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TESTS OF THE SHELL SOCK SKIMMER ABOARD USNS POWHATAN

by

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U.S. Navy
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FOREWORD

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

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

This report describes the performance testing of the Shell SOCK skimmer aboard the USNS Powhatan. The tests were the first tests performed offshore by the OHMSETT operating contractor. Further information may be obtained through the Oil and Hazardous Materials Spills Branch in Edison, New Jersey.

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ABSTRACT

An oil skimmer was tested in a controlled crude oil dumping off the New Jersey Coast in early 1980. The program was sponsored by the U.S. Navy, Director of Ocean Engineering, Supervisor of Salvage through the Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) Interagency Technical Committee. Members of the committee included the United States Environmental Protection Agency (USEPA), the United States Coast Guard (USCG) the United States Geological Survey (USGS), the United States Navy (USN), and Environment Canada. The tests were designed to evaluate the Spilled Oil Containment Kit (SOCK) developed by Shell Development Company. The skimmer had been designed as a physical attachment to an oil industry work boat in a vessel of opportunity deployment mode. The United States Naval Ship (USNS) Powhatan T-ATF fleet tug was chosen as a similar vessel and one that had an oil spill recovery operations mode.

The test program is described, including the oil/water distribution and collection system, deployment and retrieval of the SOCK, the onboard fluid measurement, data analysis, logistics, weather and environment measurements, and the Powhatan/SOCK interface. The light crude oil and ocean water collected were stored aboard the vessel and decanted; the emulsified oil was later sold as waste oil. Eight experimental crude oil dumps are described and analyzed. The sea conditions varied from calm to 1.8-m significant wave heights. During the 6 days at sea, 50 m^3 of oil were dumped, and the skimmer collected 32 m of oil.

The program is analyzed for future improvements to open ocean testing plans incorporating oil skimmers with and without vessels of opportunity. This program was fortunate to have available a skimmer that had extensive testing as a model, seaworthiness testing on commercial work boats, and oil collecting experience in a spill of opportunity.

A 16-mm color/sound film on this subject is also available; it is entitled, "Open Ocean Log."

This report was submitted in fulfillment of Contract No. 68-03-2642 by Mason & Hanger-Silas Mason Co., Inc. under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period December 1978 to May 1980, and work was completed as of June 1981.

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LIST OF CONVERSIONS

METRIC TO ENGLISH

To convert from	to	Multiply by
Celsius	degree Fahrenheit	$t_C = (t_F-32)/1.8$
joule	erg	1.000 E+07
joule	foot-pound-force	7.374 E-01
kilogram	pound-mass (lbm avoir)	2.205 E+00
meter	foot	3.281 E+00
meter	inch	3.937 E+01
$meter^2$	$foot^2$	1.076 E+01
$meter^2$	$inch^2$	1.549 E+03
$meter^3$	gallon (U.S. liquid)	2.642 E+02
$meter^3$	liter	1.000 E+03
meter/second	foot/minute	1.969 E+02
meter/second	knot	1.944 E+00
$meter^2$/second	centistoke	1.000 E+06
$meter^3$/second	$foot^3$/minute	2.119 E+03
$meter^3$/second	gallon (U.S. liquid)/minute	1.587 E+04
newton	pound-force (lbf avoir)	2.248 E-01
watt	horsepower (550 ft lbf/s)	1.341 E-03

ENGLISH TO METRIC

centistoke	$meter^2$/second	1.000 E-06
degree Fahrenheit	Celsius	$t_C = (t_F-32)/1.8$
erg	joule	1.000 E-07
foot	meter	3.048 E-01
$foot^2$	$meter^2$	9.290 E-02
foot/minute	meter/second	5.080 E-03
$foot^3$/minute	$meter^3$/second	4.719 E-04
foot-pound-force	joule	1.356 E+00
gallon (U.S. liquid)	$meter^3$	3.785 E-03
gallon (U.S. liquid)/minute	$meter^3$/second	6.309 E-05
horsepower (550 ft lbf/s)	watt	7.457 E+02
inch	meter	2.540 E-02
$inch^2$	$meter^2$	6.452 E-04
knot (international)	meter/second	5.144 E-01
liter	$meter^3$	1.000 E-03
pound force (lbf avoir)	newton	4.448 E+00
pound-mass (lbm avoir)	kilogram	4.535 E-01
pound/$foot^2$	pascal	4.788 E+01

ACKNOWLEDGMENTS

A program of this magnitude and potential impact on spilled oil control technology required a large number of organizations and dedicated people. A broad mix occurred of direct participation by government facilities and private industry. Appendix A lists those organizations contributing on a periodic basis.

The land- and ship-based teams from Mason & Hanger-Silas Mason Co., Inc. performed an outstanding job, bringing all their experience and knowledge to this successful project.

Roy Sea, John Farlow, Richard Griffiths, and Chad Doherty are acknowledged for their timely and effective support. The USNS Powhatan, with its Master, Alex Prieto, provided a safe and effective working platform. Robert Ackerman managed the land-based support activities and Debra Watson managed the production of this report.

SECTION 1

INTRODUCTION

The U.S. Navy Director of Ocean Engineering, Supervisor of Salvage (SUPSAVL), Naval Sea Systems Command has a responsibility to promote oil spill control technology. Also within the Navy is a new class of fleet ocean tug, T-ATF 166, which incorporates the capabilities and design features of commercial offshore industry tug/supply boats (Reference 1). The mission as a unit of the Mobile Logistics Support Force is to salvage and take in tow ships of the Fleet that are battle damaged or non-operational. Permanently installed equipment onboard provides for wire rope towing, synthetic hawser towing, quick reaction system for beaching/broaching problems, mooring, firefighting, and dewatering. Other designated portable equipment can be loaded onboard before additional missions for salvage, diving, and oil spill recovery.

The U.S. Navy has an extensive inventory of booms and skimming equipment that have demonstrated high performance and efficient deployment. Their interests lie in looking to the future and to new spill equipment capability. They were convinced by Shell Development Company that the Spilled Oil Containment Kit (SOCK) (Reference 2) may be a candidate for a cost-effective, vessel-of-opportunity system that could be deployed from standard offshore supply boats.

SUPSALV is a member of the OHMSETT Interagency Technical Committee and as such requested the committee in December 1978 to listen to a proposal to formulate a research plan to test a skimming system offshore using crude oil. The committee membership included representatives from U.S. Navy Supervisor of Salvage, (USN-SUPSALV), the U.S. Environmental Protection Agency, (USEPA), the U.S. Coast Guard, (USCG), and the U.S. Geological Survey (USGS). The chairman is the EPA representative from the Oil and Hazardous Materials Spills Branch, Municipal Environmental Research Laboratory. The committee assigned the responsibility to OHMSETT to research, design, deploy, test, retrieve, and report on the program. In January 1979, Mason & Hanger-Silas Mason Co., Inc., operators of the OHMSETT facility, drew up a budget for the Program.

Research began on existing permits and review of past experience. The only significant recorded recent attempts were the soybean oil experiments with a U.S. Coast Guard containment barrier and the small crude oil dumps for dispersant studies. The OHMSETT plan initially considered testing the SOCK to be tested on a leased oil industry supply boat off the New Jersey Coast in October 1979. A published survey (Reference 3) indicated that there were 2750 vessels for hire or charter around the world. We estimated that at least half of them could be considered for deploying the SOCK. A closer evaluation indicated that only four would be within reason for the program because of their cost, schedule committments, load capability, and integration to our program. The next major decision was selection of a crude oil. A published survey (Reference 4) revealed 93 different types of crude oil in the world export streams. Analysis based on this and many other factors led us to confirm that La Rosa and Murban should be primary candidates for the test oil, because their physical properties are representative of export crudes.

The research program plan was completed and submitted by the USN to the USEPA Region II Office, New York City, in May 1979 (Reference 5). Engineering was continued in parallel to design, fabricate, test and deploy a portable test platform adaptable to vessels of opportunity for the SOCK. High priority was placed on a versatile system design to be used in future testing at sea for most any skimming system, and to be available for spills-of-opportunity testing.

The planning continued despite several diversions. The SOCK was loaned to PEMEX (Reference 6) during portions of the IXTOC I spill. The Dutch government expressed interest by offering equipment and facilities on the North Sea for the offshore tests. We observed firsthand several cleanup systems at IXTOC I. We then aided the deployment at the Burmah Agate spill of a recently CHMSETT-tested system, Troil/Destroil, and tried to quantify its performance on a vessel-of-opportunity 22-m (72-ft) shrimp boat.

In January 1980, the USNS Powhatan was selected as the dedicated vessel for the experiments and the Permit was issued by USEPA (Reference 7). Hardware designs were integrated to the T-ATF 166 class, and fabrication of the test equipment began. A portable on-deck tankage was also considered preferable for crude oil and fluids storage. The at-sea schedule was fixed for mid-April 1980. The USCG offered their cutter Reliance as an observation platform at sea. Communications were firmly established with the Captain of the Port in New York City and with the Region II USEPA administrator.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

This test program yielded two significant new understandings of oil spill control technology. First, a large quantity of crude oil was dumped successfully to quantify skimmer perfomrance in the ocean environment. The second new understanding is what constitutes a vessel of opportunity.

The SOCK system performance was outstanding under specific operating conditions. The best performance was measured during the mid-morning of April 12, 1980. The sea conditions were considered sea state 2. The recorded wave heights were one meter with five second periods. The wind speed averaged 8 knots, and the Powhatan was moving into the wind and seas. The measured throughput and recovery efficiencies of the SOCK were 89 and 93 percent, respectively. The relative wind-driven surface speed was 1.5 knots. The crude oil recovery rate was 35 m^3/hour. This figure corresponds to 154 gpm, 220 barrels per hour, and 31.6 long tons per hour. The slick encountered was 2 mm thick, and the SOCK had a preload of 3.8 m^3.

At the same speed, but with rougher seas and thicker slicks, the performance dropped significantly. The afternoon test was in 1.4-m waves every 3.7 seconds and 20-knot winds. The slick was 3.3 mm. Throughput and recovery efficiencies dropped to 39 and 47 percent, respectively, and the crude oil recovery rate dropped 66 percent down to 12 m^3/hour. Other tests concluded that speeds of 0.75 knot and at 2 knots, the performance was also degraded significantly. The eight offshore combined tests of the Powhatan/SOCK dumped 50 m^3 of crude oil and the system recovered 32 m^3.

The second understanding produced from this program is that such terms as "vessel-of-opportunity" and "vessel-of-convenience" are misleading. If the spiller wants to accept that terminology, he faces significant logistics problems, long waits, and high costs. It is analogous to the misconception of many lay people that there is an abundance of empty barges and idle tugboats in every harbor in the United States that could be used for spilled oil collection storage.

A great majority of oil industry work boats cannot independently go slowly enough in the water while continually pulling low-drag force skimmers. A tugboat must be astern to provide additional load, or the workboat operator must abuse the engine system. This program was fortunate in having available a vessel with variable-pitch propellers. The Powhatan could only use one engine and its bow thruster to maintain the slow speeds with a steady heading.

This research program can produce a large quantity of recommendations based on this singular experience that was extensively documented. The most important recommendation, however, is that open ocean testing in the future should continue to be limited to those devices that have progressed through the complete engineering cycle. They must have been tank tested with oil and survived open ocean seaworthiness tests.

Before the SOCK tests, two spill-of-opportunity tests were made in the Gulf of Mexico. There were 10 days at sea, only two tests (in calm water), and fewer data (by several orders of magnitude). We recommend that spill-of-opportunity testing be given its own jurisdiction, research priority, and financial emphasis. Apparently, weather and sea-state should be the only constraints. Instrumentation must be well designed and tested. Deployment needs be planned thoroughly, and the equipment must be sturdy and dispatched on a timely basis.

SECTION 3

RESEARCH PLAN

PROGRAM PLAN

This program is based on experience and research from U.S. Government Agencies and incorporates the latest technology in spills of oil on the near-coastal waters.

Introduction

This test program was designed to evaluate the performance of the Shell SOCK oil skimmer in an ocean environment. The plan proposed a test of the Shell SOCK by collecting crude oils in the open sea typical of those which are transported on US waters. The character of the crude oil selected for dumping is well documented in field data from prior spill tests in the same geographic area (off the New Jersey Coast). The program was estimated for twelve oil dumps, each with a maximum of 13.2 m^3 (3,500 gal). A maximum of 18.9 m^3 (5,000 gal) of oil will be left at sea. The test plan was carefully designed to minimize resultant impact on the environment.

Program Justification

Skimmer design technology has diverted into several different approaches and many of these in concert with "dedicated" vessels--i.e., those designed or modified specifically for spill cleanup purposes. Availability of these dedicated vessels has often been a severe logistics problem, they are frequently costly, and storage of collected fluids is burdensome. Concepts to date may be categorized into oleophilic belts, vortex separation, rotating oleophilic discs, weirs, dynamic inclined plane, oleophilic drum discs, streaming fibers with weirs, mops, paddle wheels, and various combinations thereof (Reference 8). The forces at sea have been destructive and degraded performance of most of these concepts.

It is believed that the Shell SOCK system proposed for testing represents, overall, one of the most promising designs. If at-sea results with oil verify predicted performance, it may also prove to be unusually cost-effective.

Test Objectives

The overall objective of the program is to embark on a field test operation utilizing the quantitative and qualitative data available from industry and Federal Research and Development agencies to document and demonstrate the capability of a spilled oil skimmer collecting crude oil from the open sea.

In the past fifteen years, research has resulted in a large number of individual studies and development has produced several hundred skimmer concepts and patents. Engineers have tested skimmers in clean waters without oil, followed by tests in a large dedicated test tank collecting simulated crude oils. It is recognized that skimmers provide only one of several options to spill control and these may be complemented with or replaced by dispersants, especially offshore. Several different types of advancing skimmers have been marketed to industry and governmental agencies but none have been adequately documented in cleaning actual oil spills. Private contractors, cooperatives and the U.S. Coast Guard Strike Teams are frequently used for spill cleanup but a great deal of factual data still needs to be accumulated as the basis for future design and progress. Spills on the water (whether infrequent and large, or frequent and of small magnitude) are understandably met with immediate concerns for property, the environment, and safety. Unfortunately this does not often allow collecting data to benefit design and operation of the skimmers. The results of this program will provide new and essential data related to oil spill recovery.

Expected Benefits

The program will produce a substantial benefit to a number of federal agencies including the USEPA, the USCG, and the USN and it will provide new and definitive technicial data to assist private industry in meeting spill control and cleanup responsibilities. The skimmer system is one which is expected to be exceptionally cost-effective and the test program is needed to produce an actual discharge of oil at sea under controlled, well defined conditions. The SOCK system has been developed over a number of years, beginning with a theoretical concept followed by model testing in wave/tow tanks and full-size testing in tanks with oil. Subsequently, seaworthiness tests were conducted in the ocean without oil. Because available test tanks are too small to completely evaluate the capabilities of the system in full-scale, actual environment mode and because no other alternate means for conducting the research are available, this program is necessary to prove the device--in sea conditions with oil.

The program will allow transference of laboratory-proven experience into a field situation to evaluate oil skimming performance. In addition, field operations will allow detailed records to be made of operational features such as the ease of deployment, on-station operational procedures and retrieval of the skimmer system. The basic elements of study will include:

(1) selection and dockside outfitting of a single vessel of opportunity typical of those normally available in petroleum producing areas.

(2) deployment of the skimmer from its transport position to its oil-collection position.

(3) measurement of the weather/sea conditions on station and the sea-worthiness of the skimmer/boat in that environment.

(4) creating an actual crude oil spill for the skimmer/vessel system to collect. This will be accomplished by first releasing a small preload quantity of oil directly in front of the skimmer's entrance followed by a

slick equivalent to that likely to be encountered in continuous operations during a spill.

(5) measuring the skimmer's actual performance in collecting oil, including throughput efficiency, recovery efficiency, and recovery rate in increasingly difficult combinations of wave and speed conditions.

(6) managing of collected fluids (oil and water) on the vessel.

(7) retrieval of the skimmer to the vessel of opportunity and subsequent return to port.

(8) equipment cleaning and environmentally safe disposition of the collected fluids.

(9) production of a written report of the program and resulting data, including a documentary film.

TEST PLAN

The plan is designed to ensure minimum opportunity for an accidental spill. It incorporates the best known resources of engineering and equipment for the remote operations.

Background and Previous Research

The OHMSETT Interagency Technical Committee (OITC) membership currently represents the USN, USCG, USGS, and the USEPA. The OITC has jointly sponsored skimmer testing/development at OHMSETT for the last four years to discover cost-effective solutions to oil spill cleanup technology. To date, the OITC has jointly conducted 16 weeks of intensive performance tasks with oil on eight different types of skimmers. This test program is intended to "bridge" the effort between designer and user and to integrate performance efficiency with the logistics of deployment, operation, and retrieval.

Under OITC sponsorship and control, 730 m^3 (192,940 gal) of test oil has been spilled in tests at OHMSETT using three refined naphthenic grades of different viscosities to simulate the major span of crude oil properties. OHMSETT, in the past five years has dumped 6,000 m^3 of test oil. Table 1 illustrates typical properties of the test oils, all of which have less than 0.24% sulfur content.

TABLE 1. TYPICAL PROPERTIES OF TEST OILS USED AT OHMSETT

	Light	Medium	Heavy
Specific Gravity	0.89	0.92	0.94
Viscosity, (cSt @ 75°F)	9.0	200.0	1300.0
Surface Tension (dynes/cm)	32.9	33.5	34.4
Interfacial Tension, Saltwater (dynes/cm)	27.0	26.4	26.3
Gravity, °API	26.4	20.3	18.4
Density, lb per gal	7.46	7.76	7.86
Pour Point, °F	-50	-20	-5
Aniline Point, °F	131.0	156.0	168.0
Flash Point, °F	225.0	350.0	390.0

The only documented (Reference 14) intentional offshore spills employed to test oil collection techniques utilized soybean oil (27,000 gal in the Gulf of Mexico off Tampa, Florida and 50,000 gal in the Pacific Ocean off Point Conception, California). While possibly simulating the hydrodynamic properties of a single crude, this test oil could not model other, more important, chemical properties peculiar to other crudes commonly shipped in U.S. waters. The specific gravity of the soybean test oil is so high that only seven of the 93 popular exported crudes throughout the world have equal or higher values. Tank testing technology improved following the soybean oil tests, initially by using paraffin-based refined oils and finally progressing to the naphthenic oils. Nevertheless, these latest improvements cannot simulate the chemical properties of raw crude stocks.

Crude oils should be avoided in test tank facilities for many reasons. Safety of personnel and property is paramount in that flammability and storage containment requires expensive precautions and presents a danger to the land-based environment. Refined test oil entrainment in large saltwater tanks has a straightforward engineering filter design solution and refined oil does not weather or form a mousse like the typical raw crude stock. Emulsions of crude oil and saltwater are difficult to break and thus economy is also a benefit in using the refined stocks. Reclamation and reuse of these oils is technically straightforward. Equipment cleaning and service life is much better with the known test oils. The laboratory environment can predict hydrodynamic response but not the chemical response that so often is reported on real spills where synergism displays additive effects different from singularly tested phenomenon.

