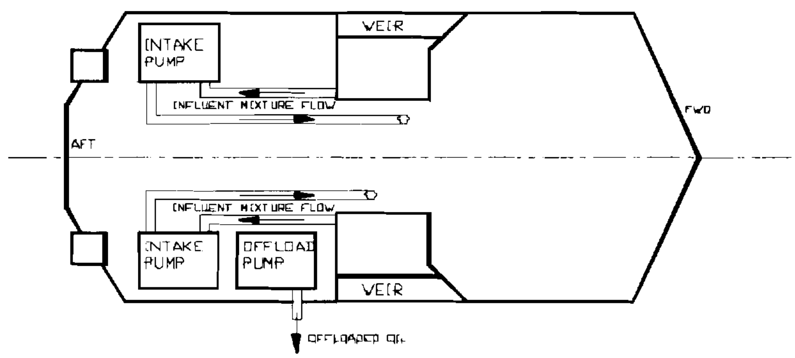


Figure 3.4 Deck Plan of the RST Emergency Response Unit.

Detailed Description of Figure 3.4 and 3.5

The RSTERU is a self-propelled aluminum-hulled vessel incorporating two weir-type oil skimmers and two internal gravity oil/water separation devices. The RSTERU's hull is 7.3 m (24 ft) long with a 3.5-m (11 ft-6 in) beam and a 1.5 m (5-ft) draft. It has vertical sides at the operating waterline and a small, flat bottom. In normal operation the hull free-floods to within 6 inches of the underside of the main deck through a rectangular, roughly vertical, water discharge opening in the bottom. A hydraulically operated flap, which is fully opened during oil recovery operations, closes the discharge opening to allow the hull to be pumped out for transit. Floatation chambers inside the hull provide buoyancy while the hull is free-flooded. A 123-kw (165-hp) diesel engine powers all onboard systems. Two steerable outboard



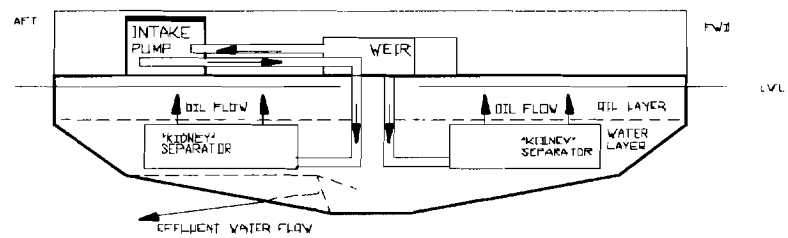


Figure 3.5. RSTERU Fluid Flow Diagram.

hydraulic drive units are mounted to the stern transom. Skimming wings collect oil during forward motion of the vessel. Several modifications were made to the RSTERU for testing. The wings were lengthened, a discharge water sampling system was installed, and flowmeters were installed in the intake lines, which required modifications to the piping arrangement.

Recovered fluids are pumped from sumps behind the weirs into gravity oil separators ("kidneys") located inside the hull below the inside waterline, one forward and one aft of amidships. A discharge port is located near the bottom.

Minerals Management Service and the U.S. Coast Guard Research and Development Center sponsored this test. The RSTERU was developed and built by RST Systems, Inc., of LaRose, LA, which provided trained operators, the RSTERU, and support personnel for the tests.

Description of Test Procedures:

Figure 3.6 shows the test setup for deployment of the RSTERU in Ohmsett's tank. The RSTERU was towed at 0.39 m/sec (0.75 kts) in both calm water and in waves having an average period of 3.5 sec and an average significant height of 27 cm (10.6 in). Oil was distributed on the water at rates varying from 17 to 48 m^3/hr (75 to 213 gallons per minute [gpm]) during calm water tests, and from 12 to 43 m^3/hr (53 to 191 gpm) during wave tests. Two hoses, floating on the surface at each side of the unit, distributed oil onto the water surface immediately in front of the RSTERU's skimming weirs. Total amounts of oil distributed in various tests were 0.76, 1.14, and 1.7 m^3 (200, 300, and 450 gal).

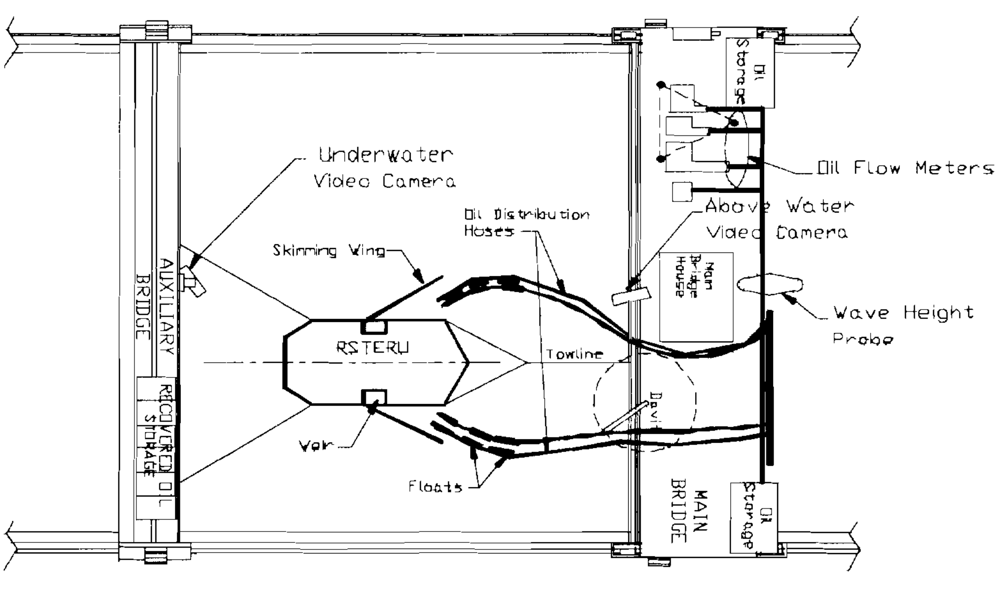


Figure 3.6. RSTERU Test Setup.

Various oil/water samples were taken for oil/water content analyis including:

- the water/oil mixture at the intake
- the water discharged from the RSTERU's bottom discharge port, and
- the top inch of the recovered oil layer inside the hull.

Oil Recovery Rate (ORR) was calculated as the amount of oil recovered divided by the duration of recovery. The amount of oil recovered was determined as follows. After sampling the recovered oil from the RSTERU hull, the oil was offloaded to recovery tanks on Ohmsett's Auxiliary Bridge. After settling, the free water was decanted, and the recovered oil volume was measured. The oil from the recovery tanks was sampled and tested for water content. The values for water content were used to correct the volume of oil recovered, to account for incomplete oil/water separation. Time and limited tank space prevented complete segregation of the oil recovered in some tests from the oil recovered in previous tests. In those tests where the oil could not be segregated, average water content was used for the oil/water volume correction.

The duration of recovery was the time during which the weirs on the RSTERU (**see Figure 3.4**) encountered full oil flow. It spanned the time between the first encounter with oil (shortly after the oil began discharging onto the water from the supply hoses) and the diminishment of encounter (shortly after the flow was secured).

Flowrate readings from flowmeters installed in the RSTERU's starboard and port intake streams were averaged over the duration of oil recovery. They represent total flowrate of the oil and water into the device.

Summary of Results:

The effectiveness of the oil/water separator was determined by measuring how much water was present in the recovered oil and how much oil was present in the discharge water. The oil recovered and separated by the RSTERU had from 1.2% to 5.2% water for tests in calm water, and from 3.0% to 11.0% water for tests in waves. Due to the rather shallow layers of recovered oil in the RSTERU after these tests (as shallow as 13 mm (1/2 in)), it is possible that some water was entrained in the oil sampled from these layers during the sampling process itself. This would increase the apparent water content of the oil. Water content of the recovered oil under actual operational conditions (where the oil layer would be deeper) would be expected to be at least as low, and possibly lower, than the values reported.

The oil content of the effluent water at the discharge port ranged from 0.9 parts per million (ppm) to 13 ppm for tests in calm water and from 16.0 ppm to 47.2 ppm for tests in waves. However, the test time was short (1.5 to 3 minutes), and the maximum total amount of mixture inflow (300 to 600 gal) was small compared to the large amount of water in the hull (approximately 3000 gal). Therefore, the water which exited the discharge port during the test (and which was sampled during the test) was not necessarily water that entered during that test run. During early runs, most of the water exiting the discharge port would have been clean basin water taken into the hull during launching. The effluent water sampled represents a mixture of all the water taken in during previous tests, combined with the clean basin water taken in during launching. In no case was the discharged water primarily water that entered the unit during the test run in question.

With the exception of two repeat calm-water runs, the tests in waves occurred chronologically after the tests in calm water, which might have led to a gradual increase in the oil content of the water inside the RSTERU hull during testing. However, the data for the repeat calm-water tests, which were the last runs made, show a significantly lower value of oil content than previous runs in waves, indicating that a simple chronological increase in effluent water oil content did not occur.

In calm water, the oil recovery rate ranged from 15.2 to 33.4 m^3/hr (67 to 147 gpm), while in waves the values were 2.3 to 25.7 m^3/hr (10 to 113 gpm). Flow rates of the influent oil/water mixture, which were monitored continuously and time averaged, varied from 31.8 to 47.2 m^3/hr (140 to 208 gpm) in calm water and 16.1 to 44.5 m^3/hr (71 to 196 gpm) in waves.

Summary of Findings:

The average water content values in the oil sampled from the RSTERU were higher for wave tests than for calm-water tests. Two possible explanations are given: 1) sampling the oil layer (which was shallower in wave tests than calm-water tests) may have introduced some underlying water into the sample, and 2) agitation due to wave action might have decreased the effectiveness of the separation process.

Investigation of possible correlations between the principal test results and the influent mixture flow rates and oil recovery rates indicated that the water content of the recovered oil was independent of the influent mixture flow rate and oil recovery rate over the range of flow rates tested. The oil content of the effluent water appeared to increase with increasing oil recovery rates for tests in both calm water and in waves; however, this correlation was found to be statistically significant only for tests conducted in waves.

Final Report References:

McClave, E.F., D.S. DeVitis, S.L. Cunneff, J.H. Nash, R.L. Custer, D.L. Backer and M.J. Goodwin, 1993. Ohmsett TESTS OF RST EMERGENCY RESPONSE UNIT (RSTERU). Contract Report OHM-93-02, Minerals Management Service Contract 14-35-0001-30544. Prepared by MAR Incorporated, 6110 Executive Boulevard, Suite 410, Rockville, MD 20852, 91 pp.

Test Title: **Ohmsett Test of LORI LSC-2 SKIMMING SYSTEM**
Test Date: **April - August 1993**
MMS/OHMSETT Work Order #: **04**

Background and Objective:

This test was part of a U.S. Coast Guard program to evaluate mechanical oil recovery devices for upgrading their National Strike Force equipment inventory. The LORI Side Collector oil recovery system has been identified as a promising candidate for incorporation into the USCG inventory; hence, it was selected for full-scale testing at Ohmsett.

The Canadian Coast Guard provided the workboat with the Navenco-LORI side collector units attached for testing at Ohmsett. The USCG Research and Development Center provided funding and technical assistance throughout the project. MAR Inc. executed all testing and reporting under the sponsorship and guidance of the Minerals Management Service.

The LORI LSC-2 is one of many oil skimming devices commonly referred to as oleophilic surface skimmers. These devices recover oil by moving an oleophilic surface (such as a brush, disc, belt, drum or rope mop) through the oil/water interface. The LORI LSC-2 uses a chain brush as the oleophilic surface. The brush is rotated through the oil, and oil is "scraped" from the brush and allowed to flow into a collection area. The type of brush used can be changed to match the adhesion properties of the type of oil that has been spilled.

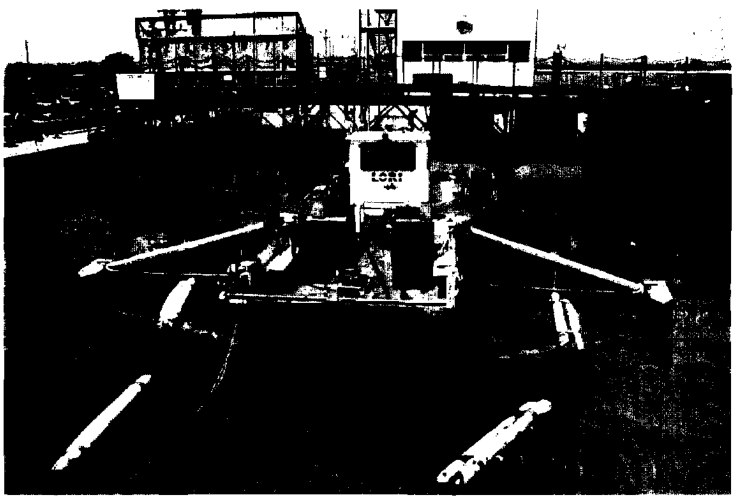


Figure 3.7 Lori Skimmer Deployed for Testing at Ohmsett.

The LORI LSC-2 skimming system tested is mounted on the side of a vessel. Collection booms deployed to each side of the vessel are used to divert the oil toward the vessel as the vessel advances through the oil slick. **Figure 3.7** shows the LORI Skimmer deployed for testing in the Ohmsett test basin. **Figure 3.8** depicts its operating principles.

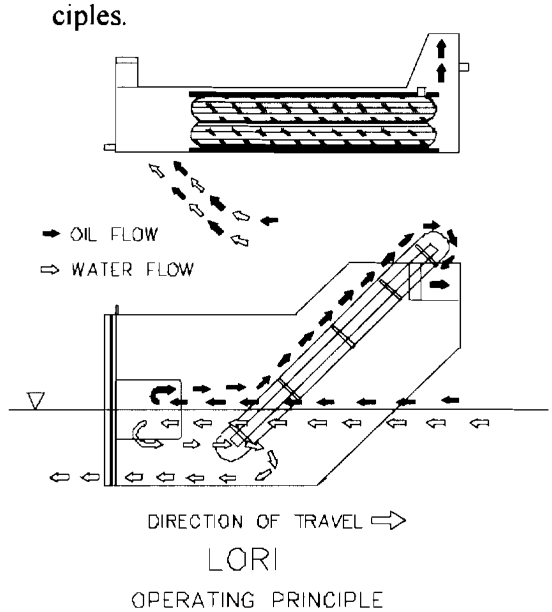


Figure 3.8 Operating Principles of the LORI LSC-2 Skimming Unit.

The type of brush material can be interchanged to match the type of oil that has been spilled.

The objectives of the testing were to determine the following:

- The Oil Recovery Rate (ORR), the Oil Recovery Efficiency (ORE), and Throughput Efficiency (TE) of the fine brush and coarse brush LORI systems at five (5) different forward velocities in calm water and waves (see note next page). Three different types of oil were used to represent a wide range of viscosities.

- The maximum Oil Recovery Rate of the LORI side collectors with heavy oil in calm water.
- The First Loss and Gross Loss Speeds of the entire skimming system with heavy oil in calm water.
- The debris recovery capability of the collectors with heavy oil in calm water.

Note: Oil Recovery Rate is the volume recovered per unit time, Oil Recovery Efficiency is the volume fraction of oil in the recovered oil/water mixture, and oil Throughput Efficiency is the ratio of the oil recovered to the oil encountered.

It was anticipated that these test results would provide the USCG with information regarding the ability of the LORI Side Collector System to collect and recover a variety of oil types in calm and wave conditions.

Description of Test Procedures:

The work boat with the LORI system attached was connected to the Ohmsett Main Bridge with a bridle as shown in **Figure 3.9**. The Ohmsett Main and Auxiliary Bridges are mounted on rails and can be moved through the tank basin at varying speeds. When the system is pulled through the water the collection arms assume a "U" shape as shown in **Figure 3.9.** In all, five separate skimmer performance tests were planned using three different types of oil. Three test oils were used to assess the ability of the LORI system to handle a wide range of oil properties using either the fine-brush collector or the coarse-brush collector. The test oils included:

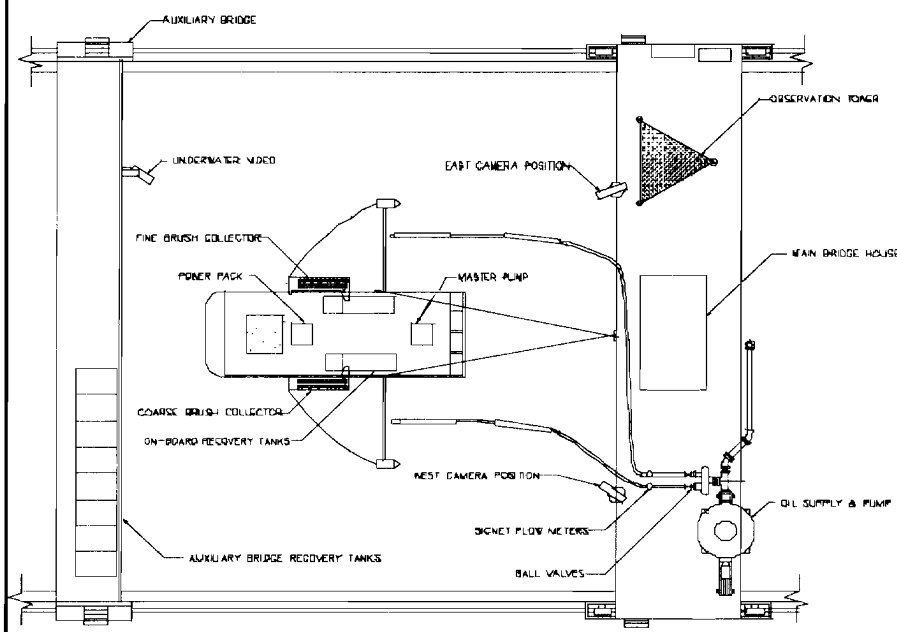


Figure 3.9 Test Configuration for the LORI LSC-2 Skimmer Tests in the Ohmsett Test Basin.

- A light diesel oil having a viscosity of approximately 5 centiStokes (cSt) and a specific gravity of 0.83.
- A medium viscosity refined oil having a viscosity which ranged from 520 to 700 cSt, and a specific gravity of 0.93.
- A heavy viscosity refined oil blend having a viscosity ranging from 8,800 to 71,000 cSt, and a specific gravity of 0.95. The viscosity of this oil varied during the testing due to inconsistent mixing, and low temperatures during some tests.

Five test series were conducted as follows:

Light Oil Recovery Tests

Light oil recovery tests were scheduled to be conducted with diesel oil using the fine brush collector. During the set-up run it was observed that no measurable quantity of oil was collected. No further tests were run.

Medium Oil Recovery Tests

Medium oil recovery tests were scheduled for both the fine-brush and coarse brush collectors. During the set-up tests it was observed that the coarse-brush collector did not recover any measurable quantity of oil. Only the fine-brush collector was used. Ten test runs were conducted at five speeds in both calm water and waves.

Heavy Oil Recovery Tests

Ten test runs were conducted at five different speeds and in both calm water and waves, with both fine-brush and coarse-brush collectors operating.

The test procedure for the oil recovery tests was as follows:

The collector brushes were started as the main tow bridge began to accelerate. Oil distribution was started. A pre-load of 50 gal of oil was introduced to ensure that the collectors would reach a steady state recovery condition as soon as possible. As the skimmer was towed down the basin, test oil was distributed into the collection arms on each side of the vessel using floating hoses. Oil was recovered as the skimmer moved down the basin, with oil distribution ending just before the tow bridge stopped. After each test run, the volume and temperature of the recovered fluid were measured, and samples taken to determine water and sediment content.

Oil Loss Tests

First and Gross Oil Loss Tests were conducted in calm water with the collecting brushes not operating. First Loss Tow Speed is the lowest speed at which oil droplets continuously shed from beneath the boom. Gross Loss Tow Speed is the speed at which massive continual oil loss from the boom is observed. The oil loss tests were conducted by preloading the boom with oil, then accelerating the bridge from 0 – 3.5 knots while oil was being distributed in the same manner as in the recovery tests.

Debris Test

One test was run in calm water using the same distribution procedure as for the oil recovery tests, but with a pail of debris introduced into the skimmer. The debris consisted of various types of plastic strips, plastic rope, wood and marsh grass.

Maximum Recovery Rate Tests

A maximum recovery rate test, using a high oil distribution rate (100 gpm per side collector) was scheduled to check the maximum recovery rate which was predicted to be 53 gpm. However, in view of the highest measured recovery rate during the oil recovery tests (14.5 gpm per side), this test was cancelled.

Summary of Results:

A fairly large volume of data were collected and analyzed. The full results are presented in the final report. Some of the more significant results are as follows:

Medium Oil Recovery Tests

Medium oil runs were conducted with only the fine-brush unit in operation. The maximum oil recovery rate observed was 4.2 gpm at 3.5 kts in calm water. The average oil recovery rate in calm water was 2.7 gpm, and the average recovery rate in waves was 3.0 gpm.

Heavy Oil Recovery Tests

Heavy oil recovery tests were conducted with both the fine-brush and coarse-brush units. The maximum oil recovery rate for the fine-brush collector was 11.7 gpm at 2.5 kts in calm water. The average oil recovery rate for all fine-brush tests with heavy oil was 7.7 gpm. The maximum oil recovery rate for the coarse-brush collector was 14.9 gpm at 2.0 kts in calm water. The average oil recovery rate for all coarse-brush tests with heavy oil was 9.4 gpm.

Oil Loss Tests

Two oil loss test runs were conducted using an oil with specific gravity of 0.96 and a viscosity of 22,000 cSt. During the first test run the First Loss Speed was 1.15 kts and the Gross Loss Speed was 1.35 kts. In the second run, only the Gross Loss Speed was recorded at 1.41 kts.

Debris Test

None of the debris interfered with the brush operation during the test; however, much of the debris remained un-recovered within the collection boom.

Summary of Findings:

The recovery test data were further analyzed to determine the dependence of Oil Recovery Rate, Oil Recovery Efficiency, and Throughput Efficiency upon tow velocity, oil viscosity and wave conditions. The significant results are as follows:

- For both brush types, and with both medium and heavy oil, the Oil Recovery Rate increases with velocity up to 2.5 to 3.0 kts, and then decreases with further increases in velocity.
- For both brush types, the Oil Recovery Rate increases with increasing viscosity over the entire range of viscosities tested.
- For the fine-brush collector, the Oil Recovery Efficiency increases with Oil Recovery Rate. For the coarse-brush, the Oil Recovery Efficiency was fairly constant at about 85% over the range of Oil Recovery Rates measured.
- For both brush types, the Throughput Efficiency increases with increasing viscosity over the range of viscosities observed.
- The Oil Recovery Rate for both fine and coarse brushes was considerably less dependent upon velocity in waves than in calm water. Maximum Recovery Rate was lower in waves than in calm water.

In general, the Oil Recovery Rates for the LORI Skimmer were somewhat less than expected by the manufacturer. It is apparent that the system works best in heavier oils. The system is capable of handling a moderate amount of debris as might be encountered in normal open water and harbor applications.

Final Report References:

McClave, E.F., D.S. DeVitas, S.L., Cunneff, D.L. Backer, R.L. Custer, and S. McHugh, 1993, OHMSETT TESTS OF LORI-LSC-2 SKIMMING SYSTEMS, Minerals Management Service Contract 14-35-0001-30544. Prepared by MAR Incorporated, 6110 Executive Boulevard, Suite 410, Rockville, MD 20852.

Related Publications:

Ohmsett Tests of LORI LSC-2 Skimming Systems, MAR, Incorporated, 6110 Executive Boulevard, Suite 410, Rockville, MD 20852, November 1994. U.S. Coast Guard Report No. CG-D-17-94, Accession No. AD-A294352.

Test Title: **CANFLEX "SEA SLUG" TEMPORARY STORAGE DEVICE AND THE DOAS FLOTATION COLLAR**

Test Date: **August - September 1993 and August - September 1994**

MMS/OHMSETT Work Order #: **006**

Background and Objective:

This series of tests was sponsored by the Minerals Management Service and the USCG Research and Development Center. This Sea Slug was purchased by the Canadian Coast Guard and loaned to Ohmsett for this test. The DOAS Flotation Collar was provided by Hyde Products, Inc.

Figure 3.10. Canflex "Sea Slug" Deployed in the OHMSETT Basin

The CANFLEX Sea Slug is an ocean towable submarine-shaped collapsible bladder that is used to store and transport fluid, including oil that is recovered from oil spills. At the time of the test, the subject Sea Slug was the first unit to have a capacity of 25,000 gal. This Sea Slug was built as a prototype for testing. **Figure 3.10** shows the device in the OHMSETT Basin.

The Desmi Offload Adapter System (DOAS) pumping unit is a positive displacement fluid pumping system that was specifically designed and built to offload towable bladders like the CANFLEX Sea Slug. The system is attached to the stern of the bladder, and it is remotely operated by a hydraulic power supply.

The effectiveness of offloading the 25,000-gallon Sea Slug under the following conditions was investigated:

- Offload with the DOAS unit hooked to the stern while providing no other assistance such as lifting the bladder.
- Offload while the Sea Slug is being dragged bow first over a raised fairlead to gravity assist oil flow toward the pump. This method simulates dragging the Sea Slug over a stern roller or platform on a ship.
- Offload while the bow section of the sea slug is submerged to enhance oil flow to the DOAS offload pump by buoyancy.
- Offload while the Sea Slug bow is being lifted by a crane to enhance oil flow to the DOAS offload pump by gravity.
- Offload the Sea Slug by submerging a pump through a "top-center" access port. This test was added during the course of the evaluation.
- Offload any "decanted" water that has separated from the oil/water mixture within the Sea Slug.

Collapsible storage bladders can be essential to a successful spill response as they provide primary and supplemental storage for recovered oil during a spill. Transport of the bladders to a spill site is simplified because they are made from flexible materials and can be folded for compact shipment by land or air.

Offloading high viscosity oil from collapsible storage containers was considered to be a problem at the time of this test, and is still a problem today if advance preparations are not adequate. Testing of innovative and traditional offloading methods were incorporated into this test to help improve collapsible storage offloading

Figure 3.11 Underwater View of the Off-loading End of the Canflex "Sea Slug" with DOAS unit in place.

techniques. The DOAS unit was included in these tests because, at the time, the USCG was evaluating its ability to be used as an innovative offloading system for towable bladders.

Note: the higher an oil's viscosity, the greater its resistance to flow. High viscosity oils are typically heated during transfer operations. Temporary storage devices such as the Canflex system are not equipped with heating, so that transferring high viscosity oils is often a problem, particularly at lower temperatures.

Description of Test Procedures:

Figure 3.12 below shows a plan view of the basic tank layout with the Sea Slug floating in the tank basin. The DOAS pump was connected to the stern of the Sea Slug for all tests except the center offloading test. Test oil was transferred from heated storage tanks into the Sea Slug using the USCG CCN-150 offloading pump. Once oil was transferred into the Sea Slug it began to cool, the viscosity increasing as it cooled.

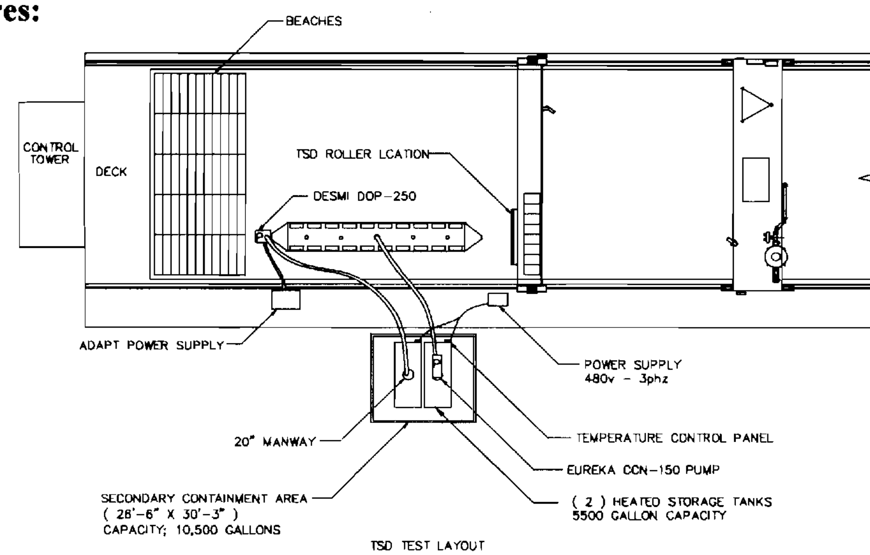


Figure 3.12 Plan View of Tank Layout for CANFLEX Sea Slug and DOAS Flotation Collar Tests.

The DOAS floating pump had a knife gate valve that was remotely opened and closed using hydraulics. When the DOAS valve was opened, a 10" diameter connection was made available so the pump could pull oil from the Sea Slug and return it to the heated storage tanks. The DOAS pump was powered by the USCG Air-Deployable Anti-Pollutions Transfer System (ADAPTS) hydraulic power supply.

An overhead crane was rented to lift the bow section for the crane-assisted offload tests. During these tests the crane "incrementally" lifted the Sea Slug bow to help the oil flow to the DOAS offloading pump connected to the Sea Slug stern.

A roller was connected to the Auxiliary Bridge to test offloading while the Sea Slug bow was pulled over the stern roller on a ship. As the bow was slowly pulled over the roller, oil was forced back toward the offloading pump. This test simulated a typical operational scenario where the Sea Slug is pulled by a winch onto a vessel over a roller mounted on the stern/fantail.

The submersible pump offloading tests were done with a setup similar to that shown in **Figure 3.12**, except the CCN-150 pump was used for offloading, being inserted into the Sea Slug through a top center connection. When inserted, the pump was positioned inside the bladder near the bottom.

A very high viscosity test oil was used for the testing because it presented the most challenging scenario for fluid offloading. The test oil was Califlux 550, which has a kinematic viscosity 500,000 cSt at 86 deg. F.

The amount of oil transferred into and from the Sea Slug was determined by sounding the heated oil transfer tanks. The rate of oil transfer was measured by timing the offloading period and measuring the amount of oil offloaded.

Summary of Results:

The results of the tests are summarized in **Table 3.4** (next page). Two problems contributed to the apparent poor performance of the system during these tests. The first problem involved the liner within the Sea Slug. This particular Sea Slug had an experimental lightweight urethane liner within the main body of the Sea Slug. The high viscosity oil adhered to the liner, and the liner was continuously sucked into the DOAS offloading pump. The second problem was a result of the first problem. As the offloading process was delayed by the liner ingestion, the oil cooled to the point where it would no longer flow.

The slow process of removing the test oil was fully completed by lifting the bow end with a crane and nursing the pump as it ingested, tore, and pumped out sections of the internal urethane liner. This process was stopped occasionally to manually cut sections of the liner out.

Based on these developments, the Test Team decided to: 1. Remove as much of the Sea Slug's internal liner as possible; 2. Obtain an oil with a lower viscosity; and 3. Perform an offloading test using a center-mounted submersible pump under the new testing conditions. The oil used for the revised test procedure had a viscosity of approximately 2,600 cSt.

The results for the center offload testing were more favorable. Based on the results of this test it was estimated that the submersible pump could remove up to 95% of the oil within the storage bladder. The remaining 5% was removed by lifting with a crane to assist the oil flow to the pump.

TEST	OIL VISCOSITY (cSt)	INITIAL AMOUNT (gal)	PUMPING TIME (min)	PUMPED AMOUNT (gal)	AVERAGE PUMPING RATE (gpm)	PUMPED AMOUNT (%)
Offloading w/DOAS only (Scheduled)	50,000	9,729	— (1)	200	0	2%
Offloading w/DOAS only (Repeat)	50,000	10,564	1	Not Measured (2)	0	0%
Fairlead Assisted (Scheduled)	50,000 at beginning 200,000 at end	10,235	206	4,815	23	47% (3)
Weight Assisted (Scheduled)	50,000	7,054	91	4,945	54	70% (4)
Crane Assisted (Scheduled)	50,000	10,564	38	10,564	278	100% (5)
Crane Assisted (To Empty)	90,000	9,529	105	6,510	66	68% (6)
Crane Assisted (To Empty)	200,000 +	—	135	2,598	19	100% (7)
Center Offload Test 1		9,450		7,001(8)		
Center Offload Test 2		8,950		6,754(8)		
Center Offload Test 3		8,200		7,050(8)		

1 Time not recorded, TSD walls sucked into cone stopping flow almost immediately.

2 TSD walls sucked into cone cutting off flow immediately - pump stalled. Believe liner was sucked into pump.

3 Pumping stopped – pump stalled. Believe liner caused stall.

4 Pumping stopped – pump stalled. Liner might have caused stall.

5 There was a small residual fluid left. Believe it is oil/water from previous tow test.

6 Stopped pumping – pump stalled.

7 Pumped to near empty condition.

8 Numbers approximate.

Table 3.4 Summary of Test Results for CANFLEX Sea Slug and DOAS Flotation Collar Tests.

Summary of Findings:

The test results did show that the center submersible pump fittings have merit as an innovative offloading method for collapsible storage bladders. During these tests, the pump was positioned at the bottom of the Sea Slug. Since then it has become apparent that even better offloading results are achieved when the pump is positioned inside the bladder, but at the surface because the bottom of the bladder rises as offloading proceeds.

The testing also showed that mechanical assistance to the bladder (i.e., crane hoist, pulling over a roller, or submerging a section of the bladder) can help the offloading process by using gravity or buoyancy to help push oil into an offloading pump. It was apparent that using these mechanical assistance methods to assist offloading exerts a great deal of force on the bladder; thus it must be built to handle such forces. The Sea Slug test bladder proved to be resilient enough to handle repeated crane lifting and winch pulling while filled with oil.

The DOAS floating offloading pump proved effective in connecting to the unit, floating, and pumping oil as long as sufficient oil was being fed to the pump. Problems due to liner ingestion are not reflective of the system's ability to pump high viscosity oil.

Final Report References:

Goodwin, M. & R.L. Custer, OHMSETT TESTS OF THE CANFLEX "SEA SLUG" TEMPORARY STORAGE DEVICE AND THE DOAS FLOATATION COLLAR, April 1995, Minerals Management Service Contract 14-35-0001-30544. Prepared by MAR Incorporated, 6110 Executive Boulevard, Suite 410, Rockville, MD 20852. U.S. Coast Guard Report No. CG-D-05-96, Accession No. AD-A308226.

Test Title:	**Ohmsett Tests of U.S. Coast Guard VESSEL OF OPPORTUNITY SKIMMING SYSTEM (VOSS)**
Test Date: **October 15, 1993 – November 16, 1993**	
MMS/OHMSETT Work Order #: **03**	

Background and Objective:

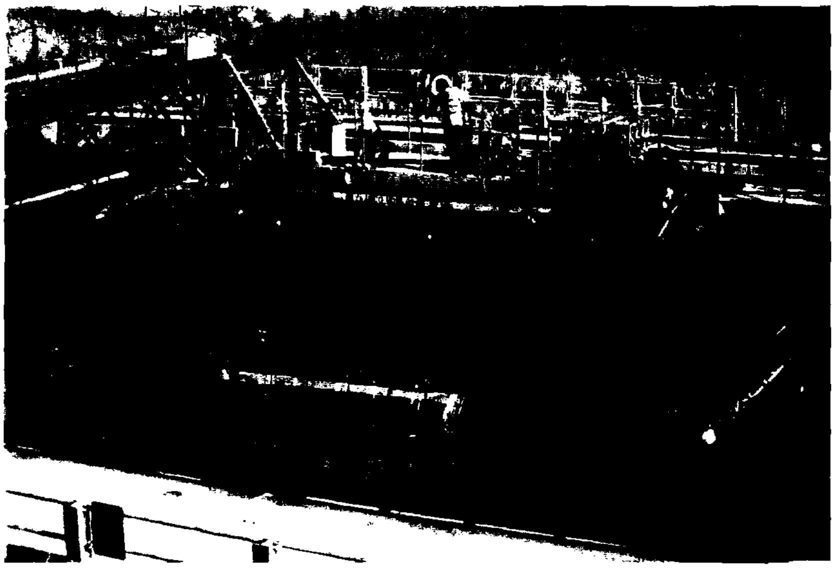


Figure 3.13 USCG VOSS in Ohmsett Basin.

