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EXECUTIVE SUMMARY

FOR

HARBOR OIL SPILL REMOVAL/RECOVERY SYSTEMS

PHASE II

Civil Engineering Laboratory
Port Hueneme, California

Sponsored by
Naval Facilities Engineering Command

July 1976
Y41-21-001-01-001

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Introduction

The Navy has committed itself to the development of adequate capabilities to remove oil attributable to accidental spills from harbor waters. The overall program has evolved into three phases. The objective of Phase I, completed in FY-73, was to identify the best commercially available "off-the-shelf" equipment for cleaning up spills in both confined and open harbor areas. The objectives of Phase II were to develop standard performance test procedures applicable to the EPA (Environmental Protection Agency) OHMSETT (Oil and Hazardous Materials Simulated Environmental Test Tank) facility, to improve equipment and procedures, and to evaluate utility equipment in a harbor. The objective of improving equipment and procedures included the following subtasks: development of a support system for containment booms; laboratory testing of a model skimmer and boom; full scale testing at OHMSETT; conducting a human factors study of oil spill cleanup equipment; development of oil spill cleanup scenarios, an oil spill cleanup data report form, and alternative methods of using oil spill containment boom; and a study of boom materials. This report summarizes Phase II. The objectives of Phase III, currently underway, are to conduct cost and system effectiveness studies of oil spill cleanup procedures, and to evaluate new equipment at OHMSETT.

A short film depicting the tests conducted during Phase II is available on request from the Naval Facilities Engineering Command.

Development of Standard Performance Test Procedures

Shell Development Company developed and validated, in their wave tank, standard test procedures for booms and skimmers. During the course of validating the test procedures, repeatability data were obtained which provide an indication of the inherent experimental error in obtaining test measurements. At a tow speed of 1.1 knots, and with no waves, there was no scatter in the oil loss rate, 0.8 percent/minute, for an Aqua Fence boom. At a tow speed of 1.4 knots, however, the maximum measured oil loss rate was approximately 1.7 times the average measured rate of 8 percent/minute; the minimum measured oil loss rate was approximately 0.7 of that average rate. Similar high data scatter was obtained at a tow speed of 1.0 knot in the presence of 0.8-foot waves.

For the SLURP skimmer, a self-equilibrating saucer-type weir skimmer, the degree of repeatability was quite good. At the maximum pumping rate, in a 1-inch-thick oil slick of a 9-cp oil without waves, the maximum measured oil collection rate was approximately 1.1 times the average measured rate, 26 gpm; the minimum measured oil collection rate was approximately 0.9 of that average rate. At the lower pumping rates the data scatter was less. For the JBF DIP 1001 skimmer, an inverted belt skimmer, being towed at 1 knot, without waves, in a slick of 9-cp oil 1 mm thick, the maximum measured oil collection rate was approximately 1.1 times the average measured rate, 2 gpm; and the minimum measured oil collection rate was approximately 0.8 of that average rate. As the wave height increased to 1 foot, the data scatter also increased.

Improved Equipment and Procedures

A support system for deploying and retrieving oil containment booms was identified. A boom with a frontal screen to improve the oil containment capability was fabricated and tested. The parameters which have the greatest effect on the performance of the DIP-type skimmers were identified.

The support system comprises the following elements: container for boom storage; transportation equipment (e.g., forklifts, flatbed trucks); and power assistance unit for deploying and retrieving booms. After testing several boom containers, Murphy Pacific Marine Salvage Company requested Transequip, Inc., the manufacturer of the LD-9 aircraft large container which Murphy tested, to design a Special Fiberglass Boom Container to meet all the requirements of boom storage and transportability, but eliminating the features not needed for these purposes. The significant features of the design are: fiberglass shell and doors, built-up forklift base, stackable, and transportable on any wide-body aircraft.

A survey showed that there were no commercially available power assistance units which could be easily and inexpensively adapted for the deployment and retrieval of boom. Consequently, Murphy Pacific developed such a unit with the following features: 4 low pressure (1.5 psi) cleated tires, master on-off switch, two foot switches for immediately disengaging the clutch during retrieval, and forkliftable. The unit is 49 inches long, 53 inches wide, 28 inches high, and weighs 650 pounds. Tests showed that 500 feet of 36-inch boom could be deployed in less than 15 minutes, and could also be retrieved in less than 15 minutes. A crew of five men was required: four on the pier, and one in a workboat.