There are perhaps several hundred test tanks in the world that can generate wave motion for studying vessel response on a sub-scale or model basis; however, only a few can deploy oil for skimmer studies. None can generate the combination of random waves, tidal currents, and wind forces to be experienced by a full-size vessel collecting spilled crude oil on the open water. To date, the OITC program has conducted 483 tests in waves with oil in EPA's OHMSETT test facility at speeds from one-half to 6 kt. The waves vary from one-half to 4 ft high, and include harbor chops, confused seas, and wave periods between 1.5 and 4.0 seconds. The

Committee, with its broad-base sponsorship, is constantly being advised, consulted and supplied information from spill equipment users. This offshore test program is designed to answer most of the users' needs and provide data not otherwise obtainable by industry.

Test Oils

The La Rosa and Murban crude oils to be used for this offshore test program were selected based on (1) rank in the 93 such varieties currently in the export stream and (2) previous offshore research spills in the same geographic location. The characteristics and composition of these two crudes are indicated in Table 2. An existing Ocean Dumping Permit No. 11-MA-143 provides a program opportunity for dispersant research studies, and this follow-on should provide newer hardware and logistics data for removing the same type of spilled crude oil from the ocean. Crude oil is one of the constituents listed in 40 CFR 227.6(a) 4, "Constituents prohibited as other than trace contaminants". However, the prohibitions and limitations of this section do not apply for the granting of research permits if the substances are rapidly rendered harmless by physical, chemical, or biological processes in the sea.

TABLE 2. CRUDE OIL DATA AND COMPOSITION OF NAPHTHA FRACTION

Crude Oil		La Rosa	Murban
API Gravity @ 15.6°C		23.9°	39.0°
Sulfur (wt. %)		1.73	0.82
204°C minus fraction		11 vol. %	19 vol. %
		Percent by Weight	
Benzene		0.6	0.7
Toluene		2.0	2.6
C_8 Aromatic		3.4	4.6
C_9 Aromatic		2.7	3.9
C_{10} Aromatic		1.3	1.8
C_{11} Aromatic		0.5	0.7
C_{12} Aromatic		0.2	0.2
C_{13} Aromatic		0.1	0.0
Naphthalenes		0.0	0.0
Indans		0.5	0.4
	Total Aromatics	11.3	14.9
Paraffins		46.7	65.8
Cycloparaffins		38.3	17.5
Dicycloparaffins		3.7	1.8
	Total	100.0	100.0

It is estimated that nearly 70% of the exported crudes will fall between the range of the API gravity of the La Rosa and Murban crudes. Only 31% of the crudes have a pour point greater than freezing temperatures. Weathering tests of La Rosa at

OHMSETT for 144 hours in saltwater and waves showed a slight increase in specific gravity, an order of magnitude increase in viscosity, a slight decrease in surface tension and a 50% drop of interfacial tension.

Skimmer

The Spilled Oil Containment Kit (SOCK), designed by Shell Development Company, has been selected for this program. Shell Oil Company reports development began on the device six years ago as a solution to the high cost of fast current skimmers on dedicated vessels and to address acceptable performance in realistic ocean wave conditions. A one-eighth scale model was tank-tested to study work boat hydrodynamic actions and a one-half scale model was built and tested for oil/water interactions. The Gulf of Alaska Clean-up Organization (GOACO) then began sponsoring a program to build and test a full-scale prototype model, and the pumping system has been tested successfully with debris, ice, and heavy and light test oils. The full-scale prototype has been tested for seaworthiness alongside work boats in the Galveston, Texas area of the Gulf of Mexico and the Port Hueneme, California area in the Pacific Ocean. Emphasis on, and modifications in deployment, seaworthiness, and retrieval in all development test programs has produced a viable integrated package for easy, quick attachment to many vessels of opportunity capable of withstanding four foot seas. Recovery efficiencies are estimated at greater than 80%.

Shell Oil also reports SOCK's unique design responds to realistic ocean wave conditions by dampening the oily surface with a flexible curtain as opposed to using a rigid shallow-draft dedicated vessel hull. Compared with 16 existing skimmers in the world market, the cost and scope of deployment indicates promise as the most favorable offshore crude oil test candidate, based on skimmer cost to recover 60% of a 7,570-m^3 (2-million gal) spill. The quick response time resulting from the ability to be used with a vessel of opportunity (as opposed to a dedicated vessel) makes the SOCK even more attractive.

Test Site

The test site (identified in Figure 1) was selected to coincide with prior tests of the same crudes and to benefit from other experimenters' data. This test program will be scheduled so as not to conflict with other tests which may be planned in the area. In selecting specific sites for conducting the proposed controlled spills, the principal consideration was to minimize the chance that the oil could drift to shore or into any environmentally sensitive area. Additional criteria applied in the selection process included: (1) avoidance of areas of high activity such as shipping, commercial and/or sport fishing, etc.; (2) water depth sufficient to assure that no spawning areas are contaminated; and (3) a shore-to-shore test area distance compatible with transit and on-station times of work boat and support vessels. Alternate test sites are considered unacceptable due to their inability to conform to the above criteria.

The general area proposed for conducting the test is within the New York Bight, and lies on a line extending generally southeast of Sandy Hook at a distance of 25 to 50 nautical miles.

The surface drift currents in this area are small (1/10 to 1/4 kt) and set generally to the south. During the proposed test period (April, 1980) weather

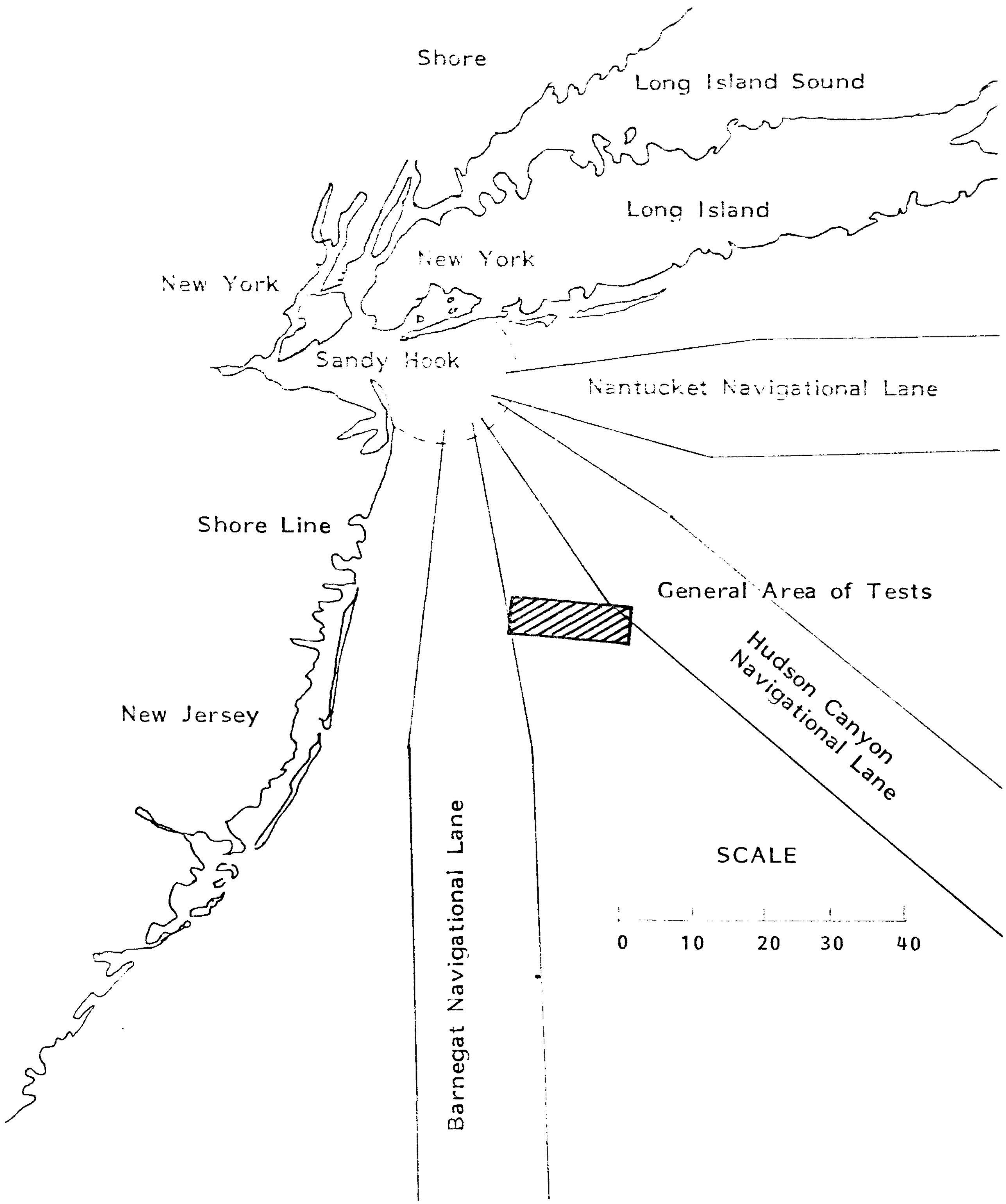


Figure 1. General area for proposed test sites.

records indicate the prevailing winds will be westerly. Observations of oil spills have indicated that oil on the surface will move at a speed and direction that is the vector sum of the water velocity and a fraction or percentage of the wind velocity. Thus, when conditions are normal, the oil spilled for research purposes will tend to move in approximately a southeast direction; that is, away from the land and out to sea. If these normal, favorable conditions do not prevail, test spills will be delayed pending acceptable changes in the weather.

The proposed test area is located near the Hudson Shelf Valley leading to the Continental Shelf, providing water depths in the range of 40 to 80 m (approximately 131-262 ft, or 22 to 44 fathoms). Such depths will be more than adequate to assure that the spilled oil will not contaminate the bottom sediments.

The U.S. Coast Guard has established three traffic separation zones leading into Ambrose Channel and the ports of New York and New Jersey. These are identified as the Barnegat, Hudson Canyon, and Nantucket navigational lanes and are shown in Figure 1. The area under consideration within which the test site has been selected, has been located so as to be outside the navigational lanes. Because of this, it should be possible to avoid the bulk of commercial shipping traffic.

Test Procedures on Station

There is a specific order of procedures to follow that interact to provide an effective test program.

Preliminary Actions

The actual skimmer performance test will begin after the wind and sea conditions are confirmed and the water sampled for baseline conditions. Site location, communications, safety, and ancillary equipment will all be checked to insure that they are in proper order.

Skimmer Deployment

The powered contingency Zodiac boat, MonArk launch, or MARCO Skimmer will be deployed in the water to its starboard position alongside and amidship of the work boat. The SOCK boom-skimmer will then be lowered from its shipboard position to the water and moored in position to accept dumped oil from the work boat.

Seaworthiness

A practice deployment will be made to insure launching and retrieval compatibility of the SOCK, Powhatan, and fluid management systems. The work boat will be steered into the wind and current at slow speed, increasing in ¼-kt increments to 2.5 kt. Rigging and boom-skimmer response integrity will be observed in both head and overtaking seas.

Preload Capability

The La Rosa crude oil will be dumped during the first test series. Murban crude will be used for the last. A metered quantity 1.89 m^3 (500 gal) of crude oil will be deployed from the work boat upstream from the boom-skimmer at a rate of 68 m^3/hr (300 gpm) with the forward speed at 1 kt causing a 5 mm thick slick herded with water jets into the skimmer's mouth. The boat will maintain course and speed for several minutes to assure there is no excess oil loss from the skimmer.

The test will then begin. After the test and all data have been collected, speed will be increased by ¼ kt. Another preload of 1.89 m^3 (500 gal) will be deployed for the SOCK to check for excess oil loss and seaworthiness. If all functions are working properly the speed will be increased in quarter kt increments to 2.5 kt. The boat will maintain course and speed for several minutes to assure there is no excess loss from the skimmer. The test will then begin, increasing speed until a definite oil loss is observed. These tests in overtaking seas will be repeated in an abbreviated fashion in head seas and with the Murban crude oil.

Test Procedures

- Maintain speed,
- deploy 1.89 m^3 (500 gal) preload test,
- maintain course and speed for several minutes,
- check preload for excess loss of oil,
- deploy oil slick at 68 m^3/hr (300 gpm) for 10 minutes,
- collect data,
- increase speed by ½ kt,
- deploy 1.89 m^3 (500 gal) preload,
- check preload for excess loss of oil,
- increase speed by ½ kt,
- check seaworthiness and for loss of excess oil,
- deploy oil slick at 68 m^3/hr (300 gpm) for 10 minutes, and
- repeat appropriate steps .

The tests were originally planned for runs at 1, 2, 3, and 4 kt with seaworthiness and preload checks at 1, 1.5, 2, 2.5, 3, 3.5, and 4 kt. Shell's more recent observations suggest these speeds are too fast and should be reduced to quarter kt increments up to 2.5 kt maximum.

Performance Efficiency

The skimmer preload is required to keep the multiple oil suction ports collecting pure oil instead of unnecessary sea water that would render onboard collected fluids storage inefficient. Performance efficiency testing will begin with a 1.89 m^3 (500 gal) preload at a 1 kt speed, then deploying an oil slick from the work boat at 68 m^3/hr (300 gpm) for 10 minutes. The test matrix for the twelve tests will be as indicated in Table 3.

TABLE 3. TEST MATRIX

OIL	LA ROSA		MURBAN	
Speed (kt)	Overtaking Seas	Head Seas	Overtaking Seas	Head seas
0.75	x	x	---	---
1.00	x	x	x	x
1.50	x	x	x	x
2.25	x	---	---	---

Two tests will be performed with La Rosa in head seas at 1.5 kt--one with the standard 68 m^3/hr (300 gpm) oil slick and the other with 37 m^3/hr (165 gpm). With a fixed oil distribution rate (300) and fixed oil/water removal rate of 75 m^3/hr (330 gpm), the oil slick thickness will vary from 1.25 mm to 5.0 mm depending on work boat speed. Metering of crude oil distributed, balanced with metered fluids (oil/water) recovered on the work boat will be used to calculate the performance efficiencies and rates. Throughput efficiency is the ratio of oil recovered to that presented to the skimmer. Recovery efficiency is the ratio of oil recovered to the fluids recovered (oil/water). Recovery rate is the oil recovery rate measured in gal per minute.

Fluids Management

Crude oils will be stored separately on the deck of the work boat in closed seaworthy containers. Distribution of the oils will be channelled through flow meters and cross checked with volume measurments. Collected fluids will be metered, aliquots taken to determine proportion of oil/water staged through the SOCK, and then transferred to the deck storage tanks. Small volumes of crude oil lost under the SOCK during specific tests will briefly surface and then be caught, mixed, and dispersed due to the work boat propeller wash. Fluid recovery samples from the skimmer will be analyzed after each test and calculations completed before the next. Gross volume figures indicate that the 159 m^3 (42,000 gal) of crude oil will result in recovery fluids volume of 200 m^3 (53,000 gal) oil and water at 80% recovery efficiency (RE), 318 m^3 (84,000 gal) at 50% RE, and 530 m^3 (140,000 gal) for 30% RE.

Skimmer Retrieval

The transfer pumps and piping system will be purged, capped and the fluids collected. The boom skimmer will be retrieved by its integrated rail/crane system, cleaned with fire hoses, and stored. The support boats will then be retrieved and stored.

Flotilla Maneuvers

Historical sea/weather conditions are utilized to produce the scenario in the proposed general test area. The surface rectangular envelope (see Figure 3), will be five miles wide and 20 miles long with major axis ESE, between the outer boundaries of the Barnegat and Hudson Canyon navigational lanes. This is based on worst conditions with wave crests parallel to NNE/SSW. Overtaking sea tests will begin in the western most section of the envelope. One hour will be spent on station rigging, deploying, and confirming sea/weather conditions. Then 15 minutes of upwind seaworthiness tests (0-2.5 kt) will be performed, followed by four one hour downwind performance efficiency tests at speeds of 0.75, 1.0, 1.5 and 2.25 kt. The six hours required for these flotilla maneuvers should span 11 to 20 miles straight line travel distance. Retrieving, derigging, and cleaning will take an additional hour before returning to port. The second day at sea will begin in the eastern most section and move WNW, with resulting headseas. The last day will be a combination of head and overtaking seas.

Schedule

The combinations of at-station maneuvering, safety precautions, and onboard oil sampling will require three test days at sea with approximately four test spills per day each requiring an hour's time. Each 10 hour day will consist of traveling to station, deploying the SOCK, running tests, retrieving the SOCK, and returning to port. No tests will be commenced after 2:00 PM local time (1900 Greenwich Mean Time) in order to ensure adequate daylight to cope with any complications that may develop. Additional oil clean-up capability will be on site during all test operations.

Safety

Safety practices will be observed at all times and conform to all federal regulations applicable both offshore and dockside. The captain of the work boat will be in charge and thoroughly cognizant of the test program for close coordination with the test engineer, vessels in the flotilla, and the observer vessel. All participants and authorized observers will be required to follow safety regulations.

Communications

In addition to normal marine communications equipment, the flotilla will have mobile radio capability. The command station for the entire operation will be the bridge of the work boat. This central location allows for quick response to any and all problems which may arise. Fixed and portable radio communication will be established so as to avoid interference with other radio frequencies.

SAFEGUARDS AND CONTROLS

The planning for the test has been a cautious approach to experimental procedure so as to minimize environmental impact. The detailed cautious planning is evident in the site characteristics, monitoring and control, and contingency measures of the experiment.

Site Characteristics

- The proposed test site is more than 20 miles from nearest shore.
- The oil slick will travel seaward.
- Water depths are 40 to 80 m.
- Outside navigational lanes.
- Prevailing winds are directed offshore.
- Impact to environment is small.

Monitoring and Control

Weather conditions and forecasts will be consulted before beginning every test. Upon determination of satisfactory weather, the command station will ensure there is no conflict with other marine activities within a specified radius. A small amount of oil will be preloaded into the SOCK to ensure no excess loss of oil before the experiment begins. If there is indication of large loss of oil, the experiment will not begin. Complete communication with all vessels will ensure full control over the test procedure. A pump will be used to spread the oil and it can be stopped at any moment should a problem situation warrant such action. When in the course of an experiment, excess loss of oil is noticed either by the bridge spotter or by the spotter at the rear of the work boat, the experiment will be discontinued.

Contingency Measures

An additional contingency force will be available for an as-needed basis. This includes one observer vessel, a MonArk launch, two small maneuverable work boats (Zodiac), and an additional skimmer vessel (MARCO V). The distance from shore is approximately 20-30 miles and emergency help can be summoned immediately.

At all times during the proposed test, a combination of monitoring activites will be aimed at controlling test operations to assure potentially adverse conditions are avoided. Before any test is allowed to start, command station will conduct a reconnaissance of surrounding waters to ensure no conflict with other marine activities. Continual monitoring of the National Weather Service forecasts, marine weather broadcasts, and Coast Guard channels will ensure complete up-to-date information on winds, meteorlogical, and sea conditions. In the event that a slick presents potential adverse affects, the test vessels and contingency force will proceed to the slick and employ appropriate measures until the slick is picked up, dispersed, diluted and/or poses no threat.

