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EPA

Performance Testing of Selected Sorbent Booms

Interagency Energy/Environment R&D Program Report

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PERFORMANCE TESTING OF SELECTED SORBENT BOOMS

by

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report describes full-scale testing of three sorbent commercial oil spill booms. Based on the results presented here, more efficient operating techniques for booms used in water currents can be developed. The methods, results, and techniques described are of interest to those interested in specifying, using, or testing such equipment. Further information may be obtained through the Resource Extraction and Handling Division, Oil and Hazardous Materials Spills Branch, Edison, New Jersey.

David G. Stephan
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ABSTRACT

Performance tests on three commercially available sorbent booms were conducted at the U.S. Environmental Protection Agency's Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) test facility. Test variables included wave condition, tow speed, and quantity of oil encountered. The maximum no-oil-loss containment tow speed was determined for each wave and oil quantity test condition.

The no-oil-loss tow speed in calm water was consistently near 0.25 m/s, but in a 0.3-m harbor chop wave, this figure decreased to between 0.05 and 0.1 m/s. In the 0.3-m harbor chop wave, the failure mode was typically droplet shedding from the contained oil slick, whereas in calm water, the oil slick passed under the booms. No sorbed oil appeared to wash out of the booms when they were towed.

When saturated boom sections were wrung out, the recovered fluid weighed from 9.5 to 14 times boom dry weight and was 16 to 50 percent oil.

This report was submitted in fulfillment of Contract No. 68-03-0490, Job Order No. 41, by Mason & Hanger-Silas Mason Co., Inc. under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period August 16 to 19, 1977, and work was completed as of February 9, 1978.

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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
metre	foot	3.281 E+00
metre	inch	3.937 E+01
$metre^2$	$foot^2$	1.076 E+01
$metre^2$	$inch^2$	1.549 E+03
$metre^3$	gallon (U.S. liquid)	2.642 E+02
$metre^3$	litre	1.000 E+03
metre/second	foot/minute	1.969 E+02
metre/second	knot	1.944 E+00
$metre^2$/second	centistoke	1.000 E+06
$metre^3$/second	$foot^3$/minute	2.119 E+03
$metre^3$/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	$metre^2$/second	1.000 E-06
degree Fahrenheit	Celsius	$t_C = (t_F-32)/1.8$
erg	joule	1.000 E-07
foot	metre	3.048 E-01
$foot^2$	$metre^2$	9.290 E-02
foot/minute	metre/second	5.080 E-03
$foot^3$/minute	$metre^3$/second	4.719 E-04
foot-pound-force	joule	1.356 E+00
gallon (U.S. liquid)	$metre^3$	3.785 E-03
gallon (U.S. liquid)/ minute	$metre^3$/second	6.309 E-05
horsepower (550 ft lbf/s)	watt	7.457 E+02
inch	metre	2.540 E-02
$inch^2$	$metre^2$	6.452 E-04
knot (international)	metre/second	5.144 E-01
litre	$metre^3$	1.000 E-03
pound-force (lbf avoir)	newton	4.448 E+00
pound-mass (lbm avoir)	kilogram	4.535 E-01

ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

m	--metre
HC	--harbor chop (confused sea) wave
m/s	--metres per second
cm	--centimetre
kg	--kilogram
kg/m	--kilograms per metre
m^2s	--square metres per second
N/m	--Newtons per metre
m^3	--cubic metres

SYMBOLS

V_c	--Critical No Oil Loss Tow Speed
%	--percent
JO	--Job Order
x	--times
°C	--degrees Celsius
>	--more than

SECTION 1

INTRODUCTION

Some of the first sorbents used to contain and pick up oil spills were loose straw and corn cobs. Now sorbent blankets, pillows, and booms are made from a variety of natural and synthetic materials. The structural soundness and tensile strength of sorbent products have been augmented to increase their integrity, especially when saturated. The advantages of using sorbent booms include their light weight, flexibility (which allows use in confined quarters), and the elimination of skimmers (the booms pick up the oil and contain it as well). Disadvantages include the lack of a skirt on the booms, a finite sorptive capacity, and the cost of replacing a nonreusable boom.