The oil loss due to entrainment under an oil containment boom can be reduced by reducing the kinetic energy of the oncoming stream. A boom with a frontal screen attached to it was fabricated by SwRI (Southwest Research Institute) and then used to experimentally evaluate this concept, first with a laboratory-scale model and then with a full-size boom. Both the laboratory and full-scale tests showed that the oil containment capability of booms can be significantly improved by the use of a frontal screen. Selected numerical results are presented in the section on testing at OHMSETT.

With the objective of improving the performance of the DIP-type skimmers, SwRI also investigated the effects on performance of the following skimmer parameters: belt speed, backplate opening, belt angle, use of an induction propeller and use of a cleated belt. The tests were conducted on a laboratory-scale model. It was found that the induction propeller and the cleated belt did not improve performance. The belt angle which maximized performance was 23 degrees, the value currently used on the DIP-type skimmers. Belt speed and backplate opening were found to affect performance. On the basis of the laboratory tests it was decided to conduct tests on the full-scale JBF DIP 1001 and 3001 skimmers at OHMSETT to determine the optimum values of backplate opening and belt speed. Results are presented in the section on testing at OHMSETT.

Boom and Skimmer Tests at OHMSETT

Oil containment capability tests at various tow speeds, both in the presence and absence of random waves, were conducted using 85 feet of Bennett Class III, 36-inch boom and 85 feet of the Class III SwRI prototype boom with the frontal screen. The booms were arranged in a catenary configuration with a 56-foot opening. In addition, the booms were towed in both the head seas and following seas conditions. Each test was conducted by placing 150 gallons of No. 2 fuel oil downstream of the boom and then towing the boom down the tank. Without waves the Bennett boom started to lose oil at a tow speed of 0.75 knot, whereas the SwRI boom started to lose oil at 1.0 knot. After both booms had started to lose oil, the Bennett boom lost oil at a faster rate than the SwRI boom. In 1-foot random waves, in the head seas condition, both booms lost oil at tow speeds of less than 0.4 knot. In the following seas condition, the Bennett boom started to lose oil at a tow speed less than 0.25 knot, whereas the SwRI boom started to lose oil at a tow speed of 0.5 knot. In its present configuration, with permanently attached outrigger floats, the SwRI boom cannot be deployed and retrieved as rapidly as conventional booms, and also requires considerably more storage space than conventional booms. These problems could be alleviated by the use of hinged attachments for the floats.

For the tests on the JBF DIP 1001 in the stationary mode, two 50-foot sections of Bennett Class III boom were attached to the bow of the skimmer to form an open-based trapezoid. For each test, 31.5 gallons of No. 2 fuel oil were applied to the surface of the water within the trapezoid. This volume of oil would have created a slick 1 mm thick if it filled the entire trapezoidal area. The oil was then hosed into the skimmer by a man sitting in a punt on the water surface. It was found that the oil collection rate increased as the belt speed increased. At a belt speed of 1.4 knots (horizontal component), the oil collection rate was 3.4 gpm. At a belt speed of 4.3 knots, the oil collection rate was 10.1 gpm. The recovery efficiency* decreased as the belt speed increased. At a belt speed of 1.4 knots, the recovery efficiency was 84 percent. At a belt speed of 4.3 knots, the recovery efficiency was 59 percent. Performance of the skimmer was not affected by the value of

*Recovery efficiency is the percentage of oil placed on the water surface recovered by the skimmer.

the backplate opening. Because the oil which is not recovered surfaces behind the skimmer and could be difficult to recover in an actual oil spill cleanup operation, it appears advisable to operate the belt at a low speed to allow the greatest percentage of oil to be recovered, even though the low belt speed results in a low collection rate.

In the advancing mode, the DIP 1001 skimmer was towed from the towing bridge at 0.5 knot. The tests were conducted without waves with a slick, 1 mm thick, of No. 2 fuel oil. The tests showed that, at a constant value of the backplate opening, the performance increased as belt speed increased, reached a maximum, and then decreased. The maximum oil collection rate attained was 2.7 gpm with a corresponding throughput efficiency of 42.4 percent.* This performance was attained with a belt speed (horizontal component) of 1.9 knots and with backplate openings of both 2.0 and 6.0 inches. Underwater photography (video tape and motion picture film) showed a mist escaping from the skimmer at the end of the belt at the leading edge of the bottom plate, and bubbles escaping through the backplate opening. It is believed that a significant quantity of oil was contained in the mist and bubbles.