SECTION 4

PORTABLE TEST FACILITY

USNS POWHATAN

This T-ATF 166 Class ship is a new class combining the capabilities of the U.S. Navy's tugs, ATF's, and commercial offshore tug/supply boat (Figures 2 and 3). It is manned by a civilian crew of the Military Sealift Command (MSC) and a Navy communications team. The normal complement is 16 men from MSC and 4 Navy communication men. There are good accommodations for 20 additional men as transients to support portable equipment missions.

The ship utilizes twin diesel drive supplied through separate shafts to controllable pitch propellers in nozzles. Commercially proven equipment is installed throughout the vessel. The vessel is 226 ft long, 204 ft at the waterline, beam width 42 ft, draft of 15 ft and full load displacement of 2260 tons. The free route speed at design waterline and 80% ship horsepower is 15 kt, cruising speed is 13 kt, and optimum towing speed is 6 kt. The vessel forward speed was controllable in 0.1 knot increments at low speeds. The endurance cruising range is 10000 miles. Ship power includes two 3600 brake-horsepower (BHP) diesels, a 300 horsepower (HP) bow thruster, and three 400 kW diesel generators.

Permanent equipment on board includes a 10-ton crane telescoping to 64 ft, a towing winch capable of holding 500,000 lb, a traction line machine capable of a static line pull of 400,000 lb, a permanent capstan capable of 30,000 lb at 20 ft/min, a 9,000-lb MOORFAST type anchor, two combination vertical capstan and anchor windlass units, each capable of 27,000 lb pull at 20 ft/min, a 24 ft aluminum workboat powered by 4-53-N Detroit Diesel, a towing bow, a stern roller, norman pins, bulwark rollers, a tow wire guide, and two small portable capstans capable of 5,000 lb pull at 20 ft/min. One unusual feature is a main deck bolt-down grid pattern. It consisted of threaded recessed sockets every 2 ft (1-in, eight UNC threads) in the clear deck area rectangle of 38 ft by 88 ft. The allowable deck load was considered 300 tons for transient equipment.

ORGANIZATION

The integration of the skimmer test program and portable test facility to the USNS Powhatan was based on minimizing the physical interface.

The master operated the ship in accordance with MSC standard operating procedures. The senior member of the transient crew was in command of the transient crew and the oil dumping operations and equipment as an agent of the U.S. Navy. The transient crew was grouped into ten for test operations, two for environmental support, three for skimmer operation (launch and retrieval required three extra from

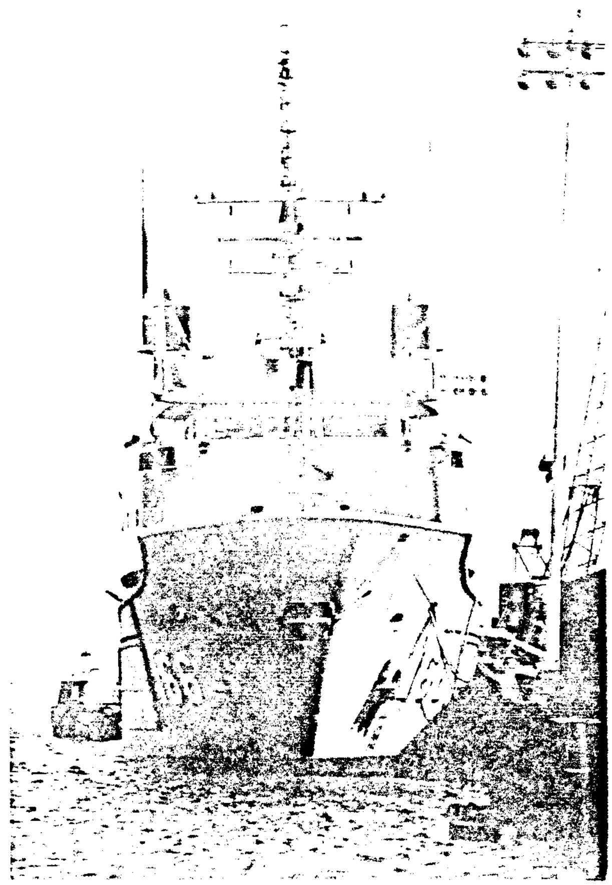


Figure 2. USNS Powhatan, bow view.

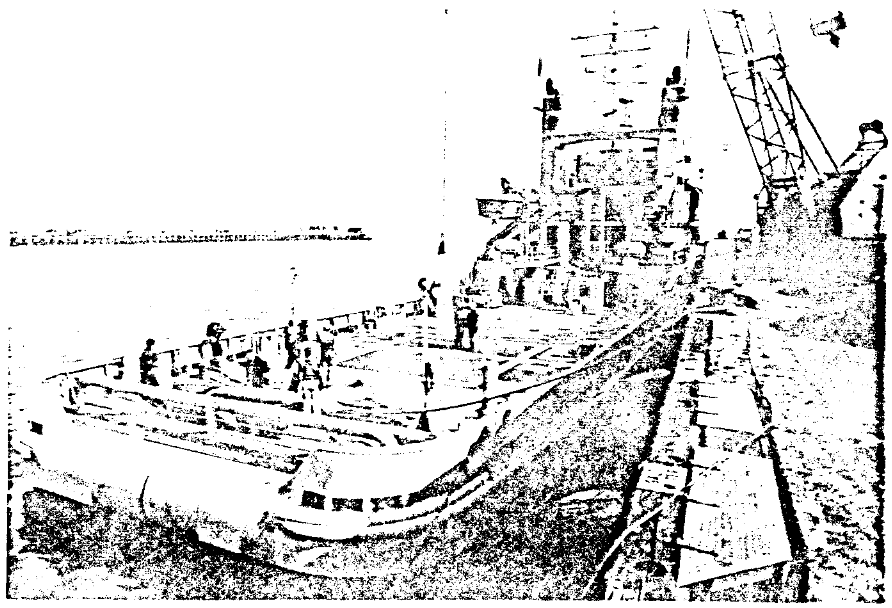


Figure 3. USNS Powhatan, stern view.

the test operations group), three OITC observers, and one operator for the MARCO contingency skimmer. Another group of transients was periodically onboard as official observers. A land based crew of 11 supported ship loading, special supplies, and base station.

TEST EQUIPMENT

Most of the portable test facility for deploying on the Powhatan was designed and tested at OHMSETT based on six years experience of testing in the tank and the most recent experience of testing in offsite spills-of-opportunity. Thirty-one short tons of equipment was transferred to the ship. The basic elements of the shipboard facility were:

- large storage containers for crude oil and collected sea water (6)
- slick generator (deployed at sea)
- fluids distribution manifolds (3)
- gasoline engine hydraulic power pack (1)
- water jet slick control system (deployed at sea)
- gear pump for crude oil distribution (1)
- air-driven double-diaphragm fluid transfer pumps (2)
- crude oil, vane-type totalizer flow meter (1)
- tank sounding instruments
- venturi meter for collected fluids (1)
- miscellaneous measuring tools and gauges
- acoustic flow meter for collected fluids (1)
- flexible hose, fluids transfer (350 ft)
- tool house, spare parts and tools
- video cameras and playback equipment
- photo equipment, 16-mm motion picture and 35-mm stills
- chemistry laboratory, oil/water separation analysis
- environment measuring laboratory, waves, current, weather
- automatic Loran-C tracking, position, depth

- special radio communication equipment
- cleaning equipment and sorbents
- detailed library of engineering calculations
- detailed data-gathering manuals and sampling procedures
- detailed onboard calculation procedures with contingencies
- well-trained and supervised transient crew
- property management procedures
- detailed safety program
- spill prevention control and countermeasures plan
- recreation plan

The portable test facility was capable of storing 114 m^3 (30,000 gallons) of fluids on each cruise. The distribution system could dump test crude oil at a rate of 127 m^3/hr (558 gpm), higher than the skimmer capacity and could be accurately throttled to lower rates simulating thinner slicks. All skimmer collected fluids brought aboard could be monitored. All measurements and test data could be evaluated on station to produce preliminary performance results.

Dockside support was vital to the portable test facility. This program utilized the deepwater pier located on Naval Weapons Station Earle at Leonardo, NJ. A 70-ton crane was used for lifting the SOCK equipment. Tractors were required to move large equipment on flatbed trailers and 19 m^3 (5,000 gallon) fluid tank trailers. Each late-night docking required offloading of the crude oil and sea water collections of the day. Test crude oil tanks had to be filled with fresh crude each evening.

FLUIDS MANAGEMENT

A flow diagram best describes the fluids management and includes integrating manifolds, sampling piping, storage tanks, and pumps for three separate floating sea platforms. Figure 4 illustrates symbolically the basic elements and connections of the platforms. Designator legends are "M" for manifolds, "S" for individual sampling station, conventional pump symbol, and lines representing piping and dashed lines circumscribing floating platform limits. The piping system was designed to remain intact once onboard, and not to be opened except for emergency repair. The 23 unique sampling techniques are discussed in detail later in this report in regard to skimmer performance. Some, had a primary function to monitor crude oil as designed in the research plan and permit constraints. All crude oil measurements were to be at least redundant. For example, crude oil loaded onboard for each tank was quantified with two dipstick measurements and a totalizer meter. Crude oil dumped to the skimmer was quantified in the same way. Crude oil collected by the skimmer was measured for total and rate, then evaluated for water content and stored in tanks. Low skimmer performance could cause high water content settling in a few instances. Decanting

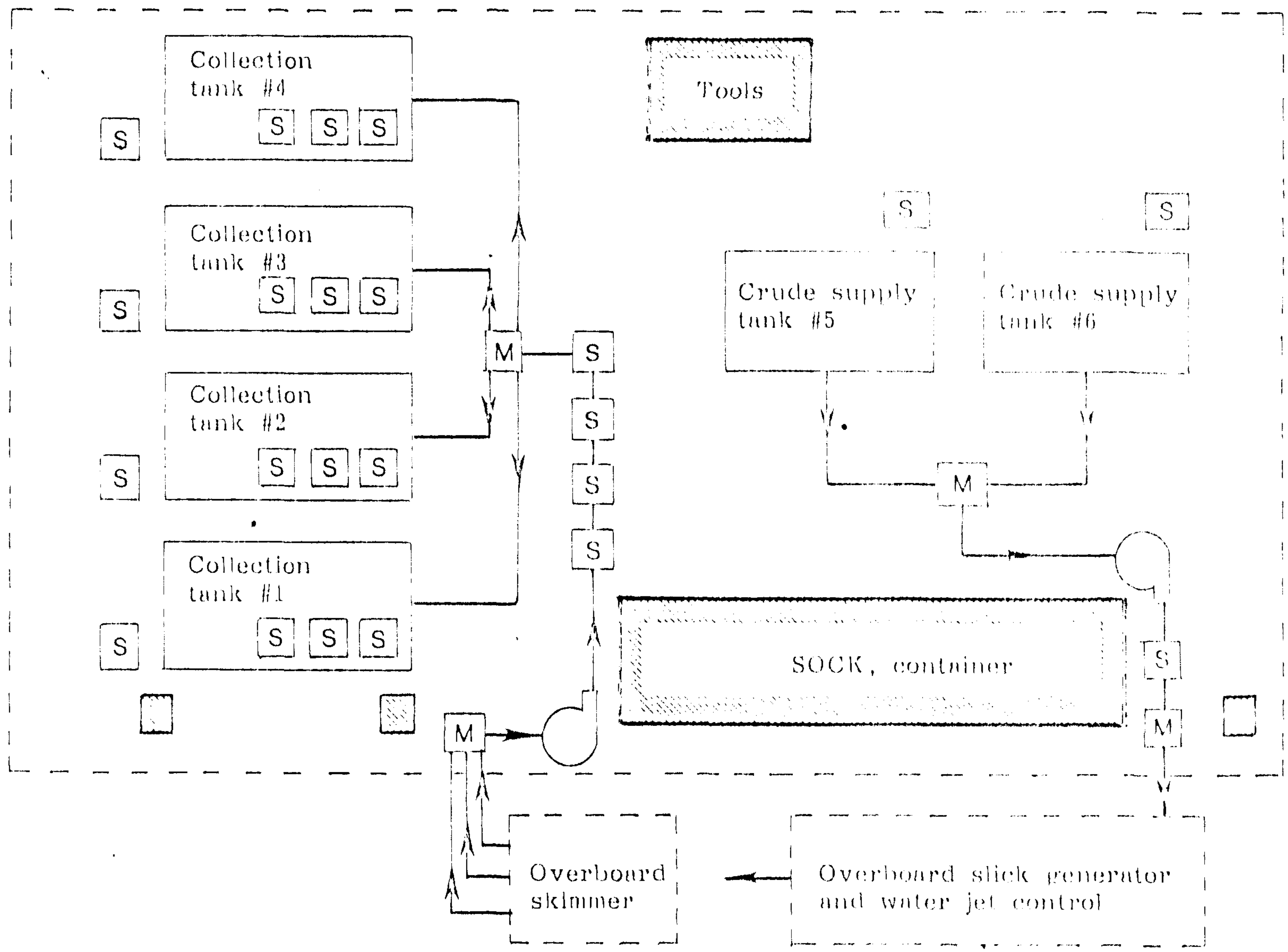


Figure 4. Fluid management diagram.

water at sea was to be monitored with grab samples and dipstick meaurements, totalizer meter, and an oil/water separation chemical analysis.

Details not shown in the previous flow diagram represent an extensive piping design consisting of 36 valves, 15 skid-mounted platforms, three at-sea floating platforms, and six active flow meter instruments.

STABILITY AND TRIM

A weight program was used to control and monitor the equiment impact on the Powhatan's stability and trim. The maximum deck cargo load was tabulated to be 41 long tons, plus 18 long tons of fluid for each of the six collection tanks. The Research Program did not require more than four full tanks, in the worst case 113 static long tons onboard. The comparisons of metacentric height and draft data for the Powhatan (Reference 11) were made by Hydrounatics Incorporated (Reference 12). While we did *not expect to skim oil in 12 foot seas, we had to prepare the high gravity loads on the* main deck to withstand pounding seas. The program also depended on the ship's crane which has restricted operation for high deck loads and sea conditions. The calculations to account for heavy seas were made with a 159.6 ton load in the dynamic mode. Detailed results contained in the previous references indicated the ship would be a stable platform to deploy the experiment. The reader is advised that the ship's master is the authority on the stability and trim, and the research program estimates were made to ensure a reasonable impact on the Powhatan.

MEASUREMENTS AND ANALYSIS

Redundancy

Redundancy was designed into the measurements and analysis section of the portable test facility. All members of the transient crew were assigned tasks for making visual estimates and/or reading gauges. Specific detailed responsibilities were delegated to only 14 members. There were 12 onboard data retrieval stations, three moored buoy stations in the vicinity, and two land-based stations. The majority of measurements were considered active instrumentation. The passive measurements were oil and water samples collected for chemical evaluation and photographic film to be developed.

Data Management

Data management was accomplished by assigning specific responsibilities to transient crew members and by distributing a printed set of data records forms with instructions that included contingencies and sample calculations. Instantaneous audits were made through radio contact with key stations and playback of portable audio tape cassette recorders throughout the Powhatan and other vessels in the flotilla.

Photography

Photography and video records were designed for several purposes. A video camera was mounted on the top fire-fighting platform for constant surveillance of the main deck activity which included all deployment and retrieval, oil distribution to the water, water jet performance, skimmer reaction to the waves and forward speed, and finally the SOCK losses forming a slick. A roving close-up second video camera was used to record individual operations and skimmer performance. Voice-over sound and instant portable playback options were utilized. Motion picture and still photography were used for high resolution and measurement records. These cameras were always roving and deployed near operations and skimmer loss stations. Specific phases of the test program required the visual records to be made from other vessels in the flotilla and one cameraman would be deployed from the Powhatan. Underwater photography capability was considered but not fielded for these tests at sea.

The basic elements were:

- cameramen (2)
- color video cameras (2)
- B/W video camera (1)
- color video portable record/playback with sound (2)
- 16-mm motion picture cameras (3)
- 35-mm SLR still cameras (4)
- photo/video cinema lights (2)
- lenses, mounts, and support equipment

Visual recording of the at-sea tests produced 14 hours of video tape, 6,000 ft of motion pictures, and 1,600 still photographs/slides.

Surface speed

Surface speed measurements were made with wood chips, two men, and a stopwatch. The fir wood chips were half-inch slices of 2x4's for a stable low wind profile and painted with fluorescent glowing yellow-orange for visibility. The thrower was stationed amid-ship exactly 100 ft from the timer stationed near the stern. The speed measurement was repeated several times for each skimmer test and considered the wind-driven sea surface current. A typical series of measurements would repeat within 0.05 knot. Forward speed of the Powhatan was set by the master as suggested by the senior member. The bridge doppler meter readout was in a nixie light digital display, XX.X kt. Once at speed, the one-tenth digit rarely would cycle in less than 30 second periods. A wood chip speed measurement was then made. If it is was within 0.1 knot of the planned test speed, the measurement would be repeated and the test dump sequence began. If not, the Powhatan would increase or decrease speed and wood chip was tossed again. The reading difference between the doppler meter and wood chip did vary +/-0.2 kt depending on the sea state.

Fluids Quality

Oil water ratio was determined in the portable chemistry laboratory that was set up in the Powhatan's machine shop. These passive samples were collected from various sources during each test at sea. A series of 100 ml discrete samples were taken from the SOCK pump discharge in prescribed equal increments during its oil collection mode. Two grab samples were taken from each collection tank before and after completing each test. Two collection tanks were used for each test, one for steady state collection and one for beginning and ending transient fluids. A stratified sample thief was used on each tank after each test to represent 3-in. incremental layers through the full 86-in tank depth. The analysis combined techniques of known volumes using graduated cylinder glassware, breaking emulsions with toluene, and laboratory centrifuges. These percentages of oil and water in known volume history were used in later calculations using measured fluid flow rates to arrive at oil flow rates.

Flow rates

Flow rates were measured with various techniques to provide redundancy. Fresh crude oil distribution rate was measured and calculated with three different techniques. First, dipstick readings before and after discharge were divided by a stopwatch reading. Second, the positive displacement Roper pump revolutions were multiplied by the displacement volume. Third, the pumped crude oil passed through a Tokheim vane-type totalizer meter that read total gallons, which were then divided by a stopwatch reading.

The flow rate of the SOCK collected seawater and skimmed crude oil was to be measured five different ways. First, a stroboscope/tachometer reading of the Tuthill rotary positive displacement pump was taken while counting revolutions timed with a stopwatch. Next, the flow went through a Nusonics acoustic flow meter where a voltage reading was compared to a calibrated chart that yielded a flow rate calculation. Then the flow went through a venturi concentric bell reducer, where the differential pressure was measured with an ITT Burton indicating switch. The pressure difference measurement was then used in calculations to arrive at a flow rate. Next, the flow rate was calculated from before and after dipstick readings in the collection tanks divided by stopwatch timing of each tank filling. The fifth and last possible flow rate measurement was liquid level in the collection tanks determined with the stratified sample thief and a stopwatch timing of each tank filling.

