NAVY HARBOR OIL SPILL CLEANUP: A PROGRESS REPORT

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ABSTRACT

After four years, significant progress has been achieved in the development of new equipment and techniques for the Navy oil spill program. Utilizing the systems analysis approach, the Navy has undertaken both intermediate and long-term efforts. The intermediate effort developed systems utilizing the best commercially available equipment with Navy-developed techniques. The long-range effort is refining and optimizing the intermediate systems.

The intermediate systems and cleanup techniques developed are now operational. Experience, to date, reveals that commercially available equipment is effective when properly applied to a well-defined spill problem. Significant progress is reported which should be of interest to others involved in research and development efforts, those involved in complex port facilities operation, and those involved in development of an effective oil spill cleanup capability.

INTRODUCTION

The Navy oil spill program is divided into two parts under two separate Commands. Spills in open oceans and spills related to ship salvage are the responsibility of the Naval Sea Systems Command, Supervisor of Salvage. The Naval Facilities Engineering Command is charged with central management of the inland waters oil spill problem.

Development of an oil spill cleanup system has been divided into five subsystems: (1) detection and surveillance, (2) containment, (3) removal, (4) storage and transfer, and (5) disposal-reclamation. Significant work is underway and progress is being recorded both in open oceans and inland waters on all subsystems. This paper reports on the progress in the inland waters program and is restricted to the containment, removal, and storage-transfer subsystems; the latter is an integral part of the removal subsystem.

Navy rationale

The Navy oil spill problem was recognized as somewhat unique in that it did not possess the character of the more classic large spill, and thus, would undoubtedly not benefit directly from the equipment or techniques being developed for these problems. Accordingly, a multi-faceted approach was adopted which would provide a cost effective solution in a reasonable time for the particular Navy problem. The ultimate objective definitely required a long range effort since the state-of-the-art was considered rather archaic. On the other hand, the problem was current and required immediate corrective action. Based on this assessment, both intermediate and long-term approaches were undertaken utilizing the systems approach as diagrammed in figure 1. The intermediate effort would develop systems utilizing the best commercially available equipment with techniques tailored to the Navy's problem. The long-range effort would refine and optimize these systems and techniques into a more efficient and cost-effective solution. As part of both efforts, appropriate advances in technology and the progress of others would be closely monitored and adapted throughout the program.

Figure 1. System development diagram

Problem definition

The first step in the systems analysis approach was to define the specific problem to be solved. Navy spills had to be categorized by size and location before equipment requirements could be identified.
Spill history. An effort was initiated early in the program to develop and analyze the Navy's oil spill history. The first Navy-wide survey undertaken by Dorrier in 1968 and reported on in 1969 [1] identified the typical Navy spill as between 50 and 500 gallons with an average quantity of 50 to 100 gallons. Further, this characteristic spill normally occurred in confined areas around piers and ships in a harbor. This early characterization basically holds true today.

Since 1971, all Navy oil spills have been reported to the Naval Environmental Support Office, Port Hueneme, California. This data provides a spill history which is used as a decision-making aid in directing the continuing oil pollution abatement program. A summary of the 1972 and 1973 spill record [2,3] is shown in Table 1. This summary shows that oil spill preventive techniques have been highly effective in reducing the number of spills, but the character of the typical spill remains basically the same. Spills normally occur near shore, from shore facilities and berthed ships undergoing external or internal fuel or oily water transfer. The water conditions, on which spills occur, vary depending on geographical location and season, but the prevailing condition is usually below sea state three. Harbor debris, nested ships, yard craft, floats, lines, piling, and piers are ever-present obstacles to cleanup operations.

Table 1. Summary of Navy spills

<table>
<thead>
<tr>
<th>Category</th>
<th>1972</th>
<th>1973</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of spills</td>
<td>528</td>
<td>290</td>
</tr>
<tr>
<td>Percentage Navy Special</td>
<td>40%</td>
<td>29%</td>
</tr>
<tr>
<td>Percentage Navy Distillate</td>
<td>14%</td>
<td>22%</td>
</tr>
<tr>
<td>Percentage Oily Waste Water</td>
<td>10%</td>
<td>15%</td>
</tr>
<tr>
<td>Percentage Jet Fuel</td>
<td>8%</td>
<td>6%</td>
</tr>
<tr>
<td>Percentage Marine Diesel</td>
<td>6%</td>
<td>4%</td>
</tr>
<tr>
<td>Percentage Lubes, Hydraulic, Gas, Other</td>
<td>22%</td>
<td>24%</td>
</tr>
<tr>
<td>50 Gallons or Less</td>
<td>64%</td>
<td>70%</td>
</tr>
<tr>
<td>100 Gallons or Less</td>
<td>78%</td>
<td>82%</td>
</tr>
<tr>
<td>200 Gallons or Less</td>
<td>86%</td>
<td>89%</td>
</tr>
<tr>
<td>Total Quantity Spilled</td>
<td>116,221 gal.</td>
<td>53,151 gal.</td>
</tr>
</tbody>
</table>

Spill classification. A careful analysis of the Navy's spill history identified two general locations: (1) near shore—primarily around ships and piers, and (2) open waters—away from shore, in harbors, estuaries, and streams.