Tests on the JBF DIP 3001 skimmer were conducted at a towing speed of 0.988 knot, using a slick 1 mm thick of No. 2 fuel oil. The variation of oil collection rate with belt speed was similar to that noted for the tests on the JBF DIP 1001 skimmer in the advancing mode. With no waves, the best performance, i.e., oil collection rate of 28.6 gpm and throughput efficiency of 77.6 percent, was obtained with a belt speed (horizontal component) of 5.0 knots and a backplate opening of 5.5 inches. With 1-foot random waves, the best performance, i.e., oil collection rate of 20.0 gpm and throughput efficiency of 54.2 percent, was obtained with a belt speed of 2.0 knots and a backplate opening of 5.5 inches. The above results were obtained with the skimmer sweeps in operation.

Human Factors Study

The Human Factors Engineering Branch, Pacific Missile Test Center, conducted a human factors engineering study of oil spill cleanup equipment being procured by NAVFAC (Naval Facilities Engineering Command) for Naval activities. An Oil Spill Operations Questionnaire was prepared. It was based on data obtained in personal interviews with oil spill cleanup operations personnel and in related reports, specifications, equipment manuals, and handbooks. The questionnaire was designed to obtain the opinions of the oil spill cleanup operations personnel

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*Throughput efficiency is the percentage of oil encountered which is recovered.

concerning the desirability of incorporating changes to the existing equipment. The questionnaires were mailed to all Naval activities which had been issued oil spill skimmers by NAVFAC. Replies were received from 13 Naval activities.

A summary of recommendations made in the human factors study report which have been or are being implemented by NAVFAC follows:

<u>JBF DIP 3001 Skimmer</u>

- Provide a protective pipe railing at the stern in order to protect the rudder and screws.

- Provide an angle iron framework covered by expanded metal for the stern underside and side areas in order to protect the rudders and screws from debris or from backing into submerged objects.

- Provide a screen-type device to be used in collecting trash from the oil collection well.

- Add a debris grinder.

- Have bilge pumps discharge into the oil collection well rather than over the side.

- Add sound absorbent insulation around the engine compartment.

- Hinge the pilot house console assembly top at the forward end so that it may be raised to gain access for maintenance.

- Provide a floodlight on top of the pilot house.

- Add fold-down seats in the pilot house.

- Replace the Ford Diesel engine with a Detroit Diesel engine.

- Provide longer aluminum sweep seals.

- Provide chains at the top of the sweep seals to eliminate loss of seals in rough seas.

<u>JBF DIP 1002 Skimmer System</u>

- Provide a better chain hoist.

- Provide shock mounting for the Diesel engine.

- Provide male and female oil containment boom connectors for the bow of the JBF DIP 1001 skimmer.

Scenarios

Ten oil spill cleanup scenarios were written describing the equipment, procedures, manpower, and funding required to clean up each of ten different types of oil spills. The ten different types of oil spills are:

- Confined area, less than 100 gallons
- Confined area, 100-1000 gallons
- Confined area, greater than 1000 gallons
- Open area, less than 100 gallons
- Open area, 100-1000 gallons
- Open area, greater than 1000 gallons
- Confined area, 100-1000 gallons, small current, small waves
- Open area, 100-1000 gallons, small current, small waves
- Strong unidirectional current
- Small spill, less than 10 gallons, boom not required

In Phase III, different procedures for cleaning up each of the ten oil spills will be analytically evaluated and the most cost-effective procedure will be described. This evaluation is a part of the system and cost effectiveness studies to be conducted during Phase III.

Oil Spill Cleanup Data Report Form

An oil spill cleanup data report form has been developed. The form includes questions on the following items:

- Type and volume of oil spilled
- Cause
- Equipment, procedures, and manpower required to clean up the spill
- Time and money spent on cleaning up the spill.

It is planned to distribute the form to the 15 naval activities most active in oil spill cleanup operations. After the information on the completed forms has been compiled and analyzed, the information will be used in the system and cost effectiveness studies to be conducted during Phase III.

Evaluation of Utility Equipment

Tests were conducted in Port Hueneme Harbor on the following items of utility equipment: two 20-foot utility boats, a 28-foot flattop boat, three boom mooring systems with rated holding capabilities of 2,500, 5,000, and 10,000 pounds, a power assistance unit for deploying and retrieving boom, and a simulated sorbent distribution system. For those tests which required boom, 900 feet of Class III boom were used.