The U.S. Coast Guard evaluates mechanical oil spill response equipment that has the potential to help the Coast Guard National Strike Force (NSF) respond to oil spills effectively. One of the evaluation goals is to test skimming systems that can be mounted on Coast Guard cutters and other government and commercial vessels of opportunity. These systems are used as Vessel of Opportunity Skimming Systems (or VOSS). The current Coast Guard VOSS is comprised of two sections of boom deployed from either side of a vessel in a J-Configuration, using davits and outriggers mounted on the vessel. A DESMI 250 weir skimmer is placed in the boom apex. The power pack for the system and the control panel are mounted on deck. **Figure 3.13** shows one boom section and the DESMI Skimmer deployed in the Ohmsett Tank for testing. **Figure 3.14** shows the details of a typical USCG VOSS operational layout.

Test results provided Coast Guard operational units with performance data that can be used in recommending operating procedures to enhance the effective deployment of this system. At the time of these tests, the Coast Guard had 22 VOSS in inventory, one each at the three Strike Teams and one at each of the 19 pre-positioned District sites. The Marine Spill Response Corporation (MSRC) has a similar need for information on the DESMI skimmers, which are included in their inventory of spilled oil recovery equipment.

Tests were conducted to determine Critical Tow Speed, First and Gross Loss Tow Speed, and the debris handling capability of the system. Recovery capability tests were conducted to determine Oil Loss Rate, Oil Recovery Rate, Oil Throughput Efficiency and Oil Recovery Efficiency – the standard performance parameters for skimmer tests at Ohmsett. These tests were conducted using different oil types and with varying tow speeds and wave conditions.

The CG VOSS consists of two oil spill containment booms, boom outriggers, davits for deployment, a power pack with control panel, and two oil spill skimmers. The boom and skimmer are shown deployed for testing in the Ohmsett basin in **Figure 3.13**. **Figure 3.14** shows the deployment configuration from the side of a vessel. The boom is deployed in a J-shape from each side of the vessel, held in place by the outrigger. The outrigger is supported by a float and held in place by lines extending from the bow and stern of the vessel. The boom configuration is maintained by distance ropes attached to a glide line. The vessel end of the boom is brought along side and secured to the deck by the inboard boom line. A DESMI 250 Weir Skimmer is placed in the apex of the J-shaped boom. The oil discharge hose is led forward and brought back on deck for subsequent discharge to an onboard storage tank or floating bladder towed behind the vessel. The power for driving the skimmer comes from a diesel-hydraulic power pack. The skimmer is controlled from the operator's control panel connected by hydraulic and air lines to the skimmer.

Description of Test Procedures:

The test configuration shown in **Figure 3.15** includes some modifications from the operational layout shown in **Figure 3.14**. An 18.3-m (60-ft) long half-hull was constructed to simulate the ship's side. This half-hull was mounted to the Main Ohmsett Bridge and to the Auxiliary Bridge near the east wall of the Ohmsett basin. The outrigger (designed to hold the oil skimming boom open) was mounted approximately 13.7 meters (45 ft) forward of the after end of the half-hull. A 12.8-m (42-ft) long outrigger was used. The forward preventer and distance rope, normally secured to the hull **(Figure 3.14)** were attached to the Ohmsett Main Bridge **(Figure 3.15)**. For the initial tests, a section of Flexi Boom 1100 was used as the containment boom.

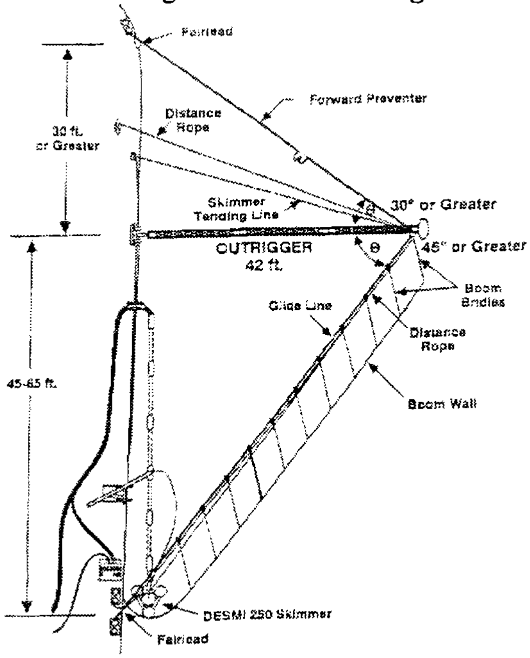


Figure 3.14 Typical USCG VOSS Layout.

At the end of the tests with the Flexi Boom 1100, an NSF Inflatable Boom was substituted for the Flexi Boom. The outrigger was shortened to accommodate the NSF Inflatable Boom. For the first five tests using the NSF boom, the boom was towed in a truncated V-shape. An additional test was conducted with the boom in a U-shape.

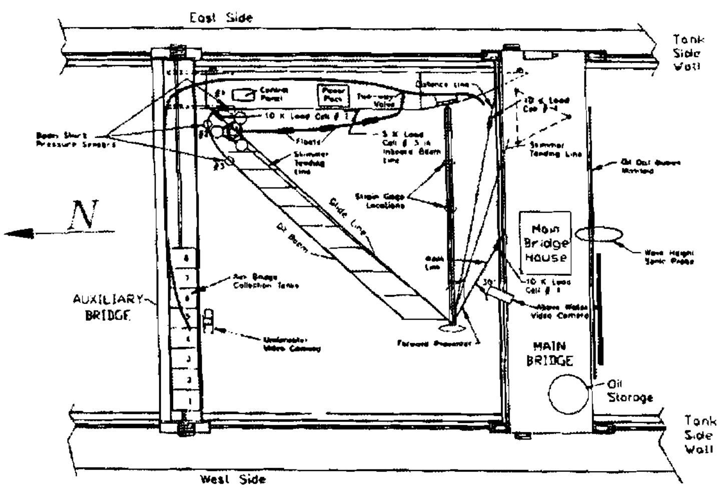


Figure 3.15. Test Configuration and Instrumentation for CG VOSS Tests

The two test oils included a "Standard" oil having a viscosity that ranged from 1,820 cSt to 5,680 cSt during the tests, and a "heavy" oil having a viscosity that ranged from 20,060 cSt to 40,120 cSt. Two wave conditions were tested in addition to calm water. One was a simulated Sea State 2 condition (SS2), which corresponds to wave heights of 0.2-0.3 m (0.5 to 1.0 ft). For SS2, the wave damping beaches available at the end of the Ohmsett tank were not used. This created a confused sea similar to what occurs in a sheltered location with high boat traffic, a typical condition at a spill site. The other wave condition used in the tests was a regular wave approximately twice the length dimension (2L) of the DESMI skimmer (as measured between the centers of its three floats), which is 1.43 m. The desired wavelength for the 2L condition is thus 2.87 m. The significant wave height measured for this wave condition is 12.4 cm (4.9 in). The 2L wavelength was chosen because it should impart the greatest pitching motion to the skimmer and have the greatest adverse effect on skimming performance.

Critical Tow Speed is the speed at which a boom loses all freeboard (submarines), loses all draft (planes), or mechanically fails. It is also the maximum safe tow speed of the test tank, or in the case of this system, the speed at which the weak link breaks. The Critical Tow Speed is a limit on how fast the CG VOSS can be towed from one location to another; it is not a speed at which it can be effectively operated.

Pre-load Tests were conducted to determine the amount of oil to be placed in the boom for the oil loss tow speed and oil recovery tests. The CG VOSS was accelerated to 0.65 kts with a small pre-load and the skimmer not operating. Additional oil was distributed in steps and the oil was allowed to reach the boom apex before more oil was added. This process continued until the leading edge of the oil slick in the boom extended 0.6 meters (2 feet) forward of the skimmer inlet. The total oil distributed was then recorded. [During oil loss tow speed and debris tests, the skimmer was operated to simulate the flow in the apex of the boom during an actual skimming process. Skimmed oil was pumped to the water ahead of the boom. An additional amount of 0.57 m^3 (150 gallons) of oil was added to the pre-load to account for oil in the pumping system and on the water flowing back to the boom due to skimmer operation.]

First Loss and Gross Loss Speed Tests were conducted to determine containment capability as a function of tow speed.

First Loss Tow Speed is the speed at which droplets of oil begin to escape under the boom.

Gross Loss Tow Speed is the speed at which large amounts of oil begin to be lost under the boom.

The tow speed was increased slowly from 0.6 knots until First Loss and Gross Loss were observed. Both oil loss tow speeds were determined through visual observations using the underwater video camera.

> **Note:** First LossTow Speed and Gross Loss Tow Speed can vary with the amount of oil pre-loaded, up to the proper pre-load amount. Because of this test, modifications to pre-load testing were recommended. In later Ohmsett tests, pre-load tests (to determine the amount of oil that should be placed into the apex of the boom before towing begins for oil loss tow speed tests) were conducted differently.

The Debris Test consisted of a single tow using a pre-load of heavy oil. This test was run with the fluid oil adapter for the DESMI-250 weir skimmer, but without the debris screen. The skimmer operated at 34.2 m^3/hr (150 gpm), with the discharge hose emptying into the water inside the boom near the boom mouth. After oil recirculation started, debris was scattered on the water. The debris consisted of soda cans, Styrofoam cups, sandwich bags, wood shavings, pieces of lumber up to 2 feet in length, sponges, sorbent sheets, lengths of polypropylene rope and salt marsh hay or sea weed. Prior to deployment, debris was placed in buckets with oil and allowed to soak overnight.

Three Skimmer Natural Frequency Tests were conducted to determine the roll, pitch and heave natural frequencies of the skimmer with its discharge hose attached. Skimmer motion was forced at its natural frequency of roll by pressing down on one of the forward floats and then releasing it. At the maximum rise the float was again forced downward. This is similar to pushing a swing. The process was repeated for 10 cycles while being timed.

Steady State Skimming Performance Tests measured the maximum steady state (not instantaneous) oil recovery potential of the CG VOSS. Steady state operations require that the rate of oil entering the boom equals the rate of oil being recovered and entraining underneath the boom. Assessment of steady state conditions requires determining the encounter rate, loss rate, recovery rate and skimmer's maximum recovery rate.

Encounter Rate is the rate at which oil enters the mouth of the boom. It is equal to the oil distribution rate. Loss Rate is the rate at which oil is being lost under (or over) the boom. Loss Rate can be determined by measuring the oil remaining in the boom after the test and subtracting this amount from the pre-load plus distributed oil quantities, and then dividing by the duration of the test run. Recovery Rate is the difference between the Encounter Rate and Loss Rate.

Further measures include Oil Recovery Efficiency and Throughput Efficiency. Oil Recovery Efficiency is the ratio of the volume of oil recovered to the volume of total fluids recovered. The volume of oil is obtained by correcting for the water and bottom solids that remain in the oil after decanting. Throughput Efficiency is the ratio of the amount of oil recovered to the amount of oil encountered during a timed collection interval.

Summary of Results:

Critical Tow Speed:

Critical tow speed for the Flexi Boom was measured at 1.8 kts in calm water. At this speed the boom submerged and the weak link failed. The Critical Tow Speed dropped to 1.3 – 1.4 kts in Sea State 2 waves. Again the boom submerged, but the weak link did not fail. No Critical Tow Speed tests were conducted for the NSF Boom.

Oil Loss Tests:

The Oil Loss Test results are provided in **Table 3.5** below for the range of oil types and wave conditions examined. The first six test runs were made using the Flexi Boom 1100 as the containment boom. The last three test runs were made using the NSF Inflatable Boom.

Run No.	Oil Type	Wave Condition	First Oil Loss Speed	Gross Oil Loss Speed
5	Heavy	Calm	1.05 Kts	1.40 Kts
6	Heavy	2L	1.05 Kts	1.28 Kts
7	Heavy	SS2	1.05 Kts	1.27 Kts
11	Standard	Calm	1.00 Kts	1.28 Kts
12	Standard	2L	0.85 Kts	1.13 Kts
13	Standard	SS2	1.13 Kts	1.17 Kts
37a	Heavy	Calm	0.74 Kts	1.00 Kts
38	Heavy	SS2	0.68 Kts	0.92 Kts
41a	Heavy	Calm	0.62 Kts	0.85 Kts

SS2 – Sea State 2 Conditions

2L - Wavelength of waves is twice the length dimension of the DESMI skimmer

Table 3-5 Oil Test Results

Debris Tests:

Debris was divided into four equal portions and distributed across the width of the boom opening. The debris tended to float straight back until it contacted the boom, then followed the boom curvature into the apex behind the skimmer, where most of the debris ended up. Very little debris went into the skimmer. For the debris that made contact with the skimmer, it was noted that the long pieces of wood caused the weir to tip and only pull oil over the low side, and all but the shortest rope sections caused the skimmer to jam.

Skimmer Natural Frequency Tests:

Three separate test runs were made and the data averaged. The average natural frequency of pitch and roll were nearly equal at 1.32 and 1.36 secs respectively. The average period of heave was slightly higher at 1.68 secs.

Skimmer Performance Tests:

The VOSS' performance as a skimming device was tested using the standard skimmer performance parameters: Loss Rate, Maximum Recovery Rate, Recovery Efficiency and Throughput Efficiency. Tests were run with both the standard oil and heavy oil, in both calm seas and Sea State 2 conditions. Test runs were made with both the Flexi Boom and NSF Boom used as the containment boom. In general, Recovery Efficiency and Throughput Efficiency decreased with tow speed, and Loss Rate increased with tow speed for both the standard oil and heavy oil, in the calm water and SS2 conditions. This is consistent with past skimmer performance results.

Most of the oil recovery capability data were taken using the Flexi Boom 1100. Tow speeds during the oil recovery capability tests ranged from 0.8 to 1.4 kts, depending on the specific test. The full data sets are plotted in the Final Report. The following is a brief summary of the results (values are approximate, taken from data plots):

Standard Oil, Calm Water Tests:
The First Loss Speed was recorded at 1.0 kts. The Throughput Efficiency (TE) ranged from 0.85 to 0.50 decreasing with increasing tow speed (0.95 – 1.25 kts.). The Oil Recovery Efficiency (ORE) decreased from 0.55 to 0.40 with increasing tow speed. Skimmer Loss Rate increased from 20 to 95 gpm, while Maximum Recovery Rate decreased from 120 to 85 gpm.

Heavy Oil, Calm Water Tests:
The First Loss Speed was recorded at 1.05 kts. The Throughput Efficiency (TE) ranged from 0.45 to 0.05 decreasing with increasing tow speed (1.0 – 1.35 kts.). The Oil Recovery Efficiency (ORE) decreased from 0.20 to 0.05 with increasing tow speed. Skimmer Loss Rate increased from 40 to 165 gpm, while Maximum Recovery Rate decreased from 55 to 5 gpm.

Standard Oil, Sea State 2 Tests:
The First Loss Speed was recorded at 1.13 kts. Only two data points were recorded. The Throughput Efficiency (TE) increased from 0.7 to 0.95 with increasing tow speed (1.025 – 1.15 kts.). The Oil Recovery Efficiency (ORE) remained constant at 0.5. Skimmer Loss Rate decreased from 40 to 5 gpm, while Maximum Recovery Rate remained constant at about 120 gpm. The results appear contradictory in comparison to the previous tests. Because of this and the limited data recorded, these results are considered inconclusive.

Heavy Oil, Sea State 2 Tests:
The First Loss Speed was recorded at 1.05 kts. The Throughput Efficiency (TE) ranged from 1.0 to 0.1 with increasing tow speed (1.1 – 1.25 kts.). The Oil Recovery Efficiency (ORE) decreased from 0.35 to 0.1. Skimmer Loss Rate increased from 0 to 220 gpm, while Maximum Recovery Rate decreased from roughly 80 to 20 gpm.

Standard Oil, 2L Wave Tests:
The First Loss Speed was recorded at 0.85 kts. The Throughput Efficiency (TE) varied erratically as did the Loss Rate with increasing tow speed (0.8 – 1.1 kts.), such that the results are inconclusive. The Oil Recovery Efficiency (ORE) remained roughly constant at 0.38-0.45, while the Maximum Recovery Rate decreased from roughly 80 to 60 gpm.

Heavy Oil, 2L Wave Tests
The First Loss Speed was recorded at 1.05 kts. The Throughput Efficiency (TE) ranged from 0.35 to 0.02 with increasing tow speed (1.05 – 1.25 kts.). The Oil Recovery Efficiency (ORE) decreased from 0.2 to 0.02. Skimmer Loss Rate increased from roughly 100 to 180 gpm, while Maximum Recovery Rate decreased from roughly 40 to 0 gpm.

Summary of Findings:

The CG VOSS tests produced results consistent with the Coast Guard's expectations and confirmed the viability of the current configuration as an effective skimming system.

In addition to the results specific to the VOSS, the tests revealed several general test modifications for future skimmer tests. First, it was noted that all recovery tanks should be tested for water and bottom solids after decanting. It was assumed that the water and bottom solids entrained in the oil depended only on the oil mixture on the water surface. However, it was found that some of the water present was a result of the quality of the decanting process, which varies from tank to tank. Second, the pre-load required for oil loss and steady state skimming tests must be determined before the tests are conducted. In the future, the pre-load oil volume should be defined as the volume at which the addition of more oil into the boom has a minimal effect on the First Oil Loss Tow Speed.

Final Report References:

Goodwin, M. and D.S. DeVitis, S.L. Cunneff, D.L. Backer, R.L. Custer and S. McHugh, 1994. Ohmsett Tests of U.S. COAST GUARD VESSEL OF OPPORTUNITY SKIMMING SYSTEM. Report No. OHM-94-02, Minerals Management Service Contract 14-35-0001-30544. Prepared by MAR, Incorporated, 6110 Executive Boulevard, Suite 410, Rockville, MD 20852, 43 pp. + app.

Test Title: **Ohmsett Tests of the LANCER INFLATABLE BARGE**
Test Date: **May 1994 - June 1994**
MMS/OHMSETT Work Order #: **07 and 10**

Background and Objective:

The U.S. Coast Guard evaluates mechanical oil spill response equipment that has the potential to help the Coast Guard National Strike Force (NSF) respond to oil spills effectively. This spill recovery equipment includes temporary storage devices that can be used to store recovered oil and transport it to shore for processing. Lancer Inflatable Barges have been purchased for this purpose.

Lancer Inflatable Barges are manufactured in several sizes. The barge purchased for use by the National Strike Force is the model B100, a 100 m^3 barge having a length of 50.9 ft, a width of 17.9 ft and a draft of 8.1 ft. The draft of this fully loaded barge exceeds the depth of the Ohmsett test basin and precludes testing the full-size barge in the basin. The smaller barge (B05) used in these tests is similar.**(figure 3.16)** It is a 5 m^3 (1,375 gal) barge, 21.0 ft long by 7.2 ft wide, with a loaded draft of 3.5 ft. The decanting hose is similar to that on the B100 barge. The barge consists of a boat-shaped inflatable flotation collar having six compartments and an oil containment bag hanging inside the collar and sealed to it.

Figure 3.16 Lancer Inflatable Barge.

The Ohmsett tests measured the effectiveness of the barge in separating oil from water and decanting the water off the bottom. The effectiveness of the decanting hose, and the integrity of an experimental liner for the barge, were also assessed.

The U.S. Coast Guard Research and Development Center sponsored the tests, which were conducted by MAR, Inc., under the review of the Minerals Management Service. Axtrade, Inc., U.S. distributor for the Lancer Barge, provided the Lancer Barge and technical support during the tests.

Description of Test Procedures:

Figure 3.17 shows the test configuration used for all tests. Nine Oil Separation tests were conducted, 4 tests in waves and 5 tests in calm water. All of the tests except one included towing the barge down the length of the basin.

At the start of each test, the barge was filled with 1,300 to 1,400 gal of an oil/water mixture. Two mixtures were tested, a 50/50 oil/water mix and a 10/90 oil/water mix. The fluid at each of four levels above the bottom of the barge (2, 11, 20 and 29 inches) was sampled at 0, 15, 30, 45 and 60 minutes after filling (except as noted below). These samples were tested to determine the amount of oil present.

During sampling, the barge was stationary; during one of the intervals between samples, the barge was towed the length of the tank at the maximum safe towing speed of 2 knots. After the tow, samples were taken immediately rather than waiting the full 15-minute interval. This procedure allowed detection of any agitation in the fluid caused by the tow.

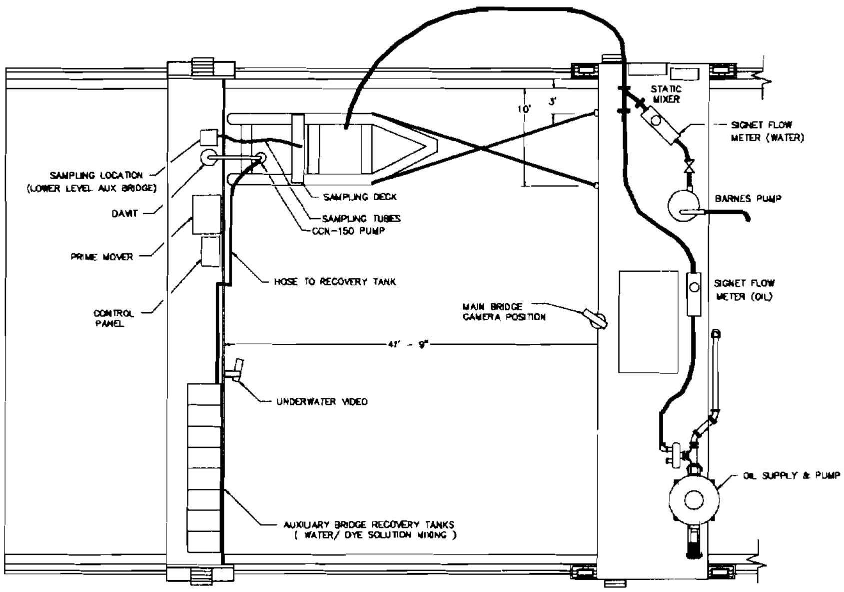


Figure 3.17 Lancer Barge Test Configuration.

Two wave conditions were tested in addition to calm water. One was a simulated sea state 2 condition, and the other was a regular wave having a wavelength of 42 ft, approximately double the length of the Lancer barge (2L wave condition). This wave condition should cause maximum agitation of the fluid mixture in the barge.

After each test, the oil/water mixture was offloaded. Not all the fluid could be offloaded, because the oil containment bag would collapse around the offloading pump. Hence 50 to 200 gal of fluid remained in the barge after offloading.

The barge decanting hose was tested to determine whether towing the barge enhances the outflow from the decanting hose. Dyed water was used to make escaping water visible; no oil was used. All Decanting Hose Tests were conducted in calm water. The barge was towed at the maximum safe speed (2 kts) and at half the maximum safe speed (1 kt). Each speed was tested with three different barge initial loads, 100%, 67% and 33% of full load (1,400 gal).

As the barge was towed down the tank, the outflow through the decanting hose was measured by a totalizing flow meter installed in the hose. It was intended that the flow rate be averaged over the last half of the test run for each loading condition; however, the flow from the decanting hose came out in surges rather than continuously. The total flow meter reading was reported, rather than a time average.

Liner tests were planned to determine the integrity of the liner during towing. Holes in a crease in the liner and in the bottom of the liner were discovered during unpacking before the first test. The holes were patched. The liner was installed with a powder dispersed between the barge and the liner. During the first test, the full barge was towed at 2 kts in calm water. After towing, the barge was emptied and the liner removed. Powder-covered surfaces on the liner and barge were examined for evidence of water paths in the powder and any signs of damage to the liner. Leaks during the first liner test led to the cancellation of a second planned test.

Summary of Results:

The relationship between volume and height above the barge bottom for the Lancer Barge is not constant due to the shape of the oil containment bag. Given a plot of fluid volume versus height above barge bottom, it is possible to calculate at what height above the bottom of the barge the oil/water interface will occur for a given oil/water mixture ratio. For a full barge with a 50/50 oil/water mix and complete separation of the oil and water, the interface should occur at 24 inches above the barge bottom. The interface for the 10/90 oil/water mix should be found at 38 inches above the bottom. In the ideal case, samples below the interface level would contain no oil, and samples above this level would contain no water. In practice, ideal separation does not occur because some water is emulsified with the oil and will not separate by gravity.

In the calm water separation tests for the 50/50 mixture, samples taken at the 20 inch level varied greatly between test runs because this is a transitional region near the interface between the oil and water layers. Samples ranged from near zero to nine percent oil. Samples of the 10/90 mixture showed less variability because all the sampling heights were below the transitional region (33 to 38 inches above the bottom). No significant effect was apparent in these runs from towing the barge the length of the basin.

Waves had a clear impact on oil/water separation (**Figure 3.18**). The 2L wave condition produced the most agitation, as expected. The 2L waves appeared to lower the transitional region between the oil and water by 10 to 15 inches for both mixtures. Sea state 2 conditions appeared to cause a slightly higher percentage of oil in the water near the bottom of the barge than did calm conditions, but the effect was very small. Sampling was done near the logitudinal center of the barge which should be the point of least agitation. The transitional region at the ends of the barge where the decanting hose is located may be affected even more due to the possibility of increased agitation with distance from the logitudinal center (center of pitch).

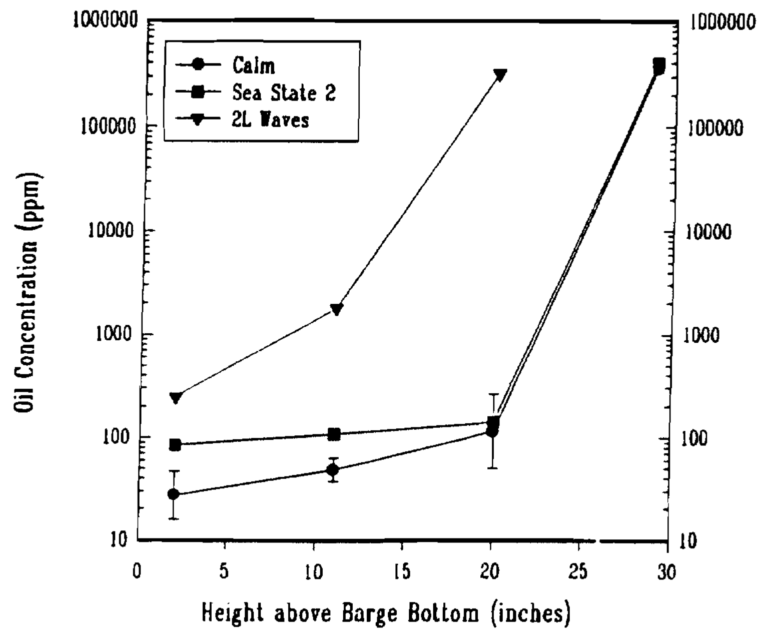


Figure 3.18 Oil Separation Test Results in Waves & Calm Water, 50/50 Oil/Water Mixture, after 15 Minutes.

In decanting tests, the outflow at 1 kt was between 0 and 15 gal/min (gpm), and at 2 kts, the range was from 0 to 130 gpm for all barge initial loads. There was no clear indication of how outflow rates varied with barge loading. There was an indication that outflow increased with speed, but the results were mixed.

During the liner test, an estimated 14 gal of water leaked through or around the liner. Because of the liner failure, further testing was not conducted. Difficulties encountered during liner installation were documented with video.

Summary of Findings:

The Lancer Barge performs well as an oil temporary storage device. Oil separates quickly within the barge, and towing has little effect on the oil separation process. Waves do affect the separation process, with waves that caused the maximum pitching having the most effect. The decanting tube does discharge fluid from the bottom of the barge while under tow. Findings were inconclusive as to whether the discharge rate increases with increasing tow speed. Fluid tends to discharge in surges rather than as a steady flow. The liner did not work well. Numerous small holes were found when the liner was unpacked. The holes found were patched, but the first test showed that water was leaking into the space between the liner and the barge. Therefore, the second planned test was not conducted.

Final Report References:

Goodwin, M., D.S. DeVitis, S.L. Cunneff, D.L. Backer, R.L. Custer and S. McHugh, 1995. OHMSETT TESTS OF LANCER INFLATABLE BARGE. Report No. OHM-94-04, Minerals Management Service Contract No. 14-35-0001-30544. Prepared by MAR, Incorporated, 6110 Executive Boulevard, Suite 410, Rockville, MD 20852. (Also USCG R&D Center Report No. CG-D-04-96)

Test Title: **Test Tank Evaluation of a FREQUENCY-SCANNING, MICROWAVE RADIOMETER to ESTIMATE OIL SLICK THICKNESS and PHYSICAL PROPERTIES**
Test Dates: **October 1994 and September 1996**
MMS/OHMSETT Work Order #: **011 and 022**

Background and Objective:

In October of 1994 a Frequency Scanning microwave Radiometer (FSR) was tested at Ohmsett by MAR Inc. under the sponsorship of the Minerals Management Service and the USCG Research and Development Center. The FSR was developed by Lincoln Laboratories of the Massachusetts Institute of Technology (MIT) to measure oil slick thickness.

Before this test, **single frequency** microwave radiometers had been used to estimate oil slick thickness, but the results were often ambiguous. In order to curtail the ambiguity involved with slick thickness estimation, the MIT Lincoln Laboratory proposed the concept of using an FSR to sample multiple points across a frequency band. Based on this premise, a laboratory prototype FSR capable of scanning over the ka-band (26-40 GHz) was designed and built by Lincoln Laboratories and tested at Ohmsett.

The theory and application of the FSR technology is somewhat complex; a full explanation is provided in Section 2.1 of the project report (Hover, Murphy, Brown, Hogan, and McMahon, 1994). The microwave radiation (as measured by a passive radiometer) emanating from an oil/water surface is expressed as an apparent "brightness temperature" (T^B), and the strength of this radiation varies as a function of frequency. The received T^B signal is a combination of the radiation emitted from the water that is transmitted from the oil/water interface, and the radiation emitted by the reflection of the sky from the oil/water interface. Theoretical variations in "brightness temperature" as a function of oil layer thickness can be calculated and plotted for a range of radiometer frequencies. Measurements of brightness temperature can then be made at frequencies within the same range, plotted and compared to the theoretical curves. The oil thickness observed in the environment can be estimated by determining the best fit between the calculated and observed curves. An experienced observer could ideally estimate the oil thickness to within a millimeter by viewing the pattern of the brightness temperature curve.

At the time of these tests, the USCG and MMS were interested in the potential for FSR systems to identify the thickest areas of oil from an aircraft during a spill. One advantage of using **passive** microwave radiometry is that it requires fewer components and less power than a system that produces its own illumination (e.g., radar or laser-induced fluorescence). Such detection ability would provide the means to direct spill response vessels where they are most needed, and to update spill trajectory models with timely information. Of particular interest to spill responders is locating heavier concentrations of oil that can be efficiently removed from the surface using skimmers, or possibly burned using fire-resistant booms to capture and concentrate the oil.

The objective of the Ohmsett test program was to assess the ability of the FSR to measure oil thickness in a simulated ocean environment. The data collection goals were to determine the FSR thickness measurement capabilities for: (1) oil layers having a uniform thickness, and (2) oil layers having a non-uniform thickness. All measurements were made in ambient weather conditions. A key goal of the data analysis was to comment on the comparison of the "theoretically predicted results" and the "actual test results."

Description of Test Procedures:

Figure 3.19 Photograph Showing the FSR Mounted on the Main Bridge (being aligned over an oil pool).

The FSR equipment was mounted on the Main Bridge nearly at the lateral center of the collection boom. Then the FSR operator used bore sights on the FSR to direct the longitudinal movement of the Main Bridge until the test oil was correctly targeted **(as shown in Figure 3.19)**. When the FSR was in the proper position over the test oil, and the desired wave condition was in place, the FSR thickness measurements were recorded. A minimum of two independent measurements was taken over each oil pool. During all but two of the FSR thickness measurements, the Main bridge was stationary. Two measurements were made with the bridge moving as crude simulation of an aircraft-mounted FSR system.

The output from the FSR measurements was compared to Ohmsett Staff's "Reported Thickness." The Reported Thickness was computed by dividing the known volume of oil within a test pool by a visual estimate of the oil's surface area within the test pool. The Reported Thickness value was computed assuming a uniform thickness throughout the pool, but this did not necessarily reflect the actual oil thickness distribution. Specific parameters and procedures are outlined below:

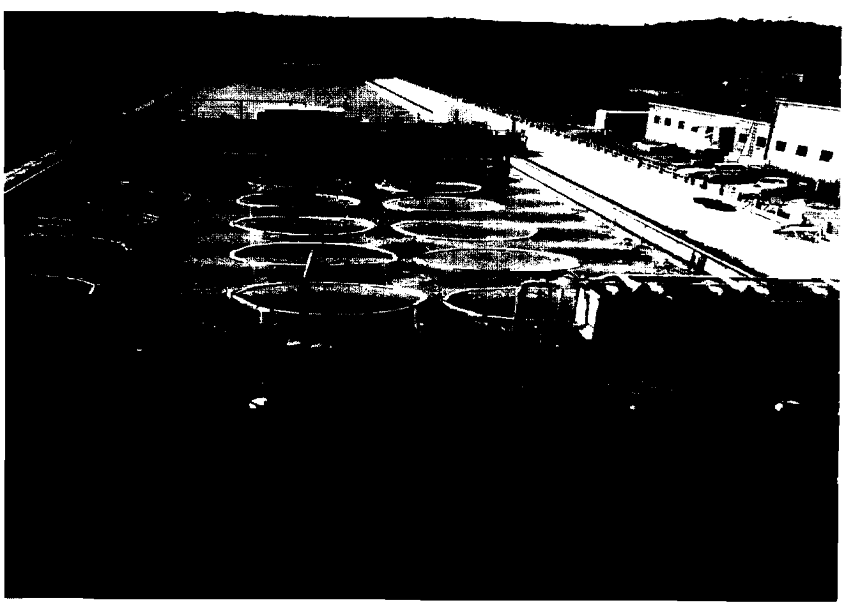


Figure 3.20 Photograph Showing Test Oil Pools in the Ohmsett Test Basin.

Oil Enclosures:

Several 3-meter diameter boom sections were rigged to contain floating oil in the Ohmsett test basin as shown in **Figure 3.20**.

Oil Types:

Three different types of oil were chosen for testing; these oils are referred to as Type-1, Type-2, and Type-3 as shown below. FSR scans of both thin pools (height < 2 mm), and thick pools of oil (height > 2mm) were recorded.

Type 1: Oil with the ability to form thin uniform oil layers
Type 2: Oil with the ability to form stable "lumpy" oil targets
Type 3: Oil with the ability to form a stable emulsion.

An oil called RECCO 60 was originally planned to be used for the Type 1 (uniform) Oil; however, it was discarded as it showed a tendency to form small globs. The test engineers decided to use diesel fuel mixed with a red dye as the Type 1 Test Oil. The red dye was added because the diesel was nearly colorless, thus difficult to see. A test run was reported to show that the red dye did not affect the FSR's T^B signature of the oil.

An Alberta Sweet Mix Blend was used for the Type 2 Test Oil. This oil was reported to be 15% weathered while still containing a high percent of volatiles. This oil did not distribute evenly throughout the 3-m diameter pools; instead, it formed patches within the containment area. Because of the patchy areas, the photo and video images had to be correlated with the FSR signatures in order to analyze the results.

A 20% and a 40% oil/water emulsion were used for the Type 3 Test Oil. The intent was to cover the entire 3-m diameter pool with this test oil; however, the oil/water mixture had a tendency to stay clumped together in a thick mass near the edges of the containment area.

Wave Conditions:

Initially eight different wave conditions were planned for the tests; this was cut back to five wave conditions as shown below. Ohmsett waves are generated using a reciprocating paddle located at the far end of the Ohmsett tank. There is a perforated metal wave absorber at the opposite end of the reciprocating paddle. The wave absorber is elevated (activated) when the test tank is simulating sinusoidal wave action, and lowered when a "confused sea" or a harbor chop is being simulated.

	Waves	Height	Frequency
Calm Water	no wave generated by paddle		
Wave Condition 1	Small Waves	~ 2"	~ 0.3 cycles/sec
Wave Condition 2	Medium Waves	~ 4.5"	~ 0.6 cycles/sec
Wave Condition 3	Harbor Chop 1	~ 3"	a simulated confused sea with no breaking waves
Wave Condition 4	Harbor Chop 2	~ 5.5"	a simulated confused sea with some breaking waves

Table 3.6 Wave Conditions Used for FSR Tests at Ohmsett.