The range of spill sizes were categorized and this information was then integrated with the two general locations. This resulted in the identification of five specific oil spill classifications which formed the basis for defining the remainder of the system. The five classifications are:

1. minor spill at pierside: oil spills less than 100 gallons
2. medium spill at pierside: oil spills greater than 100 gallons, but less than 1,000 gallons
3. minor spill in open waters: oil spills less than 100 gallons
4. medium spill in open waters: oil spills greater than 100 gallons, but less than 1,000 gallons
5. major spill anywhere in harbor: oil spills in excess of 1,000 gallons

Equipment development

Equipment development was accomplished in three phases: (1) development objectives (requirements) were established, (2) available components deemed acceptable were selected, and (3) the remaining requirements were met through an applied research and development program.

Equipment requirements. Equipment requirements were established via an iterative evaluation process. Tentative operating scenarios were developed which would potentially support the operating scenarios. This list was prepared from commercially available components but performance requirements were increased where there was reasonable confidence that the equipment could be improved. After several iterations, in which adjustments were made to both the operating scenarios and the list of equipment, the following equipment requirements were established:

3 skimmer types
3 boom sizes
utility boats
floating work platforms
ancillary equipment, consisting of:
- modular mooring systems
- monomolecular surface film
- artificially induced surface currents
- sorbents
- equipment storage and cleaning facilities
- other minor tools and devices

Systems development required test and evaluation of equipment components, subsystems, and finally total systems. Adjustments were made at the completion of each test and evaluation phase. Dr. Der [4] reported on the results of the individual equipment evaluations conducted by the Civil Engineering Laboratory (CEL) in 1973. Further equipment evaluations were conducted during first article tests. These tests are included in the equipment procurement contracts in order to measure acceptance of the product. User comments were also integrated with the R&D results and equipment tests.

During the first phase of the CEL equipment development program, the best commercially available off-the-shelf items of equipment were identified through tests and evaluation. The best classes of items were assembled into two viable in-harbor recovery systems for further testing, one for confined areas and one for open areas. The second phase of the program, now underway, deals with investigations to improve the performance, logistics, and deployment of these systems.

Concurrently with the first phase of the CEL work, another program was initiated in Boston Harbor to test and evaluate the operating scenarios. The objective of this effort was to assess the use of ancillary equipment in combination with skimmers and booms, and to develop techniques for cleaning up spills. Tests were conducted with the large and medium skimmer systems, containment boom, air and water jets, monomolecular surface films ("piston film"), and sorbent materials. Test reports [5,6] concluded that the ancillary equipment and techniques were effective in enhancing the containment and removal subsystems developed by CEL and should be incorporated into the Navy program for oil spill cleanup.

Equipment selected. As a result of the work discussed above, the following containment and removal subsystems were identified for procurement and distribution to Navy activities.

Containment subsystem. The primary containment device used by the Navy is boom. Three sizes of boom have been selected for use by the Navy in inland waters. (See figure 2.) The exact size employed in any of the five oil spill classifications depends on the
water environment, boom use experience, and the preference of the operators. The key performance parameters for Navy procured boom are stability and durability. A secondary parameter is compatibility with shoreside manpower and support facilities for deployment and retrieval.

The stability parameter specifically addresses the requirement for good wave following characteristics, vertical stability to minimize oil splash over and entrainment, and stability during high speed towing of boom to the spill site. Catenary sweeping and diversion of oil from high current areas usually provides the most severe tests of boom stability, whereas deployment and retrieval severely tests boom durability. Boom requirements have been refined with each procurement. Successive generations of boom have exhibited more durability in terms of higher tensile strength and abrasion resistance. Durability is required to resist deterioration from the spill environment, including floating debris and rough handling by personnel. Operationally, boom must be stowed in containers that provide pre-positioning plus protection from the elements. Boom is procured with Navy-designed end connectors, bulkhead attachments, and towing attachments, as shown in figure 2. Fifty-foot boom sections with standard end connectors can be quickly connected to form any required length or boom perimeter. The connectors also couple with bulkhead attachments and towing attachments.