The primary objectives of the tests were to determine the best procedures for using the equipment, to determine the manpower and logistic requirements, and to determine whether the equipment was suitable for its intended purpose.

The information obtained from the tests included the following performance data:

Utility Boats

- Capability to tow boom
- Capability to tow flattop boat
- Feasibility as a platform for connecting and disconnecting boom sections
- Feasibility as a platform for deploying and retrieving the boom mooring systems
- Maximum pulling force

Flattop Boat

- Capacity for storing boom
- Stability while carrying 900 feet of Class III boom
- Feasibility as a platform for deploying and retrieving boom
- Capability of towing a 2,500-gallon flexible storage bag for recovered oil

Mooring Systems

- Force required to drag the mooring systems along beach sand
- Compatability with Class III booms

Power Assistance Unit

- Manpower and time requirements for deploying and retrieving 900 feet of Class III boom

Simulated Sorbent Distribution System

- Effective means for minimizing dust generation

Boom Materials Study

The purpose of this analytic study was to determine the technical suitability of materials for use as oil spill containment booms. Boom material requirements were defined and weighted according to their relative importance, and standard test procedures for evaluating each requirement were identified. The study was directed at synthetic-coated fabrics. Fabric weaving techniques and methods for applying coatings were studied. Information on the properties of available fibers and coatings was obtained, and those exhibiting the most promising characteristics were identified. Some of the coated fabrics currently being used in containment booms and other material composed of the promising fabrics and coatings were evaluated.

The following conclusions were drawn from the study:

- For coated fabrics, breaking strength, elongation, flexibility, and tear resistance are dependent on the fabric weaving technique and the characteristics of the fabric.

- The chemical resistive properties of a coated fabric are primarily determined by the coating material and its thickness.

- The lamination method of coating fabrics does not result in the substrate yarns being as well incapsulated or chemically tied to the coating and is, therefore, not as desirable as the knife edge, dip, or calendering methods.

- A coating containing no plasticizer can be expected to maintain its properties over a longer period of time than one with plasticizers.

- The substrate material exhibiting the most desirable characteristics for use in containment boom is polyester, followed by nylon.

- The coating materials exhibiting the most desirable characteristics are chlorosulfonated polyethylene, polyurethane with a polyether base, chlorinated polyethylene and polyvinyl chloride properly formulated to resist ultraviolet light degradation.

- The large variations in material properties due to changes in coating formulations, weaving techniques, and processing methods prevent the identification of one combination of substrate and coating as the best for use on containment boom.

- Standard test procedures do not exist for all of the defined requirements, making it currently impossible to establish quantitatively the capability of candidate materials to meet these requirements.

- For properties where adequate test methods exist, sufficient data are not available on candidate materials to permit a numerical evaluation using the weighted requirements. Where test data are available, comparison is hampered by variations in procedures and conditions under which the data were obtained.

As a result of the study, the following recommendations were made:

- Develop standard tests for containment boom material requirements for which none exist.

- Initiate a test program to collect the data needed to perform a quantitative evaluation and comparison of candidate boom materials.

- Establish minimum acceptable values for all containment boom material requirements and include the values in boom specifications.

- Identify material requirements in procurement specifications for oil spill containment booms, and require that data substantiating the capability of the material to meet the requirements, obtained through performance of the standard tests, be provided by prospective boom suppliers.

Alternative Methods of Using Oil Spill Containment Boom

A study was conducted on alternative methods of using oil spill containment boom. The objectives of the study were to identify those parameters which influence the effectiveness of oil spill containment boom, and then, using these parameters, develop a decision analysis plan which would permit the selection of the most effective method of utilizing boom.

Three alternative methods of using oil spill containment boom were defined:

Method I: The water adjacent to all berthed ships is routinely enclosed with containment boom. A portion of this enclosure may be made up of permanently installed boom and the remainder deployed as ships are berthed. That portion of boom deployed with each berthing may be stowed in the water near the berth or on nearby piers, floats, craft, etc.

Method II: All berthed ships conducting an external transfer of any contaminated liquid (fuel, lubricating oil, oily waste, etc.) are routinely enclosed with containment boom. Generally, none of the boom is permanently installed; rather it is deployed from its stowed position, either in the water near the berth or from a nearby pier, float, craft, etc.