Data Quality Control:

Before the Ohmsett test runs were started, the equipment was tested in a laboratory to confirm that the oil thickness measurements correlate to the theoretical results. This process was referred to as the "On-Site Equipment Checkout".

"Dry runs" of the testing were also done to fine tune the position of the FSR on the Main Bridge, the settings for the wave maker, the method to fill the containment booms with oil, and the structure of the containment areas. Standard equipment calibrations were done before each day of testing.

Surface Truth Information:

All meteorological data, wave data, bridge position data, and oil data were recorded for each test. Videotapes and still photographs were also taken during each test run.

Oil Thickness Estimation Algorithm:

An oil thickness algorithm was developed to help analyze the data output from the FSR measurements. Full details concerning the development of this algorithm are contained in the USCG Final Report, and "Reference 1" of the USCG Final Report. The algorithm was developed empirically by analyzing the output FSR curves from known thickness targets, and then developing a mathematical relationship between the brightness and frequency received by the FSR and the actual oil thickness.

Summary of Results and Findings:

In Calm Conditions and Wave Condition 1 with Uniform Oil Films the FSR operator was able to estimate oil thickness on-site with the laptop computer display. On-Site estimates of oil thickness could not be made under Wave Condition 2 or under Harbor Chop Conditions. Even when the FSR results appeared to provide unambiguous data (i.e., Calm Conditions and Wave Condition 1 with Uniform Oil Films), the estimates often did not agree with the Ohmsett Reported Thickness value. It was postulated that factors such as evaporation, oil herding due to wind, and occasional oil dispensing errors caused the Ohmsett Reported Thickness to be inaccurate. It was further postulated that future FSR tests would benefit from closer attention to the factors affecting Reported Thickness estimates.

For Non-Uniform Oil Films (patchy oil) and emulsions, the FSR operator was not able to estimate the oil thickness. In some of these cases the FSR operator could declare the presence of oil or an emulsion but the thickness data was misleading as it was skewed by other variables such as bubbles and clean water T^B signals.

There were five calm water data collection runs made where the FSR operator did not have prior knowledge of the oil thickness; thus, the operator could not compare the received signal with a theoretical signal. Never-the less, the operator was able to make a "reasonable oil thickness estimate" for four of these five calm water runs after three to four measurement sweeps over each oil film.

Modifying the FSR system to give it the ability to simultaneously observe the entire 26 - 40 GHz band (a "snap shot" of the surface) was offered as a possible solution to measuring thickness in wave conditions greater than Wave Condition 1. This modification was said to have potential as long as the oil has not begun to mix with water. Once air bubbles and water began to mix with the oil, the FSR system could not estimate oil thickness. The mixing of air and water with oil was reported to be a limiting factor to the FSR system.

The thickness estimation results for oil films less than 2.0 mm were poor even in calm water. Adding bandwidth to the FSR system was presented as a possible solution to this problem. A bandwidth of 75 - 110 GHz was suggested as the next logical bandwidth to test for measuring thin oil films.

During post-collection data analysis, an algorithm was developed for the purpose of providing an estimate of oil slick thickness with minimal human intervention. The algorithm was reported to "show some promise although significantly more effort is needed to develop a truly robust and operationally useful algorithm."

Final Report Reference:

Nash, J., 1995. Ohmsett Tests of U.S. COAST GUARD – MIT LINCOLN LABORATORY FREQUENCY SCANNING RADIOMETER. Minerals Management Service Contract No. 14-35-0001-30544. Prepared by MAR, Incorporated, 6110 Executive Boulevard, Suite 410, Rockville, MD 20852.

Ohmsett Tests of THE FREQUENCY SCANNING RADIOMETER AND COMPARISONS WITH INFRA-RED IMAGING. Technical Memorandum Contract Report No. OHM-96-022, May 1997, 10 pp. + app.

Hover, G.L., R. Shemo, and J. T. Parr, 1997. Investigation of a Multi-Sensor Method to Map Oil Spill Thickness. U.S. Coast Guard Report No. CG-D-09-98, Accession No. AD-A343664.

Related Publications:

Hover, G.L., T.J. Murphy, E.R. Brown, G.C. Hogan, and O.B. McMahon, 1994. DESIGN, CONSTRUCTION, TEST AND EVALUATION OF A FREQUENCY SCANNING RADIOMETER FOR MEASURING OIL SLICK THICKNESSES. Department of Transportation Report, Prepared for the U.S. Department of Transportation, United States Coast Guard, Office of Engineering, Logistics, and Development, Washington, D.C. 20593.

Murphy, T.J., O.B. McMahon and G.L. Hover, 1996. TEST TANK EVALUATION OF A FREQUENCY SCANNING MICROWAVE RADIOMETER TO ESTIMATE OIL SLICK THICKNESS AND PHYSICAL PROPERTIES. Department of Transportation Report No. CG-D-18-96.

Test Title: **An Investigation of SIDEWALL EFFECTS OF THE OHMSETT TOW TANK**	
Test Date: **December 1994**	
MMS/OHMSETT Work Order #: **10**	

Background and Objective:

Oil spill containment boom testing, carried out at the Ohmsett facility since its inception in 1974, has been performed on many types, sizes and configurations of booms. In all of the testing in the 1970s and early 1980s, barriers, regardless of design or manufacturer, failed to contain oil when tow speeds reached 0.7 to 1.0 kts. During tests in the early 1990s, that relative speed increased. The reasons for the change needed to be investigated.

In previous years, oil properties, pre-load volumes, aspect ratio and the acceleration of the boom being tested had also varied from test to test. In-depth quantitative understanding of the testing parameters during boom tests was needed. Understanding the significance of varying test parameters would provide information about the validity of test results.

The First and Gross Loss Tow Speed Test, where oil loss is influenced by flow patterns in and around the boom, is likely to be most sensitive to varying test conditions. During oil loss testing, the independent controllable test parameters are the oil pre-load volume, the test oil, the wave conditions, and the boom gap ratio. The boom gap ratio is the overall boom-length to mouth-opening ratio when in the catenary configuration. Commercially available booms vary in length, resulting in variations in boom mouth opening and hence basin sidewall clearance.

Establishment of a standard set of parameters for boom testing is essential for producing results that will be meaningful in comparing containment booms. Maintaining independent test parameters as constants for comparative testing will yield results substantiating improved performance between different products and new designs. Accurate assessment of boom capabilities is essential to facility owners for whom the difference between 0.75 kts and 1.0 kt could translate to "a 30% 'savings' in committed equipment and labor for on-water recovery" (DeVitis and Hannon, 1995).

The objective of these tests was to investigate the following:

- The quantitative effects of sidewall clearance on boom performance during First and Gross Loss Tow Speed testing,
- The dependency of First Loss Tow Speeds on pre-load volumes, and
- The effects of oil viscosity on First and Gross Loss Tow Speeds.

In addition, these tests evaluated Critical Tow Speeds, First Loss and Gross Loss Tow Speeds and Tow Forces for the USCG/NSF Oil Stop Boom and the MSRC Sea Sentry II Boom. The Oil Stop Boom (Offshore Model), manufactured by Oil Stop, Inc., is an inflatable curtain-type boom with a 25-in draft and 18-in freeboard. Standard length is 100 ft, and the boom weighs 4.4 lbs/ft. Engineered Fabrics Corp. manufactures the Sea Sentry II Boom (model 23-44) which has a 44-in draft and 23-in freeboard. Standard length is 110 ft, and the boom weighs 8.5 lbs/ft.

Minerals Management Service (MMS), the U.S. Coast Guard Research and Development Center (USCG R&DC) and the Marine Spill Response Corporation (MSRC) sponsored the tests. USCG provided an Oil Stop boom and MSRC provided a Sea Sentry II boom to MAR, Inc., which performed the tests.

Description of Test Procedures:

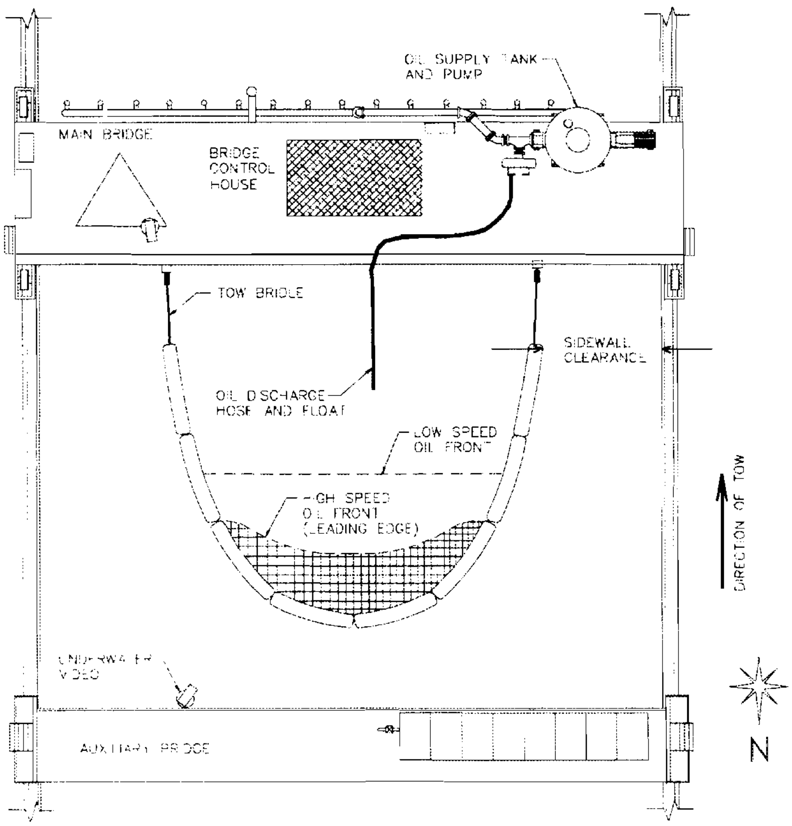


Figure 3.21 Typical Test Setup.

A typical test setup for the booms tested in the Ohmsett tank is shown in **Figure 3.21.**

Pre-load Determination Tests were conducted to determine comparative oil volumes for the varying boom lengths used during the sidewall effects tests. The tests also were undertaken to quantify the dependency of First Loss Tow Speeds on pre-load quantities of oil. First Loss Tow Speed is the lowest speed at which oil droplets continuously shed from the boom. All tests were conducted in calm water with Standard Test Oil (viscosity of 530 cPs at an average test temperature of 45°F [7°C]). The USCG/NSF Oil Stop boom was rigged with a boom length of 82 ft, a 41-ft mouth opening and a sidewall clearance of 12 ft.

An initial pre-load volume of 60 gal of standard oil was discharged into the boom mouth by the Ohmsett Main Bridge oil distribution system for the first test. After the oil pre-load stabilized in the apex of the boom, the bridge speed was increased in increments of 0.1 kts. First Loss Tow Speed was determined visually from observing the underwater video, and a time mark was triggered on the test data. The oil pre-load was increased by 60 gal for each subsequent test. As pre-load volume increased, First Loss Tow Speed approached a speed independent of pre-load volume; i.e., further increases in pre-load volume did not significantly change the First Loss Tow Speed. This pre-load value (500 gal) was also used to calculate the gallons of pre-load required per foot of deployed boom for booms of different lengths used during the sidewall effects tests: i.e., six gallons of oil per foot of boom deployed.

Two **Sidewall Effects Tests** were designed to investigate and quantify the effects of test basin sidewall clearance. These two tests were the First and Gross Loss Tow Speed Test and a Relative Horizontal Current Velocity Measurement Test. (Gross Loss Tow Speed is the speed at which massive continual oil loss is observed escaping past the boom.) During both types of tests it was necessary to isolate the related testing parameters and attempt to maintain them as constants. Independent parameters included the test boom, the boom gap ratio, and basin surface conditions. Independent parameters for First and Gross Loss Tow Speed Test included oil properties and the pre-load volume of oil. With these test parameters as constants, varying sidewall clearance became the remaining dependent variable.

First and Gross Loss Tow Speed Tests were conducted with sidewall clearances of 1.0 ft, 3.5 ft, 6 ft, 12 ft and 14.5 ft using the USCG/NSF Oil Stop boom. In terms of gap width, mouth openings varied from a minimum of 36 ft (55% of basin width) to 63 ft (97% of basin width). The gap ratio (between boom length and boom mouth opening) was constant at 2:1. This was accomplished by folding one end of the boom back onto itself to shorten the overall length. An adjustable tow plate was clamped at the fold for attachment of the tow bridle.

For the First and Gross Loss Tow Speed test, the pre-load volume of oil was pumped into the boom apex. After the towing bridge reached a speed of approximately 0.5 kts, the system was allowed to stabilize. The process of increasing speed and allowing the system to stabilize continued, using speed increments of 0.1 kt. After First Loss Tow Speed was reached, the incremental speed increases continued until Gross Loss Tow Speed was observed.

First and Gross Loss Tow Speeds were obtained for each of the five sidewall clearances. Two runs were conducted at each clearance and averaged for that clearance. Obtaining First and Gross Loss Tow Speeds for each clearance while holding other factors constant shows whether differences in sidewall clearance cause differences in oil loss tow speeds.

Current measurement tests investigated the effects of boom-to-basin sidewall clearance by measuring relative horizontal water current velocities from within the boom apex. These tests (using the USCG/NSF Oil Stop Boom without oil) measured the current velocities while the boom was being towed in each of the five configurations at 0.5, 0.75, 1.0, 1.25 and 1.5 kts. Measurements were obtained at three locations: 1 ft, 4 ft and 7 ft perpendicularly out from the apex. The relative current velocity measurements were obtained using a propeller-type current meter. The flow sensor was manually positioned from 0.5 ft to 6.0 ft below the surface in 0.5-ft increments. The measurements were made from a platform area located on the lower level of the Auxiliary Bridge. This provided a velocity profile for the area forward of the boom apex.

In addition to the tests performed to meet the objectives of this study, other tests conducted included pre-load tests for the MSRC Sea Sentry II, First and Gross Loss Tow Speed Tests, and Critical Tow Speed tests. Tow forces were measured during the Critical Tow Speed tests.

During **Pre-load Tests**, the MSRC Sea Sentry II was configured with a length of 110 ft, a mouth opening of 55 ft, and a sidewall clearance of 5 ft. Testing methods were similar to those used for the USCG/NSF Oil Stop boom; however, the MSRC Sea Sentry II has a significantly larger skirt depth. Therefore, the initial pre-load test volume used was 300 gal, and the pre-load volumes were increased by 150 gal for each subsequent test.

During **First and Gross Loss Tow Speed Tests**, two different oil types were tested: “standard” oil (viscosity of 530 cPs at an average test temperature of 45°F [7°C]) and “heavy” oil (viscosity of 20,600 cPs at an average test temperature of 45°F [7°C]). Pre-load volumes used were determined in pre-load tests and held constant for these tests. The booms were rigged in the same manner as for the pre-load tests with a 2:1 gap ratio.

Pre-load volumes were discharged by the Main Bridge oil distribution system into the mouth of the boom. After the bridge was accelerated to 0.5 kts and the oil and the towed boom had stabilized, bridge speed was increased in 0.1 kt increments. After First Loss Tow Speed was observed, bridge tow speed was decreased by 0.25 kts; the system was allowed to stabilize and then accelerated as before to confirm the First Loss Tow Speed. The speed was then increased until Gross Loss Tow Speed was reached. Determinations were made visually using an underwater camera. Time marks were entered on the recorded data when First Loss and Gross Loss Tow Speeds were observed.

Two wave conditions were tested, a regular sinusoidal wave and a Sea State 2 (SS2) condition. The regular wave had a wavelength approximately twice the boom flotation section length (2L). Significant wave heights were 8.8 in. for the regular wave and 12.1 in. for the Sea State 2 condition.

Critical Tow Speed Tests were used to determine the maximum speed at which the boom may be towed before exhibiting one or a combination of failure modes. Typical failure modes include submerging (the boom loses all freeboard), planing (skirt pulls out of the water), splashover and/or mechanical failure. No oil was used in this test. The boom was towed until the initial speed of 0.5 kts was reached and the catenary shape was formed.

Tow speed was then increased in increments of 0.2 kts, with the boom being allowed to stabilize at each speed, until the critical speed was reached. Failure mode was determined visually, and the corresponding tow speed was noted.

Tow Forces were measured for each of the five test boom configurations and each of the tow speeds during the current measurement tests. Tow bridles were connected to the Main Bridge tow points using shackles in series with load cells.

Summary of Results:

Sidewall Effects were determined from First and Gross Loss Tow Speed results obtained at different sidewall clearances. Results **(Figure 3.22)** show little variation in First Loss and Gross Loss Tow Speeds with changes in sidewall clearance.

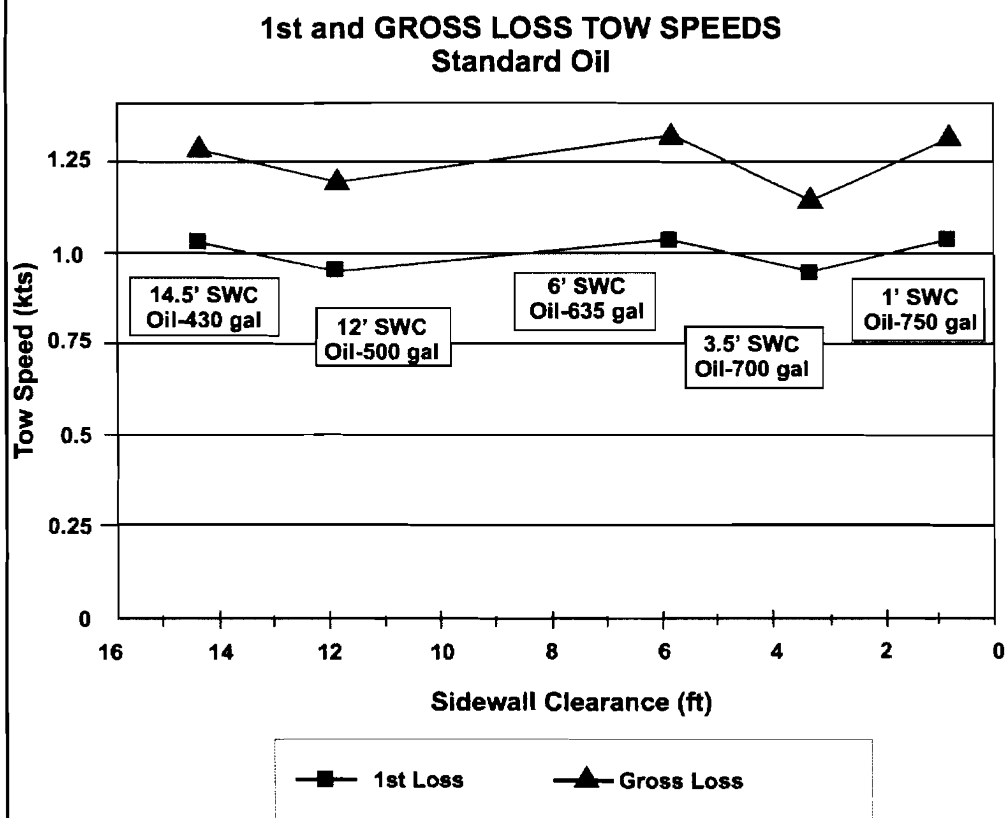


Figure 3.22 First and Gross Oil Loss Tow Speeds (for each sidewall clearance).

In relative current velocity tests, measurements for different sidewall clearances taken at the same location relative to the apex of the boom seldom differed by more than 0.1 kt. For example, for a sidewall clearance of 1 ft and a measurement position three feet forward of the apex and two feet below the surface, the flow velocity was 0.55 kts. For a sidewall clearance of 14.5 ft and the same coordinates, the velocity was 0.65 kts.

The relative current measurements showed that a zone of low current velocities is created within the boom apex. For the USCG/NSF Oil Stop boom with a sidewall clearance of 12 ft, a boom length of 82 ft and a tow speed of 1.0 kt, the surface current velocity seven feet in front of the apex measured 0.74 kts. The maximum velocity measured below the boom was 0.80 kts at a depth of three feet. The lowest relative current velocity occurs at the apex pocket near the surface. The maximum current speeds are obtained at locations farthest from the apex.

Pre-load tests of the MSRC Sea Sentry II using Standard oil determined a pre-load volume of 900 gal. Nominal pre-load volume for the USCG/NSF Oil Stop Boom determined during these tests was 500 gal.

First Loss Tow Speed occurred at 0.9 kts for both booms in calm water with Standard oil. First Loss occurred at lower speeds in tests with heavy oil. The presence of waves lowered First Loss Tow Speed slightly in some cases and raised it slightly in others. Gross Loss Tow Speeds were 1.05 to 1.15 kts for both booms in calm conditions with both oil types. The presence of 2L waves resulted in slightly lower Gross Loss Tow Speeds, while results for SS2 were mixed.

Critical Tow Speed tests of both booms produced similar results. At low speeds, both booms maintained freeboard until speed reached approximately 0.75 kts; beyond 0.75 kts, freeboard lessened as speed increased. Significant loss of freeboard occurred at the apex, gradually diminishing to only slight loss of freeboard at the radius ends of the catenary. When failure did occur, it was at the apex and happened very rapidly with only a small increase in speed. The USCG/NSF Oil Stop boom experienced splashover at 2.3 kts in the regular wave condition (2L) and at 2.7 kts in Sea State 2; submergence occurred at 2.7 and 2.8 kts respectively. Submergence in calm water occurred at 3.8 kts. The MSRC Sea Sentry II Boom submerged at 2.75 kts in both wave conditions, and at 3.0 kts in calm waters.

Tow Forces at given speeds increased with increasing boom length. This was a consistent trend except for the 126-ft boom with a sidewall clearance of one ft. The tow forces for the 126-ft boom at intermediate speeds (0.75, 1.0 and 1.25 kts) were 40 to 60 pounds less than the forces on the 116-ft boom (3.5-ft clearance). Although not a significant difference, this indicates a discontinuity of behavior in and around the test boom for sidewall clearances from three and one-half feet to one foot.

Summary of Findings:

This study demonstrated that boom-to-sidewall clearances can be varied test to test without significant impact on First and Gross Loss Tow Speed test results. Therefore, if physical characteristics and independent test parameters are comparable, comparative studies may be performed. This conclusion is significant since boom lengths differ by design, resulting in dimensionally different configurations when rigged for testing. Although effects of varying aspect ratios were not defined, a constant boom-length to mouth-opening ratio of 2:1 was chosen. Given that the boom length is determined by the manufacturer and aspect ratio is a constant, this leaves the sidewall clearance as a variable. The other test parameters that were constant during this study (surface conditions, oil properties and pre-load volumes) may be closely replicated. Maintaining independent test parameters as constants for comparative testing will yield results substantiating improved performance between products and new designs.

The flow data illustrate that within the apex pocket a relatively low surface current exists. The measured flow velocities at the same coordinates and tow speeds show negligible differences throughout the range of sidewall clearances tested. The horizontal flow velocities measured within this one plane demonstrate that variation of sidewall clearance does not notably affect flow behavior in this vicinity.

Most significant are the relative current velocities that exist at or near the oil/water interface. Oil loss due to entrainment typically occurred first at the leading edge of the oil front and at the points farthest from the apex centerline.

Pre-load test results indicated that there is a quantity of oil at which First Loss Tow Speed became independent of pre-load volume. When this contained volume was reached, the capacity versus speed dependency diminished, and the critical speed between the oil/water interface became the factor determining when oil loss would occur. At this point, the volume of oil is large enough to extend beyond the low flow region within the apex pocket.

Other observations include:

- Standard oil (~500 cPs) was retained in each boom to higher tow speeds than the heavy oil (~20,000 cPs). The viscosity and specific gravity differed significantly.
- The MSRC Sea Sentry II with a 44 in. skirt depth contained significantly larger volumes of oil at given tow speeds than the Oil Stop with the 25 in. skirt.

The results of this study illustrate that variations in boom-to-basin sidewall clearance produce no notable bias and may be considered an independent test parameter during oil loss tow speed testing.

Final Report Reference:

DeVitis, D., 1997. AN INVESTIGATION OF SIDEWALL EFFECTS OF THE OHMSETT TOW TANK. Report No. OHM-95-10. Minerals Management Service Contract No. 14-35-0001-30544. Prepared by MAR, Incorporated, 6110 Executive Boulevard, Suite 410, Rockville, MD 20852.

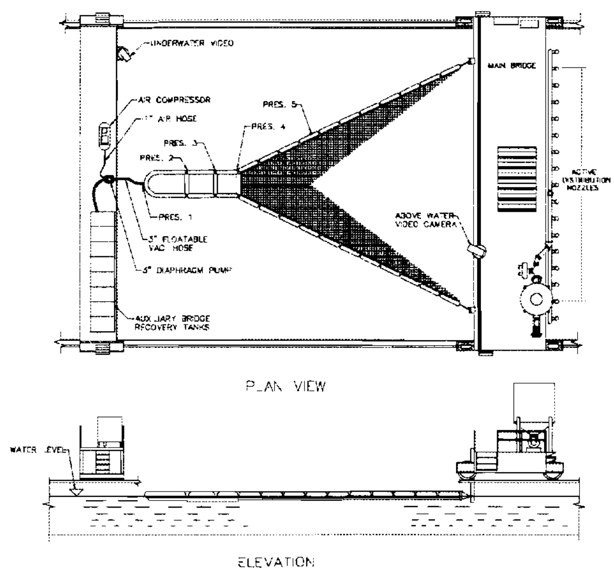
Related Publications:

DeVitis, D.S., and L. Hannon, 1995. Resolving the Tow Speed That Causes Oil Loss From a Boom. Proceedings of the 1995 International Oil Spill Conference. American Petroleum Institute, Washington, D.C. pp. 865-866.

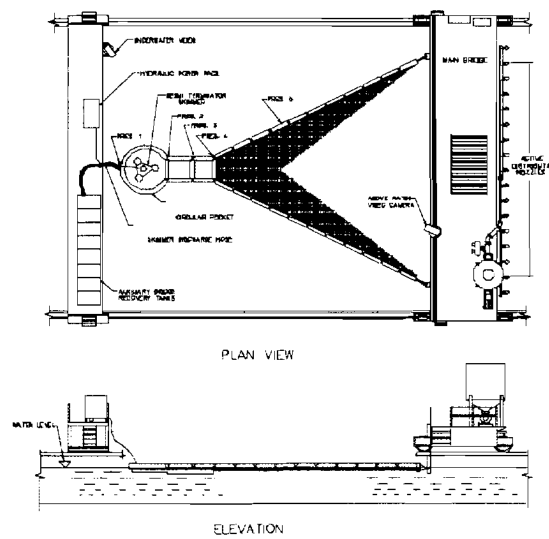
Test Title: **PACIFIC LINK MULTI BOOM TESTS**
Test Date: **June - November 1995**
MMS/OHMSETT Work Order #: **13**

Background and Objective:

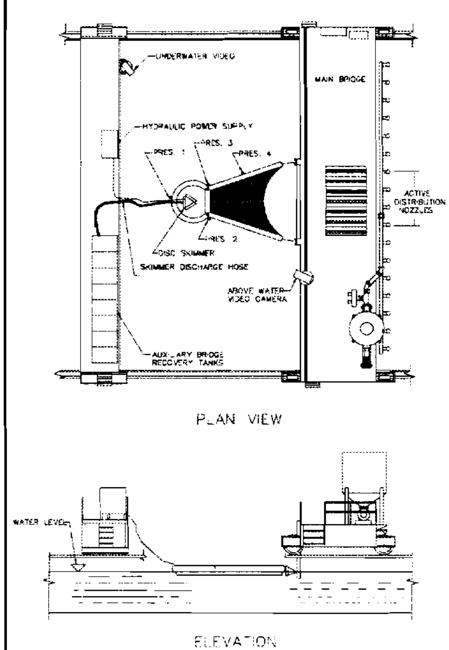
Historically, oil booms have not been able to recover oil efficiently at speeds exceeding 1.5 knots. At the time of this test, the Pacific Link Multi Boom System was identified as having the potential to recover oil efficiently at towing speeds greater than 2 knots. The designers of the Pacific Link System used their extensive hands-on experience with commercial fishing trawl nets to develop the Pacific Link Multi Boom System.



Configuration 1



Configuration 2



Configuration 3

Figure 3.23 Pacific Link Multi Boom System (Three Configurations)

The system has three configurations as shown in **Figure 3.23**. The Pacific Link Multi Boom is towed through the water by the end of each extension arm as with conventional sweeping booms. In each configuration, an air-inflated V-shaped trawl funnel is positioned in front of the specially designed oil trap. The subsurface netting is attached to the skirt of the trawl; the net's purpose is to maintain the V-shape of the boom. Two trawl funnels were tested with the system, one with a 50-ft maximum funnel width, and one with a 15-ft maximum funnel width.

An oil trap, with air-inflated cross baffles, is positioned aft of the funnel net. The oil trap is designed to reduce the relative fluid velocity and wave action within the trap. The forward tube in the trap floats on the water surface; this tube is meant to reduce surface chop, slow the relative fluid velocity, and block debris from entering the trap. The middle tube is 40% submerged; this tube is meant to act as a submersion plane skimmer that forces oil and water under the tube and then allows oil to rise to the surface behind it while forcing water down and out of the system. The last transverse tube is almost 100% submerged; this tube is meant to act like a weir skimmer allowing oil to flow over the top while forcing water down and out of the system.

The after section of the oil trap is referred to as the sump; this is where the oil is pumped out of the system and recovered. The system design was meant to provide a relatively (when compared to ambient conditions) low current and wave-free environment for oil recovery.

A circular pocket was used in configurations 2 and 3 **(Figure 3.23)** of the oil trap. The circular pocket allows insertion of a larger oil skimmer than the trap sump does in configuration 1. The circular pocket is also meant to create a "quiet" environment by a reduction in relative fluid velocity as the fluid flows from the small diameter funnel to the larger diameter pocket.

The objectives of these tests were to measure and record the oil collection performance and the seakeeping performance of the Pacific Link Multi Boom system, and to determine if this system can efficiently recover oil at towing speeds in excess of 2 knots.

Description of Test Procedures:

Each end of the boom was connected to the Ohmsett Main Bridge. The boom gap ratio was 2:1 (that is, the total boom length was twice as wide as the opening).

The Ohmsett Main and Auxiliary Bridges are mounted on rails and can be moved through the tank basin at varying speeds. The movement of the main bridge is remotely controlled from the Ohmsett Control Tower from which the entire tank basin can be seen. Video monitoring of the test (above and below water) and data collection from the various sensor suites are also done from the Control Tower.

Three wave conditions were used for testing:

1. Calm Water - no wave generated by paddle,
2. Significant wave height of 7 in. average period of 1.9 sec., and
3. Significant wave height of 9 in. average period of 2.8 sec.

These wave conditions reflect average values taken from the Final Report. Wave Condition 2 has a wavelength approximately twice the length of the trap, which in theory provides maximum excitation of the trap section.

The **Pre-load** testing and the **First Loss Tow Speed** testing were done simultaneously. The tow speed in which a boom first begins to lose oil is defined as the First Loss Tow Speed. The Pre-Load test determines how much oil will be placed into the apex of the boom before towing begins. There is a point when adding more oil into the boom pocket has a minimal effect on the speed at which the First Loss of oil occurs. This volume is defined as the Pre-Load volume. The proper Pre-Load volume is determined empirically by incrementally adding more oil to the boom pocket before towing, and then measuring the speed at which First Loss Tow Speed occurs. When the First Loss Tow Speed does not increase significantly with the addition of more oil, the Pre-Load volume and the First Loss Tow Speed are recorded.

The speed at which oil is continuously entrained underneath the boom is defined as the **Gross Loss Tow Speed**. The Gross Loss Tow Speed is determined by monitoring underwater video camera images from the Control Tower.

The **Oil Loss Rate** test is done by pre-loading the boom with oil and towing the boom at increasing speeds. During the Oil Loss Rate test, oil is added to the boom during tow in an attempt to create a semi-steady state condition where the amount of oil within the boom is constant throughout the test.

The **Critical Tow Speed** is defined as the speed at which the boom being towed loses its freeboard or its draft (planes or submerges). The boom is towed at increasing speeds until the "failure mode" is observed.

The **Towing Force** is defined as the tension force in each of the boom's towing lines during tow. The towing forces are continuously measured using load cells, and the data are recorded in the Control Room data collection computer.

The oil **Throughput Efficiency** is the ratio of the oil volume recovered to the oil volume encountered by the system.

The **Oil Recovery Efficiency** is the ratio of the volume of pure oil recovered to the total volume of oil/water mixture recovered.

The **Maximum Oil Recovery Rate** is the maximum value of oil volume recovered per unit time.

Summary of Results:

First Loss/Gross Loss:

None of the three configurations tested showed a significant increase in First Loss or Gross Loss speeds when compared to conventional boom systems. By design, the system operates above the First Loss Tow Speed because oil must entrain beneath the two cross baffles in order to reach the sump section for skimming. First Loss and Gross Loss Tow Speed were determined by observing oil lost outside of the system; thus, oil that successfully entrained into the sump area was not considered indicative of First Loss or Gross Loss.

Throughput Efficiency (TE) and Recovery Efficiency (RE):

The primary objective of this test was to determine if any of the system configurations tested could efficiently recover oil at speeds in excess of two knots; the results showed that they could not. Throughput Efficiencies at the speeds tested were found to be 30% or less (30% or less of the oil encountered was recovered). A possible reason for the low efficiencies was that at high tow speeds, a significant amount of oil was lost before it reached the trap's sump.

The type of skimmer being used and the oil collection capabilities of the boom affected the Recovery Efficiency (percentage pure oil recovered). The lowest recovery efficiency was observed when oil was removed with a suction hose. The best overall performance was achieved with configuration # 3, which had a RE as high as 90%, and a TE as high as 54%; however, these values were obtained at speeds less than 0.75 knots.

Summary of Findings:

In general, the performance characteristics of the three Pacific Link System configurations were similar to those of other conventional boom/skimmer oil recovery systems. The three configurations did not exhibit enhanced oil containment and recovery capabilities at speeds above 2 kts.

Final Report Reference:

Nash, J., D. DeVitis, D. Backer, and S. Cunneff, 1997. PACIFIC LINK MULTI BOOM TESTS, Minerals Management Service Contract No. 14-35-0001-30544. Prepared by MAR, Incorporated, 6110 Executive Boulevard, Suite 410, Rockville, MD 20852, 40 pp. + app.

Test Title: **Ohmsett Tests of Various REMOTE OIL SENSORS**	
Test Date: **August 7, 1995 - August 11, 1995**	
MMS/OHMSETT Work Order #: **014**	

Background and Objective:

Information on oil location, areal extent of oil on water, oil composition and spill thickness is vital to containment and recovery efforts during and after an oil spill. In the early stages of an oil spill, this information can identify the nature and extent of a spill and allow deployment of appropriate equipment to the heaviest oil concentrations. In the later stages, the information can aid in identifying areas still requiring attention. Remote sensing (using methods such as thermal sensing and imaging systems, microwave sensor systems and reflectance imagery) offers a possible method for determining the extent and movement of oil (Satterwhite et al., 1995). The Remote Sensing/GIS Center (RSGISC) for Civil Works Programs of the U.S. Army Corps of Engineers (ACOE) as part of its Oil Spill Research Program (OSRP) has developed or identified a number of different devices for sensing oil remotely. The Army Corps of Engineers tested these devices as part of an on-going effort to identify an optimum sensor array for detecting oil on water (Bolus, 1995). General information about the remote sensing devices tested is included in **Table 3.7**.