The objectives of this test program were to:

1. Obtain performance data on the maximum no-oil-loss tow velocity for a sorbent boom in the containment configuration,

2. Determine handling characteristics,

3. Determine if regeneration and reuse of boom sections is feasible.

Three different types of commercially available sorbent booms were examined at the U.S. Environmental Protection Agency's (EPA) OHMSETT facility on August 16-19, 1977. A length of each boom (about 61 m) was towed in the catenary configuration at various speeds in both a calm and a 0.3-m harbor chop wave condition. Maximum no-oil-loss tow speed was determined for various percentages of the manufacturer's maximum recommended boom oil capacity. A single, medium-grade oil was used.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

Maximum observed no-oil-loss tow speed for the three sorbent booms tested was 0.30 m/s in calm water conditions and 0.25 m/s in the 0.3-m harbor chop (HC) wave. This figure is lower than the 0.46 m/s reported for conventional spill containment booms (with greater draft) in calm water by McCracken[1]. Average no-oil-loss tow speed during the 11 calm water tests with sorbent booms was 0.22 m/s, whereas the average of 11 0.3-m HC tests was 0.15 m/s.

Failure in HC wave conditions occurred as interfacial oil droplet shedding under the boom. Most of the oil splashed onto the boom by the waves was absorbed (Figure 1). Failure in calm water occurred at higher speeds as the oil slick passed under the boom. Oil loss also occurred at the attachment points between boom sections at tow speeds near 0.1 m/s (Figure 2)-- well below the failure speed of the entire boom section. Connecting boom sections by overlapping their ends was superior to joining their ends butt to butt. During towing, the oil slick collected in the apex region; the booms saturated and failed there first.

Using sorbent boom sections in a layered raft configuration (Figure 3) is expected to increase the probability that all the sorbent sections will encounter the oil slick. Also, any oil loss at section attachment points of the leading raft rows would be encountered by the trailing rows, thus decreasing the likelihood of ultimate loss. Unfortunately, this boom deployment configuration could not be tested during this program because of time constraints, but it should be examined in later studies.

The lightness of the dry (unused) sorbent booms made handling relatively convenient. Two men can carry and deploy 61 m of boom easily and rapidly. The manufacturers recommend joining sections together by means of integral fasteners (two cases) or by tying the ends together with rope (one case). Based on these tests, we recommend overlapping the ends of adjoining sections to lessen the oil loss between them.

An attempt was made to regenerate the used boom sections by squeezing

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[1]McCracken, W.E. Performance Testing of Selected Inland Oil Spill Control Equipment. EPA-600/2-77-150, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1977. 113 pp.

Figure 1. Oil splashed onto boom by 0.3-m HC waves and absorbed.

Figure 2. Oil loss at attachment points of booms joined butt to butt (tow speed about 0.1 m/s).