Method III: Containment boom is deployed only in the event of an actual oil spill. The stowage location may be either in the water or on a pier, float, craft, etc.

A decision model was structured to permit the evaluation of each alternative method in terms of the objectives and the uncertainty associated with harbor oil spills. The model required the development of a utility function for each of the objectives and consideration of the probability of specific events occurring to allow the assessment of the expected value of each alternative.

A decision analysis plan was formulated for implementing the decision analysis technique. The plan consists of a series of data sheets designed to gather all the information needed to perform the analysis at a specific activity, and worksheets showing all the steps and calculations required to complete the analysis.

A decision analysis plan was then conducted on a sample activity to demonstrate the workings of the plan and to test its sensitivity.

Based on the information obtained from the oil spill containment data sheets, and the results of sample calculations, the following conclusions were made:

- The most prevalent method of utilizing oil spill containment boom is to deploy the boom after a spill occurs.

- Considerable savings can be realized (up to 95 percent) in terms of both dollars and extent of damage to the environment if boom is deployed prior to a spill.

- Ships berthed for extended periods of time and those ships having a high spill frequency, such as aircraft carriers, are generally good candidates for permanent boom.

- The decision analysis plan developed by the study provides an effective means for selecting the best method of boom use for an activity. It does so by measuring the extent to which each of the alternatives meets the objectives, in light of the uncertainty associated with the occurrence and damage caused by oil spills.

The following recommendations were made:

- Utilize the decision analysis plan to determine the best method of using oil spill containment boom.

- Reevaluate, periodically, the method of boom use at each Naval fuel station as the operating characteristics change.

- Maintain complete records on the cost of oil spill control at Naval activities. Include charges for military personnel as well as for civilians and contractors.

Conclusions

- Standard test procedures for the Environmental Protection Agency's OHMSETT (Oil and Hazardous Materials Simulated Environmental Test Tank) facility were developed and validated.

- Because of irregular hydrodynamic phenomena, wave tank tests of oil spill cleanup equipment do not have the degree of repeatability attainable in controlled laboratory scientific experiments.

- A specially designed fiberglass, stackable boom container was identified as the most suitable container.

- A prototype boom with a frontal screen for reducing the kinetic energy of the oncoming stream was experimentally shown to have a greater oil containment capability than a conventional boom without a screen. Design changes are required, however, to improve the logistic characteristics of the prototype boom.

- Performance of the DIP-type skimmers is affected by the following skimmer parameters: belt angle, belt speed, backplate opening.

- Changes being made and/or already made on Navy oil spill cleanup equipment will improve the performance of the equipment.

- Two 20-foot utility boats with samson posts, a 28-foot flattop boat, mooring systems, and a power assistance unit for deploying and retrieving boom proved to be effective utility equipment for harbor oil spill cleanup operations. However, modifications are necessary to improve the performance of the power assistance unit.

- Standard test procedures do not exist for all boom requirements, making it currently impossible to establish quantitatively the capability of candidate materials to meet the requirements. For properties where adequate test methods exist, sufficient data are not available. Where test data are available, comparison is hampered by variations in procedures and conditions under which the data were obtained.

- Considerable savings can be realized (up to 95 percent) in terms of both dollars and extent of damage to the environment if boom is deployed prior to a spill.

- Ships berthed for extended periods of time and those ships having a high spill frequency, such as aircraft carriers, are generally good candidates for permanent boom.

Recommendations

- Request Naval activities to use the oil spill cleanup data report forms for a period of 1 year.

- Develop an automated oil spill cleanup data information storage and retrieval system.

- Use the data from the oil spill cleanup data report forms, the ten oil spill cleanup scenarios, and data from personal visits to Naval activities to conduct system and cost effectiveness studies on oil spill cleanup operations.

- Conduct performance tests at OHMSETT on new, selected oil spill cleanup equipment.

- Modify the power assistance unit for deploying and retrieving boom by replacing the tires with a rubber coated cylinder.

- Install samson towing posts on the 20-foot utility boats.

- Develop standard tests for containment boom material requirements for which none exist. Initiate a test program to collect the data needed to perform a quantitative evaluation and comparison of candidate boom materials.

- Utilize the decision analysis plan to determine the best method of using oil spill containment boom.

- Maintain complete records on the cost of oil spill control at Naval activities. Include charges for military personnel as well as for civilians and contractors.