Participant	Equipment Tested	Description/Comments	Deployment
Bolus Platform: Cessna 206 Aircraft	3 single bandpass filtered video cameras	Center wavelength (in microns): 0.55 (visible green) 0.65 (visible red) 0.85 (near infra-red, NIR) Bandwidth: 20 nanometers (nm)	Airborne
Altitudes: 500, 1000,	Thermal infra-red (TIR) camera	4- to 5-micron short-wave thermal infra-red region	Airborne
2000, and	Ultra-violet (UV) camera	Center wavelength: 350 nm	Airborne
3000 ft.	2 variable interference filter video cameras	1: 450-650 nm, 10 nm bandwidth 2: 620-890 nm, 15 nm bandwidth	Airborne
Satterwhite et al.	Xybion multispectral video system	User selected wavebands; Center wavelengths: 365, 397 nm (UV band) 410, 434, 486 nm (blue bands) 656 nm (red band)	Tower on bridge: 30-40 ft. above water
Airborne Platform: DeHavill and "Beaver"	Digital Multispectral Video System (DMSV)	4-channel scanner system: Center wavelength: 0.37. 0.55, 0.65, 0.77 microns	Airborne
Altitudes: 2000, 3000 ft.	Spectroradiometer (Geophysical Engineering Research)	Spectral range: 350 nm to 2500 nm (used to measure background surfaces)	Tripod
	Field Spec spectro-radiometer (Analytical Spectral Devices)	Spectral range: 350 nm to 2500 nm (used to measure spectra of petroleum products)	Hand-held
Balick	**AGEMA 880 Thermal Imager**	**Broadband thermal IR measurements** 3-5 micron band 8-12 micron band	Tower on bridge: 30-40 ft. above water

Table 3.7 Remote Sensing Devices Tested at Ohmsett.

The objective was to test the various sensors over a period of time to determine their capability to detect the presence of oil and quantify its thickness in daylight and at night. Tests were run on oil slicks ranging from 0.5 to 4 mm thick and consisting of one of three types of oil or emulsified oil.

An additional intent of the testing program was to develop expertise in a controlled outdoor setting intermediate between laboratory and open water testing (Balick, 1995).

RSGISC, Cold Regions Research and Engineering Laboratory (CRREL), U.S. Army Corp of Engineers sponsored this test. MAR, Inc., managed the test under the direction and review of the Minerals Management Service (MMS). Personnel from the U.S. Army Corps of Engineers Topographic Engineering Center (CE-TEC), U.S. Army Night Vision and Electronic Sensors Directorate (NVESD) and Department of Energy (DOE) Remote Sensing Laboratory (RSL) provided equipment and assisted in the data collection and data reduction efforts.

Description of Test Procedures:

As shown in **Figure 3.24**, the test setup in the Ohmsett basin consisted of 15 50-ft sections of boom formed into 15.9-ft diameter circles and 16 inflatable 2-ft diameter rings. Flexible PVC pipe was used to form the boom sections into circles. The fifteen large target pools were organized into a three-row by five-column matrix. Each row contained one of three types of oil: diesel fuel, Hydrocal 300 (a severely hydro-treated heavy naphthenic distillate), or Sundex 8600T (a highly viscous aromatic oil). Each column contained a nominal thickness of the oil: 0.5 mm, 1 mm, 2 mm or 4 mm. The other three large pools contained emulsions (20, 30 and 40% water) which were created by mixing Sundex 8600T and test basin water using a re-circulating water jet. Fifteen of the smaller target pools had the same contents as the larger pools; the sixteenth was a blank control pool.

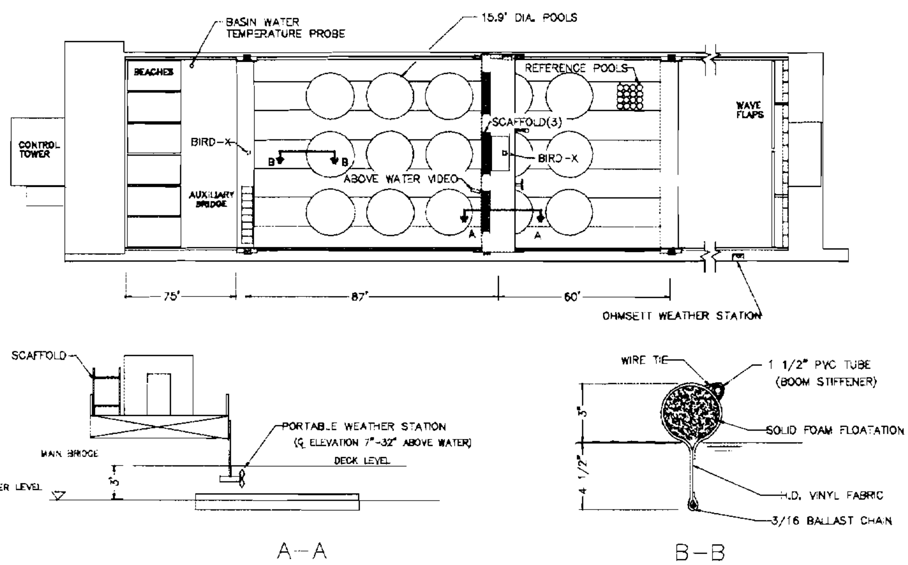


Figure 3.24 Ohmsett Facility Remote Sensor Test Setup

The oils were poured into the target pools from containers to create the desired slick thickness of from 0.5 to 4.0 mm. Nominal slick thickness was calculated by dividing the volume (in gallons as measured in the container) by the surface area of the target pool.

Although the intent was to test a uniform thickness of oil within each target pool, the oil did not necessarily spread evenly. Sundex 8600T tended to form globs, while Hydrocal 300 had discontinuous films (0.5-mm, 1.0-mm and 2-mm thickness) or films of varying thickness (Satterwhite et al., 1995). Diesel spread out over the surface, but wind (which also affected the other oils) caused the diesel to collect unevenly, forming “holes” in the thinner (0.5-mm, 1.0-mm) layers (Satterwhite et al., 1995). The Sundex 8600T emulsions formed globules that thinned out from the center into films; holes also formed in these samples (Satterwhite et al., 1995).

Wind speed and direction, water temperature, and wave measurements (when waves were produced) were recorded. The one test that was conducted with waves used waves with the following characteristics: frequency of 0.57 hertz; wave length of 15.9 ft; one third significant wave height of 4.3 in.

Near-surface instruments were operated from the Main Bridge, Control Tower, or the top of an adjacent building. Reflectance measurements of background surfaces were made using the Geophysical Engineering Research, Inc., (GER) spectroradiometer; while the Field Spec spectroradiometer system obtained spectra of the petroleum products (Satterwhite et al., 1995).

Airborne testing of the Digital Multispectral Video system employed a DeHavilland "Beaver" aircraft that flew at 2,000 and 3,000 ft above mean sea level (Satterwhite et al., 1995). A Cessna 206 aircraft carried the single bandpass filtered video, thermal infra-red (TIR), ultra-violet (UV), and variable interference filter video cameras on flights at altitudes of 500, 1,000, 2,000, and 3,000 ft (Bolus, 1996). All sensors on the Cessna were activated during daytime flights, and thermal infrared sensors were also used in flights after nighttime cooling (Bolus, 1996). Testing occurred in varying conditions of daylight from early morning to past midnight. During tests, the Main Bridge remained at one of six positions while remote sensor data were taken, then moved on to the next position.

Comparing oil inside the test targets with water outside the test targets assumes that there is no oil in the water. Water outside the test targets contained "fugitive" oil that was not uniformly distributed; however, this background contamination was not a critical problem (Balick, 1995).

Summary of Results:

Data generated at the Ohmsett facility during this test are included in the Final Report, referenced below. Remote sensing data was analyzed and published by the principal investigators. Reports and papers discussing sensor performance are referenced below under Related Publications. Extensive discussions of results are available in those references. Only a brief summary of general results is presented here.

For spectral reflectance measurements, Balick (1995) reported that "all sensors operating in the visible and infrared were able to discern differences of oil thickness and different oil types at equivalent thickness." However, he noted that different oil types did not produce any identifying spectral features and cautioned that "the results cannot be easily extrapolated to open water conditions" (Balick, 1995).

Thermal IR contrast provided a measure of oil thickness in daylight measurements, but the relationship was less obvious at night (Balick, 1995).

The Xybion and Digital Multispectral Video imaging systems tested by Satterwhite et al. (1995) "proved capable of detecting the oil against the spill tank background and were able to discern relative oil film thickness gradients." Fluorescence spectra imaged in the laboratory were not able to be produced for oil in the test tank due to the light source, integration time and distance of the imaging system from the test pool (Satterwhite et al., 1995).

Final Report References:

Nash, J., 1996. Ohmsett Tests of VARIOUS REMOTE OIL SENSORS. Report No. OHM-95-014, Minerals Management Service Contract No. 14-35-0001-30544. Prepared by MAR, Incorporated, 6110 Executive Boulevard, Suite 410, Rockville, MD 20852, 10 pp. + app.

Related Publications:

Bolus, R.L., 1996. Airborne Testing of a Suite of Remote Sensors for Oil Spill Detection on Water. Paper presented at the Second International Airborne Remote Sensing Conference and Exhibition, San Francisco, California, 24-27 June 1996. Robert L. Bolus, U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Remote Sensing/GIS Center, Hanover, NH, 11 pp.

Balick, L.K., 1995. Ohmsett Oil-on-Water Field Tests: Summary of Ground-based Measurements, DOI/MMS OHMSETT Facility, Leonardo, NJ. DOE Remote Sensing Laboratory, Bechtel Nevada, Inc. (BNI), Las Vegas, Nevada, August 1995, 17 pp. + figs.

Satterwhite, M.B., R.L. Fisher, J.E. Anderson, 1995. Spectral Analysis of Oil Products on Water at the Ohmsett Spill Facility, Leonardo, NJ. U.S. Army Topographic Engineering Center, 7701 Telegraph Road, Alexandria, VA 22315-3168, 54 pp.

Test Title: **Ohmsett Tests of the WATER JET BARRIER SYSTEM**
Test Date: **August 20, 1995 - August 25, 1995**
MMS/OHMSETT Work Order #: **015**

Background and Objective:

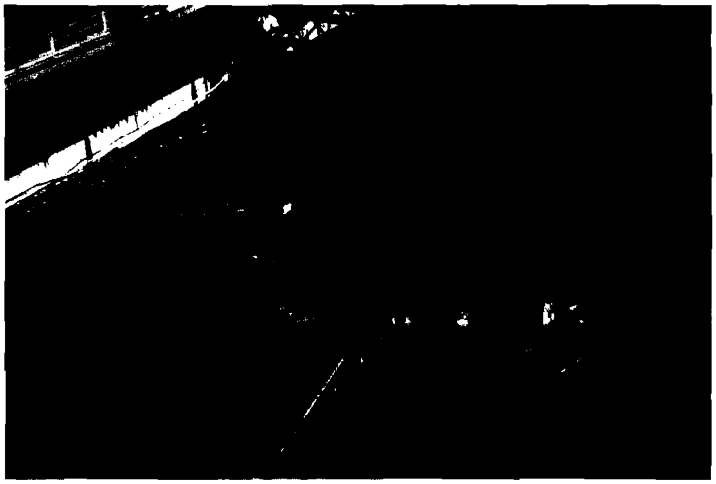


Figure 3.25 Photograph of Water Jet Barrier

Environment Canada, supported by the Minerals Management Service, has developed and tested a high pressure Water Jet Barrier for containment of spilled oil. The Water Jet Barrier consists of nozzles mounted on floats and arranged in a V-formation **(Figure 3.25)**. The nozzles, located 15 to 30 cm above the oil slick surface, spray water horizontally in a fan-shaped pattern; sprays from adjacent nozzles overlap, forming a continuous barrier. Nozzles aimed in the opposite direction (away from the slick) receive water from a separate line, allowing an operator to control movement of the barrier. A pump on the support vessel provides high-pressure water (1500 psi). A four-way control manifold allows the nozzles on the two arms of the V (or the front and back of each arm) to be supplied with water independently.

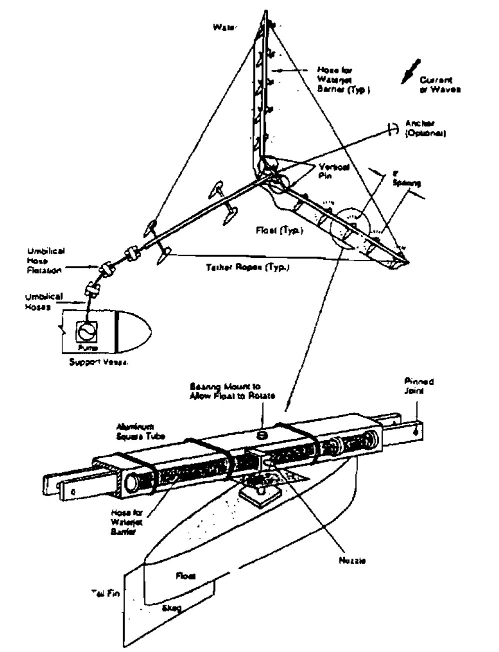


Figure 3.26 Schematic of Water Jet Barrier.

Field tests conducted in 1991 at the Canadian Coast Guard Base at Prescott, Ontario, evaluated the flotation system and movement control capabilities of the barrier. Test results led to design modifications. After tests in 1992 (including a test spill of 46 liter [12 gal] of canola oil), further changes were made to the Water Jet Barrier System. Ohmsett testing was conducted to evaluate the new configuration during August 1995.

The objectives of these tests were to determine the maximum velocity the Water Jet Barrier can attain using its jets for propulsion and the Pre-load Volume and First Loss Speeds for the system.

Environment Canada sponsored the tests, which were conducted by MAR, Inc., under the direction and review of the Minerals Management Service.

Description of Test Procedures:

Figure 3.27 shows the test setup for the Water Jet Barrier in the Ohmsett tank. The Water Jet Barrier was positioned between the Main and Auxiliary Bridges of the tank; the pump and control manifold were placed on the Main Bridge. As the Main Bridge advanced along the tank, the Water Jet Barrier operator tried to match the speed of the barrier to the speed of the Main Bridge. If control was lost, slack lines extending from the Auxiliary Bridge would restrain the barrier; otherwise, the lines would not affect control or speed of the barrier.

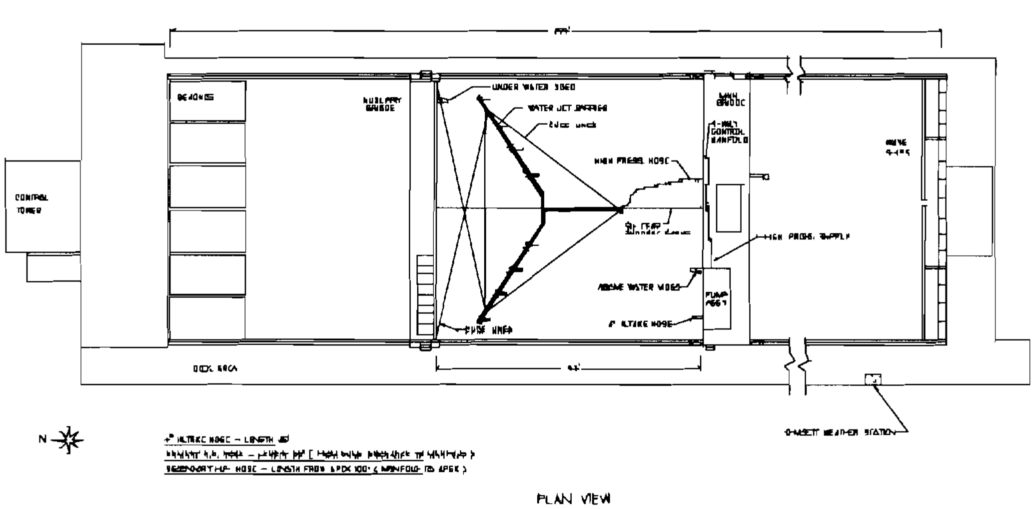


Figure 4.27 Water Jet Barrier Test Setup (Plan View).

Eleven Speed Tests were planned to determine the maximum speed that the barrier could attain in the tank. In these tests, the barrier operator would use the nozzles to move the barrier, matching the speed of the main bridge, which would be increased incrementally. The speed of the barrier would be determined by the speed of the Main Bridge. Three wave conditions were planned for the tests: calm, a single-frequency sinusoidal wave with wave-dampening beaches used to minimize reflected waves, and a Sea State 2 condition. Several runs with increasing speed were planned for each wave condition.

Pre-load Tests determined the amount of oil to be placed in the barrier for conducting First Loss Speed Tests. A small amount of oil was placed in the barrier and First Loss Speed for the barrier was determined. Additional amounts of oil were added and First Loss Speed was determined for each amount of oil until the First Loss Speed no longer depended on the amount of oil placed in the barrier. Refurbished Hydrocal 300, a refined naphthenic oil with a test viscosity of 300 cPs, was used for the Pre-load and First Loss Speed Tests.

First Oil Loss Speed is the lowest speed at which oil droplets continuously shed from the barrier. First Loss Speed Tests began with the barrier moving at 0.25 kts while being Pre-loaded with test oil. Once the pre-load stabilized in the apex of the barrier, tow speeds increased incrementally until oil began to escape under the barrier. First Loss tests were conducted in calm and regular wave conditions.

Summary of Results and Findings:

Overall, the Water Jet Barrier tests were difficult to perform and inconclusive. Of the five speed tests planned for calm conditions, two were cancelled because the target speed was reached in a prior run. One test was rerun twice due to equipment problems. Three tests were planned for regular wave conditions. Operational problems caused two of the tests to be combined and rerun. Because the target speed was reached during the repeat run, the third test was cancelled. Sea state 2 conditions were too severe for the barrier, so the first test was aborted and the other two were cancelled. Because of the inherent difficulties in deploying and operating the system, further development of the device has been suspended by Environment Canada.

Final Report References:

DeVitis, D., 1996. Ohmsett TESTS OF THE WATER JET BARRIER SYSTEM. Report No. OHM-95-15, Minerals Management Service Contract No. 14-35-0001-30544. Prepared by MAR, Incorporated, 6110 Executive Boulevard, Suite 410, Rockville, MD 20852, 16 pp. + app.

Test Title: **Ohmsett Demonstration of HYDROGROWTH INTERNATIONAL'S OIL AQUATIC RECOVERY SYSTEM (OARS)**	
Test Date: **October 17, 1995 - October 20, 1995**	
MMS/OHMSETT Work Order #: **16**	

Background and Objective:

HydroGrowth International of Tucson, Arizona, manufacturer of the Oil Aquatic Recovery System (OARS), had previously conducted laboratory tests and two field tests of its product. A company-sponsored demonstration was held at Ohmsett to allow selected guests to view deployment, operation and retrieval of the OARS. Video recordings were made during the demonstration for future use in marketing efforts by HydroGrowth International.

An OARS unit consists of "pucks" contained in a mesh bag made of polypropylene. The pucks are made of a co-polymer; its hydrophobic material is designed to absorb oil. Each puck weighs 35-40 grams (gr) and has the shape of a truncated cone one inch thick with a maximum diameter of three inches. AB-Tech Industries of Tucson, Arizona, supplies the pucks. Mesh bags range in diameter from 3 to 18 ft. Six-ft diameter bags were used for the demonstration. Deployment platforms for the bags can include ships, boats, docks, airplanes and helicopters.

The objective of the demonstration was to show how the OARS units could be deployed, absorb oil, and be retrieved in an at-sea environment. The deployment demonstration showed how the OARS units reacted to being dropped from a crane at different heights or tossed into a full-scale simulated oil/water environment. The absorption properties of the OARS were to be demonstrated by using different pools of several types of oil and various soak times in the pools and drop zone. The demonstration was designed for viewing by guests of HydroGrowth and for video taping for later showing to other interested parties.

Figure 3.28 shows two views of an OARS unit, one during retrieval, the other deployed in the Ohmsett basin.

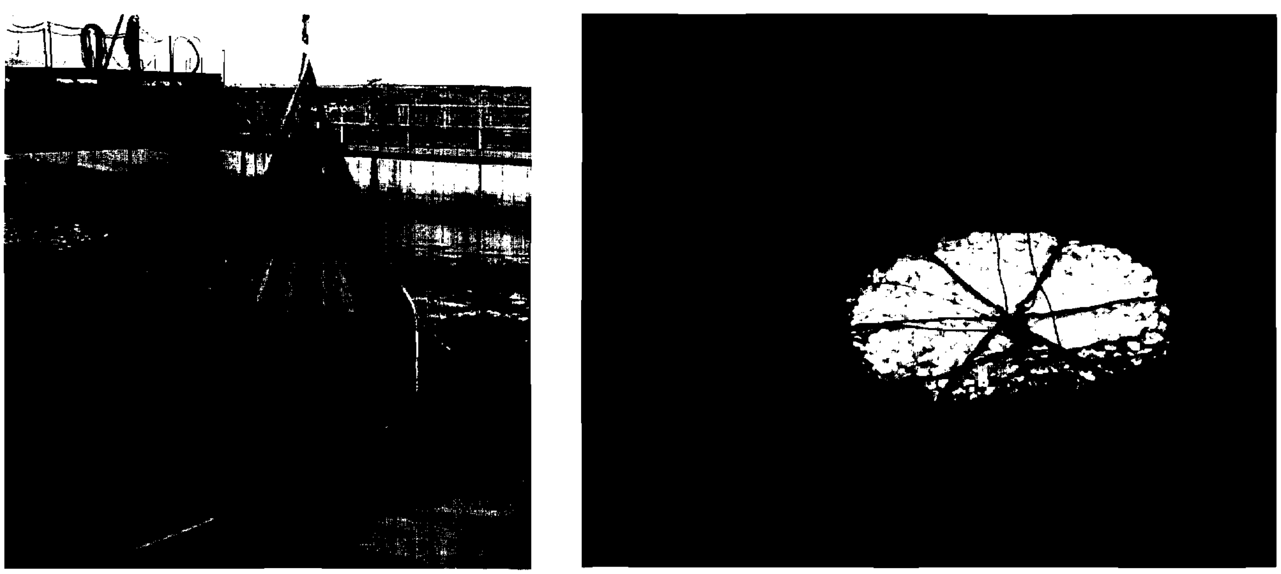


Figure 3.28 The OARS During Retrieval and Deployed in the Ohmsett Basin.

Description of Demonstration:

Figure 3.29 shows the Ohmsett basin arrangement for the OARS demonstration. Three boomed areas were provided for containing oil to demonstrate how the OARS functions. Two of the boomed areas were 16-ft diameter circles, one containing Hydrocal 300 and other diesel oil. The third containment area was a 50-ft square that contained Hydrocal 300. The square was used for demonstrating dropping and tossing the OARS into an oiled area. Video cameras were positioned in three locations to cover the drops and losses. Practice drops were conducted the day prior to the actual demonstration.

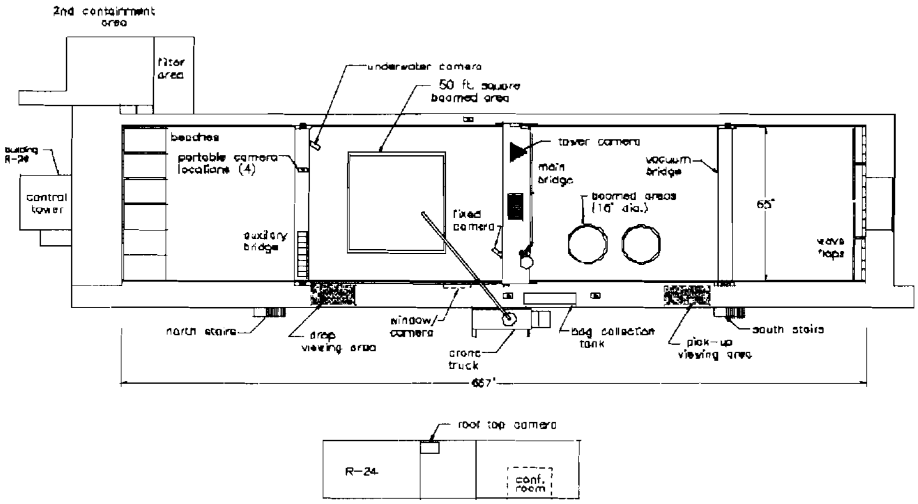


Figure 3-29 Ohmsett Basin Arrangement for OARS Demonstration

For the deployment demonstration, the 50-ft square boomed area between the main and auxiliary bridges was loaded with 300 gal of Hydrocal 300 and the wave generator was started. A crane dropped the OARS units to simulate a drop from a helicopter or an airplane. On the day of the demonstration, two OARS bags were dropped by a crane from a height of three ft into the center of the boomed area. Another OARS bag was dropped from a height of 35 ft into the east side of the boomed area. Three OARS bags were tossed manually from the west deck of the basin. Bags were removed from the boomed area by the crane in the same order as they were dropped. The OARS bags were then deposited in a collection tank.

Two 16-ft-diameter boomed areas between the main bridge and the vacuum bridges were used for the oil absorption demonstration. Thirty-five gal of diesel fuel were placed into the south boomed area; 35 gal of dyed Hydrocal 300 were placed into the north boomed area. One OARS bag was deployed by crane into each of the two 16-ft boomed areas.

Summary of Results:

Results of the absorption demonstration are shown in **Table 3.8**. The data represent more than 100 gal of total absorbed oil. The bags contained primarily Hydrocal 300 and some diesel oil.

In general, the observers of the test and the Hydrogrowth personnel were satisfied with the demonstration. The test demonstrated how the OARS system could be deployed and retrieved, effectively absorbing oil in an at-sea environment. The results of the demonstration are more fully described in the Final Report which contains data on the oil properties, water sample test data, weather data, and video logs for the test. Data on the amount of oil absorbed by each bag of the Hydrogrowth product are shown in **Table 3.8**.

Bag Wt. (Lbs.)	Gross Wt. (Lbs.)	Net Oil Wt. (Lbs.)
112	168	56
115	135	20
119	155	36
120	174	54
112	160	48
115	184	69
115	190	75
115	225	110
115	234	119
115	173	58
115	166	51
115	174	59
115	244	129
115	174	59
Total Net Oil Weight		943 lbs.

Table 3.8 Absorbed Oil Weights Recorded During OARS Testing

Final Report References:

Custer, R.L., 1996. Ohmsett Demonstration of HYDROGROWTH INTERNATIONAL'S OIL AQUATIC RECOVERY SYSTEM (OARS). Report No. OHM-95-016, Minerals Management Service Contract No. 14-35-0001-3054. Prepared by MAR, Incorporated, 6110 Executive Boulevard, Suite 410, Rockville, MD, 20852, 6 pp. + app.

Test Title: **Tests of the CANADIAN COAST GUARD AIRBORNE REMOTE SENSING SYSTEM**	
Test Date: **December 12, 1995 and June 20-21, 1996**	
MMS/OHMSETT Work Order #: **17 and #21**	

Background and Objective:

The Canadian Coast Guard (CCG) purchased an oil spill remote sensing system from the Geophysical and Environmental Research (GER) Corporation of Millbrook, New York. Prior to acceptance, the CCG wanted to test the overall performance of the system using a known fixed target. The objective of the test was to check the ability of the sensors to detect different types of oil of varying thicknesses. The Ohmsett test basin provided a suitable venue for a series of test overflights of the system aboard an aircraft. The tests were sponsored by the Minerals Management Service and conducted by MAR, Inc. The Canadian Coast Guard was responsible for data collection, compilation and interpretation.

Description of Test Procedures:

Figure 3.30 shows a typical test setup in the Ohmsett test basin for the fly-over tests. A series of circular oil spill containment booms were placed in the tank, separated from each other by at least one target diameter.

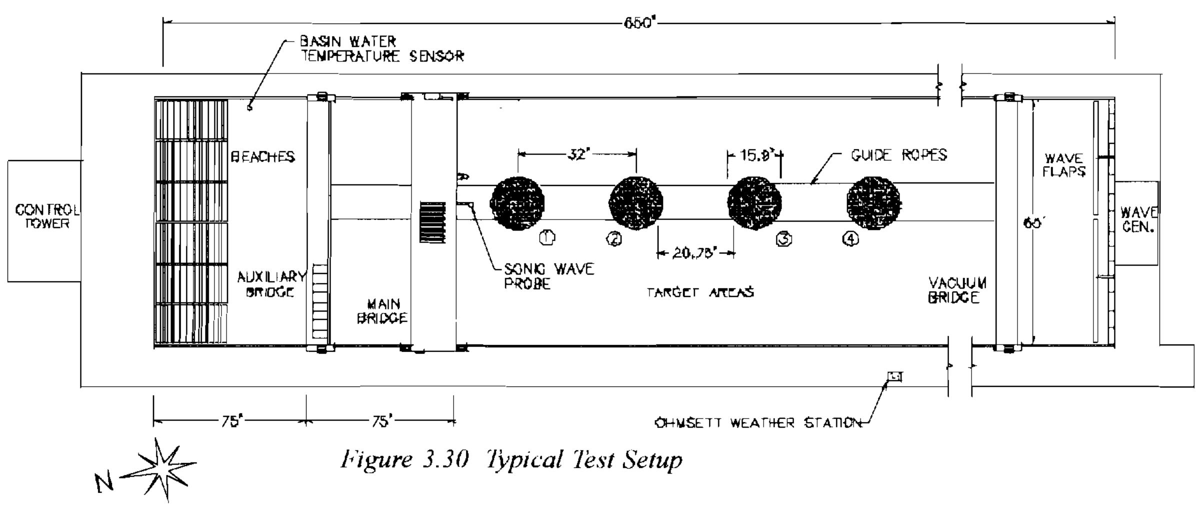


Figure 3.30 Typical Test Setup

Each boom contained a known type of oil used for testing at Ohmsett (e.g., Hydrocal, Sundex or Diesel), with the amount of oil in the targets varied (25-50 gal), to achieve a nominal thickness between 0.5 and 1.0 mm (See **Figure 3.31**). One target pool contained emulsion and one pool contained no oil to serve as a reference target.

Difficulties were encountered in achieving a uniform thickness throughout the oil pool, as the wind would herd the oil to one side of the target area. The tests were all performed in calm water; no waves were generated during the tests.

Figure 3.31 Target Pool

Several test overflights were made during each test series. The test aircraft flew from north to south along the length axis of the test basin while the remote sensing system operators checked the system's performance. Test runs were made at different altitudes.

Summary of Results:

The overflight test observations were made by the Canadian Coast Guard. During the December 1995 tests, the system did not function according to CCG expectations; this necessitated the second series of tests in 1996. The tests were designed to be a performance verification check of the system, so that extensive data were not taken. No formal test report has been published to date.

Summary of Findings:

The full findings of these tests have not been published. Difficulties were encountered in verifying the performance of the GER system. The Canadian Coast Guard should be consulted for further information .(Contact Point is Mr. David Yard at (613) 990-3382.)

Reference:

Custer, R.L., 1996. Ohmsett Tests of the Canadian Coast Guard – Airborne Remote Sensing System, Report No. OHM-95-017, Minerals Management Service Contract No. 14-35-0001-30544. Prepared by MAR, Inc., 6110 Executive park Blvd., Suite 410, Rockville, MD 20852, 6pp.

Test Title: **Testing SPILLED OIL RECOVERY SYSTEM (SORS) CONTAINMENT and COLLECTION COMPONENTS at Ohmsett**

Test Date: **April to June 1996**

MMS/OHMSETT Work Order #: **18**

Background and Objective:

Figure 3.32

The United States Coast Guard (USCG) is building a new JUNIPER Class Sea Going Buoy Tender (WLB) which has the ancillary task of carrying and operating a Spilled Oil Recovery System (SORS). SORS consists of sweeping booms that collect and concentrate oil; skimmers to recover the oil; an on-board oil water storage and separation system; and towable bladders for additional oil storage. This Work Order tested three candidate systems for the "sweeping boom" and the "skimming" components of the SORS system. The containment boom and skimmer combinations are deployed from the side of the vessel.

The primary objective of this test was to provide system performance measurements to a Coast Guard Evaluation Team (CGET). The CGET planned to use this information to help determine if the systems tested meet SORS performance requirements, and to help select system components for placement aboard the new JUNIPER Class Buoy Tenders. The test results were one of several selection criteria for the candidate systems. The quantitative objectives of these tests were to determine the oil collection performance, the oil recovery rates and efficiencies, and the seakeeping ability of the three candidate SORS Systems.

The three candidate SORS systems that were tested are briefly described here. These descriptions are excerpts from vendor information provided to Ohmsett. A more detailed description can be found in the Final Report for this Work Order.

1. Framo TR-100 Belt Skimmer System

The Framo TR 100 Belt Skimmer/SORS is a complete system for collecting, skimming, and pumping spilled oil from the sea surface into a ship's separation tank. When not in use, the system can be stored aboard the USCG WLB Buoy Tender.

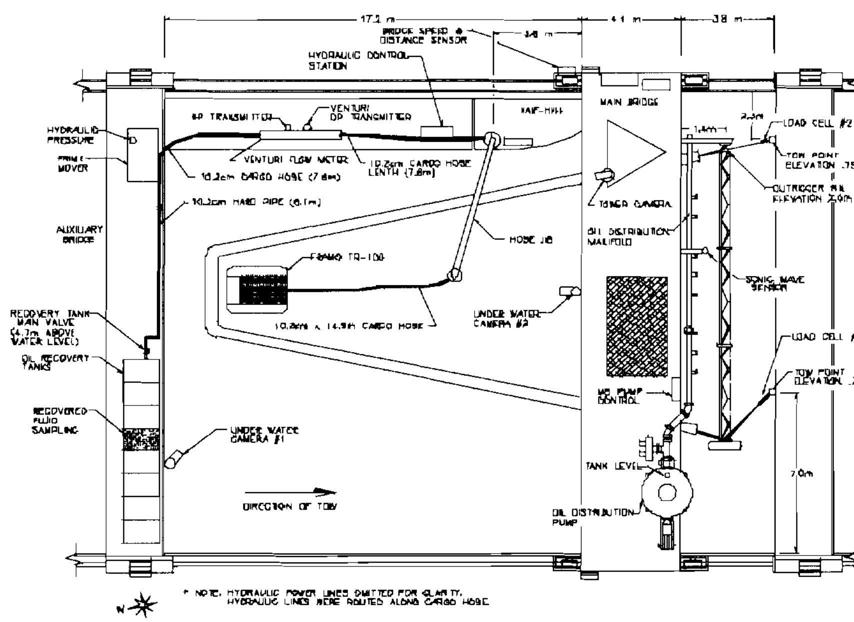


Figure 3.33 Framo TR-100 Belt Skimmer System Test Setup.

The system consists of the following main components: a NOFI Vee-Sweep type 600 oil diversion boom; a TR-100 Armadillo oil belt skimmer; a remote hydraulic control unit; and supporting equipment. The NOFI Vee-Sweep is deployed by means of an outrigger arm creating a 40' wide sweep that concentrates oil at the aft end. The hydraulically operated belt skimmer lifts oil into the feed screw where it is pumped through hoses into a shipboard storage tank. The configuration of the system in the Ohmsett boom is shown in **Figure 3.33**.

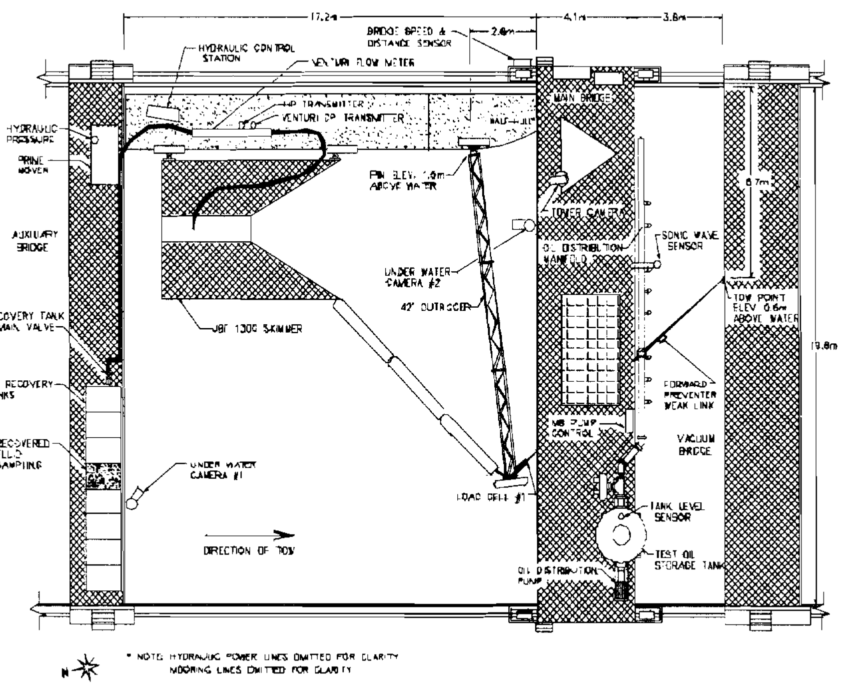


Figure 3.34 JBF Dip 1300 Skimming System Test Setup.