Environment

Environmental measurements included those from the Powhatan's station, portable station onboard fielded by the Naval Underwater Systems Center, (reference 7) and a group of remote stations. The remote stations were a series of three buoys deployed in the area, NOAA NYC radio, USCG stations at Ambrose, Sandy Hook, Manasquan, Barnegat, and Montauk Point, and finally the USN satellite system (NAVEASTOCEANCEN). Historical data came from the MESA New York Bight Atlas (reference 10).

One week prior to the ocean dumping, forecasting was begun each day for the specific area and continued through the test period. The following at sea measurements were taken:

- Air and Water temperature,
- Wind direction and speed,
- Wave height, length estimate, and period,
- Near surface current and direction,
- Surface water samples in the area, and
- Sub-surface water samples downstream at 5-10 m depths.

Measurements were made of the Powhatan's response and position as a portable test platform during each crude oil dump. These included speed, heading, position, maximum pitch and roll taken from the bridge instruments. A special portable lab fielded by the Naval Underwater Systems Center provided an automatic Loran-C record, video display, and mapping of the vessel's position within the approved dump envelope (see Figure 5).

The burden of visually estimating the sea state was assigned to ten transient crew members, most of which had sea duty experience. They were each given a typed format data folder that portrayed typical and conventional characteristics to observe.

<u>Slick Character</u>

Trained observers evaluated the slick encounter by the skimmer and interactions between the slick generator, the Powhatan starboard side water jet slick control, and the action of the skimmer itself. Eight transient crew members were given a typed format data folder in which to record their observations. Some of the observers had portable audio tape cassette recorders and a radio transceiver. They were backed up by video and film records. Each observer was required to specifically comment on:

- Water jet slick control...
  general appearance and effectiveness.

- Oil slick...
  general appearance and uniformity,
  width and thickness,
  gas bubbles and emulsion,
  percent entering the skimmer pontoons, and
  crisp start and stop of the slick.

- Floating platforms, relative movements...
  slick generator to Powhatan,
  slick generator to skimmer,
  Powhatan to slick,
  tow rigging to slick generator and skimmer, and
  bow wave interactions.

- Skimmer...
  general appearance and conformity,
  motion caused by waves and towing,
  oil encounter loss, quantity and location,
  oil losses due to headwave, entrainment, and drainage.

The quantified thickness was made by taking width estimates from marks on the skimmer entrance frame and calculating thickness based on the known flow rate and vessel speed. Several slick thickness guages were considered for the program, but none appeared either adaptable or proven in the field.

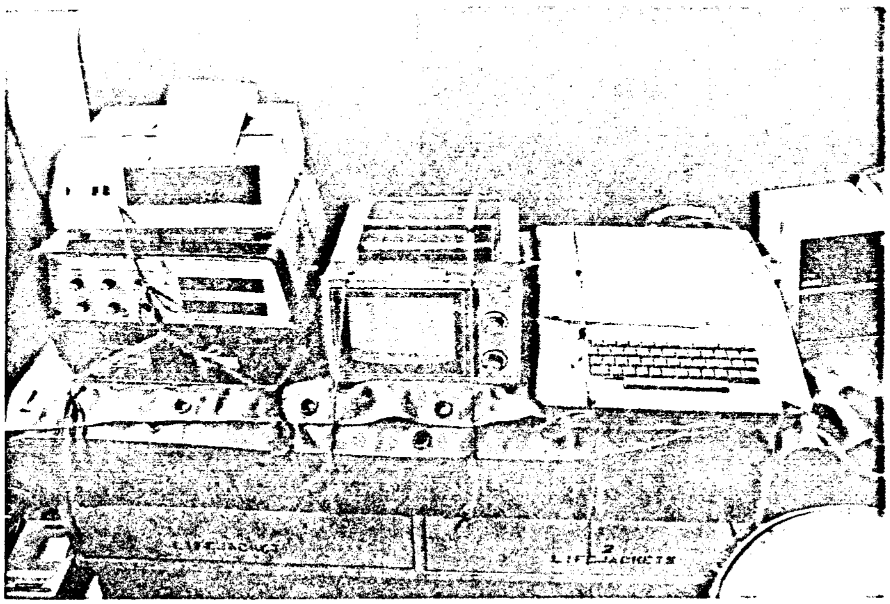


Figure 5. Auto Loran-C data station.

SECTION 5

SPILLED OIL CONTAINMENT KIT

INSTALLATION AND CONSTRAINTS

The Spilled Oil Containment Kit (SOCK) was loaned to the OITC for this program by Shell Oil Company through their Emergency Response - Oil Environmental Conservation Operations staff in Houston, Texas. All liaison was through the staff with support from the Shell Development Company, Westhollow Research Center, Houston, Texas. The SOCK was exclusively operated by Shell-trained personnel, two from Tidewater Contractors, Inc., Amelia, Louisiana and one from the Westhollow Research Center.

The launching and retrieval required support from three OHMSETT people. The rigging and installation onboard was a mutually-agreed upon design that was dependent on the Powhatan's deck equipment and constrained by a rule disallowing welding or cutting on the vessel's structure or covering deck bits. The need also was to have it deployed as far forward of the ship propellers as possible which forced the starboard side installation (Figure 6). The possibility of a port side installation was not considered because it would require a retrofit. Also, there would be port side interference from the Powhatan's permanently installed vertical capstan.

One of the outstanding capabilities of the Powhatan is her variable pitch propellers. The majority of industrial work boats in this class do not have that versatility or the resulting low speed control capability. Use of a conventional boat for this program would have required a tug boat to restrict speed or a continuous clutching in and out of a propeller.

The SOCK hardware available for this program was significantly different from that described in 1977 (reference 2). The 70,000 ft-lb crane installed forward had been abandoned and was not part of the current operations. The oil separator compartment could not be used because the hinged cover and baffle plates were missing. The number of suction hoses and ports by design were reduced to three 3-in hoses. The 1977 Sock (boom-skimmer component) used a floatation scheme combining air, foam, and inflated into 42 longitudinal cells and 32 transverse. The 1980 version tested utilized six transverse and two longitudinal foam cells. The 1977 Sock had a fabric bottom extending from the forward rigid floating frame back (over halfway) to the midpoint area. This bottom was conceived to be an advantage in directing fluid flow, controlling vertical turbulence, and causing the SOCK to act as a skimmer rather than a splash-over-proof boom. The 1980 version tested did not have a fabric bottom.

The SOCK system arrived at OHMSETT packed on three large tractor-trailers (two flatbeds and one lowboy). One oversized load required day-time only trucking and special permits. One trailer contained the main rigid float frame, one transported the

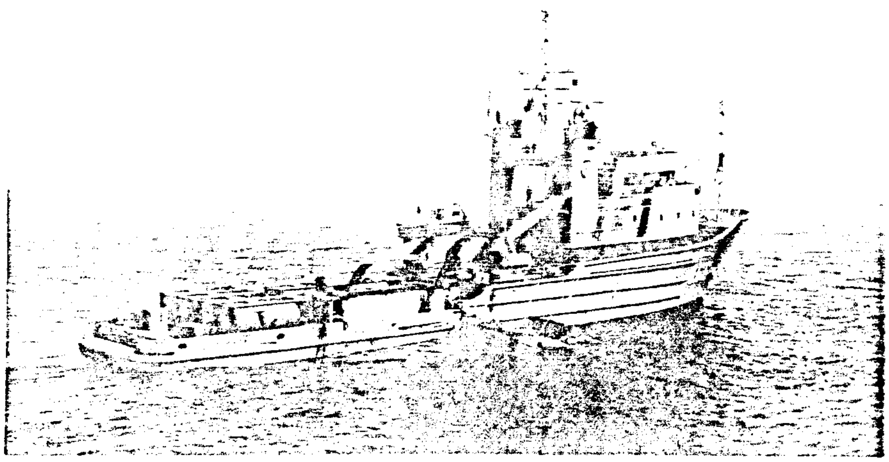


Figure 6. SOCK mounting, starboard side.

SOCK integrated container, and the lowboy was used to transport a tool house with a separate skid containing the Sock fabric system. The OHMSETT location at the foot of the Navy pier on the NWS-Earle made it an ideal operations center and staging area for all equipment in the Research program. A Shell (Westhollow) technician arrived and utilizing four OHMSETT technicians readied the SOCK for ship installation. Some refurbishment of the system was required to ready the SOCK after its prior storage environment. Two 20-ton cranes, a forklift, and various hand tools were utilized in the assembly and shipboard readiness operations. The assembly area was approximately 10,000 ft^2. The work schedule included one 12 and one 6-hour day. The assembly was straight forward with minimum skill requirements and good supervision. Special color strips were painted by OHMSETT on the rigid float system for measuring draft and freeboard oscillations at sea. An overnight rain storm did not delay the assembly but did identify a Sock fabric quality problem. Several of the closed fabric cells that contained the flexible foam floatation were not completely sealed. The next morning the cells were bulging with rain water. Shell decided to cut water relief holes topside and in five transverse cells. The delaminated cell seams were not repaired and the relief holes were left open for the at-sea tests.

The actual installation of the SOCK onto the Powhatan required three large crane lifts and four small crane lifts. A 70-ton crane was required to accomplish the reach from dock/pier to the vessel deck positions. Dunnage was not used for the SOCK container, pontoons, and fabric assembly. The loading required a foreman, a crane operator, and four tag line men. Figures 7 and 8 illustrate the main deck with the SOCK in place without tie-down rigging, tool house, air tuggers, or strainer in place. The tie-down rigging was the same OHMSETT design used for all components on the main deck. It was a modified design that the Navy diving equipment riggers use for their mission installations on the Powhatan. The SOCK container was secured with eight tie-down cable units using a combination of thimbles, 5/8-in steel cable, cable clips, and turnbuckles. Termination points were a standard I.S.O. container shackle to the container and an eyebolt screwed into the deck. The Sock was atop the container secured with steel cable and safety chain binders. The two air tuggers were screwed to special OHMSETT designed swivel mounting plates that in turn were bolted to the main deck. The SOCK hose manifold/strainer was welded to a steel plate that was bolted to the main deck. The tool house was secured to the main deck with steel cable, thimbles, and eyebolts.

PRACTICE AND FINAL CONFIGURATION

The SOCK deployment/retrieval at sea from the Powhatan was thoroughly planned and practiced before crude oil was dumped. The first practice was from a small barge in an inland waterway near Morgan City, Louisiana in early March 1980. Figures 9 and 10 illustrate two views of the SOCK in that launch process. This practice session was to ensure the SOCK working order after a long storage period and the deployability of the new SOCK design. The barge deck was 4 ft above water and the SOCK was 5 ft from the railless starboard edge. The barge was moored in a small lagoon that had no water current flow that is normally required to unfold the Sock. A special rigging was used to adjust the Sock axis to the barge. This experiment concluded that the SOCK was ready for the Powhatan. Several possible launching problems were anticipated for the at-sea experiments. First the outboard aft D-ring snatch block cable assembly may snag during deployment. A solution was to grind down the cable clip to a better taper. The second anticipated problem would be the

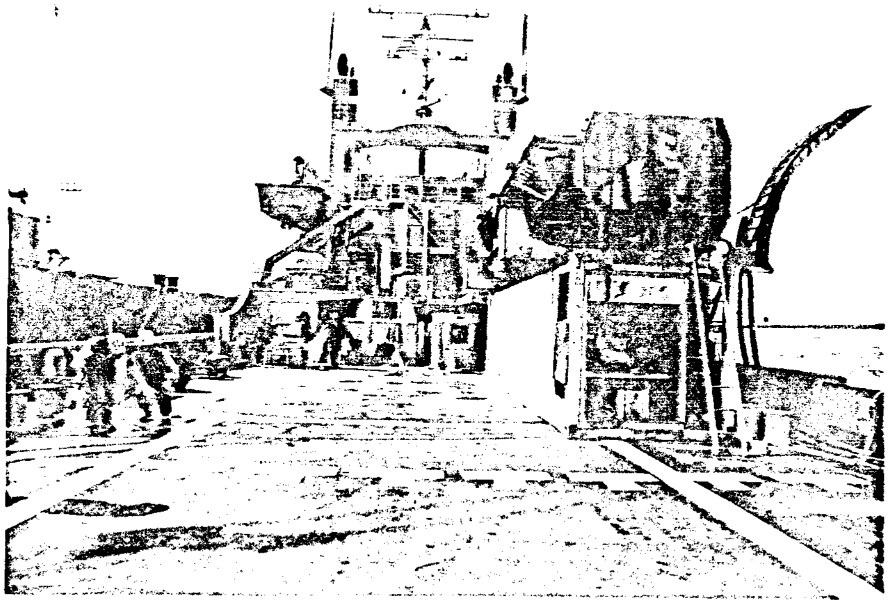


Figure 7. SOCK, deck view from stern.

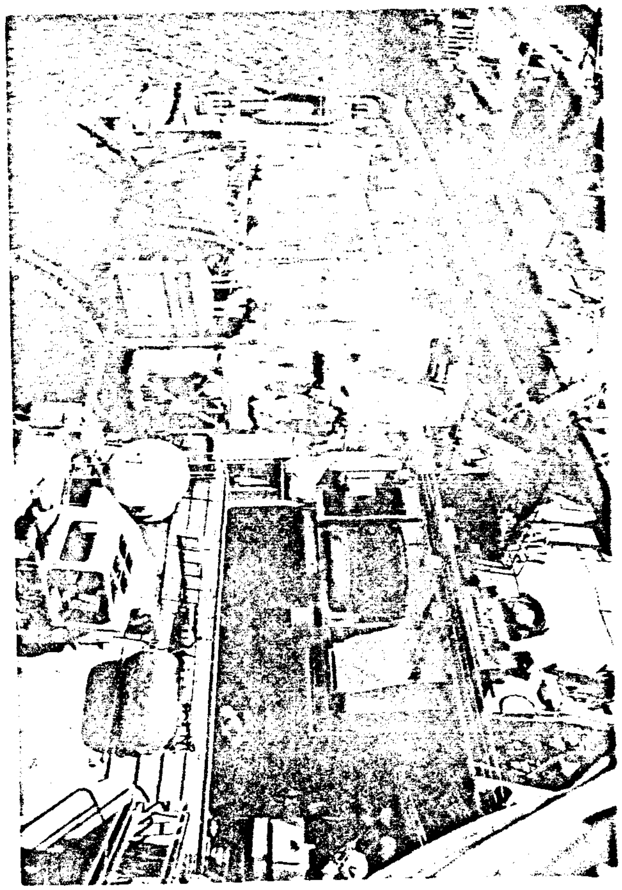


Figure 8. SOCK, view from bridge deck.

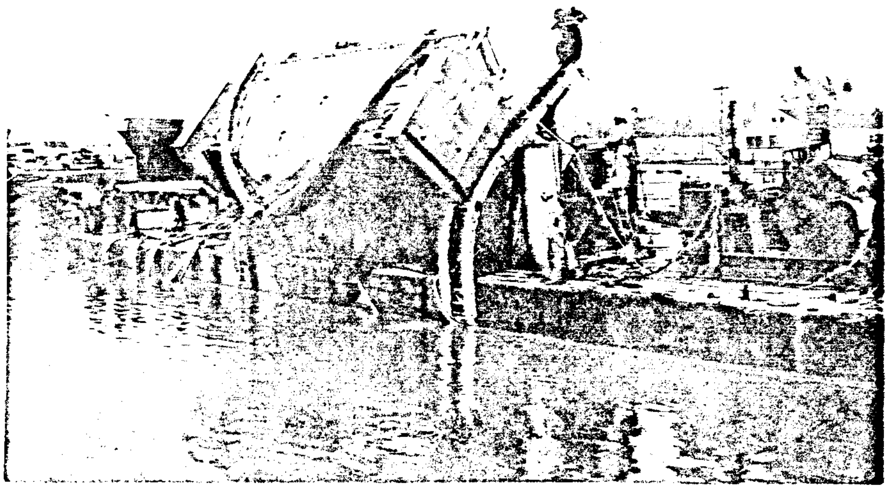


Figure 9. SOCK deployment from barge, forward outboard, starboard view.

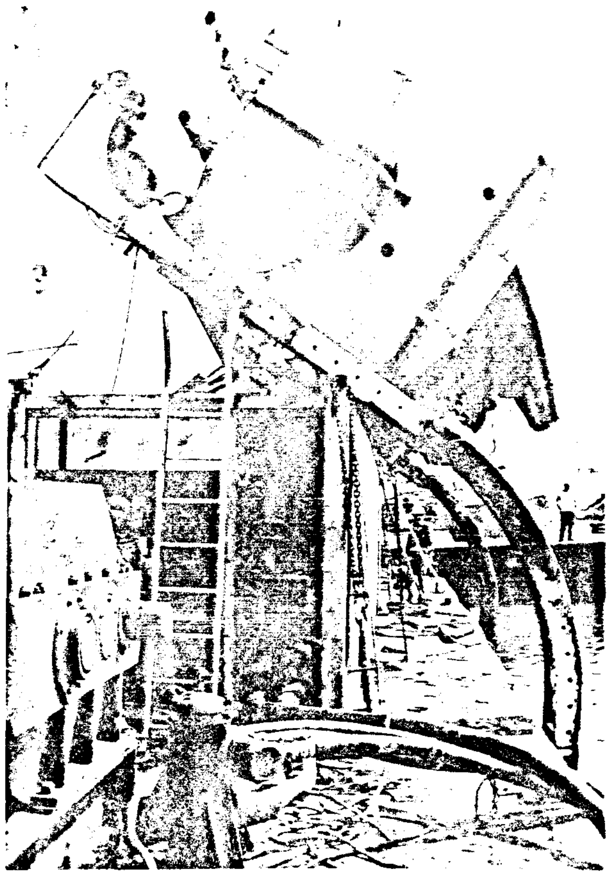


Figure 10. SOCK deployment from barge.

aft Sock fabric being drawn under the Powhatan's hull. One solution to this was to add large inflatable spherical floats as a safety contingency. The system arriving at OHMSETT included two one meter diameter spherical floats. The design intent was that the floats tethered to the Sock apex would provide a contingency floatation that would aid in the deployment over the starboard side.

The SOCK hardware and operators were integrated into the USNS Powhatan and the test program. The following items had significant impact, floor space, and weight loads:

- Containers, 8x35 ft, 32,000 lb (dry),
- Sock fabric/frame, 8x29 ft, 6,500 lb,
- air tuggers (two each), 3x3 ft, 200 lb each,
- fluids strainer/manifold, 3x3 ft, 200 lb, and
- tool house, 7x12 ft, 5,000 lb.

The container includes an integrated diesel hydraulic power plant, valves and rigid piping, controls, launching ramps and the positive displacement suction pump. The fabric/frame, referred to as "Sock" previously, sits on top of the container when not deployed, therefore its weight is important. The height of the stack is approximately 19 ft above the deck and it hangs 3 ft over the starboard side. Height and overhang are important in safely calculating ship stability and docking constraints. Figure 11 illustrates the deck layout proportions on the main deck of the USNS Powhatan. The ship's structural frame stations are noted at two foot intervals for scale. SOCK floor space is designated with thick lines with the test hardware and ship's hardware in thinner lines.