The loss of oil at one-knot current perpendicular to the boom has been recognized as the prime factor limiting boom performance. This physical phenomenon requires considerable research and development before a significant advance can be made in boom technology. Accordingly, the Navy approach recognizes this hurdle and stresses wiser use of state-of-the-art boom. It is surmised that if existing boom designs are durable and stable, then the oil loss can be substantially overcome by fast recovery and other boom enhancement techniques. These techniques include: better deployment and handling for faster containment; interchangeable sections for quick alterations to boom geometries; slick deflection techniques in fast currents; and deployment of skimmers downstream at the apex of V boom configurations, among others.

To aid containment operations in boom deployment and retrieval, the following support equipment has been included into the containment subsystem:

**Twenty-foot utility boats** (figure 3) provide mobility for cleanup personnel in locating the spill and positioning boom. They also provide other in-water support, such as mobile coordination between the various components employed in containment and recovery.

**Equipment mooring systems** (figure 4) aid in securing boom away from shore where currents or wind may cause the boom to drift. With a mooring system, one boat can deploy and position boom, and there remain mobile to perform other tasks such as applying piston film, creating prop wash for hearding oil to the boom or skimmer, or deploying sorbents.

**Floating work platforms** (figure 5) provide an alternate type of work boat. They are less maneuverable than utility boats and cannot be easily deployed or transported across land. Once in the water, however, they provide a mobile surface for stowing and deploying boom (figure 6) and flat deck for personnel to effectively work an oil spill. In addition, the platform can be combined with boom and the small skimmer system to provide a mobile, small spill response system, as shown in figure 5.

**Boom cleaning systems** (figure 7) were developed to routinely clean boom (and other equipment) prior to storage. A high pressure hose is used for removing oil from the boom surface. The trough serves as a working surface, as well as a crude oil-water separator. The separated oil is skimmed prior to draining the oily water into a sanitary sewer.

**Removal subsystem.** Three skimmer systems have been selected for use by the Navy. They have been designated as small, medium, and large, and are designed to operate in the five oil spill classifications. The proposed distribution of these systems to Navy activities is based on size and type of the activity, the frequency and size of oil spills, and the existing cleanup capability. The total Navy requirement for oil skimmers is now 251 to be procured over the next five years. The estimated initial cost is in excess of 10 million dollars.

**The small skimmer system** is designed to collect small oil spills at pierside. In selecting a system for procurement, three requirements were considered.

1. The system must be fully self-contained and composed of commercially available components.
2. The initial cost should be less than $5,000.
3. The system must collect and store a 100-gallon spill.

The components, assembled in the configuration depicted in figure 8, perform the following functions. The pickup device operates in a stationary mode and removes oil as the oil is induced toward the device. The suction hose transports the skimmed oil-water mixture via the pump into the oil-water separator for gravity separation of the high water content mixture. After an appropriate retention time the valves are adjusted and the concentrated oil is pumped from the separator into the pillow tank. This high oil content mixture is then transported to a reclamation site. Depending on head conditions, the pump delivers approximately 20 gallons per minute. The system can be transported in a standard pickup truck or placed on the floating work platform for in-water mobility.
The medium skimmer system is designed to collect small and medium oil spills at pierside. In selecting a system for procurement, two requirements were considered.

1. The system had to be fully self-contained. Power and oil transfer and storage components had to be incorporated into the system, thereby eliminating shore support requirements.
2. The system had to be compatible with other oil spill cleanup subsystems.

The JBF DIP 1002 system was selected as the optimum system to meet Navy requirements. The system is trailer mounted and fully self-contained (see figures 9 through 11). Figure 12 shows the oil collection concept for the DIP skimmers. The skimmer is designed to be effectively operated in both the stationary and the maneuvering modes. It is equipped with Navy standard boom end connectors to permit its use at the apex of a boom configuration. A contract is now underway to improve the performance of the system in the stationary mode. A combination of air and water jets will be designed into the system to increase the flow of oil to the mouth of the skimmer. At least two people are required to operate the skimmer system.

DIP SKIMMER MODEL 1001
200 FT OIL CONTAINMENT BOOM
OIL STORAGE RESERVOIR
DIESEL DRIVE AIR COMPRESSOR
JIB BOOM
TOOL & SPARE PARTS BOX
OIL TRANSFER HOSE
SKIMMER CONTROL PANEL

Figure 9. Medium skimmer system

The large skimmer system is designed to collect small, medium, and large spills in open harbor waters. In selecting a system for procurement, the following requirements were considered.