2. JBF DIP 1300 Oil and Debris Skimming System

The JBF Dip 1300 SORS is shown in **Figure 3.34**. As this system moves through the water, oil and debris are forced to follow the surface of a moving inclined plane into a collection well within the skimmer. Buoyant forces of the oil cause it to surface in the collection well area. When a sufficient amount of oil is collected within the well area, oil is pumped from the well using a hydraulically operated pump.

3. Hyde/Desmi Skimming System

This system is composed of the following major subsystems: a Desmi -250 weir oil skimmer; a skimmer hydraulic flow control stand; and an outrigger arm with an inflatable sweeping boom which provides a sweep width from 34.8 ft to 42 ft. **Figure 3.35** shows the system deployed in the Ohmsett Test basin. The side-sweeping boom is operated in a "U" configuration to form an oil collection pocket within a "cusp" at the aft end of the boom. The cusp at the apex is formed using a mitered heavy-duty neoprene rubber boom designed to keep a "U" shape during tow. Once a sufficient amount of oil has accumulated within the cusp, the skimmer operator (who is positioned at the remote control

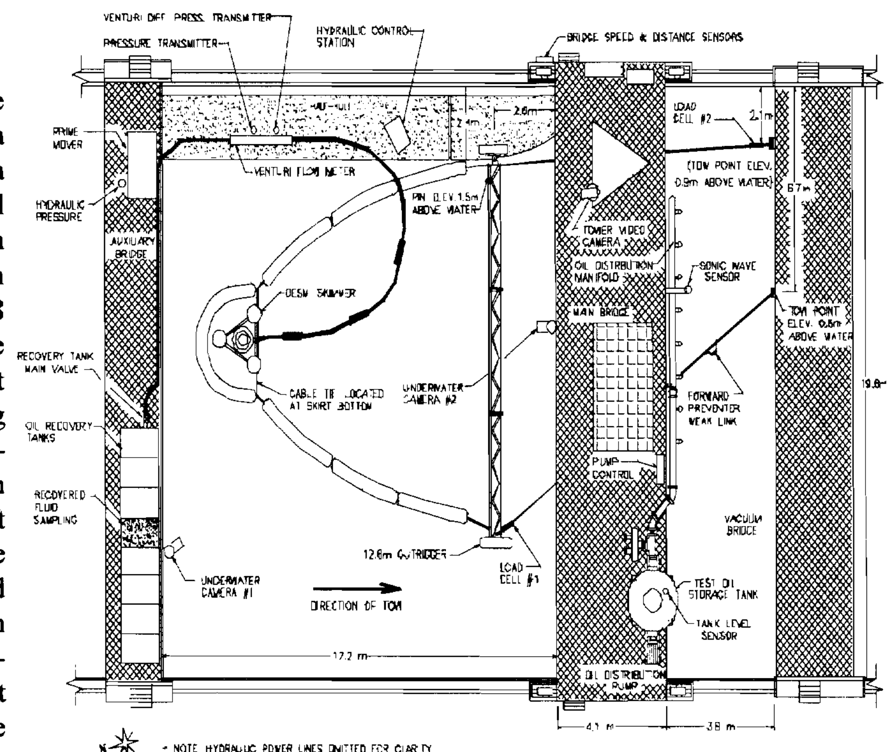


Figure 3.35 Hyde/Desmi Skimming System Test Setup.

stand) adjusts the skimmer so it begins removing oil from the water surface. The skimmer has a variable height weir that can be pneumatically adjusted depending upon the oil thickness within the cusp.

Description of Test Procedures:

A half-hull was constructed and suspended between the Main and Auxiliary Bridges in the Ohmsett tank. This half-hull was used as a crude simulation of the starboard side of a USCG Buoy Tender. The half-hull with the test systems attached was towed through the Ohmsett tank under a variety of tow speeds and wave conditions.

The Ohmsett Main and Auxiliary Bridges are mounted on rails and can be moved through the tank basin at varying speeds. Before towing begins, oil is pre-loaded from the Main Bridge into the boom opening. For some tests, oil is continuously added into the boom throughout tow test. Video monitoring of the test (above and below water) and data collection from the various sensor suites are accomplished from the Control Tower. The underwater video camera is used to identify oil loss from the booms.

For testing that involves waves, Ohmsett waves are generated using a reciprocating paddle located at the far end of the Ohmsett tank. There is a perforated metal wave absorber at the opposite end of the reciprocating paddle. The wave absorber is elevated (activated) when the test tank is simulating sinusoidal wave action, and lowered when a "confused sea" or a harbor chop is being simulated.

Four wave conditions (shown below) were used for the testing. These wave data are average values taken from the Ohmsett Final Report.

Waves	Height	Average Period
Calm Water	no wave	generated by paddle
Wave 1	Significant wave	9" 1.8 sec
Wave 2	Harbor chop condition	9.8"
Wave 3	Significant wave	10.6" 3.2 sec
Wave 4	Significant wave	12.2" 2.3 sec

Table 3.9 Wave Conditions for SORS Testing at Ohmsett

Two types of test oils were used during this test. The first was a medium viscosity oil called Hydrocal 300, and the second was a higher viscosity oil called Sundex 8600. The Hydrocal 300 viscosity ranged from 150 cPs to 800 cPs at 25 deg C, and the Sundex 8600 viscosity ranged from 10,000 cPs to 22,000 cPs at 25 deg C.

The Pre-load testing and the First Loss Tow Speed testing were done first and simultaneously. The tow speed where a boom first begins to lose oil is defined as the First Loss Tow Speed. The Pre-load test determines how much oil will be placed into the apex of the boom before towing begins. The Pre-load is defined as that point when adding more oil into the boom pocket has a minimal effect on the First Loss Speed. The proper Pre-load amount is determined empirically by incrementally adding more oil to the boom pocket before towing, and then measuring the speed at which First Loss occurs. When the First Loss Tow Speed does not increase significantly with the addition of more oil, the Pre-load Volume and the First Loss Tow Speed are recorded.

Gross Loss occurs when oil is lost continuously entrained underneath the boom. The Gross Loss Speed is determined by monitoring underwater video camera images from the Control Tower.

The Oil Recovery Rate (ORR), the Oil Recovery Efficiency (ORE), and the oil Throughput Efficiency (TE) were calculated for each system using measurements of the test duration, the amount of oil recovered, and the amount of total fluid recovered (oil and water). The ORR is the amount of oil that is recovered per unit time, the ORE is the ratio of pure oil recovered to the oil/water mixture recovered, and the TE is the ratio of the oil volume recovered to the oil volume encountered by the system.

The Critical Tow Speed occurs when the boom being towed loses its freeboard or its draft. The boom is towed at increasing speeds until the "failure mode" is observed. This test generally is done in calm water without oil.

The Towing Force is defined as the tension force in each of the boom's towing lines during tow. The towing forces are continuously measured using load cells, and the data are recorded in the Control Room data collection computer.

Summary of Results:

Full test results are provided in The Final Report prepared by MAR, Inc. The following is a summary of more significant results.

Framo System:

This system did not recover any oil during initial testing. The vendor was allowed to make adjustments to the system; however, it did not recover oil after adjustments were made. The authors of the MMS Final Report noted the Framo system's belt drive was low, indicating a failure within the system. The report did not state the exact nature of the system failure. This system was eliminated from the remainder of the tests.

First Oil Loss from the Framo system was observed at 1.3 knots during the pre-load testing with the Sundex 8600 oil.

JBF 1300 Skimmer:

In calm water with Sundex 8600 oil, the ORE ranged from ~ 72% to ~ 98% with three of the five test runs falling above 90%. The system maintained an 85% ORE when towed at 2.3 kts. In calm water with the Hydrocal 300 oil, the ORE ranged from ~23% at 0.75 kts to ~42% at 1.75 kts.

In general, testing with Sundex 8600 (higher viscosity of the two test oils) resulted in higher ORE. Each of the four wave conditions reduced the ORE. The resonant frequency wavelength for this system (Wave # 3) had the greatest effect on the ORR. The lowest recovery efficiency of 6.6% occurred with Wave # 2 at a tow speed of 0.75 kts when significant splashing and emulsification was observed at the skimmer mouth causing losses over and under the boom/skimmer combination.

The highest ORR for this system (51 m^3/hr) occurred while collecting high viscosity oil in waves. The oil encounter rate for this test was 48 m^3/hr; thus, either the reported ORR was too high, or the reported oil encounter rate was too low. In calm water, the ORR decreased as the speed increased. The lowest ORRs were less than 5 m^3/hr; these were recorded during the harbor wave conditions at towing speeds of 0.75 and 1.25 kts. The ORR showed an increasing trend with higher towing speeds for Wave #1 and Wave #2, and a decreasing trend for Wave #3.

Hyde/Desmi Skimming System:

In calm water with Sundex 8600 oil, the ORE ranged from ~ 42% to ~ 77%; three of the five test results were between 42% and 57% ORE. No results are provided for tow speeds above 1.75 kts. In calm water with the Hydrocal 300 oil, the ORE ranged from ~74% at 1.0 knot to ~85% at 1.25 kts. In general, testing with wave action improved the ORE for tests using the Sundex 8600 oil. There were only two data points showing recovery efficiencies below 40%; all other test results showed that the system has an ORE between 40% and 85%.

The highest ORR measured for this system was 51 m^3/hr while collecting the Sundex 8600 oil in waves. In general, the system performs better at increasing tow speeds until the First Loss Speed is reached; then the

ORR begins to decrease. In the Ohmsett final report, it was proposed that the rise in ORR with increasing tow speed was due to a thicker oil layer at higher tow speeds. The system generally had higher ORRs when exposed to surface Waves # 1 and # 2. Again, a thicker oil layer under these conditions was offered as reason for the increased ORR. Surface Wave # 3 (resonant frequency wave for this system) caused the ORR rate to decrease to ~ 10 to 24 m^3/hr.

Throughput Efficiency (TE):

Data regarding Throughput Efficiency were very limited because it takes a great deal of time to collect residual oil in the main tank. As expected, the throughput efficiency deceased with speed due to oil lost from the system at higher speeds. The TE for the JBF system ranged from 100% to 20%, and the TE for the Hyde system ranged from 100% to 40%, decreasing with higher speeds.

Critical Tow Speed:

The maximum tow speed for any test was 3 kts. At 2.9 kts, the Hyde system experienced failure due to submergence of the containment boom along the apex. The JBF system did not experience critical failure; thus, its critical tow speed was greater than 3 kts.

Summary of Findings:

The results of these tests provided the USCG with valuable data to assist with their selection of a high speed skimming system for the JUNIPER Class Seagoing Buoy Tenders. The JBF 1300 Skimming System and the Hyde/Desmi Skimming System showed the ability to efficiently recover oil at tow speeds exceeding two knots during the Ohmsett Tests.

Final Report Reference:

Nash, J., D. DeVitis, and S. Cunneff, 1996. TESTING SPILLED OIL RECOVERY SYSTEM (SORS) CONTAINMENT AND COLLECTION COMPONENTS AT OHMSETT, Final Report, Minerals Management Service Contract No. 14-35-0001-3054. Prepared by MAR Incorporated, 6110 Executive Boulevard, Suite 410, Rockville, MD 20852.

Test Title: **Test and Evaluation of SIX FIRE RESISTANT BOOMS at Ohmsett**

Test Date: **July 16, 1996 - October 4, 1996**

MMS/OHMSETT Work Order #: **019**

Background and Objective:

In-situ burning has been investigated as an oil spill response technique since the TORREY CANYON spill in 1967. In many cases, in-situ burning became an effective de facto response countermeasure for removing spilled oil from water through accidental explosion and ignition at the source. Since then, efforts have been made to develop effective in-situ burning equipment and to study the environmental effects that result from the in-situ burning of oil.

During the period of this test, and even today, fire-resistant boom designs are evolving. It was anticipated that these tests would provide the spill response industry with much needed information regarding the ability of fire-resistant booms to collect and retain oil in dynamic conditions. Manufacturers of fire-resistant booms also expected to benefit by using the test results to design a more effective fire-resistant boom.

The USCG Research and Development Center (R&DC) and the Minerals Management Service were the sponsors for this test. During the period of the test the R&DC, the Minerals Management Service, and the Canadian Coast Guard were participating in a joint project to investigate the performance of commercially available offshore fire resistant booms. The testing under this Work Order constitutes the first phase of their investigation.

Although all the booms tested are "fire" booms, they were not tested in burning oil, or any other high temperature environment under this Work Order. The tests concentrated on the booms' ability to collect and hold oil under a variety of tow speeds and simulated wave conditions.

The objectives of these tests were to determine the oil collection performance and the seakeeping performance of six different fireproof booms. The booms tested were the:

1. American Marine Inc.'s American Fire Boom;
2. Dome Boom;
3. Applied Fabrics Technologies's PyroBoom®;
4. Oil Stop Inc.'s PaddleWheel Boom®;
5. Spill-Tain™, Fireproof Oil Containment Boom, Offshore Version; and
6. Oil Stop, Inc.'s Inflatable Auto Boom™.

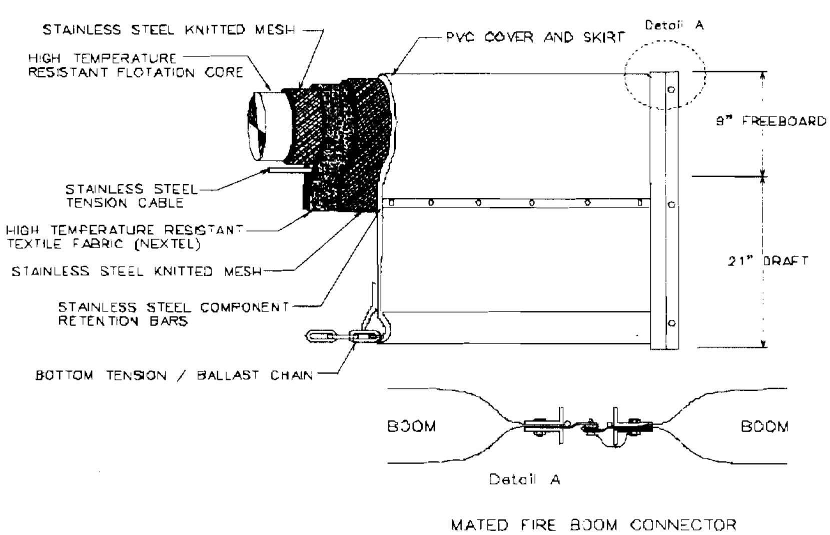


Figure 3.36 Details of the American Marine, Inc. American Fire Boom.

These six booms are shown and further described in **Figures 3.36 through Figures 3.41**.

1. American Marine, Inc.'s American Fire Boom

Each 50-ft boom section is 12 inches in diameter, 30 inches in height, weighs approximately 425 lbs and has seven segments. Each segment has a ceramic high temperature resistant flotation core. (Figure **3.36**) This core is surrounded by two layers of stainless steel, knitted mesh with a layer of ceramic, high temperature-resistant textile fabric

(Nextel) in between. The segments are encased in a tubular PVC outer cover that is extended to form the chain-ballasted skirt. A stainless steel internal tension cable runs the length of the boom section. Riveted vertical and longitudinal stainless steel seaming bars retain the ceramic component to the skirt during burns. Steel cable lift handles are located along the length of the boom, and one stainless steel end connector is bolted to each boom section end. Two sections were joined and used for this evaluation.

2. Dome Boom

The Dome Boom was developed during a three-year program. Beginning with a search for the most suitable materials of construction, an initial boom design was developed. A prototype boom was fabricated and tested for static flotation and under catenary and straight line towing up to five knots. Based on the test results, towing paravanes were added to the operational model. Fireproof fabric/mesh connectors were replaced with 0.4-mm thick, type 321 stainless steel flexible panels. The resulting boom, shown in **Figure 3.37**, was then tested in trial burns in 1980 at Port Melon, British Columbia, Canada. The following year towing tests and burn tests were conducted at Ohmsett. Eleven boom sections and towing paravanes were assembled for testing. Each section weighs 275 pounds and has a buoyancy-to-weight ratio of 3.5:1.

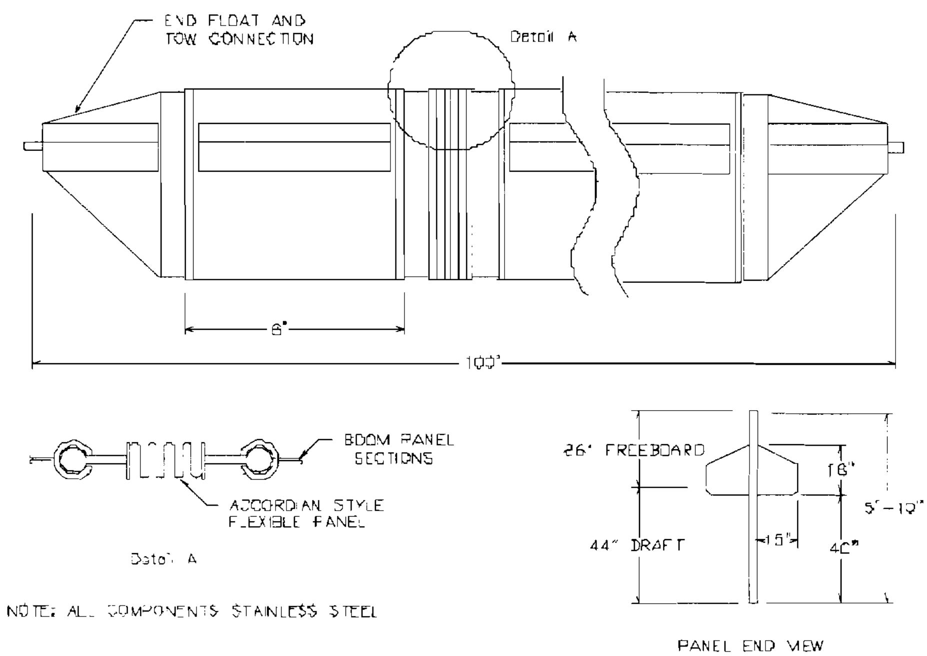


Figure 3.37 Details of the Dome Boom.

3. Applied Fabric Technologies' PyroBoom®

PyroBoom® is a solid flotation barrier that combines wire reinforced refractory fabric for the above surface barrier with conventional GlobeBoom® fabric for the skirt. The glass, foam-filled, steel hemispheres are mechanically attached to the barrier. Their modular construction allows for salvage, maintenance, and repair in the field. The boom has a 16-inch draft and a 14-in. freeboard. The single-section boom is 105 ft long. There are galvanized shackles above each flotation hemisphere for lifting. PyroBoom® behaves like GlobeBoom® and no special

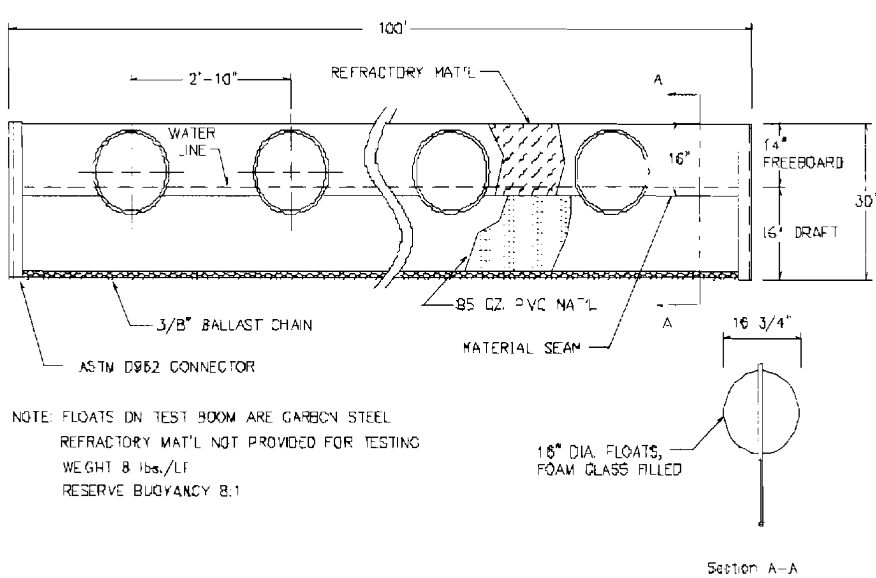


Figure 3.38 Details of Applied Fabric Technologies PyroBoom®

handling equipment is necessary. **Figure 3.38** illustrates the boom tested. A complete kit consists of a boom, a U-configuration sweep assembly with wire cross bridles, and a steel storage kit with retrieval windlass.

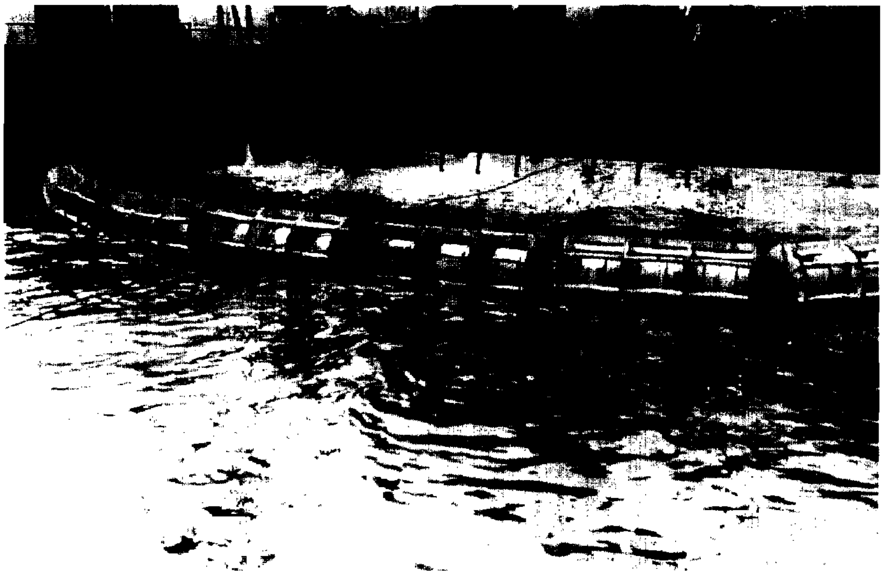


Figure 3.39 Oil Stop's Paddle Wheel Boom® Deployed at Ohmsett for Testing.

4. Oil Stop's PaddleWheel Boom®

The PaddleWheel Boom® is a dynamic oil containment device designed to contain oil in high currents. The boom system consists of a diesel engine, hydraulic motor, and a series of shaft-driven paddle wheels that create a surface current that is counter to the local current. The oil is therefore held away from actual contact with the boom. Because oil is held away from the boom and the boom is cooled by passing water, the Paddlewheel Boom® can be used as a fire boom. See **Figure 3.39**.

5. Spill-Tain™ Fireproof Oil Spill Containment Boom, Offshore Version

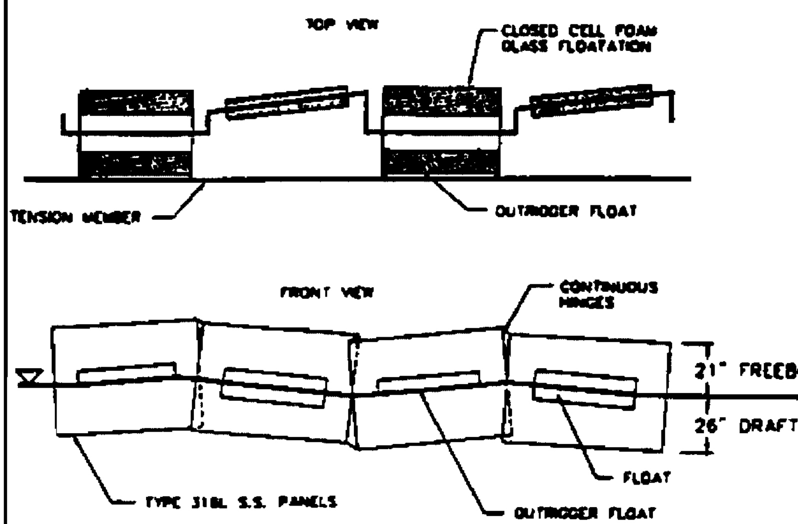


Figure 3.40 Details of Spill-Tain™ Fire Boom Offshore Version.

Spill-Tain™ is an external tension boom constructed of type 316L stainless steel sheet metal, closed cell foam glass flotation, and stainless steel cable. The boom can follow wave action due to a patented, segmented panel design. Boom panels are supported perpendicular to the water by alternating attached outrigger floats. Adjacent boom panels are attached to each other by integrally formed piano hinges. The tension cable is affixed to the bottom outer edge of the outrigger floats. Connecting plates with five thumb screws and accompanying nut plates join the 30-ft sections to one another, with shackles connecting cable eyes at each section end **(see Figure 3.40)**. Three sections were joined to form a 90-ft section for testing. Each section weighs 583 lb, with a buoyancy-to-weight ration of 2.75:1.

6. Oil Stop's Inflatable Auto Boom™ Fire Boom (Model is the Bay Boom)

This inflatable fire boom has a 14-inch float diameter and 22-inch skirt. It is equipped with universal end connectors. The boom is inflated using a patented single-point inflation design. Once inflated, the boom automatically sectionalizes the air chambers into separate compartments, so that individual air chambers stay

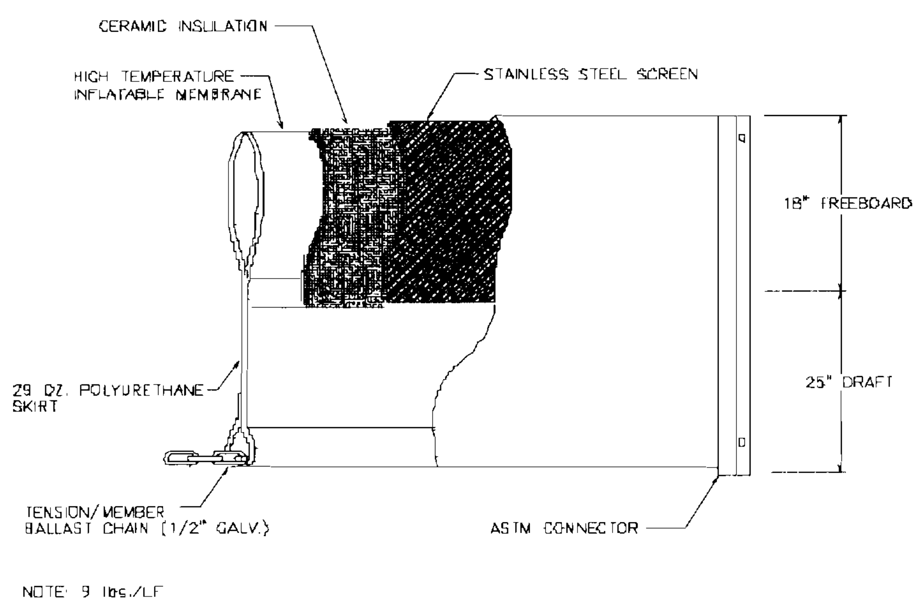


Figure 3.41 Oil Stop's Inflatable AutoBoom™ Fire Boom

inflated even if adjacent chambers are damaged or deflated. There are three layers beneath the boom's polyurethane exterior: a stainless steel screen, a ceramic insulation blanket, and a high temperature inflatable membrane **(see Figure 3.41)**. The tension member/ballast is a ½-in galvanized chain contained in the hem of the boom skirt. Two 50-ft boom sections were joined for this evaluation.

Description of Test Procedures:

A plan view of the fire boom setup and instrumentation in the Ohmsett test basin is shown in **Figure 3.42**. Each end of the boom being tested was connected to the Ohmsett Main Bridge; the boom length-to-gap ratios were 2:1. The Ohmsett Main and Auxiliary Bridges are mounted on rails and can be moved through the tank basin at varying speeds. When the boom is pulled through the water, it assumes a U-shape as shown in **Figure 3.42**. The movement of the Main Bridge is remotely controlled from the Ohmsett Control Tower, from which the entire tank basin can be seen. Video monitoring of the test (above and below water) and data collection from the various sensor suites is also done from the Control Tower.

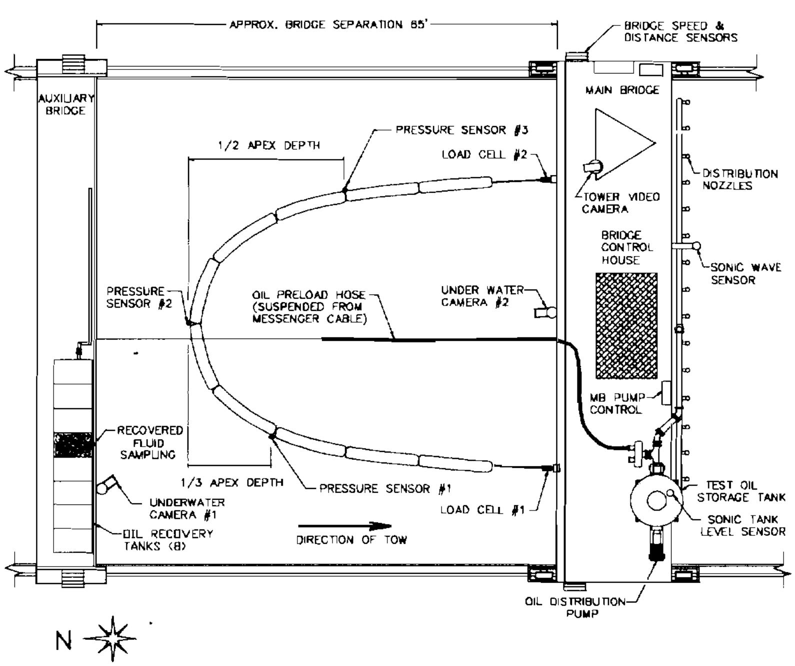


Figure 3.42 Plan View of the Fire Boom Setup and Instrumentation in the Ohmsett Test Basin.

Ohmsett waves are generated using a reciprocating paddle located at the far end of the Ohmsett tank. There is a perforated metal wave absorber at the opposite end from the reciprocating paddle. The wave absorber is elevated (activated) when the test tank is simulating sinusoidal wave action, and lowered when a "confused sea" or a harbor chop is being simulated.

Four wave conditions (next page) were used for the testing under this Work Order. These wave data are average values taken from the Ohmsett Final Report.

	Wave Type	Significant Wave Height	Average Period (sec)
Calm Water	No waves generated	N/A	N/A
Wave 1	Regular sinusoidal wave	9.9"	1.8
Wave 2	Regular sinusoidal wave	13.3"	3.1
Wave 3[1]	Harbor chop	8.9"	2.0

[1]For this wave, the wave absorber is lowered, and the confused wave condition is allowed to develop for 15 minutes.

Table 3.10 Wave Conditions Used for Ohmsett Five-Resistant Boom Tests

The Pre-load testing and the First Loss testing constituted the first test run and were completed simultaneously. The lowest speed at which oil droplets continuously shed from the boom is defined as the First Loss Tow Speed. The Pre-load test determines how much oil will be placed into the apex of the boom before towing begins. There is a point when adding more oil into the boom pocket has a minimal effect on the speed at which the First Loss of oil occurs. This volume is defined as the Pre-Load Volume. The proper Pre-Load amount is determined empirically by incrementally adding more oil to the boom pocket before towing, and then measuring the speed at which First Loss occurs. When the First Loss Tow Speed does not increase significantly with the addition of more oil, the Pre-Load Volume and the First Loss Tow Speed are recorded.

The speed at which massive continual oil loss is observed escaping past the boom is defined as the Gross Loss Tow Speed. The Gross Loss is determined by monitoring underwater video camera images from the Control Tower.

The Oil Loss Rate test is done by pre-loading the boom with oil and towing the boom at First Loss Tow Speed plus 0.1 kts, and 0.3 kts. During the Oil Loss Rate test, oil is added to the boom during tow in an attempt to create a semi-steady state condition where the amount of oil within the boom is constant throughout the test. Oil was added at a rate of 26 gpm when towing at First Loss Tow Speed plus 0.1 kts, and at 105 gpm when towing at First Loss speed plus 0.3 kts. At the end of the test, the oil is skimmed from the tank and the Oil Loss Rate is determined by dividing the volume of oil lost by the duration of towing.

The Critical Tow Speed is defined as the maximum speed at which the boom may be towed before exhibiting one or a combination of failure modes. Typical failure modes include submerging (the boom loses all freeboard), planing (skirt pulls out of the water), splashover and/or mechanical failure. The test begins by towing the boom at 0.1 kts and increasing the tow speed in increments of 0.25 kts until the "failure mode" is observed. This test is done in calm water without oil, and it is done last due to the potential for mechanical failure of the boom.

The Towing Force is defined as the tension force in each of the boom's towing lines during tow. The towing forces are continuously measured using load cells, and the data are recorded in the Control Room by the data collection computer.

Summary of Results:

The results of the fire-resistant boom tests are presented in **Table 3.11** and summarized below:

BOOM NAME	First & Gross Loss Tow Speed (kts) Wave Condition				Loss Rate Test (gpm @ kts)		Critical Tow Speed(kts)	Tow Force (lbs) @ 2 kts	Maximum Tow Force (lbs)
	Calm	Wave #1	Wave #2	Wave #3	First Loss + 0.1	First Loss + 0.3			
PyroBoom									
First Loss	1.00	0.72	1.07	0.95	65 @	141 @	2.75	2,050	3,500
Gross Loss	1.20	0.93	1.30	1.10	1.10	1.30			
Spill-Tain									
First Loss	0.85	0.40	0.85	0.88	7@	47 @	>6.00	2,000	5,800
Gross Loss	1.05	0.60	1.05	1.07	0.95	1.15			
American Marine									
First Loss	0.85	0.72	0.87	0.90	17@	80@	2.25	1,800	2,800
Gross Loss	1.10	0.90	1.15	1.15	0.95	1.15			
Dome Boom									
First Loss	0.95	0.75	0.95	1.00	8.5@	40@	2.00	2,000	2,500
Gross Loss	1.32	1.05	1.20	1.25	1.05	1.25			
Oil Stop									
First Loss	0.90	0.80	1.07	1.00	19.5 @	75.5 @	3.50	1,500	8,000*
Gross Loss	1.22	—	—	—	1.00	1.20			

*Note: Tow Force spike of 11,000 lbs. was recorded while in oscillating mode during failure.
Actual Measured Wave Conditions:
Calm: no waves generated
Wave #1: regular sinusoidal wave: H = 9.9", L = 16.2', T = 1.8 sec.
Wave #2: regular sinusoidal wave: H = 13.3", L = 42.1', T = 3.1 sec.
Wave #3: harbor chop: H = 8.9", no L or T calculated.

Table 3.11 Summary of Boom Performance Data for Fire-Resistant Boom Tests.

First Loss Tow Speed:

The calm water First Loss Tow Speed test results ranged from 0.85 kts to 1.0 kt.

The PaddleWheel boom was a prototype boom and contained virtually no oil by the end of each test run; no results are reported for this boom in **Table 3.11**. There is no explanation in the test report as to why the Paddle Wheel Boom's oil holding performance was so far below that of the other booms tested.

When exposed to Wave # 1 (1.8 sec, 9.9 in), the First Loss Tow Speed results for all the booms (with exception of the Spill-Tain™) were in the tight range of 0.72 to 0.8 kts. The Spill-Tain™ boom experienced a pulsating action that resulted in a First Loss Tow Speed of 0.4 kts. This was the only wave condition that significantly reduced the First Loss Tow Speed of the booms.

While Wave # 2 (3.1 sec, 13.3 in) and Wave # 3 (harbor chop waves) had little effect on the First Loss Tow Speed of the test booms, some booms performed slightly better with the introduction of these waves.

Although Wave # 4 (1.8 sec., 9.9 in) was shorter in height than Wave # 2 (3.1 sec., 13.3 in), the former reduced the booms' First Loss Tow Speed while the latter did not. It is apparent from these results that the wave frequency can have a greater effect than wave height on boom performance.