The SOCK as integrated to the ship required onboard services of air for the tuggers, water for wash down cleaning, and accommodations for manpower. The container as previously discussed was latched to the deck. Guy lines for launching with the air tugger went through fairlead rollers clamped to the Powhatan's starboard rail. The inboard and outboard Sock tow lines were secured forward to bits on the foc'sle deck. The Sock launching system was mechanically independent of the ship's hardware, but required special maneuvers by the ship. The maneuvers were to be commanded by the SOCK operator to the ship's master. Radio and visual contact is very important. The ship's speed initially was a slow 0.75 kt with the Sock in the lee and seas arriving from the stern quarter. Several start/stop and reverse motions are then required to position the overboard Sock correctly and secure for skimming operations.

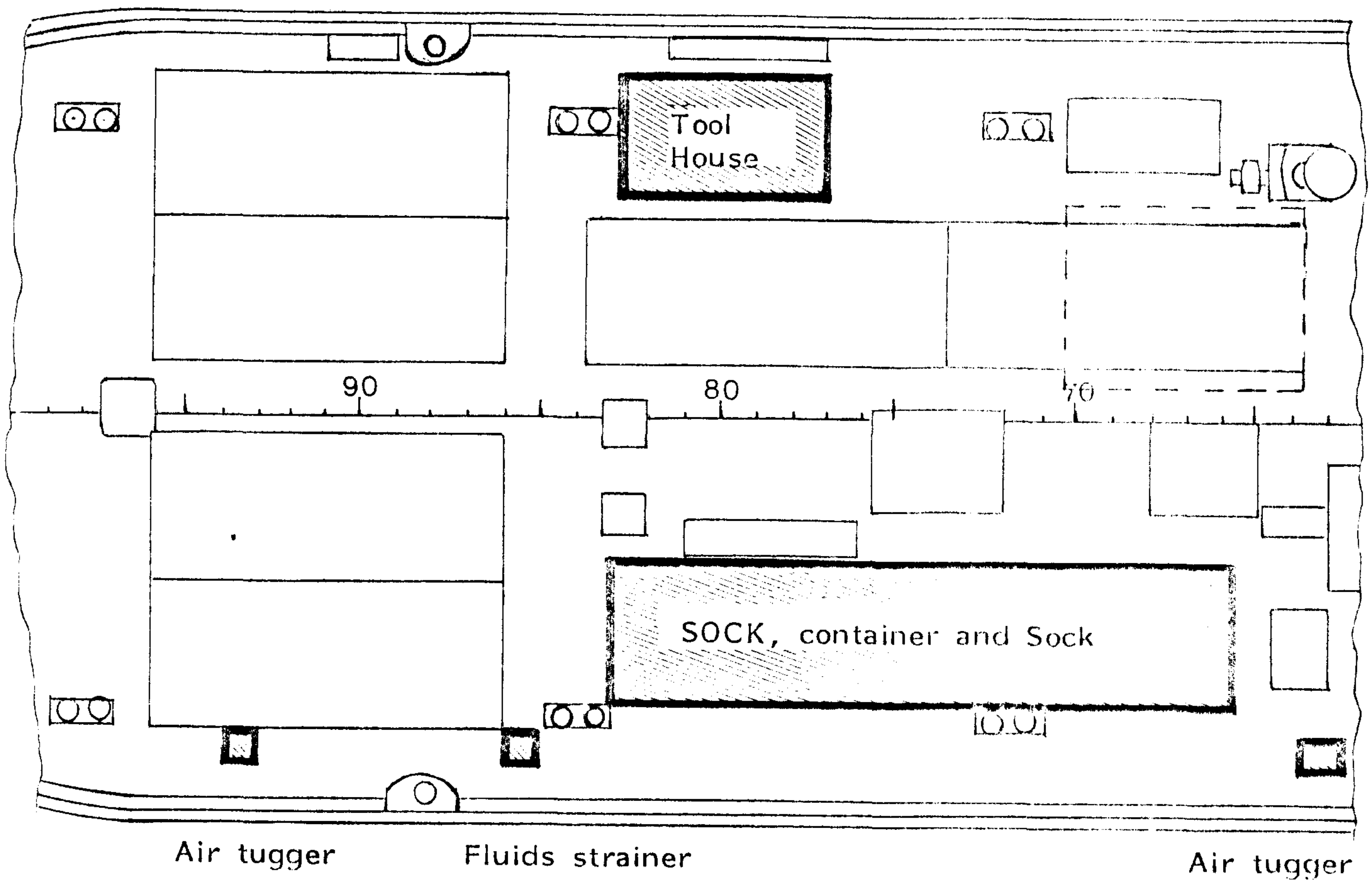


Figure 11. SOCK main deck layout on USNS Powhatan.

SECTION 6

TEST DESCRIPTION AND PROCEDURES

The most important aspect of the test design was to assume that sea states would change within small portions of a day. The major emphasis was then to control other independent variables.

Although each test at sea was different than all of the others, a general pattern was accomplished on all of the tests to ensure continuity of procedures. This pattern was adhered to with consistency allowing for the different types of testing to be accomplished.

TYPICAL TEST OUTLINE

The general test sequence followed a pattern to ensure all test crew members and equipment were in concert.

(1) Announce the commencement of test exercise.

(2) Ensure all test crew members are on station.

(3) Bring Powhatan to approximate test speed and correct heading relative to sea heading.

(4) Remind test crew of procedure with times, quantities, and rates.

(5) Answer any questions from test crew.

(6) Check Powhatan speed using wood chip and adjust as necessary.

(7) Establish announced distribution rate through recirculation loop.

(8) Record tank soundings of distribution and collection for pre-test volumes.

(9) Begin distribution of crude oil.

(10) Announce the exact time that oil distribution began.

(11) Start Tuthill pump after the established preload period.

(12) Adjust Tuthill pump rpm to four-thirds desired pump rate.

(13) Pump into initial slop tank until oil appears at discrete sampling point.

(14) Switch pumping from the initial slop tank to designated steady state tank.

(15) Stop oil distribution.

(16) Switch Tuthill pump discharge to secondary slop tank after designated steady state period.

(17) Continue pumping until discrete sampling point consistently shows mostly water.

(18) Stop Tuthill pump.

(19) End-of-test time announcement. Allow settling time in collection tanks.

(20) Record tank soundings of the distribution tanks after distribution.

(21) Record recovery tank soundings for total fluid.

(22) Decant recovery tanks.

(23) Record tank soundings on decanted volume.

(24) Take grab samples using marked 200-ml bottles of recovered oil-water emulsion.

(25) Send samples to onboard laboratory for analysis.

A time line analysis is shown below for a hypothetical test. Figure 12, a view from the aft end, illustrates collection tank positions. Note large Roman numerals on each tank. There were minor exceptions to the procedures that were noted for each test. Redundancy was built in to offer a choice of flow rate measurements using the acoustic flow meter and venturi, and total quantity measurements using the stratified sampling technique. The day-to-day and test-to-test procedure and data collection are summarized below along with time line summaries for each test and day:

(1) Confirm Powhatan's relative surface velocity using wood chip method.

(2) Establish desired distribution rate through the oil recirculation loop.

(3) Initiate oil distribution through the oil slick generator.

(4) Start Tuthill pump after preload period as defined by designated volume and theoretical distribution rate.

(5) Route skimmer discharge to slop tank until oil is observed at the discrete sampling point.

(6) Route discharge to steady state tank.

(7) Stop oil distribution.

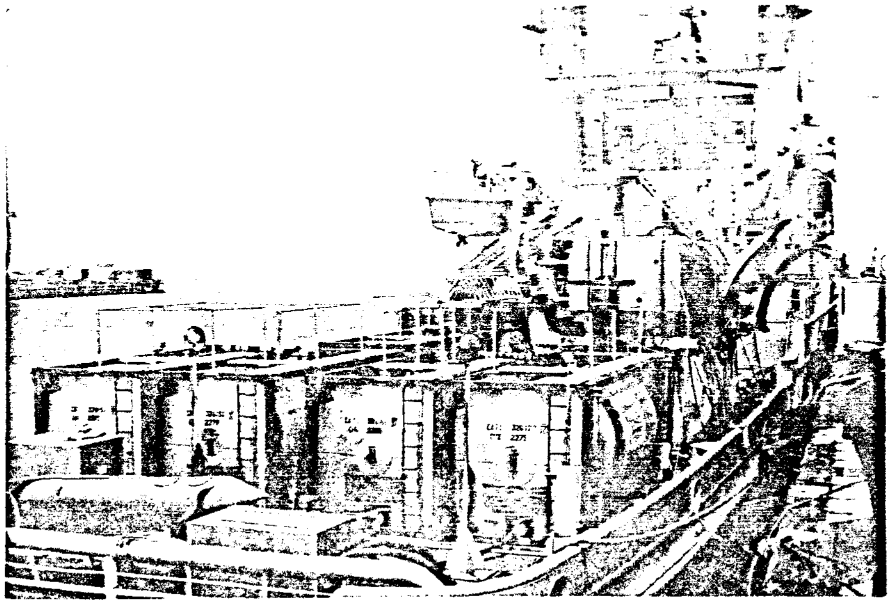


Figure 12. Collection tanks I, II, III, and IV (partially hidden).

(8) Redirect discharge to slop tank for remainder of test.

(9) Stop Tuthill pump.

DAY-TO-DAY SUMMARIES

A summary of each day's activities in regard to specific tests should relate exceptions and portray a few logistics decisions.

8 April 1980, Sandy Hook Bay

At 1300 hours, the Powhatan is fully loaded with test equipment and the SOCK. Carrying no crude oil, she leaves NWS-Earle for trial runs in Sandy Hook Bay to acquaint the test crew with the deployment/retrieval sequence of both the Sock and the slick generator.

At 1400 hours, the Sock is successfully deployed and tow line length adjustments are made for the best sea keeping arrangement necessary for integration with the Powhatan.

At 1600 hours, the slick generator is lowered to the water surface using the ship-board crane and operator. At 1730 hours both the Sock and the slick generator are brought back aboard and the Powhatan heads to port. The tarpaulin oil delivery ramp on the slick generator needs to be weighted to make it less sensitive to the wind in oil distribution process.

9 April 1980, New York Bight

At 0232 hours, the Powhatan leaves NWS Earle for the test site carrying 18.93 m^3 (10,000 gal) of La Rosa crude oil. At 1000 hours recirculation pumping begins to certify the hose connections and correlate the tank soundings to the in line positive displacement meter readings.

At 1100 hours Sock deployment procedures are activated in heavier sea state than encountered in the bay area. A hydraulic fitting is broken during deployment so the Sock is recovered and the fitting is replaced.

At 1300 hours, the Sock is redeployed. High winds speed of 20 kt with 24 kt gusts made the crane operation dangerous and prevented the deployment of the slick generator.

Since the black crude oil cannot be dyed to improve photographic resolution, at 1410 hours a small sample of the La Rosa crude oil (600 ml) was poured over the side of the vessel for visual sighting practice. This dump was considered essential to the program for qualitative data later and so was characterized as test number one.

The Sock was brought back aboard at 1500 hours for cleanup and transportation to Earle.

10 April 1980, New York Bight

Heavy fog and seas throughout the day prevented the safe deployment of the Sock. The visibility limitation was considered to cause a test control problem and thus cancellation of the deployment was prudent engineering practice.

11 April 1980, New York Bight

Having remained at sea due to fog on 10 April, the Powhatan is still fully loaded with 37.85 m^3 (10,000 gal) La Rosa crude oil onboard.

At 0500 hours the Sock is deployed over the starboard side of the Powhatan and the slick generator is lowered directly in front of the Sock mouth. The slick generator is maneuvered to the designated operating position using forward tow lines and aft tag lines and secured. The tarpaulin has been weighted with 8-mm (5/16-inch) steel chain for ballast. The water jets are turned on using the Powhatan fire fighting system as a supply source.

Test Two

At 0930 hours the preparation for the first large-scale, at-sea testing with oil is begun. The test is designed to verify the phenomenology of the Sock to contain oil prior to offloading. The test is actually a test which treats the Sock as a boom to contain an oil slick.

The Powhatan is brought to speed and verified to be at 1 kt using the flourescent yellow-orange wood chip method.

Oil distribution rate is set at 74.9 m^3/hr (300 gpm) and at 0938 hours all stations report ready. The slick generator deposits 1.89 m^3 (500 gal) of oil on the water surface over 103 seconds.

Visual observations from the bridge, fantail, starboard side, and the MonArk concur that approximately 80% of distributed oil reaches the skimmer mouth. The remaining 20% missing the mouth is approximately half inboard and half outboard of the mouth.

After visual observations were made and photographic and video tape records were taken, the oil remaining in the Sock was pumped into collection tank number III to confirm that the oil collection system functioned properly and, more importantly, to minimize the oil left at sea. It was at this point that both the acoustic flow meter and the bell reducing venturi were found to produce erroneous data or not functioning, eliminating two of the redundant means of collected fluid measurements.

Skimmer rating criteria are not given for the second test. The test was not designed to test the complete skimmer package. Only the oil keeping ability was effectively tested. Evidence of drainage, entrainment, and other loss mechanisms were monitored.

The event time line for test two is shown as follows:

(1) Start pre-test procedures.

(2) Speed check, confirm 1 kt.

(3) Start recirculation mode for oil distribution.

(4) Begin oil distribution rate at 68 m^3/hr.

(5) Water quality sample.

(6) Stop oil distribution, at 1.89 m^3.

(7) Observation of loss mechanism, visual observation of slick generator performance.

(8) Start Sock pump and collect oil.

(9) Stop collection.

(10) Stratified sample analysis.

(11) End of test.

(12) Determination of skimmer loss.

Test Three

At 1153 hours the third test was run very similarly to the second test. The Sock was used again as a boom. The test was run to determine the speed of gross failure due to entrainment of the captured oil.

Test three began with a wind-driven sea surface relative to Sock velocity of 1 kt and progressed to 2 kt with ¼-kt increments.

The Sock was pumped out after the test to quantify the skimmer loss during this exercise and to clear the remaining oil prior to the next test. The time line notes visual observations of the test at the various speeds tested and is shown below. Again, skimmer rating criteria for the SOCK are not given since the skimmer was used as a boom rather than as a skimmer.

(1) Establish surface velocity at 1 kt.

(2) Set oil distribution rate at 34 m^3/hr (150 gpm).

(3) Begin oil distribution.

(4) Losses formed at rear are indistinguishable from oil that misses the mouth of the Sock.

(5) Increase speed to 1.5 kt.

(6) Oil that has accumulated on Sock fabric begins to wash off, mixing with skimmer loss.

(7) Decrease speed to 1 kt.

(8) Oil distribution complete.

(9) Estimated loss rate through the skimmer, 2 m^3/hr (15 gpm).

(10) As oil from slick generator clears, a more defined loss mechanism is apparent at 1.5 m^3/hr (10 gpm). Skimmer loss forms a solid slick 0.5-0.7 m (5-10 ft) wide and 3-4 mm thick. The slick is black, emulsified oil.

(11) Increase speed to 1.5 kt.

(12) Vortices appear behind skimmer apex. Slick losses continue and form droplets. The loss seems to originate at inboard side in front of solid floatation chambers.

(13) The Sock skirt billows out, belching oil at random time intervals concurrent with wave crests.

(14) Speed increased to 2 kt.

(15) Sock forms massive turbulence centering behind the apex. The quantity of oil lost is noticably decreased. The decrease is caused by less oil depth in the Sock and because the oil is resurfacing downstream out of view.

(16) Decrease speed to ½ kt. The slick once again forms as a thick, solid mass behind the apex.

(17) End of test.

Test Four

The first test of the skimmer performing in its dynamic operation, the surface curent relative velocity was set at 1 kt and oil distribution was established at 68 ^{3}/hr (300 gpm). At 1503 hours, oil distribution began and lasted 665 seconds. The Sock was charged with a 1.89 m^3 (500 gal) preload prior to starting the Tuthill offloading pump. The total distribution of 12.5 m^3 (3,300 gal) was fed into the mouth of the Sock with 100% actually entering the SOCK.

Confusion and differing opinions of SOCK operators as to the established test procedure on the dynamic testing of the SOCK lead to the execution of a test that did not follow the standard procedure that had been outlined. The actual procedure followed is summarized as follows:

(1) Confirm Powhatan speed at 1 kt.

(2) Establish recirculation rate of 68 m^3/hr (300 gpm).

(3) Begin oil distribution.

(4) Preload distributed, Tuthill pump started, at oil switch to recovery tank I.

(5) Stop oil distribution.

(6) Stop pumping into tank II, begin pumping into tank III which has been designated as slop.

(7) Tuthill pump rate slowed.

(8) No pumping, Tuthill stopped.

(9) Switch to tank IV.

(10) Various pumping rates.

(11) Stop test.

During tests conducted on 11 April 1980, 16.25 m^3 (4,291 gal) of oil was distributed to the Sock 13.9 m^3 (3,667 gal) of which was recovered. The Powhatan left the operations area at 1748 hours and docked at the NWS Earle pier at 2146 hours.

12 April 1980, New York Bight

The Powhatan departs NWS Earle at 0130 hours carrying 37.85 m^3 (10,000 gal) of La Rosa crude oil. The recovered fluid from 11 April has been offloaded and transferred to land-based storage. The Powhatan arrived in the area designated by the Research Permit at 0538 hours.

Test Five

The Sock was deployed at 0700 hours in preparation for the third day of actual testing. The oil slick generator was successfully placed in front of the mouth of the Sock employing the onboard crane. The Powhatan speed is adjusted to be 1.4 kt and the oil distribution is set at 46.6 m^3/hr (200 gpm). The oil is distributed on the water surface at 1032 hours. A total of 9.31 m^3 (2,400 gal) is distributed over 720 seconds with 100% of distributed oil reaching the Sock mouth.

The SOCK recovers a 3.79 m^3 (1,000 gal) preload, requiring a 330-second wait between the start of oil distribution and the starting of the Tuthill pump at 270 rpm with steady state beginning at the first oil in the discrete sampling port.

Oil was present in the discrete sample port 35 seconds after the Tuthill is started. The steady state period begins for 360 seconds with collection routed into tank IV for an additional 600 seconds. The time line for test five is given as follows:

(1) Speed check at 1.4 kt.

(2) Establish 46.6 m^3/hr (200 gpm) flow for distribution.

(3) Oil distribution begins.

(4) Tuthill pump starts.

(5) Oil observed at discrete sample point.

(6) Switch to recovery tank.

(7) Oil distribution complete.

(8) End of steady state recovery, SOCK discharge switched to collection tank IV.

(9) End of test, Tuthill pump stopped.

Test Six

The oil distribution rate was set at 68 m^3/hr (300 gpm) and the Powhatan speed was slowed to 1.3 kt. Oil distribution was begun at 1516 hours lasting 585 seconds, the first 230 seconds of which is dedicated to preloading.