1. The system had to be fully self-contained and self-propelled.
2. The system had to be designed to collect oil in sea state two.
3. The system had to be compatible with other oil spill cleanup subsystems.

The JBF DIP 3001 system, figures 13 and 14, was selected as the optimum system to meet Navy requirements. The system is diesel powered, and has twin screw propulsion for maneuverability around berthed ships and piers. The skimmer is equipped with an onboard oil transfer and storage system. A contract is now underway to modify the oil transfer system to include a debris handling component. The large skimmer also includes Navy standard boom
end connectors to permit its use at the apex of a boom configuration. At least two people are required to operate this system.

The above equipment is the prime component in the total system. Other secondary components are employed depending on the spill situation. These components include water and air jets, prop wash, granular and mat-type sorbents, monomolecular surface film, and various shore support facilities to aid equipment deployment and retrieval. The objective of integrating these components is to enhance the total in-water cleanup operation. As previously discussed, R&D work has been completed to optimize the use of these support components [5,6].

System implementation

After the equipment had been selected and support requirements identified, the final step was to implement the system Navy-wide. This required the development of specific oil spill cleanup scenarios which could be used for personnel training and the preparation of an integrated logistics support plan for long-range support.

Cleanup scenarios. By integrating the five oil spill classifications, available equipment, and state-of-the-art cleanup techniques, eight oil spill cleanup scenarios were developed. Each scenario is discussed in the following paragraphs and summarized in table 2:

Scenario 1. Boom is deployed from its storage container and towed to the spill site with the utility boat. When possible, the spill is completely contained by the boom, taking advantage of solid quay walls, etc. The small skimmer is then deployed into the boomed off area, and oil is directed to the skimmer head with piston film or other types of induced currents. After the majority of the oil has been cleaned up, piston film and sorbents can be used as a final polishing action.

Scenario 2. The oil spill is contained in the same manner as scenario 1. The medium skimmer system is deployed into the boomed off area and operated in the maneuvering mode. Piston film can be used to herd the oil towards the skimmer head. Sorbents are again used as a final polishing agent.

Scenario 3. This step is designed primarily for activities which do not have a small or medium skimmer. Boom is deployed, but is used primarily to control the oil spill rather than completely contain it. The large skimmer is then operated in the maneuvering mode to cleanup the spill.
scenario 4. For larger spill situations, the operation of the medium skimmer is optimized when used in the stationary mode. The skimmer system is deployed down wind and current from the oil slick. Two lengths of boom are then connected to the mouth of the skimmer and deployed in a large V configuration with the skimmer at the apex. Natural and/or induced surface currents are then used to push the oil to the skimmer. Sorbents are again used for final polishing.

scenario 5. This step is designed for activities which do not have a medium skimmer system. The large skimmer can be used in the maneuvering mode like scenario 3, or in the stationary mode as in scenario 4.

scenario 6. Boom is deployed from pier and towed to spill site with a utility boat. The boom is used to control the spill rather than contain it. The large skimmer is operated in the maneuvering mode, starting at the up wind, up current end of the slick. The utility boats can be used to mark the periphery of the slick with granular-type sorbent to aid the visibility of the skimmer operator.

scenario 7. For larger spills, the skimming aperture of the large skimmer can be increased by deploying boom in a V configuration from the mouth of the skimmer. Two utility boats are used to maintain tension in the boom lines as the entire system advances through the oil slick. The floating work platform is used to assist in maintaining coordination between the skimmer and the utility boats.

scenario 8. In a large spill situation, all available equipment and manpower will be deployed to the spill site. Scenarios 4, 5, and 7 are especially effective in a large spill situation.

It should be emphasized that other techniques are being employed, and the eight scenarios do not encompass all feasible techniques. Each spill situation will dictate the type of procedures required for effective cleanup. However, the scenarios do provide a framework which can be used effectively to train personnel in effective oil spill cleanup techniques.

logistics support. Once the developmental phases of the equipment components and operating scenarios showed promise, logistics support planning intensified. The definitive systems and cleanup scenarios provided a basis for developing personnel and training requirements, maintenance and repair philosophy, spare parts support and replacement policy, among others. In addition to interim film reports [8,9], two films are nearing completion for use in training Navy cleanup personnel [10,11]. A comprehensive oil pollution control manual will be published during 1975, and the Integrated Logistics Support Plan (ILSP) for Harbor Oil Spill Removal/Recovery Systems [12] was recently distributed.

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