Oil Loss Rate:

The Oil Loss Rate testing showed that the rigid skirt fence-type booms (i.e., Spill-Tain and Dome Booms) lost oil at approximately half the rate of the other inflatable booms with the flexible fabric skirts.

Critical Tow Speed:

The Critical Tow Speed for four of the booms was between 2 and 3.5 kts. The fifth boom (Spill-Tain) did not reach critical failure even when it was towed at 6 kts which is the maximum Ohmsett Bridge speed. This boom was reported to be stable throughout the test runs. The ability of a boom to be towed at such high speeds is significant to those interested in fast water oil recovery operations.

Towing Forces:

Towing Forces ranged from 1500 to 2050 lb. at 2 kts. The maximum Towing Force was measured at a different speed for each boom because each boom had a different Critical Tow Speed (also the maximum test speed). The maximum Tow Force ranged from 2,500 lb. (Dome Boom @ Critical Tow Speed of 2.0 kts) to 8000 lb. (Oil Stop Boom @ Critical Tow Speed of 3.5 kts). Although the Spill-Tain Boom reached a Critical Tow Speed of 6.0 kts, the maximum towing force was only 5,800 lb.

Summary of Findings:

Overall conclusions for the Ohmsett fire-resistant boom tests are reported by Bitting and Coyne (1997), as follows:

The oil collection performance of the fire booms tested is comparable to that of conventional, non-fire resistant containment booms.

From the limited data recorded, it appears that an increased buoyancy-to-weight (B/W) ratio is beneficial for oil collection performance. It appears that the boom materials and configuration are also important.

It is recommended that additional testing with oil be conducted to investigate the effect of B/W ratio on the oil collection performance, and that oil loss rate be included.

Performing three tests together (Oil Loss Tow Speed Test, Oil Loss Rate Test, and Critical Tow Speed Test) provides a more balanced assessment of how booms will perform in containing oil.

It is recommended that test guidelines be developed for evaluating booms in the test tank and at sea, and that the tests be structured so that tank and at-sea tests are comparable.

Final Report References:

DeVitis, D., S. Cunneff, and J. Nash, 1998. TEST AND EVALUATION OF SIX FIRE RESISTANT BOOMS AT OHMSETT. Minerals Management Service Contract 14-35-0001-30544. Prepared by MAR, Incorporated, 6110 Executive Boulevard, Suite 410, Rockville, MD 20852.

Related Publications:

Bitting, K. and P.M. Coyne, 1997. OIL CONTAINMENT TESTS OF FIRE BOOMS. Proceedings of the Twentieth Arctic and Marine Oilspill Program (AMOP) Conference, Environment Canada, Ottawa, Canada.

Test Title: **Ohmsett Testing of the PROTOTYPE COV-400 SKIMMER**	
Test Date: **August 13, 1996 to August 29, 1996**	
MMS/OHMSETT Work Order #: **20**	

Background and Objective:

The COV-400 tested at Ohmsett is a twin-hull barge with two transversely mounted counter-rotating drums. OSR Systems of British Columbia owns the skimmer and provided the funding for the Ohmsett testing described herein.

The system is designed for operation in calm to rough sea conditions. As the drums rotate, fluid is carried over the top of the drums and scavenged off by blades extending the length of each drum. The fluid then drains into collection troughs that have screens to capture debris. As oil is recovered into the recovery troughs, water that is collected is forced out of open seacocks at the bottom of each tank.

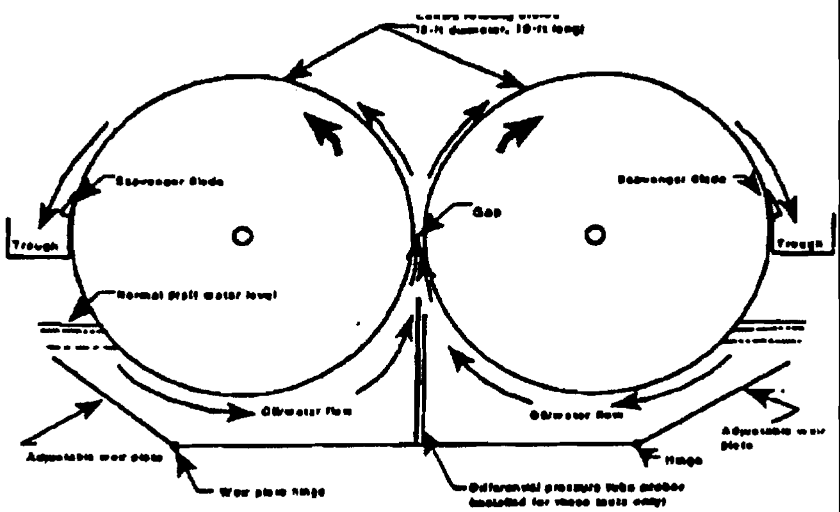


Figure 3.43 COV-400 GA with Detail of Drum Action.

The unit tested at Ohmsett had the following characteristics:

Length	40 ft
Beam	26 ft
Gross Tonnage	2 tons
Drum diameter	8 ft
Width of each hull	8 ft
Height of each hull	10 ft
Draft (Working)	6.25 ft
Draft (Light)	2.5 ft
Reception tank volume	12 m^3 in each of the four tanks
Speed of advance	IAW the vessel pushing the skimmer
Counter rotating drums	Adjustable (0 - 65 rpm)
Gap between drums	Adjustable (0 - 4in)
Hinged weir plates	Adjustable (Surface to 3 ft below surface)

OSR Systems, which sponsored the test, sought to determine the following performance parameters:

- The Oil Recovery Rate (ORR) of the COV-400,
- The optimum settings for the adjustable components on the COV-400,
- The effect of current, waves, and tow speed on the ORR,
- The efficiency and pressure differential of the pumping effect across the width of the drums,
- The capability of the bottom plate to retard the flow of oil and thicken the oil layer in the recovery chamber below the drums,
- The recovery efficiency of the system, and
- If, and to what degree, oil is emulsified due to the energy exerted during recovery.

Description of Test Procedures:

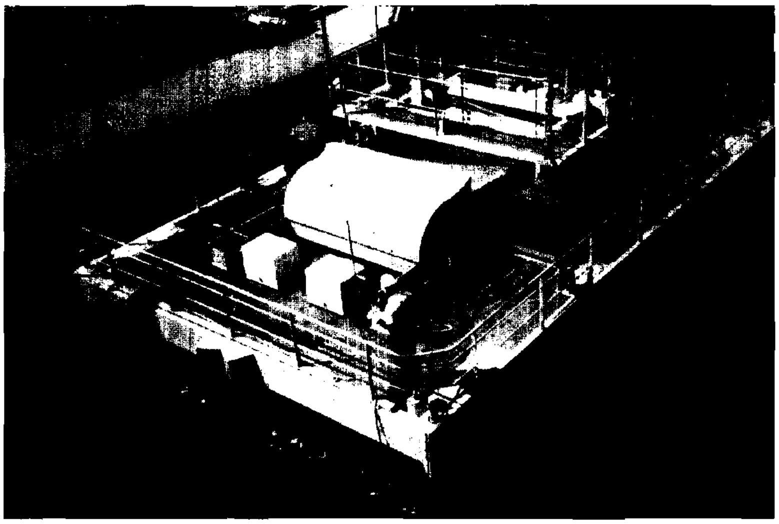


Figure 3.44 Photograph Showing the COV-400 Skimmer in the Ohmsett Tank

The COV-400 unit is shown in **Figure 3.44**. The COV-400 skimmer was secured to the Ohmsett Main Bridge with crossed towing lines as shown in **Figure 3.45**. Two 10,000-pound load cells were attached in line at each of the towing lines to measure Tow Force. The Ohmsett Main and Auxiliary Bridges are mounted on rails and can be moved through the tank basin at varying speeds. The movement of the Main Bridge is remotely controlled from the Ohmsett Control Tower from which the entire tank basin can be seen. Video monitoring of the test (above and below water) and data collection from the various sensor suites are also done from the Control Tower.

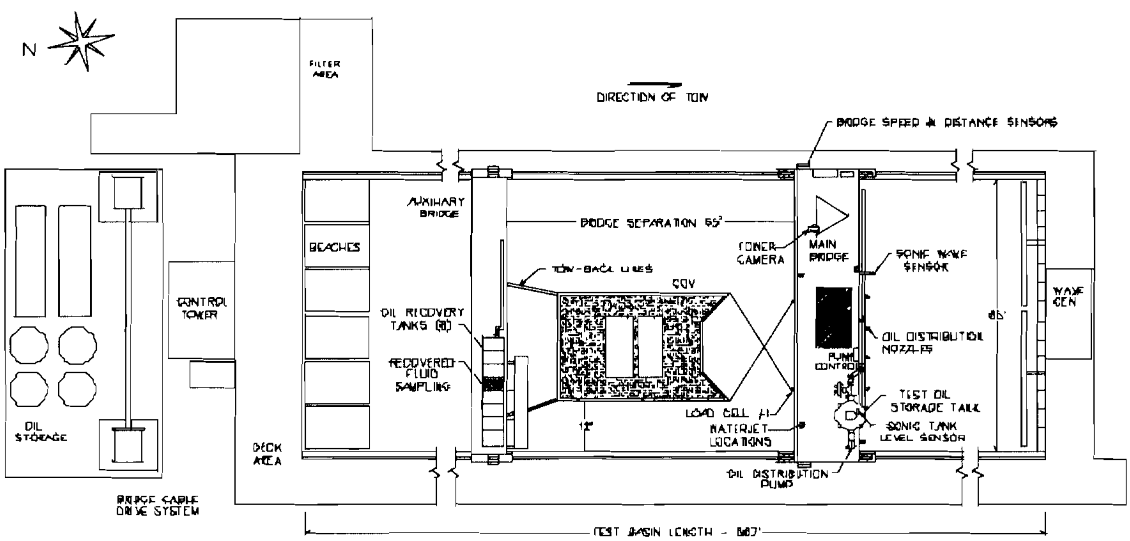


Figure 3.45 Plan View of the COV-400 Skimmer Setup and Instrumentation in the Ohmsett Tank

Two of the 31 test runs were done in waves; the remaining test runs were done in calm water. The wave height and period used for the testing in waves were not specified in the Final Report. Ohmsett waves are generated using a reciprocating paddle located at the far end of the Ohmsett tank. There is a perforated metal wave absorber at the opposite tank end from the reciprocating paddle. The wave absorber is elevated (activated) when the test tank is simulating sinusoidal wave action and lowered when a "confused sea" or a harbor chop is being simulated.

Oil recovery tests were run with a Sundex 8600 oil which has a viscosity of ~ 10,000 cSt at 25^0 C, and a Hydrocal 300 oil which has a viscosity of ~ 140 cSt at 25^0 C. The test oil was distributed in front of the skimmer during testing; the oil distribution rate approximated the skimmer's oil recovery rate. The Oil Recovery Rate (ORR), the Oil Recovery Efficiency (ORE), and the oil Throughput Efficiency (TE) were calculated using measurements of the test length, the amount of oil recovered, and the amount of total fluid recovered (oil and water). The ORR is the amount of oil that is recovered per unit time, the ORE is the ratio of pure oil recovered to the oil/water mixture recovered, and the TE is the ratio of the oil volume recovered to the oil volume encountered by the system.

The parameters for the oil recovery tests were pre-selected by OSR Systems. Throughout the test, parameters were varied as follows:

- The skimmer drums rotation speeds were varied from 12 rpm to 60 rpm,
- The skimmer draft was varied from 6 ft (standard) to 4.5 ft,
- The gap between the rotating drums was 0.5 in or 1.0 in, and
- Towing speeds of 0.5 kts, 1.0 kts, and 2.0 kts were used.

Because there was such a broad range of settings throughout the test, it was difficult for the Final Report authors to quantify the relationship between the individual settings of the skimmer and the skimmer's performance. To simplify, the Final Report authors chose six data set groupings as follows:

#1 Calm water, ½ in drum gap, 6 ft draft, 0.5 kt tow speed (Hydrocal oil)
#2 Waves, ½ in drum gap, 6 ft draft and 4.5 ft draft, 0.5 kt tow speed (Hydrocal oil)
#3 Calm water, ½ in drum gap, 6 ft draft, 1.0 kt. and 2.0 kt. tow speeds (Hydrocal oil)
#4 Calm water, ½ in drum gap, 4.5 ft, 5.0 ft, and 5.5 ft draft, 1.0 kt tow speed (Hydrocal oil)
#5 Calm water, 1 in drum gap, 6 ft draft, 1.0 kt tow speed (Hydrocal oil)
#6 Calm water, ½ in drum gap, 6 ft draft, 1.0 kt tow speed (Sundex oil)

Summary of Results: A summary of the results under each of the six parameter groupings is provided in **Table 3.12**. Some of the more significant results are summarized as follows:

The highest Throughput Efficiency (TE) recorded was 72% when using data grouping No. 6 (calm water, ½ in drum gap, 6 ft draft, 1.0 kt tow speed, Sundex oil). The lowest TE was 6% while using data grouping No. 2 (calm water, ½ in drum gap, 4.5 ft draft, 0.5 kt tow speeds, Hydrocal oil). For lighter oil, the TE appeared to be independent of the drum speed. The two tests run using Sundex 8600 oil showed a significant TE difference when the drum speed was changed.

The Recovery Efficiency (ORE) ranged from a low of 12% in waves to a high of 64% in calm water. The ORE was reported to be hampered because the drums showed a strong tendency to emulsify the oil. Apparently, fluid that was not removed by the scavenger bar was spraying down onto the encountered fluid emulsifying the oil, and preventing some of the oil from reaching the drum for recovery.

The Oil Recovery Rate (ORR) values were generally 65% to 95% less than the skimmer drums' measured pumping capacity. Like the ORE, the ORR was also reduced in part from the emulsion created from fluid spraying from the drums. The average ORR in calm water was 101.7 gpm. The two tests run in waves resulted in ORRs of 14 gpm and 25 gpm. The highest ORR rate (216 gpm) occurred when testing at data group #3 with a 1 kt tow speed (calm water, ½ in drum gap, 6 ft draft, 1.0 kt. and 2.0 kt. tow speeds, Hydrocal oil).

Test No.	Speed (kts)	Draft (ft)	Gap (in)	RPM Fore	RPM Aft	Dist. Oil (gal)	Recovery Time (min)	ORR (gpm)	TE %	RE %
CALM WATER: HALF INCH GAP, NORMAL DRAFT										
13	0.5	6	0.5	40	40	1462	7.43	96	49	62
28	0.5	6	0.5	24.7	37.7	1000	3.69	114	42	23
24	0.5	6	0.5	16	32	1000	5.88	95	56	58
			AVG	26.9	36.6	1154	5.67	101.7	49	48
			STD	9.9	3.36	218	1.53	8.7	6	18
			RSD	37%	9%	19%	27%	8.6%	11%	37%
WAVES: HALF INCH GAP, NORMAL AND DEEP DRAFT										
22	0.5	4.5	0.5	30	40	990	3.97	14	6	12
29	0.5	6	0.5	30	21	1000	7.78	25	19	12
CALM: ONE AND TWO KNOTS, HALF INCH GAP, NORMAL DRAFT										
15	1.0	6	0.5	50	50	1050	3.92	130	49	55
30	1.0	6	0.5	*	*	2289	4.17	216	39	58
31	2.0	6	0.5	12	35	815	1.88	92	21	37
CALM, ONE KNOT, EFFECT OF DRAFT										
19	1.0	5	0.5	60	—	1049	3.74	46	17	19
20	1.0	4.5	0.5	40	60	1000	3.62	83	30	17
21	1.0	4.5/5.5	0.5	10	30	1180	3.82	68	22	41
CALM: ONE KNOT, ONE INCH GAP										
23	1.0	6	1.0	20	40	1000	2.71	153	42	55
SUNDEX, CALM, HALF-INCH GAP, NORMAL DRAFT, ONE KNOT										
25	1.0	6	0.5	20	30	1000	3.85	127	49	—
26	1.0	6	0.5	30	40	1000	4.49	161	72	64

*Variable throughout test

Table 3.12 Summary of Results for COV-400 Testing at Ohmsett.

Summary of Findings:

The COV-400 proved to successfully recover spilled oil under a variety of wave and tow speed conditions. In general, higher ORR and TE values were obtained with a forward and aft drum speed of 25 rpm and 38 rpm respectively, a gap setting of ½ in, a system draft of 6 ft, and a weir depth setting of 5 in below the water. Recovery values were better for the heavier Sundex 8600 oil than the lighter Hydrocal 300 oil. The optimum speed of advance was 1.0 kt. Oil emulsification caused by fluid sprayed from the drums reduced the system's ORE, especially in waves.

Final Report Reference:

Nash, J. and S. Cunneff, 1997. OHMSETT TESTING OF THE PROTOTYPE COV-400 SKIMMER. Minerals Management Service Contract No. 14-35-0001-30544. Prepared by MAR, Incorporated, OHMSETT Facility, NWS Earle, Leonardo, NJ 07737.

Test Title: **HIGH SPEED SKIMMER TESTS at OHMSETT**

Test Date: **October 7, 1996 - November 1, 1996**

MMS/Ohmsett Work Order #: **24**

Background and Objective:

Between October 7, 1996 and November 1, 1996 four skimmers were tested at Ohmsett, each as part of an in-line skimmer system that showed potential to recover oil effectively at tow speeds above 3 kts. The term "in-line" indicates that the skimmers were attached to the end of an oil-sweeping boom in place of the boom apex. The skimmers that were tested under this Work Order were:

1. The **Marco VOSS 19 Skimmer**, which pulls spilled oil up a rotating belt;
2. The **JBF Dynamic Inclined Plane 3003 Skimmer**, which guides oil down under water using a rotating belt and then allows the oil to rise in a collection well;
3. The **Lori Brush Pack** (mounted in a prototype catamaran hull), which pulls oil from the water surface using rotating brushes; and
4. The **Webster Barnes Hydrodynamic Induction Bow Skimmer, HIB 20**, which uses the forward momentum of the skimmer to force oil down a stationary inclined plane and over a hydrofoil leading to a collection well.

The primary objective of this Work Order was to provide the USCG Evaluation Team (CGET) with measurements of the following skimmer performance parameters, which are defined below.

1. Maximum Effective Recovery Speed.
2. Skimmer Oil/Emulsion Recovery Efficiency and Oil/Emulsion Recovery Rates in waves.
3. Skimmer Oil/Emulsion Recovery Efficiency for all test runs.

Maximum Effective Recovery Speed (MERS) is the fastest speed of advance at which the system maintains an Oil Recovery Efficiency (ORE) or an Emulsion Recovery Efficiency (ERE) of 50% or greater.

Oil Recovery Efficiency (ORE) is the ratio of the volume of oil recovered to the volume of fluid recovered.

Oil Recovery Rate (ORR) is the amount of oil recovered per unit of time.

Emulsion Recovery Efficiency (ERE) and **Emulsion Recovery Rate (ERR)** are calculated in the same manner as ORE and ORR with an added term to account for the emulsion; in each case, the volume of oil recovered is divided by the percent of oil in the original emulsion.

Description of Test Procedures:

Four test oils were used during the recovery test: Hydrocal 300, North Sea crude oil, diesel fuel, and an emulsion made with Sundex 8600 oil. An emulsion is a stable mixture of oil and water which often forms in time when oil spills onto water. The test emulsion was made by circulating Sundex 8600 oil with water until the mixture became stable.

The basic test setup for the High Speed Skimmer Test is shown in **Figure 3.46** (next page).

Three setup variations were used during testing. Setup 1 used a direct connection of the oil sweep boom arms to the skimmer. An indirect connection via adapter boom arms was used for Setup 2. There was no sweep boom present for Setup 3.

Inclinometers were mounted on the skimmer to measure pitch and roll, and load cells were mounted on the towing arms to measure towing force. Voltage signals produced by the load cells and inclinometers were converted to engineering units and recorded on the Ohmsett data collection computer in the control room.

The Ohmsett Main and Auxiliary Bridges are mounted on rails and can be moved through the tank basin at varying speeds to tow the test systems. Before towing began, oil was pre-loaded from the Main Bridge into the boom opening. For some tests, oil was continuously added into the boom throughout the tow test. Video monitoring of the test (above and below water) and data collection from the various sensor suites was done from the Control Tower. The underwater video camera was used to identify oil loss from the booms.

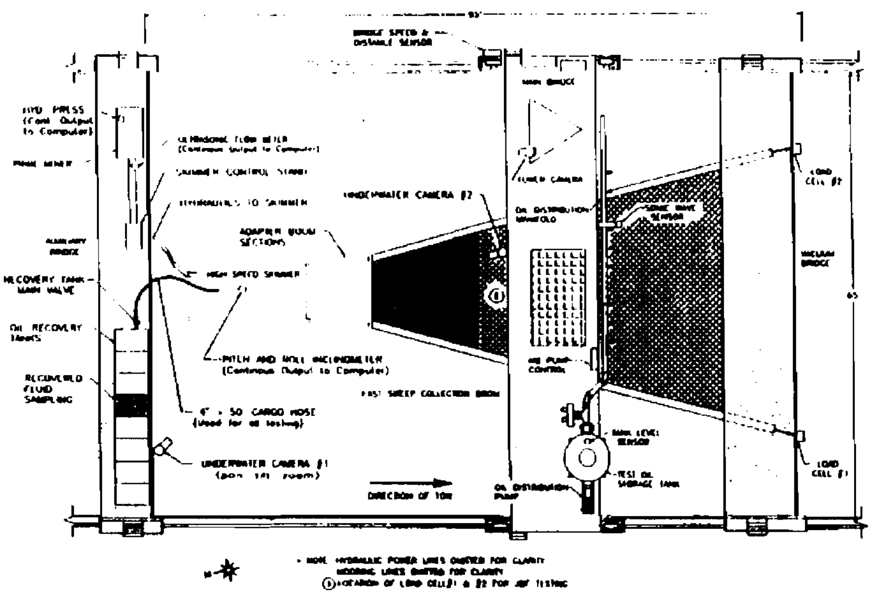


Figure 3.46 Test Setup for High Speed Skimmer System Performance Evaluation.

For testing that involves waves, Ohmsett waves are generated using a reciprocating paddle located at the far end of the Ohmsett tank. There is a perforated metal wave absorber at the opposite tank end from the reciprocating paddle. The wave absorber is elevated (activated) when the test tank is simulating sinusoidal wave action, and lowered when a "confused sea" or a harbor chop is being simulated.

The number of tests performed with each skimmer was based on its ability to achieve 50% ORE while recovering emulsified oil in calm water conditions and a minimum tow speed of 3 kts. If a skimmer failed to achieve 50% emulsion efficiency at 3 kts, no further testing was planned; all skimmers passed this phase. The next test phase investigated the maximum tow speed at which 50% oil recovery could be achieved, i.e., the Maximum Effective Recovery Speed (MERS). During the following test phase the skimmers were towed from three kts to their MERS under the following conditions: (1) a 16 in harbor chop while collecting emulsion; (2) calm water while collecting Hydrocal 300 oil; and (3) harbor chop while collecting Hydrocal 300 oil.

During oil recovery testing, oil was distributed in front of the skimmer during acceleration and while at the maximum tow speed of each test run. The width of the oil slick resulting from the oil distribution was kept small enough to present the skimmer with a 100% encounter rate, i.e., no oil was lost outside of the sweep before it reached the skimmer intake.

Summary of Results:

All four skimmers were able to achieve an ORE of greater than 50% while recovering emulsified oil in calm water and tow speeds of 3 kts or greater. The JBF and the HIB systems each had a MERS of 5 kts, while the Marco and Lori Skimmer systems had MERS of 4 kts.

Results for all tests are contained in the MAR report. Sample results are included in **Table 3.13**. The highest Recovery Rate (Oil/Emulsion) of all the tests was 325 gpm by the Webster Barnes HIB Skimming System; this was achieved in calm water at a tow speed of 3 kts. In general, the Webster Barnes HIB Skimming System had the highest Recovery Rates followed by the Marco VOSS 19 Skimming System, which achieved a 281 gpm Recovery Rate at 3.5 kts in calm water. The Recovery Rate for the Marco VOSS 19 Skimming System varied greatly between tests with a high of 281 gpm and a low of 16 gpm. The Recovery Rates for the JBF Dynamic Inclined Plane 3003 ranged from 158 gpm to 24 gpm, and the Lori Brush System Recovery Rates ranged from 40 gpm to 4 gpm. All systems tested had a trend of lower recovery values in waves. The recovery values for the emulsion versus the Hydrocal 300 oil were mixed with a general trend of higher recovery for the emulsion, except for the Lori Brush System, which had a severely reduced recovery values when recovering the Hydrocal 300 oil (lighter viscosity) versus the emulsion.

Test #	Device	Speed (kts)	Duration[1] (min)	Wave Height (in)[2]	Dist Vol[3] (gal)	Encounter Rate[4] (gpm)	%RE[5]	%TE[6]	RR[7] (gpm)[2]
1	Marco	3	0.82	calm	500	610	100	24.2	147
4	Marco	3	0.83	calm	280	337	77.6	51.5	174
5	Marco	4	0.36	calm	260	722	51.6	20.1	145
9	Marco	3	0.68	13	263	387	48	16.5	64
11	Marco	3.5	0.35	calm	260	743	46.6	37.8	281
20	JBF	3	0.89	calm	300	337	90	29	98
21	JBF	3	1.01	calm	300	297	85	53	158
23	JBF	4	0.79	calm	266	337	87	43.5	147
27	JBF	3	0.93	16.25	257	276	80	29.6	82
41	JBF	5	0.59	calm	200	339	100	23.1	78
46	Lori	3	1.07	calm	257	240	70.8	16.8	40
47	Lori	4	0.83	calm	183	220	57.5	11	24
53	Lori	4	0.85	16.1	190	224	0	2.9	6
63	HIB	3	1.06	calm	318	300	97	78.8	236
66	HIB	3.5	0.94	calm	283	301	126	26.7	80
75	HIB	3	1.11	15.7	319	287	82.9	22.8	65
81	HIB	3	1.13	calm	366	324	81.1	33.5	325
88	HIB	5	0.59	calm	166	281	98.6	32.6	92

[1]The time in minutes that the skimmer is encountering the distributed slick
[2]Average of the highest one third waves measured during the 3½-minute data period
[3]the volume of oil (or emulsion) distributed
[4]Calculated as D-Vol/Duration
[5]Recovery Efficiency (RE) is a measure of the ability of a skimming device to recover oil (or emulsion) only
[6]Throughput Efficiency (TE) is a measure of the effectiveness of the skimming device to collect the volume of oil.
[7]Recovery Rate (RR) is the rate at which the skimmer collects/recovers oil (or emulsion).

Table 3.13 Sample Results for High Speed Skimmer Tests

Summary of Findings:

It is apparent that the current models of skimmers can significantly increase the rate at which oil can be efficiently recovered. Recovery Efficiency usually exceeded 50% if the results were obtained while the test systems were being towed at 3 kts or more .

Final Report Reference:

Draft Report for the HIGH SPEED SKIMMER TESTS AT OHMSETT. Report Date November 27, 1996. Minerals Management Service, Contract No. 14-35-0001 (Work Order No. 024) and Contract No. 1435-01-96-CT-30815 (Work Order No. 01). Prepared by MAR Incorporated, 6110 Executive Boulevard, Suite 410, Rockville, MD 20852.

Test Title: **Testing of the JUNIPER CLASS SPILLED OIL TRANSFER SYSTEM at Ohmsett**
Test Date: **March 30, 1997 to April 4, 1997**
MMS/OHMSETT Work Order #: **02**

Background and Objective:

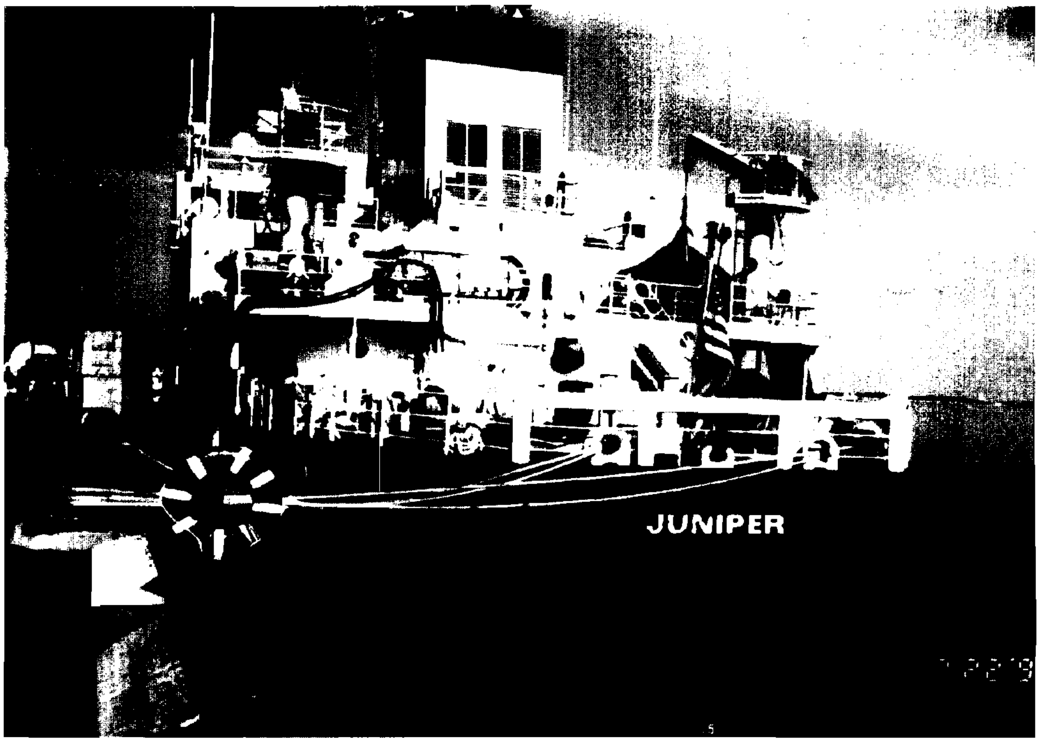


Figure 3.47 Photograph of the CGC JUNIPER

In January 1996 the Coast guard Cutter JUNIPER was commissioned as the first of a new class of seagoing buoy tenders for the USCG. The 225-foot vessel is equipped with a spilled oil recovery system (SORS).

This Work Order was designed to test the Desmi DOP-250 off-loading pump, which is a component of the SORS package. The Desmi DOP-250 pump and accompanying 10" fluid transfer piping are used to transfer oil from the JUNIPER'S onboard oil storage tank to another vessel or shore side storage tank.

The objective of this test was to evaluate: (1) the self-priming capabilities of the off-loading system under conditions similar to those on the JUNIPER; and (2) the pump rate limits for off-loading viscous oil when the oil level is below the intake level of the pump.

The Desmi DOP-250 is a hydraulic powered progressive cavity screw pump with a maximum pumping capacity rating of 440 gpm when powered by a 60 HP diesel hydraulic power pack. The JUNIPER off-load piping (through which the DOP-250 transfers oil) includes a 10-inch suction line that pivots at the inlet connection. The fluid level distance from the pump inlet ranges from 4 feet above the pump inlet when the tank is full to 19 feet below the pump inlet when the tank is empty. The piping from the storage tank to the inlet of the DOP-250 pump includes 19 feet of 10-inch pipe, a swivel connection, 3 flanged 90^0 elbows, and a 10-in to 6-in concentric reducer at the pump inlet. The pump discharge has a 6-in to 10-in adapter to match the off-load piping on the JUNIPER.

Description of Test Procedures:

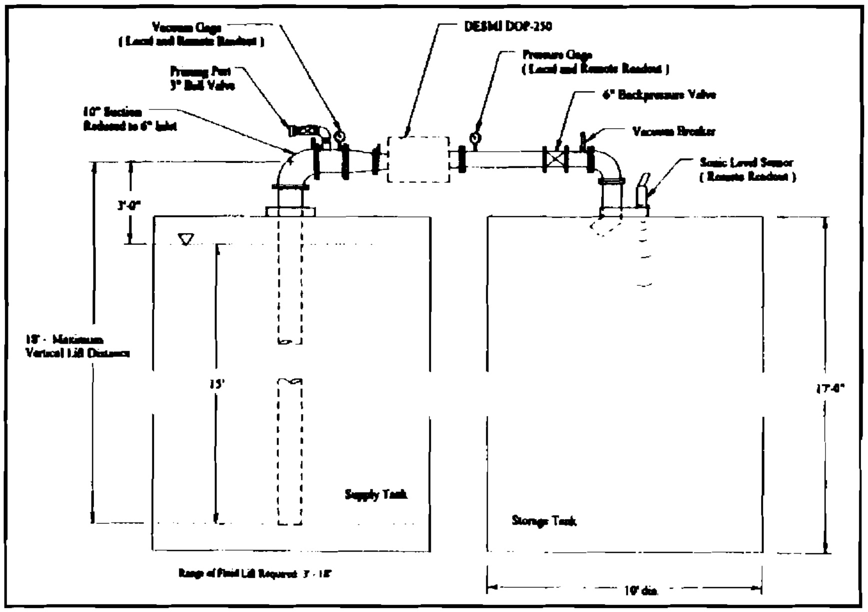


Figure 3.48 Test Setup for USCG JUNIPER Class Spilled Oil Transfer System.

The test platform at Ohmsett was designed to be similar to the oil storage tank and the transfer piping system on the JUNIPER. Notable differences included:

- Pump testing was done only for oil levels below the DOP-250 pump inlet; i.e., the oil level in relation to the pump intake ranged from 3 ft to 17.8 ft below the DOP-250 pump intake;
- One 90° elbow was used for testing rather than the three 90° elbows on the Juniper; and
- The outlet on the test pipe was 6-in rather than 10 inches in diameter, and it was terminated in a storage tank approximately 10 ft from the pump. To compensate for the shorter discharge pipe on the test platform, a vacuum breaker and a 6-in back- pressure valve were connected inline on the discharge end to provide a regulated pressure head.

Sundex 8600 oil was used throughout the entire test. This oil has a viscosity of ~ 20,000 cSt at 75° F, a specific gravity of ~ 0.95, and an interfacial tension of ~ 31 dyne/cm. Approximately 9,000 gal of oil were used for pumping during the entire test sequence; this oil was re-circulated as needed.

The DOP-250 pumping pressure and pumping rate were measured using vacuum gauges and fluid level sensors. The temperature of the oil being pumped was continuously monitored because oil viscosity changes as oil temperature changes. Hydraulic power data were obtained directly from readouts on the hydraulic prime mover.

Each test began with the Sundex 8600 oil in the test tank. To prevent pump seal burnout, water was injected into the DOP-250 pump prior to rotating the pump and during the initial test period when the pump was attempting to self prime. Once oil flow from the source tank was initiated, pumping continued until the source tank was empty, or until pump cavitation occurred. The hydraulic power supplied to the DOP-250 during testing remained constant unless otherwise noted in the data results.

Summary of Results:

A total of six test runs were completed. The various test parameters for each run are shown in **Table 3.14** (next page).

Test No.	Vertical Lift		Prime Mover		Average Oil Temperature (°F)	Average Oil Viscosity (cSt)
	Initial (ft)	Final (ft)	Hydraulic Pressure (psi)	Hydraulic Flow (gpm)		
1	3.8	12.8	2500	50	84	13,000
2	12.74	17.8	3000	22	66	46,000
3	15.25	17.8	3000	38	67	45,000
4	4	17.8	3000	38	71	30,000
5	6.3	17.8	3000	39	77	20,000
6	4.2	17.8	3100	49	74	25,000

Table 3.14 Test Parameters for CGC JUNIPER DOP-250 Pump Test

Pumping limitations of the JUNIPER oil transfer system were identified for various conditions during this evaluation. In Test #1, it was demonstrated that a pump rate of 470 gpm was achievable but cannot be sustained beyond 12-13 ft of vertical lift required when pumping 13, 000 cSt oil. Test # 1 was terminated at that time because of suspected pump cavitation and excessive vibrations of the discharge pipe.