The preload period was spent before starting the Tuthill recovery pump which was running at 400 rpm (maximum). Oil is observed at the discrete sampling point 60 seconds after the collection begins. Steady state collection begins at this point and continues for 300 seconds when the discharge is routed to tanks for the remaining 600 seconds, if necessary. The time sequence is summarized as follows:

(1) Adjust Powhatan speed and establish oil rate in recirculation mode.

(2) Begin 68 m^3/hr (300 gpm) distribution.

(3) Start Tuthill pump.

(4) Oil observed at discrete sampling point and discharged in steady state recovery tank.

(5) Terminate oil distribution.

(6) End steady state period route discharge to slop tanks.

(7) End of test, stop Tuthill pump.

During this test, oil was apparent at the trailing edge of the Sock causing a slick roughly the width of the SOCK and tapering to a sheen 7 m (21 ft) behind the apex of the Sock. The waves during this test were determined to have a one-third significant wave height of 1.4 m cresting every 3.7 seconds (Reference 7).

After measurements are recorded for tank soundings and general topside cleanup is done, the Powhatan leaves the operations area at 1638 hours for docking at NWS-Earle at 2018 hours.

On 12 April 1980, 19.9 m^3 (5,261 gal) of La Rosa crude oil was distributed on the water surface during test five and test six, of which 17.3 m^3 was recovered.

13 April 1980, New York Bight

Leaving early, fully loaded with 37.9 m^3 (10,000 gal) of crude oil for testing, the Powhatan departs NWS-Earle for the assigned operations area. The Powhatan arrives on station at 0750 hours prepared for the day's testing.

Test Seven

The SOCK is not launched until 1000 hours. The oil slick generator is overboard, the Powhatan speed is confirmed at two kt, and the oil is ready to be distributed at 41.9 m^3/hr (100 gpm) by 1115 hours with the oil first being distributed at 1138 hours. A total of 7.84 m^3 (2,100 gal) was distributed over a testing time of 1230 seconds.

The SOCK received a preload of 3.79 m^3 (1,000 gal) during the first 593 seconds of the test. The Tuthill collection pump was started 630 seconds into the test allowing for a 37 second transient time. At 540 seconds, the vessel speed was decreased from two to 1.8 kt. A time lag of 90 seconds was encountered before oil appeared at the discrete sample after the pump was started and the SOCK discharge was routed to the steady state collection tank for 600 seconds. All the remaining fluid was pumped to the slop tank for an additional 660 seconds. The time line analysis is given as follows:

(1) Bring speed of Powhatan to 2.0 kt and establish a distribution flow of 41.9 m^3/hr (100 gpm).

(2) Start oil distribution.

(3) Bring speed of Powhatan to 1.8 kt.

(4) End preload period.

(5) Start Tuthill pump.

(6) Oil detected at discrete sample point, discharge switched from slop to steady state tank.

(7) Stop oil distribution.

(8) End of steady state collection.

(9) End of test, pump stopped.

Test Eight

The second test of 13 April 1980 began at 1448 hours after establishing the distribution rate of 29.5 m^3/hr (130 gpm) and the relative surface velocity of 2.1 kt. The oil is distributed for 765 seconds.

The preload period of 480 seconds was distributed before the Tuthill pump was started. Once pumping begins, it required 245 seconds for oil to be observable at the discrete sample port. At this time the fluid is transferred from slop tanks to the steady state collection tank for 300 seconds and to the slop tanks for the final 600 seconds. The time line analysis is shown as follows:

(1) Establish rate of 29.5 m^3/hr (130 gpm) at oil distribution with Powhatan at 2.1 kt.

(2) Start distribution.

(3) End of preload and Tuthill started.

(4) Oil observed, skimmer output routed to steady state tank.

(5) End of oil distribution.

(6) Suction discharge to slop tank, end of steady state.

(7) End of test, Tuthill pump shut off.

SECTION 7

DATA COLLECTION

The data were taken at 23 separate locations scattered over the main deck and bridge house of the Powhatan, including the remote buoy for wave analysis. The information to be recorded, the means of measurement, and the units in which the measurement is recorded are tabulated for easy reference in Table 4.

The weather was monitored for one week prior to the first day of testing. The USCG and the National Weather Service recorded data daily in sheets shown in Figure 13. The National Weather Service was monitored from the continuous broadcast at 162.55 MHz from New York City. The USCG was contacted at four locations (Montauk Point, Ambrose Light Tower, Sandy Hook, and Manasquan Inlet) daily to obtain actual weather information at that time. All other data were recorded at sea.

TABLE 4. RECORDED DATA

General Category	Specific Information	Means of Measurement	Units of Measurements
Environmental, Weather			
	Dry bulb air temperature	Sheltered alcohol thermometer	°F
	Wet bulb air temperature	Sheltered, wicked alcohol thermometer	°F
	Wind direction	vane	degrees
	Wind speed	anemometer	knots
Environmental, Waves			
	Wave height	buoy	feet
	Period	buoy	seconds
Skimmer Speed			
	Wind driven current	(Wood chips/timer)	seconds

(Continued)

TABLE 4. (CONTINUED).

General Category	Specific Information	Means of Measurement	Units of Measurements
Oil Distribution			
	Oil temperature	Bimetal thermometer	°F
	Initial tank height	Dipstick	inches
	Final tank height	Dipstick	inches
	Water jet pressure	In-line gauge	psig
	Distribution time	Stopwatch	seconds
	Distribution volume	Positive displacement meter	gallons
Oil Recovery			
	Prior to test tank height	Dipstick	inches
	Tuthill speed	Stroboscopic	rpm
	Tuthill pressure	In-line gauge	psig
Vessel Statistics Controllable			
	Vessel speed	Doppler meter Powhatan bridge	knots
	Direction	Magnetic compass Powhatan bridge	degrees
	Longitude	Loran-C	degrees, minutes
	Latitude	Loran-C	degrees, minutes

(Continued)

TABLE 4. (CONTINUED).

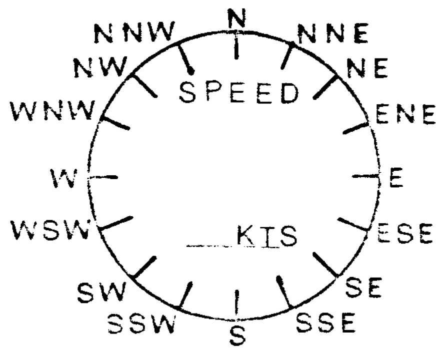
General Category	Specific Information	Means of Measurement	Units of Measurements
Vessel Statistics, Uncontrollable			
	Pitch	Bridge bubble pitch indicator	degrees
	Roll	Bridge bubble roll indicator	degrees
	Pitch (roll) period	Timing of three pitches (rolls) and dividing by three	seconds
Oil Collection			
	Volume of collection	Dipstick measurement	inches
	Decanted volume	Dipstick	inches
	Emulsion quality	Grab sample	percent oil
Oil Collection, Discrete			
	Emulsion quality	Discrete sample	percent oil
	Relative time	Stopwatch	seconds

The following secondary measurements were planned but equipment failure prevented data acquisition:

Oil Distribution	Rate	Hydraulic Pump, rpm	Voltage
Oil Collection	Rate	Acoustic Flowmeter	Voltage
Oil Collection	Rate	Venturi	Differential pressure, inches of water

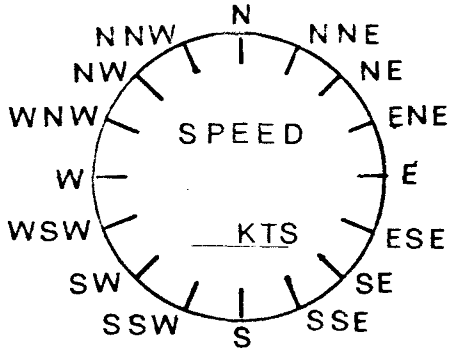
DATE	GENERAL CONDITIONS
TIME OF DAY	PREDICTIONS

MONTAUK POINT



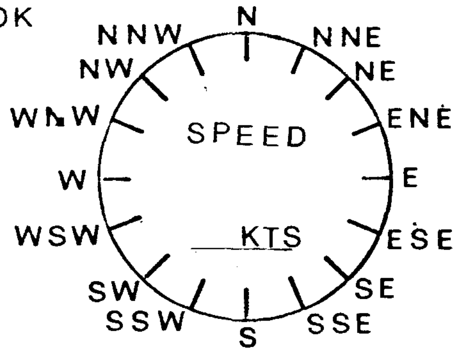
AIR TEMP.________ °F.
SEA TEMP.________ °F.
WAVE HT.________ Ft.
PERIOD ________ Sec.
BAROMETRIC PRESSURE ________ In Hg.
VISIBILITY________ n. Mi.

AMBROSE LIGHT TOWER



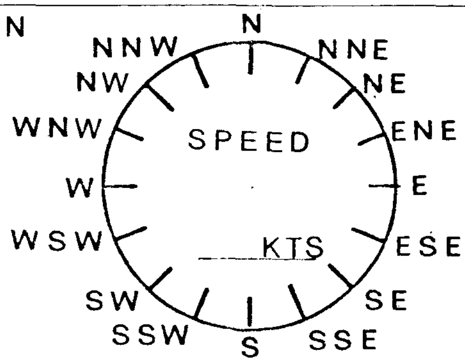
AIR TEMP.________ °F.
SEA TEMP.________ °F.
WAVE HT.________ Ft.
PERIOD ________ Sec.
BAROMETRIC PRESSURE________ In Hg.
VISIBILITY________ n. Mi.

SANDY HOOK



AIR TEMP.________ °F.
SEA TEMP.________ °F.
WAVE HT.________ Ft.
PERIOD ________ Sec.
BAROMETRIC PRESSURE________ In Hg.
VISIBILITY________ n. Mi.

MANASQUAN INLET



AIR TEMP.________ °F.
SEA TEMP.________ °F.
WAVE HT.________ Ft.
PERIOD ________ Sec.
BAROMETRIC PRESSURE________ In Hg.
VISIBILITY________ n. Mi.

Figure 13. Daily weather record sheet.

SECTION 8

LABORATORY ANALYSIS AND SAMPLING PLAN

OCEAN WATER SAMPLING AND ANALYSIS

Grab samples of ocean water in the test zone were taken during the test program. These samples were analyzed for temperature, salinity, and conductivity using a Yellow Springs Instruments Model 33 SCT Meter, pH was determined by a Fisher Scientific Model 120 pH meter, and specific gravity by a hydrometer.

Ocean Water - Summary of Properties

Salinity	32.5 ppt
Conductivity	43,500 umhos
Temperature	6.7°C
pH	7.4
Specific Gravity	1.021

Water properties obtained are shown below. Selected samples were analyzed for crude oil content. Analysis results are shown in Table 5, (Reference 3).

TABLE 5. OCEAN WATER SAMPLE ANALYSIS

Date	Sample Description	Oil Content ppm
9 April 80	Ocean	45ND*
10 April 80	Ocean	25ND*
11 April 80	Ocean	25ND*
12 April 80	Ocean	25ND*
13 April 80	Ocean	25ND*
12 April 80	Recovery Tank Draining Test #5 - Tank II	80
12 April 80	Recovery Tank Draining Test #5 - Tank II	70
13 April 80	Recovery Tank Draining Test #6 - Tank IV	200
13 April 80	Recovery Tank Draining Test #6 - Tank IV	235

*ND = content less than limit of detection

TEST OIL PROPERTIES SAMPLING AND ANALYSIS

Grab samples of the La Rosa crude were taken from the distribution tanks. Analysis results for a viscosity versus temperature curve were obtained using a Brookfield Model LVT viscometer at about 22°C and a Fisher/Tag Saybolt Viscometer

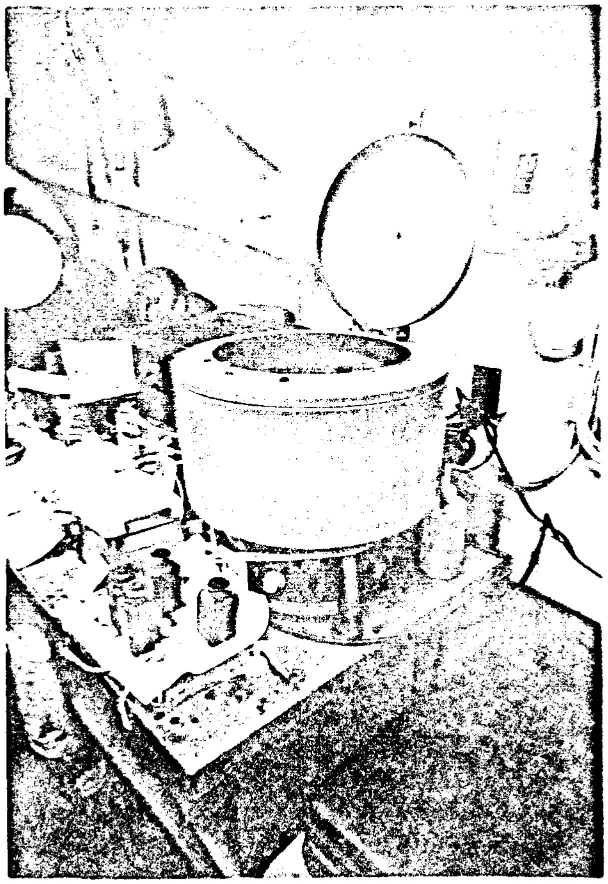


Figure 14. Centrifuge for oil/water analysis in Powhatan lab.

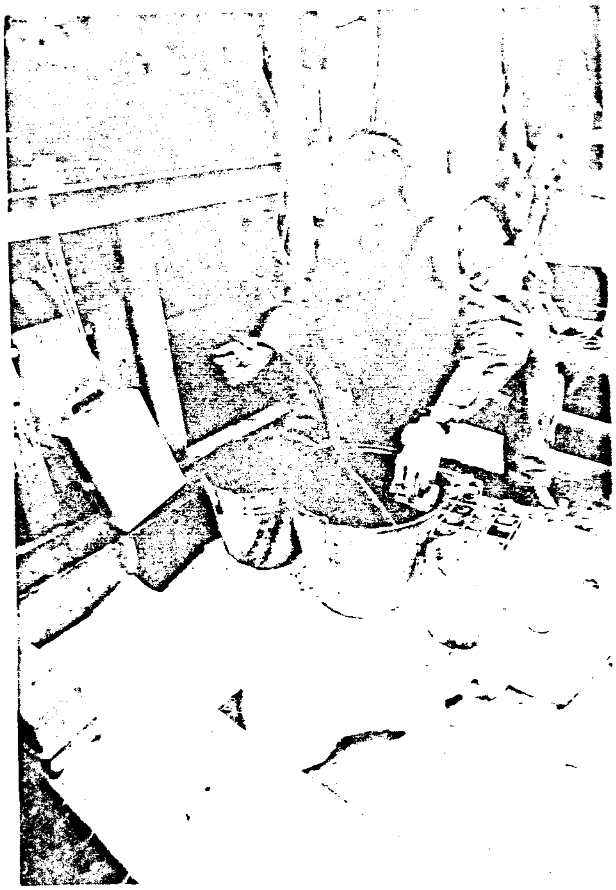
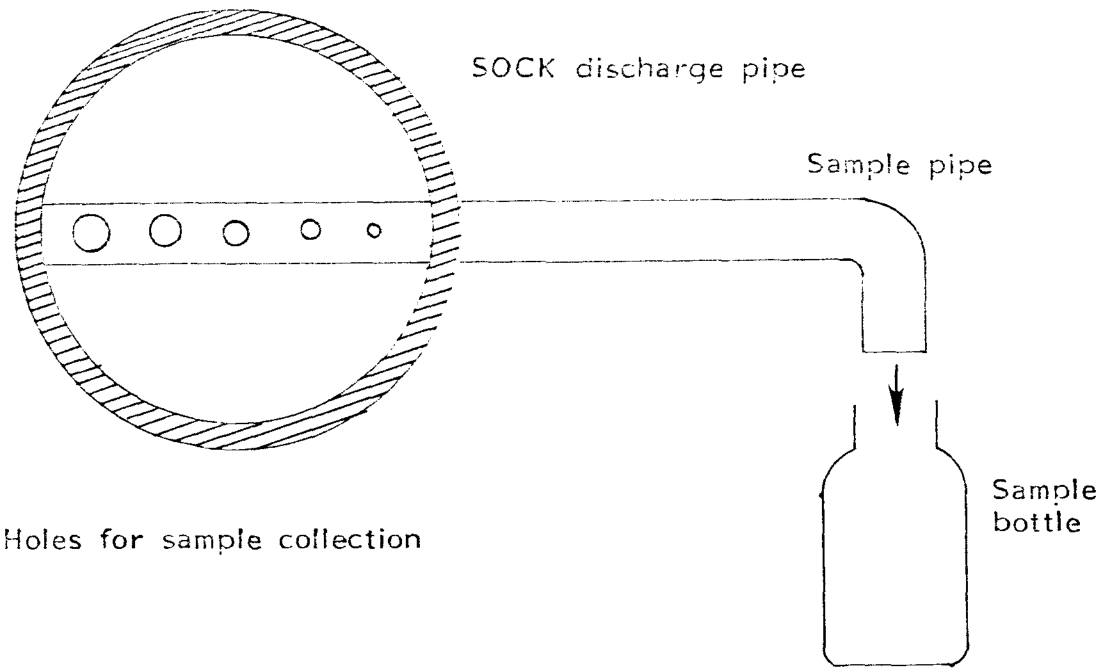


Figure 15. Discrete sampling station.



Flow in SOCK discharge pipe impacts holes in sampling pipe. Discharge pipe is full at all times and well mixed.

Figure 16. Diagram of discrete sampling pipe.

at about 75°C. Viscometer results were converted to centistokes (cSt) using procedures in ASTM STP 43C and plotted using ASTM D341 viscosity versus temperature charts. Oil viscosity at ocean temperature was then read from the chart. Oil surface tension (SFT) and interfacial tension with ocean water (IFT) were found using a Fisher Scientific Model Surface Tensiomat at a room temperature of 18 ±2°C. Water content of the crude was found by centrifuging with toluene using ASTM method D1796-75. Specific gravity was determined using a hydrometer. Oil properties obtained are shown below:

La Rosa Crude - Summary of Properties

Specific gravity	0.916
Surface tension	34.8 dynes/cm @ 18°C
Interfacial tension	27.7 dynes/cm @ 18°C
Viscosity	146 cSt @ 0°C
Viscosity	9.7 cSt @ 100°C
Flash Point	54.5°C

SKIMMER RECOVERY SAMPLING AND ANALYSIS

Fluid recovered by the SOCK was sampled using two methods. Discrete samples were taken from the recovery piping near the exit of the SOCK pump every minute and composite samples were taken from the storage tanks after each test. Samples were analyzed by centrifuge using ASTM D1796-75 to obtain oil and water percentages (see Figure 14). Analysis of the discrete samples provided the recovery efficiency (RE) for every minute of pumping time. Analysis of composite samples provided the percentage of oil in total fluid recovered. Total oil volume recovered (V_{ro}) was then calculated using tank soundings and:

V_{ro} equals (Volume total fluid emulsion in tank) multiplied by (percent oil in tank)

Throughput efficiency (TE) could then be calculated using V_{ro} the volume of oil distributed (V_{do}) and:

$$TE = (V_{ro}/V_{do})*100$$

Discrete samples were collected using a sample tap previously installed in the recovery piping near the SOCK pump exit (Figure 15). Sample tap geometry is shown in Figure 16. A 1 mm x 61 mm polyethylene tube was attached to the top for filling 200 cm^3 sample bottles. Typically, each sample bottle filled in less than 10 seconds. Since samples were taken at 60 second intervals, the flow was allowed to run continuously and diverted to a separate container for the period between samples.

Composite samples were taken from 18.9 m^3 tanks holding the fluid recovered by the SOCK. One tank contained pre and post-steady state (slop) recovery and another contained fluid recovered during steady state. Fluid levels in the tanks were measured after each test using a dipstick and ruler (Figure 17). Samples were then taken using the Johnson Sampler (Figure 18) for oil and water analysis. Each segment of the Johnson Sampler was analyzed separately, with oil percentage reported. Total volumes recovered in the slop and steady state tanks were found by comparing fluid

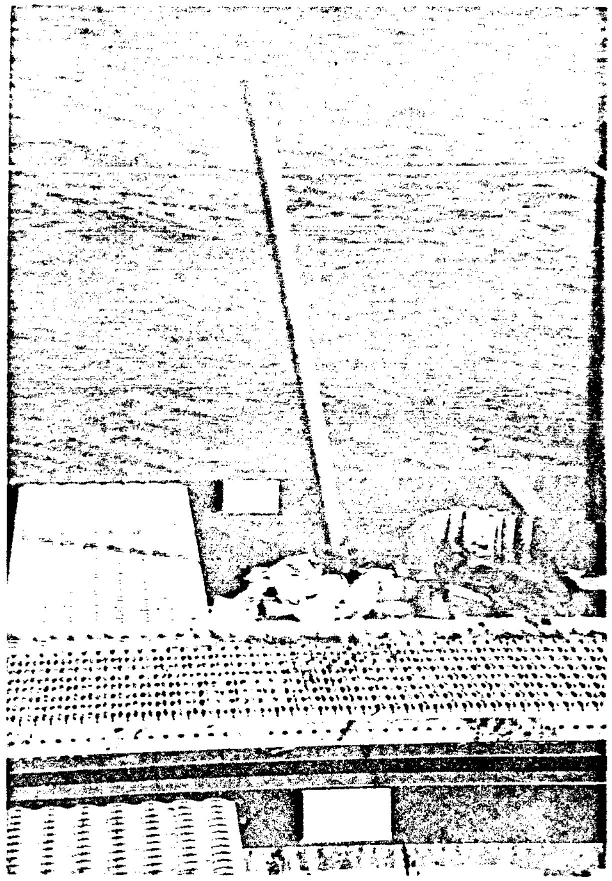


Figure 17. Dipstick sampling station.

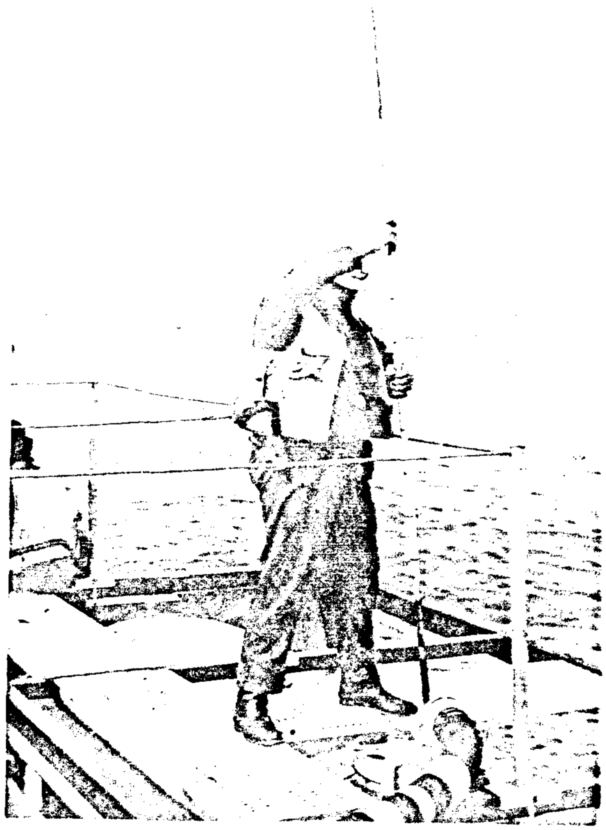


Figure 18. Johnson stratified sampling on station.

height in the tanks to a calibration curve of tank volume versus height. Oil volumes recovered in the slop and steady state tanks were calculated using the oil percentages found for each segment of the Johnson Sampler. Tank volume represented by each segment was multiplied by the percent oil found in the sample of that segment. Oil volumes for each segment were then added to give the total oil volume in the tank. Results of a hypothetical example are shown in Table 6.

TABLE 6. EXAMPLE RESULTS.

Johnson Sampler segment	Total volume per 0.3-m segment, m^3	Slop tank sample oil, %	Slop tank oil volume per segment, m^3	Steady state sample oil, %	Steady State oil volume per segment, m^3
1	.50	5	0.025	10	0.05
2	.75	10	0.075	20	0.15
3	1.10	15	0.165	30	0.33
4	1.55	20	0.31	40	0.62
5	2.20	25	0.55	50	1.1
6	3.00	30	0.9	60	1.8
7	4.00	35	1.4	70	2.8
8	5.20	40	2.08	80	4.16
9	6.70	45	3.015	90	6.03
10	8.50	50	4.25	100	8.5
Total oil recovered			12.77 m^3		25.54 m^3

Each tank was allowed to settle as long as practical before free water was drained. Tank fluid levels were again measured and samples taken with the Johnson Sampler for oil and water content analysis. Total fluid after draining and oil volumes were obtained using the calculations of the previous example. Water drained prior to sampling was added back to the total fluid after draining result to obtain total fluid recovered. Results obtained from the before and after draining samples were compared to determine error in the measurements.

One problem surfaced during sample collection using the Johnson Sampler. Oil in the sample would adhere to the sampler, requiring a toluene wash to remove the oil to a sample bottle. Unfortunately, the polycarbonate sheath was attacked and destroyed by the toluene left on the sampler. Since the entire stock of samplers was used by the middle of Test 4, an alternate method was then employed to sample the recovery tanks. Tank levels were measured after each test, then drained of free water and measured again. Comparison of the two tank levels gave the amount of water drained. An open 125 ml sample bottle was taped to a steel rod and slowly lowered from the liquid surface to the bottom of the tank and back to the surface (Figure 19). Since fluid flowed into the bottle during the entire period, the sample was assumed to represent the contents of the tank. Some error is expected as the tanks are horizontal cylinders so one level does not contain as much fluid as another and the tank may not be well mixed so water and oil pockets may be present.

Lab Analysis of the sample provided the oil percentage in the fluid left in each tank. Oil volumes recovered and throughput efficiency were calculated same as for Johnson samples taken from drained tanks.

Figure 19. Grab sampling station.

SECTION 9

DATA REDUCTION

Preliminary reduction of data onboard the Powhatan was necessary to maintain control of testing and evaluate results to determine the need, if any, to alter the preliminary test matrix. This preliminary data reduction was for purposes of on-scene evaluation only and was never intended to give the final results which required many man-hours in an environment more conducive to the detailed calculations necessary for the total reduction and evaluation of the data package.

SHIPBOARD REDUCTION

Certain data was transformed with pretest known quantities to produce a calculable quantity for decision making onboard. The wind-driven surface velocity was an important test parameter. The speed was computed by measuring the time necessary for the wood chip to travel a set distance 30.5 m (100 ft). The time was not the desired quantity, the speed in kt must be determined. Similarly the tank soundings provide the heights of fluids in the tanks but the desired quantity was the volume in the tanks at the time of sounding so that preliminary values for recovery and throughput efficiency, and quantification of skimmer loss could be computed onboard.

FINAL REDUCTIONS

Although the shipboard calculations for skimmer rating criteria were done on a test-to-test basis, the final reduction on land was done on a grouped basis. The data naturally falls into four categories: Environmental, Distribution, Collection, and Other.

Environmental

The environmental data was correlated to the vessel speed, heading, position, time, and test number. The actual reduction was done by the USN-NUSC laboratory representatives (Reference 7). Figure 20 shows the buoy deployed. Figure 21 is a sketch of the major components of the buoy.

Distribution

The quantity of oil distributed to the mouth of the Sock was measured using a 152 mm (6 in) positive displacement (PD) meter placed in the distribution line and sounding of the crude oil storage tank designated for use in this specific test before and after the test (tanks V and VI were designated as crude oil storage tanks). A third measurement of the distributed volume was to have been based on the theoretical crude oil pump rate determined by the rpm of the hydraulic power pump, but the

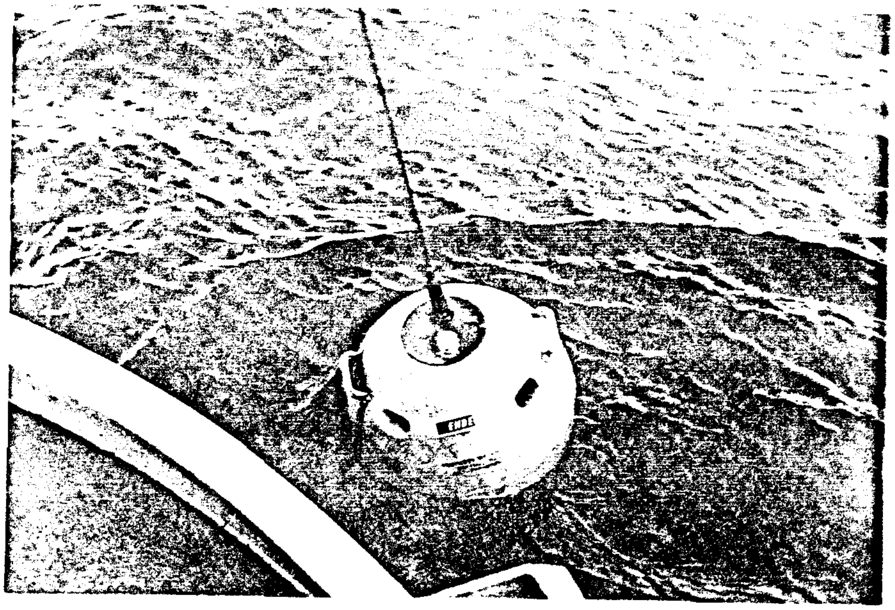


Figure 20. Wavetrack buoy at sea.

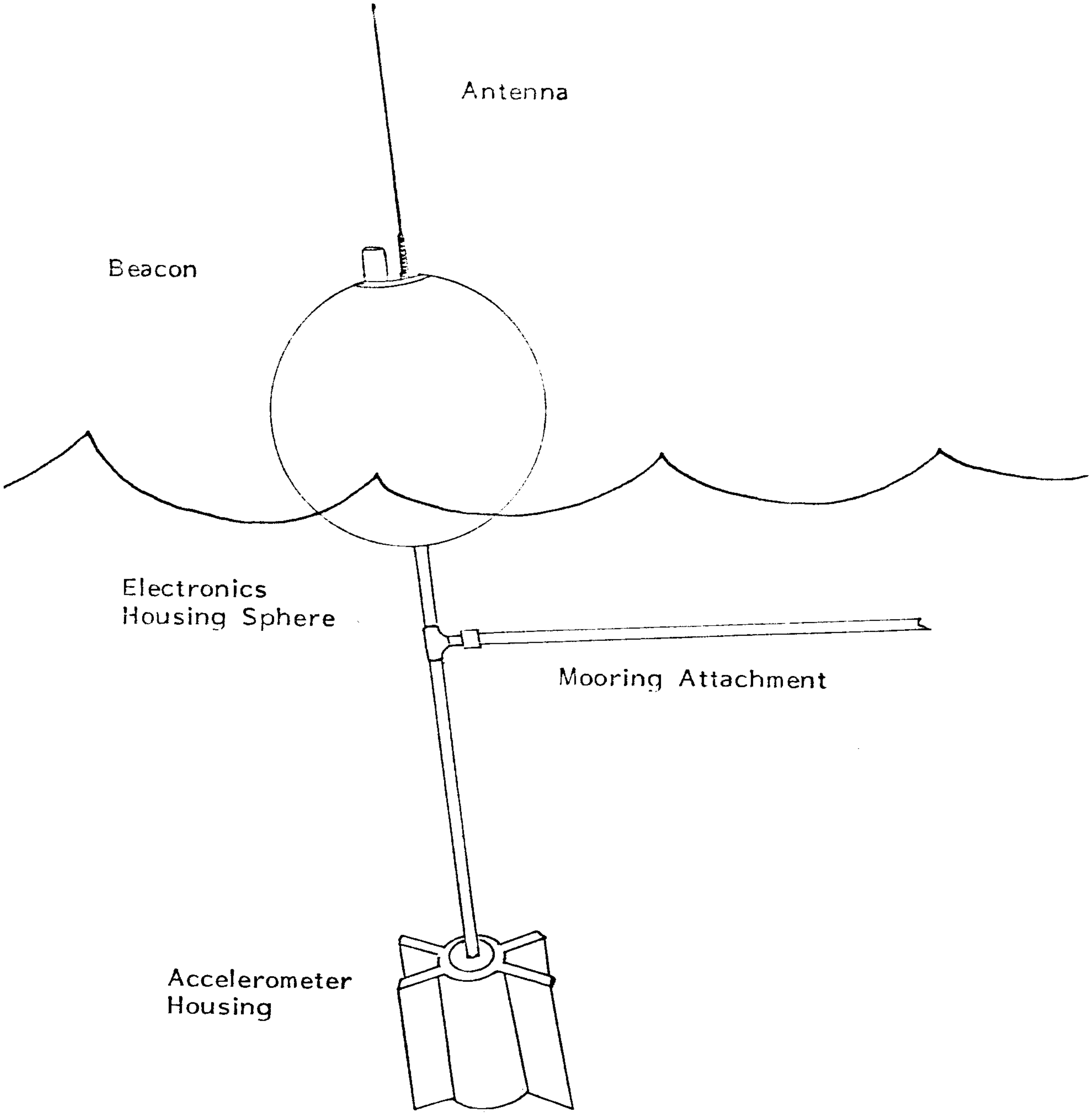


Figure 21. The ENDECO wavetrack buoy.

Note: This system includes a fiberglas buoy, double integrator, batteries, and FM transmitter.

tachometer did not function properly. The time for oil distribution was recorded in seconds as the time from when the valve to the oil slick generator was opened until the same butterfly valve was closed. The distributed volume to time ratio gives redundant rates based on tank soundings and the inline meter.

Since the preload volume had been designated rather than the preload time, the preload times are calculated based on the given preload volume and the three distribution rates (tank soundings, metered, and averaged).

The difference between the total distribution time and each of the redundant distribution times can produce the steady state time based on the distribution volumes.

A summary of the reduced distribution data is given in Table 7.

Recovery

Data reduction for the recovered fluids is similar to the tank soundings of the distribution calculations. Each recovery tank was sounded three times. The pre-collection height, total collection height, and decanted height are recorded for each collection tank. Each of these heights is translated into the appropriate volumes using linear interpolation of the computer generated numerical integration tables for the height-volume relationships. The volume of the total collection height less the volume of the pretest sounding is the total collected volume. The decanted volume less the initial volume is the total collected volume of the oil-water emulsion. It is a sample of this volume that is given to the onboard laboratory for analysis.

There is a choice as to how this data can be treated to calculate the volume of oil collected based on differing starting assumptions. The first method assumes that all of the initial volume is pure crude oil. If this is true, then the volume of recovered oil is given by:

V_{ro} equals (Volume of recovered emulsion) multiplied by (percent oil in tank) minus (initial tank oil volume)

The second method bases itself on the La Rosa crude oil being exposed to sufficient water and mixing energy to form a saturated, stable, tight emulsion in all cases. The initial (pre-test) volume is then assumed to have essentially the same relative oil content as the overall emulsion. With this assumption, the recovered oil volume becomes:

V_{ro} = (Decanted oil volume) minus (initial tank oil volume) multiplied by (percent oil in tank)

This assumption yields higher performance values in all cases and became the operational assumption for the recovered fluid data reduction.

These calculations were compiled for the steady state recovery tank(s) and the slop tank(s) for each test run. The results are given in Table 8.

A second steady state period was defined to be the total Tuthill pump time equal to the total distribution time.

TABLE 7. REDUCED DISTRIBUTION DATA

Test no.	2	3	4	5	6	7	8
Distribution volume Tank sound (m^3)	3.03	4.31	12.65	10.39	10.50	7.42	7.59
PD meter (m^3)	1.89	1.89	12.43	9.30	10.59	7.83	6.25
Average (m^3)	2.47	3.10	12.54	9.85	10.55	7.63	6.92
Total Dist. Time (sec)	103	195	665	720	585	1,230	765
Distribution rate T.S. (m^3/hr)	105.90	79.57	68.48	51.96	64.62	21.72	35.72
P.D. (m^3/hr)	66.41	34.89	67.60	46.50	45.17	22.92	29.41
Ave. (m^3/hr)	85.95	57.23	68.04	49.23	64.90	22.32	32.57
Preload volume (m^3)	----	----	1.89	3.79	3.79	3.79	3.79
Preload time Average (sec)	----	----	100	276	210	610	418
Steady State (sec) Time - Average	----	----	565	444	375	620	347

Skimmer Rating Parameters

Calculation of the skimmer rating parameters is readily accomplished using the standard OHMSETT working equations for Oil Recovery Rate, Throughput and Recovery Efficiency outlined in the OHMSETT Standard Operating Procedures (SOP's).

TABLE 8. SUMMARY OF RECOVERED FLUID

Test no.	Tank no.	Designation	Heights (cm) initial	full	decant	Volume (m^3) initial	full	decant
1	---	---	No recovery			No recovery		
2*	III	Steady State	0	19.1	19.1	0	1.0	1.0
	IV	Slop	0	43.2	43.2	0	3.1	3.1
3*	II	Only	0	7.6	7.6	0	0.2	0.2
4*	I	Steady State	0	100.3	100.3	0	9.9	9.9
	III	Slop	19.1	116.8	116.8	0.9	12.0	12.0
	IV	Slop	43.2	101.6	101.6	3.1	10.1	10.1
5*	III	Steady State	11.4	55.9	55.9	1.7	4.5	4.5
	IV	Slop	8.9	85.1	73.0	0.3	8.0	6.5
6	I	Steady State	11.4	78.7	63.5	1.7	7.2	5.3
	II	Slop	7.6	119.4	114.3	0.2	12.3	11.7
7	III	Steady State	8.3	50.8	48.3	0.3	4.1	3.6
	IV	Slop	9.5	58.4	50.8	0.3	5.0	4.1
8	I	Steady State	8.9	35.6	22.9	0.3	2.3	1.2
	II	Slop	9.5	40.6	22.9	0.3	2.8	1.2

*The stratified sample technique was used in tests 2, 3, 4 and the steady state tank for test 5. Tank soundings were recorded on the nearest 0.64 cm mark and converted to gallons.