Tests # 2 and # 3 demonstrated that the Desmi DOP-250 pump is capable of self priming with constant addition of water to the inlet side of the pump and fluid levels 15.25 ft below the pump inlet. Given similar hydraulic power delivered to the pump, Test # 3 illustrated that pump rates are significantly reduced when transferring 46,000 cSt oil, when compared to 20,000 cSt oil pumped during Test # 5. Tests # 4, # 5, and # 6 indicated that flow losses and net positive suction head available at 12 to 14 ft vertical lift, begin to significantly reduce pumping rates.

Of all tests performed, Test # 4 appeared to characterize the limitations of the simulated transfer system best. The pump rate initially was 350 gpm and decreased to approximately 0 gpm. The end conditions required 17.8 ft vertical lift while pumping 30,000 cSt oil. When the source tank was nearly empty, a vortex was formed at the suction pipe approximately six ft in diameter and below the normal test fluid surface. Test # 5 was performed with the same hydraulic power delivered to the pump as in Test # 4. The difference in test parameters was the lower average viscosity of 20,000 cSt for Test # 5. Test # 5 pump rates were higher and did not diminish as in Test # 4. Test # 6 was run with the maximum hydraulic power available from the prime mover, 3100 psi and 49 gpm. The average pump rate attainable was 400 gpm while pumping 25, 000 cSt oil. A loss in pump rate did not occur until the fluid level dropped to 13-14 ft vertical lift required.

Test oil was observed leaking at various locations on the Desmi DOP-250 pump throughout all of the test performed. The amount of test oil which leaked from the pump during all tests performed was approximately one quart. Oil leaks were detected at seams between the suction housing and pump, at the center bolt for the stator blades, from casing seams around the stator blade housing and from bolt threads in the stator housing. The pump used in this evaluation was similar but not identical to the JUNIPER transfer pump, due to improved sealing specifications.

Initiating flow for all tests performed did require wetting of the pump rotor and stator. The Desmi DOP-250 pump was in new condition, therefore negating any vacuum capability loss due to wear. The maximum "dry" achievable vacuum was observed to be 12 in-Hg. The maximum inlet vacuum recorded occurred during Test # 2, was 26 in-Hg. Controlled discharge pressures were less than the 40 psig desired due to a hammering condition which occurred at the back pressure valve.

Summary of Findings:

- The test results showed that the DOP-250 pump is capable of self priming with oil levels up to 15.25 ft beneath the pump intake. Injection of water into the pump intake is necessary during self priming.
- The maximum "dry" achievable vacuum is 12 in-Hg.
- A pumping rate of 470 gpm was achievable but could not be sustained beyond 12 ft to 13 ft of vertical lift when pumping 13000 cSt oil.
- Pumping rates are significantly reduced when pumping 46,000 cSt oil in lieu of 20,000 cSt oil.
- The DOP-250 pumping rate is relatively constant for vertical lifts of up to 3 ft to 12 ft-14 ft. After 12 ft-14 ft of vertical lift, the pumping rate decreases significantly.
- When the Desmi DOP-250 pump was operated at maximum pressure, the average pumping rate was 400 gpm while pumping 25,000 cSt oil.
- During Test # 4 a vortex ~ 6 ft in diameter occurred when the tank was nearly empty and the oil viscosity was ~ 30,000 cSt. The existence of the vortex appeared to significantly reduce the pumping rate. A vortex did not reduce the pumping rate during Test # 5, which had similar conditions except the oil viscosity was 20,000 cSt.
- Test oil was observed leaking at various locations on the Desmi DOP-250 pump throughout all of the tests performed; a total of approximately one quart of oil leaked from the pump during all tests.
- Overheating and heavy pump vibrations were also experienced during the tests.

Final Report Reference:

MAR, Incorporated, 1997. TESTING OF THE JUNIPER CLASS SPILLED OIL TRANSFER SYSTEM AT OHMSETT. Prepared under Minerals Management Service Contract 1435-01-96-CT-30815, MAR, Inc., P.O. Box 473, Atlantic Highlands, NJ, 07716, 27 pp. + app.

Test Title: **Ohmsett Testing of RAPID CURRENT BOOMS Developed by the UNIVERSITY of NEW HAMPSHIRE**
Test Date: **July 13, 1997 to July 16, 1997**
MMS/OHMSETT WORK ORDER #: **03**

Background and Objective:

In 1996, the University of New Hampshire (UNH) Ocean Engineering Division began a project to develop a new flexible oil barrier that could collect and retain oil in currents at speeds at least twice that of a conventional boom. This project was a continuation of prior research expanding on a two-dimensional oil flume tank study done at UNH. The flume tank employed an inclined plane to concentrate and guide oil toward a collection area immediately downcurrent of the inclined plane (**Figure 3.49**). During the UNH flume tank research, an in-

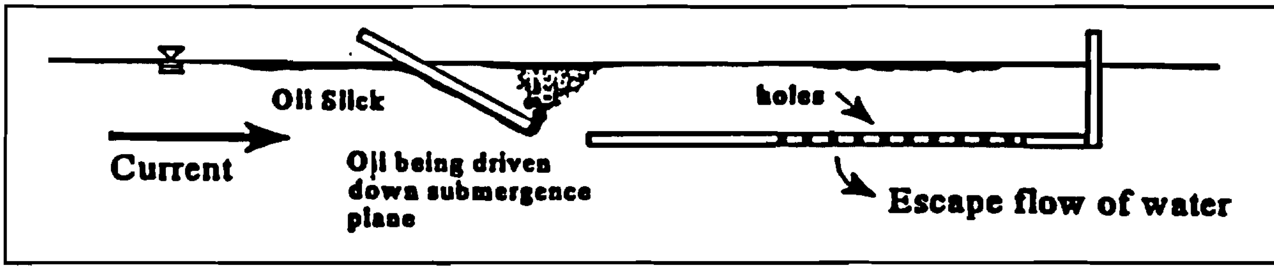


Figure 3.49 Cross-section of the Submergence Plane Barrier.

clined plane was oriented like the "reverse inclined plane" system used by some oil recovery skimmers. The inclined plane leading end was above the water surface and angled down below the water surface. As water in the flume tank moved past the system, oil was forced down the inclined plane where the oil was concentrated and transported by water current forces to a collection area where buoyant forces caused the oil to rise to the surface. Water could escape from vents located at the bottom of the collection area.

Figure 3.50 Photograph of Rapid Current Containment Boom at Ohmsett.

UNH used this research, and subsequent research done in the UNH Jere Chase Ocean Engineering Laboratory tow tank, to develop a full-scale, flexible, high-speed oil collection barrier for testing at Ohmsett (**Figure 3.50**). Two test series were undertaken at Ohmsett. Phase 2 employed lessons learned from Phase 1 to redesign and rebuild some of the system components. This document is a summary of the Ohmsett Testing of the Phase 2 Rapid Current Containment Boom System.

The primary objective of the Ohmsett Test was to measure and record the Throughput Efficiency (TE) of the UNH "Prototype" Rapid Current Containment Boom System. TE is defined as the ratio of the amount of oil retained by the system to the amount of oil encountered by the system.

The innovative "Prototype" Rapid Current Containment Boom System uses conventional boom components such as flexible fabric, flotation members and wire/chain tension members for construction. At the forward end of the system, a floating cross-baffle floats on the water surface. This baffle is connected to the leading edge of flexible fabric submergence plane, which guides oil beneath the water surface then allows the oil to rise to the surface in the collection area of the system. Horizontal baffles aft of the cross baffle are used to dampen wave action. The collection area of the system (aft end) forms a catenary shape during towing. The collection area has vents beneath the water surface to allow water to escape. The aft end of the collection area consists of a double flotation boom.

Description of Test Procedures:

At the start of each oil recovery test, the Main Bridge oil distribution pump was started in the circulation mode and brought up to maximum pump rate. The Ohmsett Main and Auxiliary Bridges are mounted on rails and can be moved through the tank basin at varying speeds to tow the test system. The Rapid Current Containment Boom tow speed was accelerated to 1 kt and then oil distribution into the collection system began. No mention of the oil distribution rate was given in the UNH report. Towing and oil distribution continued for the length of the test tank; towing acceleration stopped when the system reached the estimated maximum tow speed. Oil retained by the system during the test run was pumped directly to the recovery tanks on the auxiliary bridge for volume analysis. Two test oils were used during the recovery test: Hydrocal 300 (light) and Sundex 8600 (heavy).

The Hydrocal 300 oil had a viscosity of ~190 cSt at 20^0 C., and the Sundex 8600 oil had a viscosity of ~ 20,000 cSt at 20^0 C. Two of the ten tests involved waves with a height of ~ 0.5 ft, a length of ~ 32 ft, and period of 2.61 sec.

Summary of Results:

The TE values for the Sundex 8600 oil ranged from 69.95% to 98.94%, and the TE values for the Hydrocal 300 oil ranged from and 40.16% to 78.34% (**Table 3.15**). Tow speeds up to 2 kts were used during the oil recovery tests. High speed hydrodynamic tests showed that the aft barrier of the system lost freeboard at 2.4 kts (Critical Tow Speed), allowing contained fluid to wash out.

Test Number	Oil Type	Tow Speed (kts)	Waves	Retention (%)
1	Hydrocal	1	No	64.31
2	Hydrocal	1.5	No	78.34
3	Hydrocal	2	No	77.05
4	Hydrocal	1.5	Yes[1]	40.16
5	Sundex	1	No	69.95
6	Sundex	1.5	No	97.72
7	Sundex	2	No	98.94
8[2]	Sundex	2.5	No	
9[3]	None	2.5	No	
10	Sundex	1.5	Yes[1]	88.14

[1]Wave length = 32 ft, Wave height = 0.5 ft, Wave Period = 2.61 sec

[2]Test number 8 was a high speed test which was aborted.

[3]Test number 9 was a high speed hydrodynamic test.

Table 3.15 UNH Rapid Current Boom Performance Testing Results.

According to sources from UNH, visual observations during the Hydrocal 300 oil tests indicated that more oil was being retained than the test results showed. The UNH report went on to say that there may have been a sampling error when measuring the recovered oil/water mixture in the Ohmsett tanks, and that a "sampling error could explain the apparent contradiction between visual observation and measured results."

Summary of Findings:

The UNH Rapid Current Containment Boom System can collect and retain a significant amount of oil (up to 98.94%) at tow speeds as high as 2 knots. It may be possible for this system to collect and retain oil at higher speeds if additional reserve buoyancy were added to the aft barrier of the system.

Final Report Reference:

Swift, R., B. Celikkol, R. Steen, M. Ozyalvac, and D. Michelin, 1997. DEVELOPMENT OF A RAPID CURRENT CONTAINMENT BOOM, PHASE III, TECHNICAL REPORT, Jere Chase Ocean Engineering Center. University of New Hampshire, Durham, NH, 03824, 78 pp.

Test Title: **Testing of the UNIVERSITY of MIAMI OIL BOOM ENTRAINMENT INHIBITOR SYSTEM (EIS) at Ohmsett**
Test Date: **June 23, 1997 to June 27, 1997**
MMS/OHMSETT Work Order #: **05**

Background and Objective:

Figure 3.51 University of Miami Test Setup in the Tank Basin.

When towed at speeds greater than one knot, conventional oil containment booms have difficulty containing oil. When tow speed exceeds the oil entrainment speed, oil escapes under the boom. The University of Miami (UM) has developed an Entrainment Inhibitor System (EIS) net which increases the tow speed at which entrainment initially occurs (first loss tow speed). The objective of these tests was to confirm that the EIS nets increase boom performance.

The EIS is a system of netting 50 ft in length, and its middle portion attached to the apex of a boom. The system is 6 ft wide and has a draft of 36 in. The EIS net system also contains fiberglass poles, PVC piping, buoyancy floats and lead weights to ensure that the system maintains the desired shape to allow the attached boom to contain oil while in a current.

Slickbar, Inc., provided the University of Miami with a specially modified MKE 12-36 Ocean Boom to use at Ohmsett for testing the EIS **(Figure 3.51)**. The boom is a 60-ft conventional oil boom constructed with a urethane fabric. Each buoyancy chamber has a solid cylindrical closed cell foam core, 12 in x 48 in long. Three-eighths inch galvanized chain provides the ballast. Half-inch grommets placed every six inches at the bottom of the boom's skirt and just below the water's surface were added for attaching the EIS. MAR, Inc., prepared a separate report detailing the performance of the Slickbar Incorporated MKE 12-36 Boom and provided it to Slickbar, Inc.

The EIS nets prototype was researched and developed by Dr. K. Vincent Wong from the University of Miami. Minerals Management Service sponsored the tests for the University of Miami.

Description of Test Procedures:

Figure 3.52 shows details of the Ohmsett Test Basin setup for these tests.

Testing of the oil boom was performed with and without the EIS nets to determine whether the EIS nets increased the First Loss Tow Speed. Tests used Hydrocal 300 oil and were conducted in both calm water conditions and waves. The 60-foot boom was rigged with a mouth opening of 30 ft, giving a boom length-to-gap ratio of 2:1. The oil pre-load hose provided oil directly to the boom apex. A wave generator created a regular sinusoidal wave with a significant wave height of 7 in., a wavelength of 39 ft and an apparent period of 3 sec. Wave dampening beaches at the end of the tank were employed.

First Loss Tow Speed tests were conducted using an increasing pre-load oil volume to determine the lowest speed at which oil droplets continuously shed from the boom. Test personnel determine oil loss tow speed

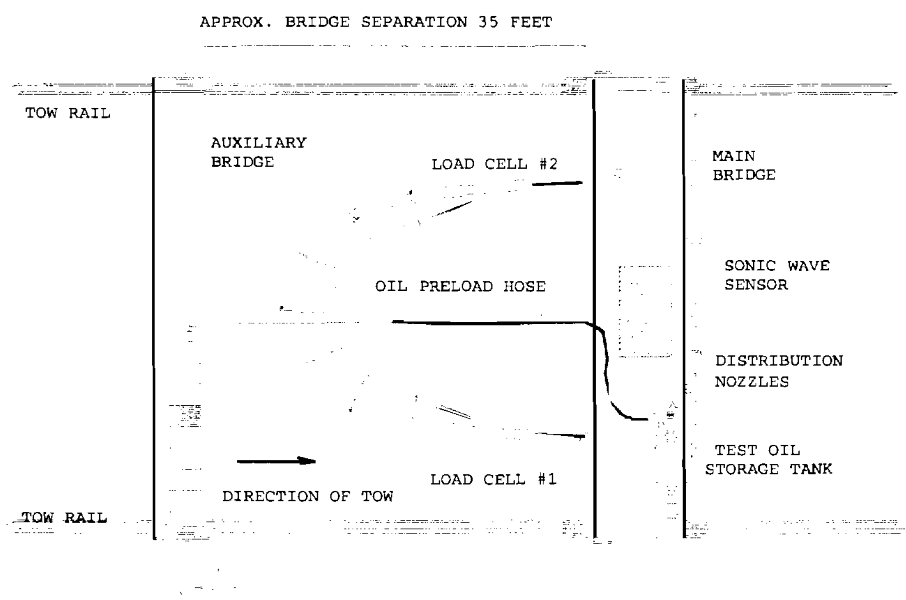


Figure 3.52 General Test Basin Setup for the University of Miami.

visually through an underwater camera suspended from the Auxiliary Bridge. Tests were conducted with and without the EIS attached to the boom.

Two in-line load cells attached between the tow bridle and the Main Bridge tow points were used to measure the tension forces in each of the boom tow lines continuously. Data were recorded on the Ohmsett data collection computer for post-test analysis. Tow Forces analysis was performed to determine whether there was a significant increase or decrease in towline tension. The analysis evaluated the average drag force for intervals of 15 sec or greater during which the bridge was advancing at a nominal constant speed of 0.8 kts in calm water.

Summary of Results: Test results for the First and Gross Tow Speed Tests are provided in **Table 3.16.** In calm water, the boom with EIS nets exhibited a First Loss Tow Speed of 1.2 kts for pre-loads of 400 and 500 gal and an average of 1.23 kts for 200-and 300 gal pre-loads (**Table 3.16**). Without the nets, the average First Loss Tow Speed was 0.83 kts for 200-and 300 gal pre-loads in calm conditions. Use of nets also increased the volume of oil that the boom could contain. Difficulty in retaining a volume of oil in excess of 400 gal within the boom without using EIS net caused the cancellation of 400-and 500-gal pre-load tests of the boom without the EIS nets. Time limitations reduced the number of tests of the boom in wave conditions. Accordingly, it is not possible to determine if the First and Gross Loss Tow Speeds are improved by the EIS when the boom is towed through waves.

	With EIS Nets			Without EIS Nets			
Test #	**Wave Condition**	**1st Loss (knots)**	**Pre-load (gal)**	**Test**	**#Wave Condition**	**1st Loss (knots)**	**Pre-load (gal)**
1	Calm	1.2	240	12	Calm	0.95	200
2	Calm	1.3	225	13	Calm	0.8	200
3	Calm	1.3	340	14	Calm	0.85	300
4	Calm	1.3	300	15	Calm	0.75	300
5	Calm	1.2	400	16	Calm	0.8	400
6	Calm	1.2	400				
7	Calm	1.2	500				
8	Calm	1.15	500				
9	Waves*	0.8	500				
10	Waves*	0.9	425	17	Waves*	0.7	350
11	Waves*	0.8	425	18	Waves*	0.8	350

*Waves Generator set to have a 3-inch stroke with 20 Cycles per minute; beaches raised

Table 3.16 Data Comparison of First Oil Loss Tow Speed With and Without the EIS nets.

Tow Force test results are provided in **Table 3.17**. The tow line force analysis indicates that there is no significant increase in drag force attributed to the EIS net system.

With EIS Nets		Without EIS Nets	
Test #	Tow Line Force (lbs)	Test #	Tow Line Force (lbs)
3	193	12	162
6	161	13	180
8	162	14	159

Table 3.17 Tow Line Force Analysis, Calm Water, Tow Speed of ~0.8 Knots

Summary of Findings:

In calm water conditions, the EIS nets increased the First Loss Tow Speed 62.5% for the boom tested. The maximum First Loss Tow Speed was 1.3 kts. A limited amount of data in wave conditions precludes a similar analysis.

Use of the EIS nets in calm water at a constant speed did not change drag force significantly as determined during the post-test evaluation. Recommendations for future tests and evaluations include different viscosity oils, and additional Oil Loss Speed Tests, and Oil Loss Rates Tests, with and without waves.

Final Report References:

Coyne, P.M., 1997. TESTING OF THE UNIVERSITY OF MIAMI OIL BOOM ENTRAINMENT INHIBITOR SYSTEM (EIS) AT OHMSETT, Draft Report. Contract No. 14-35-01-96-CT-30815. Prepared by MAR, Incorporated, P.O. Box 473, Atlantic Highlands, New Jersey 07716, 12 pp. + app.

Related Publications:

Coyne, P.M., 1997. TESTING SLICKBAR INCORPORATED MKE 12-36 OCEAN OIL BOOM AT OHMSETT, Draft Report. Contract No. 14-35-01-96-CT-30815. Prepared by MAR, Incorporated, P.O. Box 473, Atlantic Highlands, New Jersey 07716, 12 pp. + app.

Test Title: **Providing the Environment to Test an UNDERWATER MULTI-SPECTRAL FLUORESCENCE OIL SPILL SENSOR at Ohmsett**
Test Date: **August 4, 1997 to August 8, 1997**
MMS/OHMSETT Work Order #: **07**

Background and Objective:

Continuous monitoring of the marine environment near marine facilities, vessels or pipelines could lead to the "real-time" detection of oil spills. Early detection of an oil spill could potentially reduce the duration and amount of the spill (Andrews and Lieberman, 1998). The U.S. Naval Command, Control and Ocean Surveillance Center, RDT&E Division has developed an Underwater Multichannel Fluorometer System (UMFS) for long-term underwater deployment to detect oil in the marine environment.

UMFS uses a broad band of ultraviolet (UV) light excitation to illuminate the particles in the water column. UV light causes components of petroleum to fluoresce (Andrews and Lieberman, 1998). The sensor detects reflections (a multi-spectral emission) from the particles. Orienting the sensor to look in the upward direction allows it to detect and measure both dissolved phase and floating hydrocarbons. Processing eliminates false positive interference from non-petroleum-based fluorophores such as chlorophyll, cleaning detergents and sea dye, and distinguishes between several possible petroleum classes.

Because different classes of oils have different emission spectra, fluorescence data can provide information on whether the product detected is light or heavy; fluorescence intensity measurements can quantify concentrations (Andrews and Lieberman, 1998).

Biofouling during long-term deployment is reduced by the UV light, which prevents the build-up of marine life on the UMFS sensor. A 30-day test in San Diego Harbor during a period of high biological activity (June – July) showed the sensor's ability to prevent biofouling. Although the housing and a control window exhibited heavy fouling, the sensor window remained clear (Andrews and Lieberman, 1998).

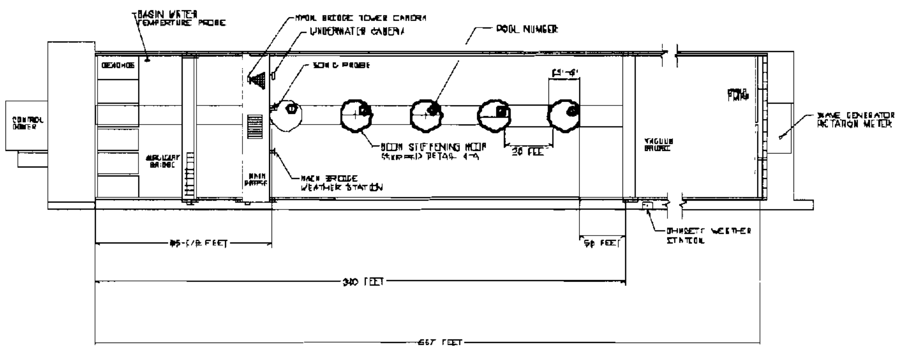
Tests at Ohmsett provided the Navy with the opportunity to test UMFS on five types of oil with different slick thicknesses in calm conditions and in three wave conditions to simulate the conditions that may be encountered in the marine environment. **Table 3.18** lists the oils tested and their properties.

Naval Command, Control and Ocean Surveillance Center, RDT&E Division, sponsored the tests. MAR, Inc., performed the tests at Ohmsett, under the direction and review of Minerals Management Service.

Description of Test Procedures:

Figure 3.53 (next page), shows the configuration of the Ohmsett Basin for the UMFS tests. Five test rings fabricated from a 50 ft length of oil boom, are arranged along the center axis of the tank. Lines connected the northernmost ring to the north (beach) basin wall and the southernmost ring to the vacuum bridge, allowing the Main Bridge to move freely over the containment rings. Shock absorbers between the connecting lines and boom rings allowed adjacent rings to move independently during wave tests.

After the UMFS was positioned within the desired boom ring, the fluorometer system collected background data. Ohmsett personnel obtained a water sample using the water sampling system, which consisted of a pump and hose, with an attached scale for measuring and recording the sampling depth. (Analysis of these samples provided information on background concentrations of oil that could affect the sensors.) The desired volume of the chosen oil type was distributed into a boom ring. After the UMSF sensor reached test depth, Navy and



Ohmsett test personnel collected data. If waves were required, the wave generator was started. Waves varied from calm to harbor chop conditions, where wave heights reached 38 cm (Andrews and Lieberman, 1998).

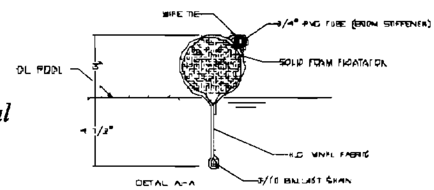


Figure 3.53 US Navy Multi-Spectral Fluorescence Oil Spill Sensor Test Setup.

Test Oil Types	Oil Properties			
	Viscosity (cPs)	Specific Gravity	Interfacial Tension (dynes/cm)	Surface Tension (dynes/cm)
Diesel	4.5	0.864	22.0	31.1
JP-5	3.2	0.803	15.8	28.4
Hydrocal	110.0	0.898	26.9	34.0
Gasoline	2.0	<0.760	11.7	21.6
Diesel/Hydrocal	13.5	0.880	12.0	31.5

Table 3.18 List of the Test Oils and Their Properties Used for the UMFS Tests.

In selected tests where light oils (gasoline, jet fuel and diesel) were used, test samples were monitored for evaporation. Evaporation measurements for light oils were made using a sample of oil in a 50-ml beaker, exposed to conditions similar to the oil in the test rings. The beaker was weighed periodically, and the weight lost by the sample indicated the amount of evaporation.

Water samples were analyzed to determine background concentrations of oil. Testing for oil concentrations is usually conducted using an Infrared Spectrophotometer at a wavelength of 2925 nm. For these tests, an additional measurement was made at a wavelength of 3050 nm (near the UMFS sensor detection threshold) at the request of the Navy.

Waves generated at Ohmsett are usually of two types, a condition that resembles harbor chop and a regular, sinusoidal wave. When testing requires regular, sinusoidal waves, beaches at the northern end of the basin are usually raised to damp reflections. Beaches are lowered when a harbor chop is being generated to add reflected waves to the surface conditions. Wave generation usually starts long enough before testing so that a "steady state" condition is achieved. These tests, however, were unique because beaches were in the lowered position during all wave tests, and testing was performed while the waves were building (before steady state was reached).

Summary of Results:

The sensor detected additions of oil to the test ring, but the magnitude of the response varied due to the inhomogeneous thickness of the oil on the surface (Andrews and Lieberman, 1998). Waves caused the oil to spread more evenly, making the detected signal less variable. Even in harbor-chop type waves, the sensor demonstrated the ability to detect oil (Andrews and Lieberman, 1998).

Summary of Findings:

The multispectral fluorometric sensor was able to detect diesel fuels, lube oils and jet fuels in tests. Waves did not prevent the sensor from detecting oil and caused the signal to be more stable. Uneven slicks in calm water may require several sensors to achieve an average signal (Andrews and Lieberman, 1998).

UV light was able to prevent biofouling of the sensor's window (Andrews and Lieberman, 1998).

Final Report References:

Coyne, P.M., 1997. PROVIDING THE ENVIRONMENT TO TEST AN UNDERWATER MULTI-SPECTRAL FLUORESCENCE OIL SPILL SENSOR AT OHMSETT. Minerals Management Service Contract No. 14-35-01-96-CT-30815. Prepared by MAR, Incorporated, P.O. Box 473, Atlantic Highlands, NJ 07716, 11 pp.

Related Publications:

Andrews, J.M. and S.H. Lieberman, 1998. Multispectral Fluorometric Sensor for Real Time In-situ Detection of Marine Petroleum Spills, in "Oil and Hydrocarbon Spills, Modeling Analysis and Control." R. Garcia-Martinez and C.A. Brebbia, eds. Computational Mechanics Publications, Southampton, UK, pp. 291-301.

Test Title: **UNIVERSITY of RHODE ISLAND Large Scale Investigation of the OIL/WATER INTERFACE USING a RIGID PLANAR BARRIER at Ohmsett**
Test Dates: **August 1997, May 1998 and September 1998**
MMS/OHMSETT Work Order #: **04 and 20**

Background and Objective:

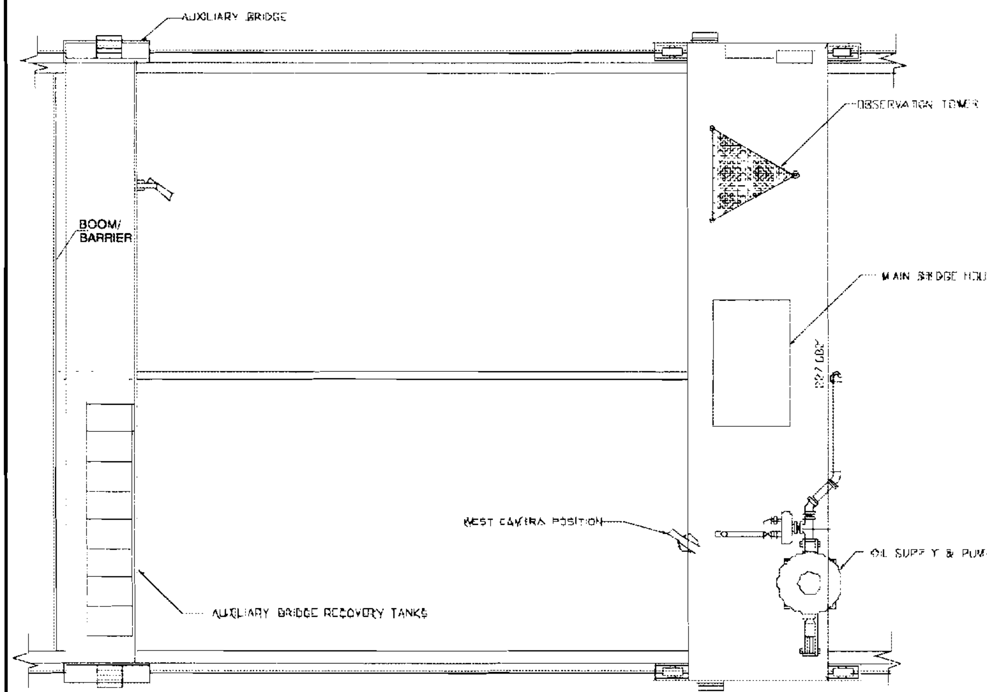


Figure 3.54. Test Setup for the University of Rhode Island.

Conventional oil booms (vertical planar barriers) are widely used for oil spill containment. They can be positioned as a vertical barrier to receive and hold oil (e.g., carried by a current) or towed to collect and contain oil. When towed, booms assume a catenary shape. A computer model developed at the University of Rhode Island (URI) simulates the dynamics of oil spill containment with a vertical barrier. This model can vary oil spill parameters such as oil and water density, viscosity, surface tension, and barrier velocity. To calibrate the model for all oil spill recovery booms, test data are needed from an oil spill containment simulation using a catenary boom as well as a vertical barrier. Such tests were conducted at the Ohmsett facility in August 1997, May 1998, and September 1998 to provide information to calibrate the model.

The experiments were designed to investigate the relationship between slick length in front of the boom and tow speed (up to the velocity when the oil entrains underneath the boom). The goals included:

- Collecting experimental data for two oils,
- Testing oil booms with different drafts,
- Processing data real time to verify experimental results, and
- Conducting multiple experiments to verify repeatability.

Table 3.19 (next page) lists three booms used in tests conducted at Ohmsett and a fourth boom used in laboratory experiments conducted previously at the University of New Hampshire (UNH).

BOOM #	DRAFT (cm)	FREEBOARD (cm)	LENGTH	COMMENTS
1	15.3		7 sections 2.2 m ea.	Shallow draft (for river deployment); buoyancy floats located at top of boom
2	30.5	30.5 cm	19.8 m (equals width of tank)	Manufactured by Slickbar, Inc.; slides up and down in sliders attached to the Auxiliary Bridge on the test tank; buoyancy floats are attached to both sides of the barrier spaced every 4 feet
3	48.3	15.2 cm	10 sections 1.5 m ea.	Buoyancy floats located at top of boom
4	6.25			Used in UNH tests

Table 3.19 Boom Characteristics

Description of Test Procedures:

Boom draft, oil types, and oil volume wave varied during the tests, as shown in **Table 3.20**.

Test Date	# of Tests	Boom Draft (cm)	Oil Type (gal)	Oil Volume
Aug. 1997	2	30.5	Setup	
	7	30.5	Sundex 8600T	165, 500, 1000
	3	30.5	Hydrocal 300	500
May 1998	3	15.3	Hydrocal 300	40
	4	15.3	Sundex 8600T	40
	3	30.5	Hydrocal 300	40
	4	30.5	Sundex 8600T	40
Sept. 1998	4	48.3	Sundex 8600T	36-46
	3	15.3	Sundex 8600T	36-40
	4	15.3	Hydrocal 300	27-41
	3	48.3	Hydrocal 300	26

Table 3.20 Boom and Oil Parameters for Ohmsett Tests.

In the August 1997 experiments, the 30.5-cm draft boom spanned the entire width of the tank basin (19.8 m). The oil-slick-volume-to-tank-width ratio at UNH is identical to this setup at Ohmsett for a test volume of 165 gallons, allowing comparison of results. Oil volume was varied during these experiments (**Table 3.20**) to test the sensitivity of oil slick behavior as a function of oil volume.

The test area at Ohmsett was modified for the May 1998 experiments to allow the experimental results to be compared with data collected during experiments at UNH. The modifications included adjusting the test area to a width of 6.1 meters by affixing wooden boards to the Auxiliary Bridge. The test boom was clamped to the downstream ends of both boards. A wire grid on the oil region side of both boards and measuring tape on the top of one board allowed the dimensions of the oil slick shape to be determined by an observer on the auxiliary bridge. The May 1998 experiments, using the 15.3 and 30.5-cm draft booms, were designed to provide information on oil slick behavior as a function of boom draft.

For the September 1998 experiments, the desired oil boom shape was a catenary. This catenary shape was achieved by attaching ropes to the ends of the oil booms and then tying them off at a desired length on the Main

Bridge, allowing the booms to take on the desired shape at tow speed. Slick length was measured using a stick extending outward from the apex of the boom and suspended a few inches above the free surface. An observer made two measurements, one at the apex position of the boom and the other at the edge of the oil slick. The difference between measurements was the actual oil slick length.

The test procedures were to:

- Increase bridge speed to 0.2 knots,
- Release measured oil into test region,
- Allow the oil slick to stabilize into its equilibrium shape,
- Incrementally increase bridge speed by 0.05 knots,
- Manually read the slick length at each incremental speed,
- Stop experiment at failure and repeat as necessary.

Oil was distributed from the Auxiliary Bridge through a hose suspended above the water in the test region. An underwater camera and a hand-held camera were used to capture videos of the experiments from various positions.

Each experimental setup was designed to allow comparison of test results, and all experimental results were scaled to be equivalent to $0.0235 m^3/m$ for comparison purposes. This value is the calculated volume per meter width of test area used in the UNH experiments.

Summary of Results:

Tests conducted at Ohmsett in August 1997 were compared to the experiments conducted at UNH with Sundex oil. In three tests, the volume of oil and width of the test region matched the oil volume per unit length for the UNH experiments. Results for the other four Sundex tests (which used different oil volumes) were scaled. Slick length as a function of tow speed was greater for the 30.5-cm draft boom used at Ohmsett than for the 6.25-cm draft boom used at UNH when tow speed exceeded about 0.3 knots.

The August 1997 tests also investigated the relationship of oil properties to oil slick behavior. Two of the Sundex tests used 500 gal of oil, the same volume used in three Hydrocal tests. Sundex is much more viscous than Hydrocal. The higher viscosity oil causes an increase in friction along the oil water interface, resulting in a shorter slick length for an increase in tow speed.

A comparison between August 1997 and May 1998 results showed that oil entrainment occurs earlier in the test results with a shallower draft (15.3-cm) boom than with the deeper draft (30.5-cm) boom. The same relationship is present in the August 1997 and May 1998 experiments with Sundex and UNH experiments with Sundex. As the boom draft decreases, the rate at which the slick length shortens is increased and the velocity at which the oil entrains is reduced.

The September 1998 experiments tested booms in the catenary configuration. To compare these data to previous experiments, the catenary boom was assumed to resemble a flat plate locally around its apex. These results also display a decrease in slick length with an increase in tow speed for a shallower draft boom. Furthermore, the results from the May and September 1998 experiments, which used booms with the same draft, the same type of oil, and similar oil volumes, have a high degree of correlation.

The maximum tow speed at which oil entrained underneath the boom occurred was typically around 0.7 to 0.8 kts for the tested cases.

Summary of Findings:

Comparison of the data collected during the UNH experiments and the August 1997, May 1998, and September 1998 Ohmsett experiments shows a high correlation when proper scaling is applied. These comparisons show that for different draft booms, the slick length should be well correlated at low tow speeds and slowly diverge as the tow speed increases. This divergence is mainly accounted for from the loss in oil due to failure reducing the volume of oil in the slick, which will prematurely shorten the slick length. Higher viscosity oil was found to have decreased slick length for an increase in tow speed. The data collected from Ohmsett will be used for calibrating URI's computer models.

Final Report Reference:

In preparation.