The Oil Recovery Rate (ORR) is a measure of the SOCK's ability to remove oil from the environment (water surface) to the onboard recovery tanks and is computed by the equation:

ORR = (Volume of oil collected) divided by (Time for that collection)

The Recovery Efficiency (RE) is the ratio of oil collected divided by the total fluids, oil and water, collected. The throughput efficiency (TE) is a measure of the quantity of oil available for recovery to that which is actually recovered. The available oil is that within the sweep width of the skimmer entrance. The operating equation is:

$$TE = \frac{\text{(Volume of oil recovered) multiplied by (100)}}{\text{(oil distributed multiplied by (percent encountered))}}$$

Because of the preloading, the oil distributed is not related to all steady state conditions and the substitution of oil distributed = $Q_D\, t_{ss}$ into the TE working equation yields:

$$TE = \frac{Vro}{Q_D t_{ss} E\%} \times 100$$

where Q_D is the distribution rate for the corresponding time interval defined as steady state, t_{ss}, and E% is the percentage oil encountered.

These dynamic equations are then applied to the various possibilities presented by the complete data package. This application yields for each test 18 possible values for TE, and two values for the RE and ORR. The combinations are illustrated in Table 9.

TABLE 9A. THROUGHPUT EFFICIENCY COMBINATIONS.

	Tank Soundings	Metered Output	Average
Throughput Efficiency			
Tank Sounding	TE_1	TE_2	TE_3
Metered Output	TE_4	TE_5	TE_6
Average	TE_7	TE_8	TE_9
Tank Sounding	TE_{10}	TE_{11}	TE_{12}
Metered Output	TE_{13}	TE_{14}	TE_{15}
Average	TE_{16}	TE_{17}	TE_{18}

TE_1 through TE_9 - Steady State #1

TE_{10} through TE_{18} - Steady State #2 (Extended Steady State)

TABLE 9B. OIL RECOVERY RATE.

Oil Recovery Rate	
	Tank Soundings for Oil Volume
Steady State	ORR_1
Extended Steady State	ORR_2

TABLE 9C. RECOVERY EFFICIENCY.

Recovery Efficiency	
	Tank Soundings for Oil Volume
Steady State	RE_1
Extended Steady State	RE_2

The reader is cautioned on comparing columns and rows, and to understand that this program was designed with redundant measuring techniques, not to be confused with duplicates as in establishing statistical confidence. The additional values for TE are, of course, generated by redundant distribution measurements. If all instruments had functioned property, the matrices for the RE and ORR would have been expanded similarly.

The rating criteria is now broken into steady state and extended steady state for comparison. The ORR and RE is straight forward, but the TE requires comparison. Fortunately, the differences between the TE values is generally small enough to be accounted for by error in accuracy and precision of the data taken. If this had not been the case, an analysis of the measurements taken and the means of measurement, and probable error would be necessary to eliminate the data that was inconsistent with other reading and measurements.

Other

Weather data, vessel heading, pitch and roll of the Powhatan and dump location did not need to be reduced, only correlated by test number, time and date. Skimmer losses were conservatively estimated at sea allowing a large enough safety factor for the simplified shipboard assumptions and to ensure confidence that the test program remained within the EPA dumping permit for total at-sea losses. These skimmer losses were recalculated without the simplifying assumptions for daily reporting to the

US EPA (Region II) and USCG Captain of the Port (3rd District). The total skimmer loss was determined to be 17.8 m^3 (4,700 gal) and the maximum allowable loss was 18.9 m^3 (5,000 gal). A summary of all reduced and correlated data is given in Table 10.

Discrete Sample Analysis

During each test, discrete samples were taken and analyzed on a percent oil basis. These values were then taken and reduced in conjunction with the Tuthill pump rpm and pumping curve of the back pressure to the pump and used for computation of skimmer rating criteria.

The skimmer rating criteria (SRC) is now defined as a dependent performance variable such as ORR, RE, or TE on a minute-to-minute basis. The average SRC is a summation of discrete SRC's divided by the specified time intervals.

$$SRC = (SRC_i + SRC_{i+1} + \ldots + SRC_n)/(n-i)$$

The RE and TE values were quite consistent with those taken on the grab sample basis. The ORR computed as ORR = (oil %)(pump rate) was in misalignment with known values from grab sample data reduction. The theoretical pump rate was computed from the Tuthill pump curves with a given rpm and back pressure. When the pump curve flowrate was compared to measured time--quantity values, they were not in agreement. A cross check of ORR rates based on tank soundings and flow rate brought the ORR into much closer alignment.

SAMPLE CALCULATIONS

Test five was selected as a sample calculation. It is a typical test conducted mid-way through the program.

Vessel Speed

Time for wood chip to travel 30.5 m (100 ft) = 44.5 s

$$V = \frac{30.5 \text{ m}}{44.5 \text{ s}} = 0.69 \text{ m/s}$$

$$= (0.69 \text{ m/s})(1.94 \text{ kts/(m/s)}) = 1.33 \text{ knot}$$

Oil Distribution

Volume from positive displacement meter = 9.31 m^3

Volume by tank sounding

$H_1 = 1.98$ m $\quad V_1 = 21.13\ m^3$

$H_2 = 1.07$ m $\quad V_2 = 10.73\ m^3$

V_1 and V_2 read from tank calibration chart.

Volume distributed = $V_1 - V_2 = 10.40\ m^3$

Time for total distribution (T) = 720 s = 0.20 hr

Distribution Rate

Based on Positive Displacement

Q_{PD} = 9.31/0.20 = 46.55 m^3/hr

Based on Tank Soundings

Q_{TS} = 10.40/0.20 = 52.00 m^3/hr

Average = (46.55 + 52.00)/2 = 49.28

Preload Size, V = 1.89 m^3

Preload Time

Based on Positive Displacement Meter

$T_{PL,PD}$ = 1.89/46.55 = 0.04 hr = 146.3 s.

Based on Tank Soundings

$T_{PL,\ TS}$ = 1.89/52.00 = 0.04 hr = 130.85 s.

Average $T_{PL,A}$ = (130.85 + 146.36)/2 = 138.60 s.

Steady State Times

Based on Positive Displacement Meter

$T_{SS,PD} = T - T_{PL,PD}$ = 720-146.36 = 573.64 s.

Based on Tank Soundings

$T_{SS,TS} = T - T_{PL,TS}$ = 720-130.85 = 589.15 s.

Average

$T_{SS,A} = (T_{SS,PD} + T_{SS,TS})/2$ = (573.64+589.15)/2 = 581.40 s.

Oil Recovery

Using the stratified sampling technique. Steady state tank No. IV.

Initial volume =0.45 m^3 oil.

Stratified sample compartment	Representative tank volume m^3	Percent, oil, %	Total Oil (m^3)
1	0.68	78	0.53
2	1.18	88	1.04
3	1.48	93	1.37
4	1.11	95.5	1.06
Total	4.45	N/A	4.00

Collected volume = 4.45 - 0.45 = 4.00 $m^3 = V_T$

Collected oil volume = 4.00 - 0.45 = 3.55 $m^3 = V_O$

Using grab sample technique.

Test four, slop tank.

Initial height = 64 mm
Total height = 851 mm
Decanted height = 731 mm

From linear interpolation of height-volume listing (tank calibration chart)

Initial volume = 0.31 m^3
Total volume = 7.97 m^3
Decanted volume = 6.45 m^3
Oil percentage = 81% (from lab analysis of grab samples)

Total collected volume = 7.97-0.31 = 7.66 $m^3 = V_T$

Total collected oil volume = (6.45-0.31)(0.81) = 4.97 $m^3 = V_O$

Calculation of Skimmer Rating Criteria (SRC)

Recovery Efficiency = RE = 100 (V_O/V_T)
Steady State
RE = (3.55/4.00)(100) = 88.75%

Extended Steady State
RE = (3.55+4.97)/(4.00+7.66) x100 = 73.07%

Oil Recovery Rate = ORR =
(Oil recovered in steady state)/(steady state time length)

Steady state
ORR = 3.55/0.10 = 35.5 m^3/hr

Extended steady state
ORR = (3.55+4.97)/(0.10+0.17) = 31.56 m^3/hr

Throughput efficiency
TE = (100 V_O)/(Q)(t_{SS})(E%)

Steady State (Repetitious calculations not shown)
TE = (100)(3.55)/(49.28)(0.10)(0.80) = 92.85%

Extended Steady State
TE = (100)(3.55 +4.97)/(49.28)(0.27)(0.80) = 80.04%

This sample illustrates the data calculations on Throughput Efficiency. The 10% difference covers a range of possible values for TE between steady state and extended steady state.

TABLE 10. COLLECTED AND RECOVERED DATA CORRELATED BY TEST NUMBER

Test no.	2	3	4	5	6	7	8
Distribution							
Metered vol (m^3)	1.90	1.89	12.43	9.30	10.59	7.83	6.25
Dipstick vol (m^3)	3.03	4.31	12.65	10.39	10.50	7.42	7.59
Dist. time (sec)	103	195	665	720	585	1,230	765
Metered rate (m^3/hr)	66.41	34.89	67.60	46.50	65.17	22.92	29.41
Dipstick rate (m^3/hr)	105.90	79.57	68.48	51.96	64.62	21.72	35.72
Encounter efficiency (%)	80	80	90	100	100	100	100
Preload							
Volume (m^3)	N/A	N/A	1.89	3.78	3.78	3.78	3.78
Dipstick time (sec)	N/A	N/A	100.65	292.65	208.81	593.72	462.70
Metered time	N/A	N/A	99.36	261.89	210.58	626.52	380.96
Vessel							
Speed (knots)	1.0	Various	1.0	1.3	1.3	1.0-1.8	2.1
Pitch (degrees)	5	5	3	2	2	2	3
Roll (degrees)	7	6	8	5	7	3	2

(Continued)

TABLE 10. CONTINUED.

Test no.	2	3	4	5	6	7	8
Pitch (degrees)	5	5	3	2	2	2	3
Pitch period (sec)	6	6	5	6	5	5	7
Roll (degrees)	7	9	8	5	7	3	2
Roll period (sec)	10	10	9	7	7	5	10
Heading (deg)	113	112	271	182	180	127	130
Location							
Starting N. Latitude	40°9.62'	40°9.65'	40°8.91'	40°9.19	40°4.76'	40°4.75'	40°1.62'
Starting W. Longitude	73°34.57'	73°32.64'	73°33.20'	73°35.65'	73°35.36'	73°33.65'	73°30.28'
Finishing N. Latitude	40°9.60'	40°9.64'	40°8.94'	40°8.83	40°4.71'	40°4.14'	40°1.29
Finishing W. Longitude	73°34.59'	73°32.54'	73°33.33'	73°35.67'	73°35.32'	73°33.12'	73°29.36'
Environmental							
Dry bulb temp. (°F)	52	52	50	47	48	48	48
Wet bulb temp. (°F)	49	48	48	46	47	50	47
Wind speed (knots)	8	8	8	8	20	11	Calm
Wind direction	SSW	SE	S	S	S	N	----

(Continued)

TABLE 10. CONTINUED.

Test no.	2	3	4	5	6	7	8
Wave height							
1/3 sig. (m)	1.3	1.4	1.2	0.9	1.4	1.0	0.7
Mean (m)	0.8	0.9	0.7	0.6	0.9	0.6	0.5
Max (m)	2.0	2.0	2.0	1.5	2.5	1.9	1.7
Wave period							
1/3 sig. (sec)	6.8	6.5	7.0	5.5	3.7	4.3	5.8
Mean (sec)	6.1	5.9	5.6	4.6	3.7	4.1	5.1
Vessel Speed (kts)	1.0	Various	1.0	1.3	1.3	1.0-1.8	2.1

SECTION 10

TEST RESULTS AND DISCUSSION

Of the eight tests run at sea with oil distribution, only the last five have dynamic skimmer rating criteria listed. The first test was run with only 0.60 l of oil distributed mainly for visual sighting purposes. The second and third tests were run to establish the quantity of unrecoverable oil in the Sock, to test the Sock for boom-type oil keeping ability, and to determine the critical speed for oil loss primarily through shedding and entrainment. The results of the oil tests are given in the test-to-test summary. Table 11 summarizes the test results.

TEST ONE

A small sample (0.60 liter) of La Rosa crude oil was poured onto the water surface directly in front of the Sock mouth. The oil spread evenly on the surface forming a thin but visible slick of black oil. The contrast between the oil and water was sufficient to visually observe the slick deposited on the sea, bow wave interactions, the skimmer losses, and encounter efficiency.

TEST TWO

A total of 1.89 m^3 (500 gal) of La Rosa crude oil was distributed to detemine the non-recoverable oil that is trapped in the Sock. Because of low water jet pressure, only approximately 80% 1.5 m^3 (400 gal) actually entered the Sock with a surface current velocity of 1 kt. Visual estimates of 1 to 3 m^3/hr (5 to 10 gpm) were made. Part way through the test, the speed is reduced to 0.75 kt and the visual estimate of oil loss was approximately 0.5 m^3/hr (3 gpm) still as entrained droplets of the oil. Later 1.6 m^3 (423 gal) was recovered using the Tuthill positive displacement pump.

TEST THREE

A second volume of 1.89 m^3 (500 gal) was distributed to the Sock and the Powhatan speed varied to ascertain the critical speed for boom-type failure. The shedding effects are obvious at 1 kt but much more pronounced at 1.5 kt. When reaching the 1.75 to 2.0 kt range, the oil shed does not resurface until 5-10 m (15-30 ft) past the Sock. When the speed is reduced to 0.5 kt, a thick slick 1 m (3 ft) wide forms and tapers to a point 5-7 m (5-20 ft) aft of the Sock. Vortices and SOCK generated turbulence is apparent at speeds greater than 1 kt. Recovery of fluid in the Sock yielded 0.68 m^3 (57 gal) of oil.

TEST FOUR

The first of the large scale distribution tests employs a 12.5 m^3 (3,300 gal) oil dump, the first 1.89 m^3 (500 gal) of which is considered to be preload. During the

TABLE 11. SOCK TEST RESULTS

Test no.	Fwd speed, kt	Pre-load m^3	Dist rate, m^3/hr	SOCK pump, m^3/hr	1/3 H m	Period T, s	Direc to sea	RE %	TE %	ORR m^3/hr
1	2.1	.0005	---	---	1.5	6	Head	---	---	---
2	1.0	1.89	66	---	1.3	7	Head	---	---	---
3	0.75- 2.0	1.89	35	---	1.4	7	Head	---	---	---
4	1.0	1.89	68	68	1.2	7	Head	44	55	10
5	1.3	3.8	47	45	0.9	5.5	Head	89	93	35
6	1.3	3.8	65	65	1.4	3.7	Head	39	47	12
7	1.75	3.8	23	23	1.0	4.3	Follow	43	43	12
8	2.1	3.8	29	29	0.7	5.8	Follow	26	18	2

testing, a head wave is observed in the Sock which tended to force oil between the Sock fabric and the pontoon floatation at the mouth of the Sock.

The Sock had a relative surface velocity of 1 kt and the waves had a significant (1/3) height of 1.2 m. The ORR was determined to be 10 m^3/hr, the RE 44%, and the TE 55%.

TEST FIVE

The fifth test was run at 1.3 kt using a 3.8 m^3 (1,000 gal) preload distributing oil at 47 m^3/hr (200 gpm). The sea was rougher than earlier, the significant wave height was lower (0.9 m) but the period was also shorter (5.5 seconds compared with 7.0 seconds on the fourth test).

The SOCK recovered oil at 35 m^3/hr (154 gpm) with the RE = 89% and the TE = 93%. This was the test with the widest variation of results based on the differing computed distribution rates and "steady state" versus "extended steady state". For example, the Throughput Efficiency could vary from 74% to 93%.

TEST SIX

The relative surface speed remains at 1.3 kt for comparative purposes, and the preload remains at 3.8 m^3 (1,000 gal). The distribution rate was increased to 65 m^3/hr (300 gpm). The results are not, however, indicative that this changes the TE. Oil was recovered at 12 m^3/hr (53 gpm) giving a TE of 47% and a RE of 39%. Unfortunately the sea state was an uncontrollable variable in the entire execution and the significant wave height changed to 1.4 m cresting every 3.7 seconds during this test. Test six was the last of the tests run into the seas.

TEST SEVEN

Run at 1.75 kt with the Sock in following seas, the oil was distributed at 23 m^3/hr (101 gpm) with a theoretical recovery rate set to be the same. The Sock encountered waves 1 m in height cresting every 4.3 seconds. The skimmer recovered oil at 12 m^3/hr (53 gpm) with a RE of 43%, of a TE of 43%.

TEST EIGHT

The final test was run at a higher speed to observe significant fall off in performance. Sea conditions were 0.7 m waves cresting every 5.8 seconds. The Sock at 2.1 kt recovered oil at 2 m^3/hr with a RE of 26% and a TE of 18%.

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APPENDIX

PARTICIPATING ORGANIZATIONS

Mason & Hanger-Silas Mason Co., Inc.

Tidewater Contractors, Inc.

Naval Underwater Systems Center

University of Rhode Island

Naval Weapons Station Earle

Crowley Environmental Services Corp.

United Tank Containers

Film Flair

Hydronautics, Inc.

3rd Coast Guard District, COTP

Region II, USEPA

Military Sealift Command, USN

National Weather Service, NOAA

Research and Development Office, USEPA

Shell Development Company

Research and Development Headquarters, USCG

NAVSEA, USN

Shell Oil Company

NAVFAC, USN

SUPSALV, USN

Cutter Reliance, USCG

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16. ABSTRACT

The Spilled Oil Containment Kit (SOCK), developed by Shell Development Company, was tested in a controlled crude oil dumping off the New Jersey Coast in early 1980. The program was sponsored by the U.S. Navy, Director of Ocean Engineering, Supervisor of Salvage through the Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) Interagency Technical Committee. The skimmer had been designed as a physical attachment to an oil industry work boat in a vessel-of-opportunity deployment mode. The United States Naval Ship (USNS)Powhatan T-ATF fleet tug was chosen as a similar vessel and one that had an oil spill recovery operation mode.

The test program is described, including the oil/water distribution and collection system, deployment and retrieval of the SOCK, the onboard fluid measurement, data analysis, logistics, weather and environment measurements, and the Powhatan/SOCK interface. The light crude oil and ocean water collected were stored aboard the vessel and decanted; the emulsified oil was later sold as waste oil. Eight experimental crude oil dumps are described and anlyzed. The sea conditions varied from calm to 1.8-m significant wave heights. During the 6 days at sea, 50m^3 of oil were dumped, and the skimmer collected 32 m of oil.

The program is analyzed for future improvements to open ocean testing plans incorporating oil skimmers with and without vessels of opportunity.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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