Test Title: **Providing the Environment to INVESTIGATE BENZENE LEVELS ENCOUNTERED at MARINE GASOLINE SPILLS**

Test Date: **August 22, 1997**

MMS/OHMSETT Work Order #: **NONE**

Background and Objective:

Coast Guard Marine Safety personnel work in and around environments with the potential for exposure to products containing benzene. Most small spills investigated by Coast Guard personnel consist of diesel fuel, gasoline or lube oils. Of these, gasoline poses the most significant health risks due to the higher levels of light aromatic hydrocarbons including benzene. Current guidance for respirator use identifies the response posture and the level of protective equipment required for different concentration ranges of benzene, but does not provide guidance on the benzene levels that might be experienced in the field.

The objective of the test was to quantify the levels of benzene vapors that might be encountered by personnel responding to a typical gasoline spill. This test was sponsored by the Minerals Management Service and conducted by Lt. Emile Benard, U.S. Coast Guard, Hazardous Materials Standards Division, USCG Headquarters, Washington, DC.

Description of Test Procedures:

Two shallow-draft containment booms were deployed spanning the width of the tank, one at the wave flap, and one 90 feet from the wave flap. This created a test area approximately 65 feet wide (the width of the tank) and 90 feet long. The Vacuum Bridge spanned the middle of the test area, and the Main Bridge was positioned just north of the contained test area. Both bridges, which were stationary during the test, were used for sampling. Unleaded gasoline was used for the test. Two spill scenarios were used: one with a gasoline slick thickness of 0.007 mm (a typical sheen thickness), and one with a thickness of 0.07 mm (ten times the normal sheen).

Samples were taken for each spill scenario to determine the following:

- Peak exposures and elapsed time for benzene levels to drop to insignificant levels
- Worst case breathing zone 8 hr and 15 minute TWA benzene exposure levels
- Total hydrocarbon content using real-time monitors.
- Levels of other constituents of petroleum products which may be useful as more information becomes available on their toxicity

Secondary goals of the tests included validation of the MSI-301 vapor monitor as an acceptable instrument for determining benzene concentrations in the field, and obtaining data for comparison with benzene measurements made during simulated crude oil spills.

Summary of Results and Findings:

The test series was completed on August 22 , 1997. The Final Report has been completed and is available from Lt. Emile Benard, U.S. Coast Guard, Hazardous Materials Standards Division, USCG Headquarters, Washington, DC.

Test Title: **EVALUATION of PTC ENTERPRISES MEGASorbent at OHMSETT**
Test Date: **September 9-10, 1997**
MMS/OHMSETT Work Order #: **11**

Background and Objective:

Sorbents are materials used in oil spill cleanup operations to remove oil from the surface of the water or from the shore. PTC desired to test MEGASorbent's potential to absorb oil contained within a boom at Ohmsett.

The product description is taken from the manufacturer's literature: "MEGASorbent" is a product processed from a plant that is currently grown in large acreage in South Texas. A hybridized seed of the mallow family has been developed that maximizes the plant's quality and yield per acre of land planted. This highly fibrous plant grows to complete maturity in 5 months or less. Depending on the farming region selected, controlled planting and harvesting can be repeated successfully from 1 to 3 times per year. This renewable resource can be processed for multiple uses that include hydrocarbon and chemical absorbents.

PTC's objectives for MEGASorbent evaluation at Ohmsett were to:

- Have a third-party evaluation of the sorbent in a large-scale controlled marine environment, and
- Record video footage of the test for independent performance validation and potential marketing purposes.

While laboratory tests could determine the minimum sorbent material to recover the maximum oil, the tests conducted at Ohmsett would demonstrate the sorbent's potential to recover oil on a large scale.

Description of Test Procedures:

Four oil containment rings formed from 50-foot sections of boom were deployed in the Test Basin, as shown in. The rings were connected with quarter-inch polyester line; "shock absorbers" were put between the connecting lines and boom rings to isolate each boom ring from the motion of the adjacent boom rings during tests with waves. Five test oils were used in the evaluation: diesel fuel, jet fuel (JP-5), Hydrocal 300, Sundex 8600T, and a mixture of Sundex and Hydrocal. Tests were conducted in calm conditions and in harbor chop conditions.

For each test, the oil and sorbent weights were determined before and after testing. The oil was distributed into a containment ring and allowed to spread to form a relatively uniform slick thickness. The weighed sorbent material was physically deployed and dispersed to cover the entire slick. After a period of time (usually less than 15 minutes) when the sorbent changed color to the color of the oil, the sorbent material was manually retrieved, free water was allowed to drain, and the oil-saturated sorbent was weighed.

Summary of Results:

The recovered sorbent weight was greater than the starting weight of the individual raw materials (oil and sorbent). During testing it was observed that most of the oil had coated the sorbent. The excess saturated sorbent weight is assumed to be the water weight.

Recovery Efficiency, Oil Recovery Efficiency, Water Absorbency and Oil Absorbency were calculated.

Recovery Efficiency (RE) is an indicator that measures what percentage of the fluid absorbed by the sorbent was oil. A high RE suggests a high oil content in the recovered sorbent, while a low RE indicates high water content in the recovered sorbent.

Oil Recovery Efficiency (ORE) is an indicator of the percentage of the spilled oil that was recovered. An ORE of 100% indicates that all of the spilled oil was recovered, whereas an ORE of 0% indicates that none of the oil was recovered.

Water Absorbency (WA) is the ratio of "water uptake" in the used sorbent to the initial weight of the dry sorbent. A low WA means the sorbent did not absorb a significant quantity of water during the test.

Oil Absorbency (OA) is the ratio of "oil uptake" in the used sorbent to the initial weight of the dry sorbent. A high OA means the sorbent absorbed a significant quantity of oil during the evaluation.

Oil Recovery Efficiency in both calm conditions and waves was estimated at 99.9%, indicating that virtually all of the spilled oil was recovered. Recovery Efficiency exceeded 78% in all tests. In the presence of oil and water, MEGASorbent will preferentially absorb oil; when oil is not present, the sorbent will absorb water. Water Absorbency tests were conducted with and without oil. For all tests with oil, Water Absorbency was less than 0.85. In the absence of oil, the Water Absorbency was 1.2. For all tests with oil, Oil Absorbency was greater than 1.6. The lowest Oil Absorbency occurred with low viscosity jet fuel (JP5) and the highest occurred with highly viscous Sundex, suggesting that Oil Absorbency may be sensitive to viscosity.

Summary of Findings:

MEGASorbent absorbed nearly 100% of the oil it encountered. Recovery Efficiency can be increased in the presence of waves or manual mixing, which mix the oil with the sorbent. Oil Absorbency was maximized and Water Absorbency was minimized when MEGASorbent was deployed in an oil slick. A change in color of the sorbent from light brown to the color of the oil was found to indicate saturation.

Final Report Reference:

Coyne, P.M., 1998. EVALUATION OF PTC ENTERPRISES MEGASORBENT AT OHMSETT. Minerals Management Service Contract No. 14-35-01-96-CT-30815, Prepared by MAR, Incorporated, 6110 Executive Boulevard, Suite 410, Rockville, MD 20852, 15 pp.

Test Title: **USCG HIGH SPEED SKIMMER Performance Tests at Ohmsett**

Test Date: **October 10, 1997 - October 13, 1997**

MMS/Ohmsett Work Order #: **012**

Background and Objective:

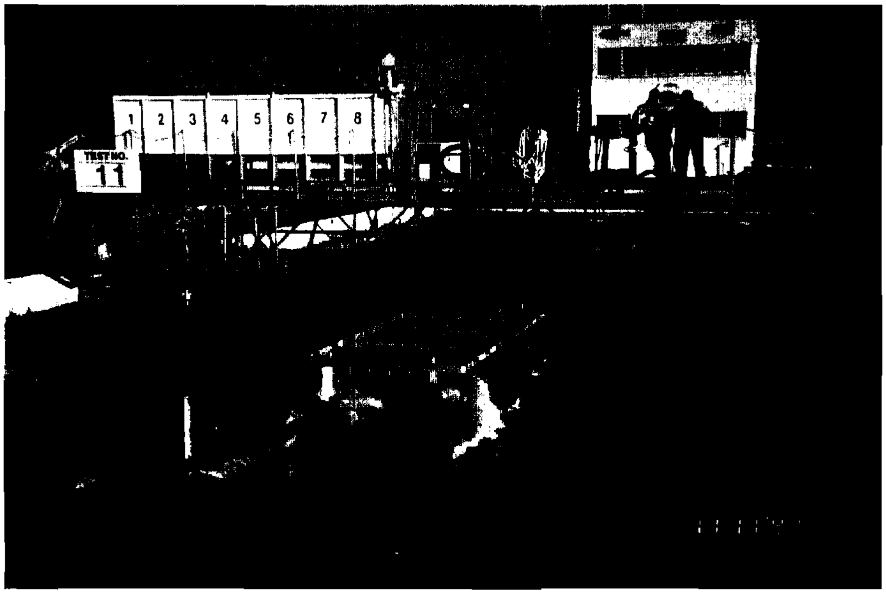


Figure 3.55 JBF DIP 600 Skimmer.

Between October 10 and 13, 1997 the JBF Environmental Systems DIP 600 Skimmer was tested at Ohmsett to ensure that it meets performance requirements as specified by the USCG. The skimmer was configured as a full, in-line skimming system compatible with the USCG Vessel of Opportunity Skimming System (VOSS). The term "in-line" indicates that the skimmer is attached to the end of an oil sweeping boom in place of the boom apex.

A JBF skimming system (JBF 1300) was included in a previous Ohmsett test that evaluated four skimming systems for their in-line high-speed oil recovery capability. The USCG evaluation and bidding process resulted in a preliminary selection of the JBF DIP 600 skimmer for the use in the USCG VOSS.

The primary objective of this Work Order was to provide the USCG with JBF DIP 600 performance data including terms of Oil Recovery Efficiency (ORE), oil Throughput Efficiency (TE) and Oil Recovery Rate (ORR) while encountering spilled oils at three knots and above. ORE is the ratio of pure oil recovered to the total fluid recovered, TE is the ratio of total oil recovered to the total oil encountered, and ORR is the amount of oil recovered per unit time.

Secondary objectives included an evaluation of the JBF System for ease of handling, assembly and deployment; system integrity after shipping; and the level of effort required to clean the system after use.

The DIP 600 skimmer is a hydraulic powered skimmer that uses the Dynamic Inclined Plane (DIP) principle to recover spilled oil. This system stores recovered oil in a built-in oil collection well that also acts as an oil separation tank. The inclined plane assembly consists of a 48-in wide rotating polyvinyl chloride belt driven by a hydraulic powered chain. The rotational speed of the belt is governed by the operator control stand. The inclined plane is oriented with the leading end above the water surface and angled down at 18 degrees below the vessel.

As the system moves through the water, the oil is forced to follow the belt underneath the water surface to the collection well where buoyant forces cause the oil to rise to the surface. Water can escape from vents located at the bottom of the collection well. Off-loading is achieved by two Desmi DOP-250 pumps mounted in the collection well. Off-loading begins when a sufficient volume of oil has surfaced within the 750 gal collection well. The hydraulic power required to run the belt chain and each pump is 5 to 7 gpm and 40 gpm respectively.

All hydraulic hose and cargo hose connections are made topside at the collection well.

Dip 600 skimmer buoyancy is provided by four inflatable pontoons; each pontoon is attached to the skimmer with D-rings and nylon strapping. The skimmer joints are welded primarily from marine grade 5052 aluminum panels with some 6061 aluminum used as reinforcements.

Description of Test Procedures:

The testing under this Work Order was designed to replicate ocean recovery operations while encountering spilled oil at tow speeds of 3 kts and greater. The JBF DPI 600 System was deployed in a full-scale VOSS configuration for testing, as shown in **Figure 3.56**.

Because this test required high tow speeds, i.e., 3 knots and 5 knots, the oil encounter time was limited to 60 sec and 40 sec respectively. Consequently, most tests consisted of multiple runs for which the volumes of oil distributed and recovered were combined for final analysis.

The following procedure was used for each test run. Test personnel assumed their positions, and the data collection computer and video cameras were activated. The Main Bridge oil distribution pump was started in the circulation mode and brought up to maximum pump rate. The Ohmsett Main and Auxiliary Bridges are mounted on rails and can be moved through the tank basin at varying speeds to tow the test systems. The towing bridges and the skimming system were then accelerated to the test speed. Once at speed, the distribution manifolds were opened and oil distribution started. Fluid recovered by the skimmer during testing was pumped directly to the recovery tanks on the Auxiliary Bridge. After the oil distribution system was shut off, the end of the oil encounter time was marked when the last amount of oil reached the skimmer intake. For standard oil recovery tests, the skimmer operator intermittently activated the offloading pumps as needed. For Maximum Throughput Efficiency (MTE) testing, the pump was run continuously to negate the possibility of oil being forced through the collection well vents from overfilling. The inclined belt rotational speed was controlled by the skimmer operator.

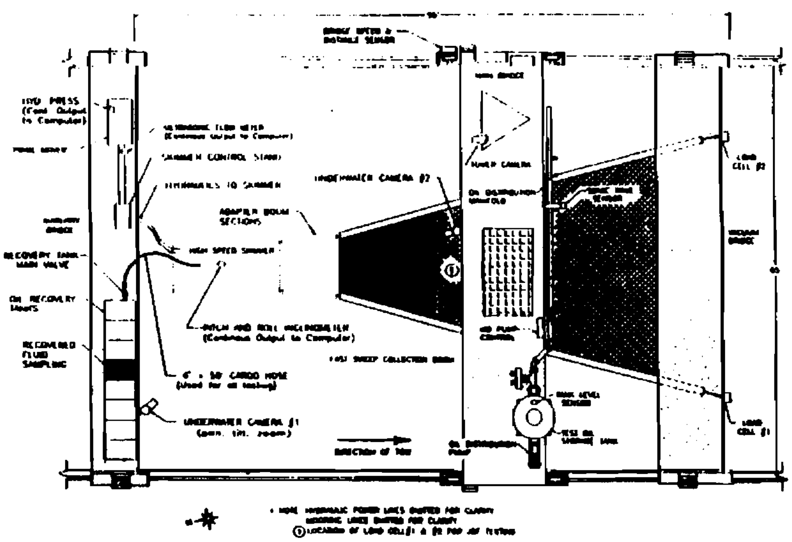


Figure 3.56 Test Setup for High Speed Skimmer System Performance Evaluation.

For testing that involves waves, Ohmsett waves are generated using a reciprocating paddle located at the far end of the Ohmsett tank. There is a perforated metal wave absorber at the opposite end of the reciprocating paddle. The wave absorber is elevated (activated) when the test tank is simulating sinusoidal wave action, and lowered when a "confused sea" or a harbor chop is being simulated.

Two test oils used during the recovery test were Hydrocal 300 (light) and an emulsion made with Sundex 8600 (heavy). The test oils were characterized from samples taken each time the Main Bridge storage tank was filled with the test oil. The Hydrocal 300 oil had a viscosity of ~130 cPs at 25^0 C., and the Sundex 8600 oil had a viscosity of ~ 21,000 cPs at 25^0 C. A more detailed analysis of the test oil properties can be found in the Ohmsett Report for this Work Order.

Two setups were used during testing. Setup 1 employed the USCG Fast Sweep boom with bottom netting; Setup 2 employed generic forty-foot-long inflatable boom arms that were held in a V-shape by cross tethers. The skimmer was attached to the collection booms by 9-ft transitional boom sections provided with the JBF skimmer package. The Fast Sweep boom is equipped with an 8.5-ft wide truncated apex segment that was removed to attach the JBF DIP 600 in-line skimmer. The mouth opening of the Fast Sweep boom is ~ 41 ft, and the length of each boom arm is 61.7 ft. The mouth opening for Setup 2 was 28 ft wide.

The Desmi DOP 250 offloading pumps located in the collection well of the JBF DIP 600 skimmer are interchangeable with the USCG DS250 offloading pump and other pumps in the USCG inventory. Test runs 4 to 18 used the Desmi DOP 250 pump, and test runs 19 to 23 used the USCG DS250 offloading pump. The DIP 600 can mount two pumps in the collection well for off-loading; only one pump was used during these tests as one pump could handle the encounter rate of oil during the tests. A 4-in by 50-ft cargo line was used to transfer oil from the skimmer to Ohmsett Auxiliary Bridge recovery tanks.

Summary of Results:

In all, twenty test runs were performed to determine the oil recovery and offloading capabilities of the JBF DIP 600 while operating at tow speeds of 3 knots and greater. The skimming system was deployed in the test basin in its full-scale designed configuration. The quantity of oil distributed and recovered were the primary measurements obtained to determine skimmer Recovery Efficiency (RE), Throughput Efficiency (TE), and Recovery Rate (RR). Oil viscosity was varied from 125 to 22,500 cPs using a low viscosity Hydrocal oil and a high viscosity Sundex oil. Wave conditions tested were either Calm Water or Harbor Chop (at various significant wave heights – H 1/3). Two test setups were used, one using the Fast Sweep Boom (Setup 1) and one using Inflatable Boom (Setup 2). Two offloading techniques were used for the test runs – one which required the skimmer operator to pump off oil from the collection well to the recovery tanks once an ample volume was reached (OR), and one which required that the off-load pump be operated continually (to allow determination of Maximum Throughput Efficiency (MTE)). The test results are summarized in **Table 3.21** (next page).

Test Setup #1 Results:

Comparing tests 7 & 8 (OR tests, Sundex oil, calm water) with tests 11 & 13 (OR tests, Sundex oil, harbor chop), it is apparent that the presence of waves improves the overall TE. Tests 10 & 12 were both MTE tests which resulted in higher TE performance while encountering waves. Tests 4, 5 and 6 (with the Hydrocal oil) resulted in high RE values in comparison the tests with Sundex oil – all were above 75% RE for calm surface conditions. RE values for Hydrocal oil in wave conditions were also higher than for the tests with Sundex oil.

Test Setup #2 Results:

Tests during calm surface conditions and the OR off-load configuration (Tests 16,17 & 21) resulted in TE values which were comparable to Setup 1. The RE values varied from 75% to 95%, whereas the RE values obtained for Setup 1 ranged from 75% to 90%. Tests 18 & 19 were comparative tests (MTE runs, Hydrocal oil, 4 knot tow speed) in which there were slightly improved values of TE, RE and RR recorded for the harbor chop wave condition.

Test No., Test Setup, Off-load Method	Tow Speed (knots)	Wave Conditions (H 1/3)	Viscosity (cPs)	Encounter Rate (gpm)	RE (%)	TE (%)	Recovery Rate (gpm)
#7, 1/(OR)	3	Calm	12,600	306	60.6	66	207.6
#9 1/(MTE)	3	Calm	12,600	297	29.3	50.8	148.9
#10 1/(MTE)	3	Calm	20,750	308	56.4	87.9	269.4
#8 1/(OR)	4	Calm	12,600	323	77.3	78.3	263
#4 1/(OR)	3	Calm	130	353	87.5	34.3	200
#6 1/(OR)	3	Calm	130	295	90	48.4	155
#5 1/(OR)	4	Calm	130	337	75	38	128.6
#22 2/(OR)	1.5	Calm	112	319	58.3	44.8	134.1
#16 2/(OR)	3	Calm	144	317	86	33.2	102.6
#17 2/(OR)	3	Calm	134	330	95.2	44	151
#21 2/(OR)	3	Calm	112	321	58.4	45	130
#23 2/(OR)	3	Calm	500	321	38.6	65.2	297.8
#18 2/(MTE)	4	Calm	134	308	32.2	34.3	105.5
#11 1/(OR)	3	H.C. (14.5)	20,750	316	62.7	64.4	202.5
#12 1/(MTE)	3	H.C. (13.5)	20,750	348	62	100	371
#13 1/(OR)	4	H.C.	22,500	341	65.4	87.7	295
#14 1/(OR)	3	H.C. (13.4)	165	333	71.2	54.3	196
#15 1/(OR)	4	H.C. (13.7)	165	341	80.6	39.6	144
#19 1/(MTE)	3	H.C. (11.1)	125	343	37.2	46.2	272.5
#20 2/ (OR)	4	H.C. (11.2)	125	316	24.6	26.2	82.5

Table 3. 21 Oil Recovery Performance Data for the JBF DIP 600 Skimming System

Summary of Findings:

The target for the CG High Speed Skimming System evaluated was to demonstrate a Recovery Efficiency greater than or equal to 50% at 3 kts in calm water while encountering slick thicknesses of 0.2 to 50 mm at the apex, with oil viscosity ranging from 5 to 100,000 cSt. The target performance level was achieved even when operating above 4 kts.

Final Report Reference:

DeVitis, D., S. Cunneff and E. Fitzgerald, 1997. U.S.C.G. HIGH SPEED SKIMMER PERFORMANCE TESTS AT OHMSETT. Minerals Management Service Contract No. 1435-01-96-CT-30815, Report No. OHM 98-12. Prepared by MAR, Incorporated, OHMSETT Facility, NWS Earle, Leonardo, NJ 07737, 30 pp. + app.

Section 4.0 Summary of Testing Conducted at Ohmsett during 1998

This section includes a brief summary of tests completed during 1998 for which no final reports are yet available. Included are background information, test objectives and test procedures (if available), and status of the test results (e.g. tests successfully completed, report in preparation, final report available). At the time of publication, results, findings and final report references were not available for all of these tests. Final reports for these tests can be obtained from the Minerals Management Service as they are completed.

Work Order #	Title	Test Dates
17	Evaluation of Oil Gator Sorbent	May 1998
18	Evaluation of High Extension Sorbent Boom	May 1998
21	Estimation of Towing Forces on Oil Spill Containment Booms	June – July, 1998
22	Testing of Rapid Current Booms Developed by the University of New Hampshire	July 1998
23	Ohmsett Test and Evaluation of the Pocket Fire Boom	July 1998
24	Burned Fire Boom Performance Tests	Sept. – Nov. 1998

Table 4.1 –Tests Completed at the MMS Ohmsett Facility During 1998.

Additional information on current research activities and opportunities at Ohmsett can be obtained from the Ohmsett Web Site at “http://www.ohmsett.com”.

Test Title: **Evaluation of OIL GATOR SORBENT at OHMSETT**	
Test Dates: **May 1, 1998**	
MMS/OHMSETT Work Order #: **17**	

Background and Objective:

Product Services Marketing Group manufactures and markets "Oil Gator," a sinking absorption, encapsulation and remediation product that is a by-product of the cotton seed de-linting process. " Oil Gator" is a lightweight, nontoxic product that meets all OSHA requirements. It is non-abrasive and will not harm plants, animals, or machinery. This product is part of a new technology and so will require testing to satisfy legislative standards as well as the end user.

The primary objective of this work was to provide Product Services Marketing with a large-scale test and evaluation of Oil Gator sorbent material. These tests were carried out by MAR, Inc. under the direction and supervision of Minerals Management Service (MMS).

Description of Test Procedures:

An optically clear cylindrical liner used during the tests to hold a contained pocket of oil was deployed adjacent to the Auxiliary Bridge walkway. Stones (with a diameter less than 2 in) were placed inside the liner to determine if the oil-soaked sorbent stuck to the rocks after the sorbent sank and contacted the rocks.

The evaluation used two different types of oils: a medium viscosity Hydrocal 300 (nominal viscosity 300 cPs at 20°C), and high viscosity Sundex 8600T (nominal viscosity 20,000 cPs at 20°C). Fifteen gallons of each type of oil were stored on the Main Bridge during testing. After the weight and volume of the oil and sorbent were measured and recorded, the oil was distributed into the liner, and the slick thickness was allowed to equalize. The Oil Gator sorbent was then added to the test area over a measured period of time.

Underwater video footage documented the action of the sorbent and oil. At the end of the test, the sorbent was removed from the liner. The amount of residual oil left on the surface was estimated, and the added stones were examined for oil contamination. Videotapes were used to aid in the residual oil slick estimation process.

The tests were conducted in calm and in harbor chop wave conditions. Harbor chop is a waveform where the wave reflections are maximized by lowering the wave-absorbing beaches. A short chop (short distance between wave heights with a low wave amplitude) was used to provide mixing for the sorbent and oil, while maintaining the liner's integrity and shape.

Status:

The test series was completed during the period May 1,1998. The Final Report has been completed and is available from Product Services Marketing Group, 20354 Empire Avenue, Bend Or, 97701.

Test Title: **HIGH EXTENSION SORBENT BOOM**
Test Dates: **May 22, 1998**
MMS/OHMSETT Work Order #: **18**

Background and Objective:

Relatively thin flexible sheets of oleophilic, hydrophobic substrates, such as polyethylene film, are used as sorbent media for defending against oil spills. Sorbent booms using such substrates with the combination of a high storage density and a high affinity for oil, are intended for deployment on sensitive areas of open water or shoreline as a first line of defense against approaching oil slicks, or for early assistance in the containment of oil near the source of a spill. The boom is deployed from a compact, high storage density condition onto the area to be protected. One or more layers of a sorbent material may be extended onto the oil-contaminated surface of an expanse of open water, or may be extended onto a shoreline area to protect from approaching oil spills. Sorbent materials used may incorporate oil-degrading additives.

The objective of the tests was to evaluate the containment and shoreline protection capabilities of such a product, the High Extension Sorbent Boom (HESB).

Description of Test Procedures:

Seven tests were conducted to evaluate the performance of HESB in calm water and waves using three different oil types. During the first five tests, six circles formed of HESB were filled with 15 gal of oil (two each of Diesel, Hydrocal and Sundex). The first test was conducted in calm water; the other four tests were conducted with waves of increasing significant wave heights. The oils and sorbent remained in the rings of sorbent throughout the entire test series.

During three containment tests, three strings of sorbent boom were positioned on either side of the Main Bridge. One hundred gal of oil were spilled within the containment area. No waves were generated during these tests.

During the shoreline protection evaluation, eight strings of sorbent boom were positioned along the tank wall in front of the wave absorption beach at Ohmsett. One hundred gal of oil were spilled. Wind and/or water motion (water cannons) moved the oil toward the "beach" to demonstrate the boom's effectiveness in keeping the oil "off the beach."

Status:

The test series was completed on May 22,1998. The Final Report has been completed and is available from the Test Sponsor, Mr. Henry van der Linde, RR2, Baltimore, Ontario, Canada, K0K1C0.

Test Title: **Estimation of TOWING FORCES on OIL SPILL CONTAINMENT BOOMS**

Test Dates: **June 22, 1998 to July 3, 1998**

MMS/OHMSETT Work Order #: **21**

Background and Objective:

Effective skimming or in-situ burning of an oil spill generally requires that the spill first be contained using booms. An oil spill containment boom is typically towed in a U-configuration or held stationary against a current to collect and concentrate oil for recovery or burning. The potential forces imposed on a boom affect the choice of boom, tow vessel and towing equipment.

Currently, boom towing forces (and, therefore, required tensile strengths) are estimated using such formulae as those published in catalogs and specific field manuals. These formulae are based on an estimation of loads on a boom determined by the boom dimensions, water current, wave height, and wind, and include boom cross-section and gap ratio constants. Recent field-testing has shown that these formulae may severely underestimate boom drag forces. As a result, commonly accepted values for the minimum required tensile forces on a boom might be well below the actual required values.

The objective of the tests was to determine the tow forces on booms of various drafts and profiles under differing wave conditions and towing speeds. The tests were conducted by S.L. Ross Environmental Research, Ltd. of Ottawa, Ontario, Canada under the direction of the Minerals Management Service.

Description of Test Procedures:

Full-scale tow tests were conducted using several specific representative boom profiles. Towing forces were measured and recorded for various boom drafts, profiles, wave conditions and towing speeds. Video documentation was included as part of the tests.

Status:

The test series was completed during the period June 22, 1998 to July 3, 1998. The Final Report has not been completed, but is being prepared by S.L. Ross Environmental Research, Ltd. 200-717 Belfast Road, Ottawa, Ontario, Canada.

Test Title: **Testing of RAPID CURRENT BOOMS DEVELOPED by the UNIVERSITY of NEW HAMPSHIRE at OHMSETT**

Test Dates: **July 1998**

MMS/OHMSETT Work Order #: **22**

Background and Objective:

The University of New Hampshire (UNH) has been involved in developing and designing a rapid current oil boom. Under an earlier project funded by the US Coast Guard, UNH completed a study of oil flow patterns around a two-dimensional submergence plane in a flume tank; and designed, constructed and tested a flexible, three-dimensional submergence-plane system using a two-dimensional test cross-section.

Currently, UNH is in its second year of a Minerals Management Service (MMS)-funded effort. The first year of MMS funding was dedicated to testing the three-dimensional system for oil collection capabilities and developing the design for commercial manufacture. The submergence plane concept was tested at Ohmsett in June and August of 1997 to evaluate the correlation between flume and large tow tank oil retention tests at speeds between 1 and 2 kts. Those test results enabled UNH to return to Ohmsett to evaluate a production-type barrier under the same conditions but at increased tow speeds.

The primary objective of the 1998 work was to provide UNH with performance data for their redesigned rapid-current oil barrier. The rapid-current boom system uses a submergence plane, a bottom plate and a trailing barrier as components of the collection mechanism. A complete barrier is composed of numerous segments that are attached to form a barrier system. Each barrier segment measures approximately 2 ft, 5in by 10 ft , 3 in; the overall barrier size is approximately 40.5 ft by 19 ft.

The tests performed were advancing oil recovery tests in which Throughput Efficiency (ratio of the amount of oil recovered by the system to the amount of oil encountered by the system) was the primary parameter of interest. These tests were conducted by MAR, Inc., under the direction and sponsorship of the MMS for UNH Mechanical/Ocean Engineering.

Description of Test Procedures:

The barrier system was tested at 1, 1½, 2 and 3 knots using two types of oil (Hydrocal 300 and Sundex 8600T, nominal viscosities 200 cPs and 20,000 cPs at 20°C) in calm and wave conditions. The barrier system was rigged from the Main Bridge tow points. The Main Bridge oil distribution system distributed oil through four nozzles located approximately 10 feet in front of the barriers. When the barrier encountered the slick end, water jets were started to induce a current toward the barrier containing the collected oil.

Throughput Efficiency was recorded for each test run. Two underwater cameras and a hand-held camera were used to obtain video documentation.

Status:

The test series was completed during the period July, 1998. The Final Report has not been completed, but is being prepared by the University of New Hampshire, Mechanical/Ocean Engineering Department, Durham, NH.

Test Title: **OHMSETT TEST and EVALUATION of the POCKET FIRE BOOM**	
Test Dates: **July 13, 1998 to July 24, 1998**	
MMS/OHMSETT Work Order #: **23**	

Background and Objective:

At-sea incineration (in-situ burning) of marine oil spills is an effective response technique and has been approved for spill response use in coastal waters off Alaska and in the Gulf of Mexico. Previous testing at Ohmsett under the sponsorship of the U.S. Coast Guard Research and Development Center evaluated the oil containment and sea-keeping abilities of selected fire-resistant booms in dynamic conditions (WO # 19, July-October 1996). This testing also led to the development of a standard test protocol for determining the oil containment performance and sea-keeping ability for fire booms.

The Pocket Fire Boom is a redesign of the Dome Fire Boom that was previously tested at Ohmsett in July 1996. The boom is made of stainless steel and consists of alternating float and flexible connector sections. Each float section is 39 in high, 67 in long, and has an approximate weight of 110 lbs. Each connector section is 36 in high, 26 in long and has an approximate weight of 108 lbs. The boom, consisting of seven floats and six connector sections, has an approximate length of 52 ft. The boom is designed to be used as the pocket at the apex of a contained area, with other less fire-resistant boom forming the arms of the U-shape. Two 25-ft sections of Applied Fabrics globe boom connected to the Pocket Fire Boom formed a total test length of approximately 100 ft.

The objective of the 1998 testing was to measure the oil collection/containment performance and the sea-keeping ability of the Pocket Fire Boom under tank towing conditions. S.L. Ross Environmental Research Limited sponsored the test, which was conducted by MAR, Inc., under the direction and review of the Minerals Management Service.

Description of Test Procedures:

Pre-load Determination Tests, Oil Loss Tow Speed Tests, Oil Loss Rate Tests and Critical Tow Speed Tests were conducted. Tests were documented with photos (35mm or digital) and raw video footage (above and underwater). In-line load cells measured Tow Forces.

Pre-load tests are a series of First Loss Tow Speed Tests conducted with increasing amounts of oil loaded into the boom prior to starting each test. When the addition of oil to the pre-load has minimal or no effect on the First Loss Tow Speed, the amount of oil pre-loaded becomes the pre-load volume for subsequent Oil Loss Tow Speed Tests. First Loss Tow Speed is the lowest speed at which oil droplets continuously shed from the boom. Gross Loss Tow Speed is the speed at which massive continual oil loss is observed escaping past the boom.

The Oil Loss Rate Test quantifies the severity of oil loss from the boom when experiencing tow speeds or relative currents greater than First Loss Tow Speed.

Critical Tow Speed is the maximum speed at which the boom may be towed before exhibiting one or a combination of failure modes, including submerging (the boom loses all freeboard), planing (skirt pulls out of the water), splash-over and/or mechanical failure.

Calsol 8240 oil (viscosity of 2,000 cSt, specific gravity of approximately 0.95) was chosen for the tests. The boom was rigged with a 3:1 boom length-to-gap ratio. Pressure transmitters were mounted at three locations along the length of the boom and at the bottom of the boom skirt (or fence). One of the transmitters was fastened at the halfway point so that it was at the apex of the boom. The other two transmitters were located at one-third and two-thirds the boom length. Three wave conditions were tested.

Status:

The test series was completed during the period July 13 to 24 ,1998. The Final Report has been completed and is available from S.L. Ross Environmental Research, Ltd., 200-717 Belfast Road, Ottawa, Ontario, Canada.

Test Title: **BURNED FIRE BOOM Performance Tests**
Test Date: **September 1998 - November 1998**
MMS/OHMSETT Work Order #: **24**

Background and Objective:

Previous testing at Ohmsett under the sponsorship of the U.S. Coast Guard Research and Development Center evaluated the oil containment and sea-keeping abilities of selected fire-resistant booms in dynamic conditions. This testing also led to the development of a standard protocol for oil containment performance and sea-keeping ability for fire booms.

The objective of the these tests was to measure the oil collection/containment performance and sea-keeping ability of several commercially available fire-resistant booms that had undergone burn tests at the Coast Guard Fire and Safety Test Detachment facility in Mobile, AL. These tests were conducted using the proposed ASTM-F20 burn test protocol. The booms evaluated at Ohmsett had successfully passed the burn tests. The U.S. Coast Guard sponsored these tests, which were conducted by MAR, Inc., under the direction and review of the Minerals Management Service.

Description of Test Procedures:

Pre-load Determination Tests, Oil Loss Tow Speed Tests, Oil Loss Rate Tests and Critical Tow Speed Tests were conducted on fifty-foot lengths of each burned fire boom. Test series were documented with photos (35mm or digital) and raw video footage (above and underwater). In-line load cells (attached at each tow bridle between the tow bridle and the Main Bridge tow points) measured Tow Forces.

Pre-load tests are a series of First Loss Tow Speed Tests (defined below) conducted with increasing amounts of oil loaded into the boom prior to starting each test. When the addition of oil to the pre-load has minimal or no effect on the First Loss Tow Speed, the amount of oil pre-loaded becomes the pre-load volume for Oil Loss Tow Speed Tests. First Loss Tow Speed is the lowest speed at which oil droplets continuously shed from the boom. Gross Loss Tow Speed is the speed at which massive continual oil loss is observed escaping past the boom.

The Oil Loss Rate Test quantifies the severity of oil loss from the boom when experiencing tow speeds or relative currents greater than First Loss Tow Speed.

Critical Tow Speed is the maximum speed at which the boom may be towed before exhibiting one or more failure modes, including submerging (the boom loses all freeboard), planing (skirt pulls out of the water), splash-over and/or mechanical failure.

Calsol 8240 oil (viscosity of 2,000 cSt, specific gravity of approximately 0.95) was chosen for the tests. Booms were rigged with a 3:1 boom length-to-gap ratio. (To extend the burned boom, one 25 ft section of curtain boom was attached at each end, creating a boom approximately 100 ft long.) Three wave conditions were tested.

Status:

The test series was completed during the period September to November, 1998. The Final Report has not been completed, but will be available from the USCG Research and Development Center, Groton, CT 06340.