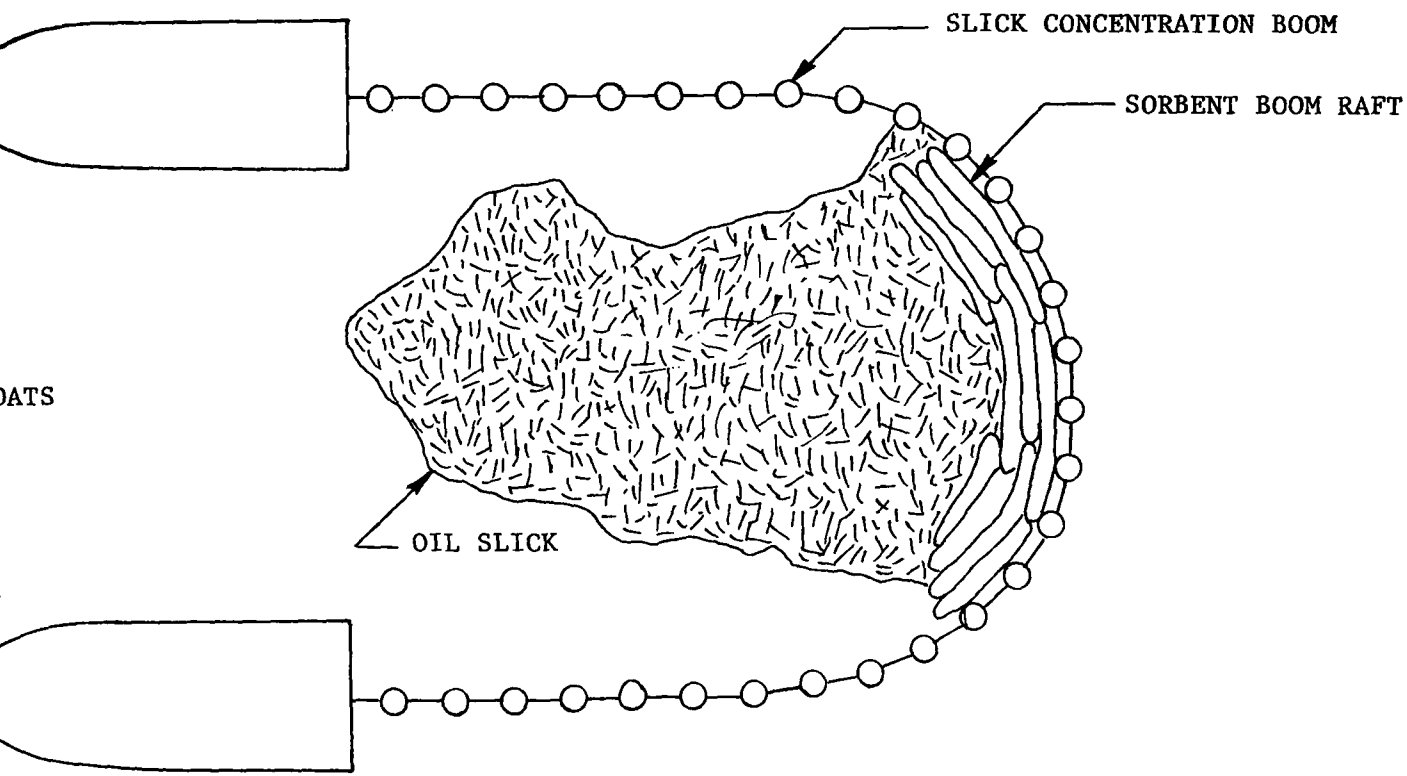

Figure 3. Proposed sorbent boom deployment: As a sorbent boom raft with either a conventional or sorbent boom in the containment mode.

out the recovered fluid. Each saturated section was pulled between two squeeze rollers (the top roller was filled with water and weighed 250 kg). In all cases, the boom sections were extremely hard to pull through, suggesting the need for a power-operated roller system. A major difficulty with this simple system was that as the booms were pulled through the rollers, the sorbent would bunch up at the end of the covering bag. When this sorbent plug entered the rollers, the resulting pressure would break the bag open and the sorbent would fall out. Perhaps two converging, powered conveyor belts might overcome both problems.

The fluid recovered during regeneration weighed 8.5 to 13 times as much as the original (dry) boom and contained 16 to 50 percent oil. This collected oil weighed 2.1 to 4.3 times as much as the boom. It should be noted that only the medium viscosity, naphthenic oil was used in these tests; different oils will yield different results.

SECTION 3

MATERIALS

Three sorbent booms representing three different types of sorbent materials were procured for testing (Table 1).

TABLE 1. SORBENT BOOM SPECIFICATIONS

Manufacturer	Sorbent type	Boom section dimensions Diameter (cm)	Length (m)	Weight (kg/m)	Sorbed oil capacity (multiples of boom weight)
Coastal Services 22 River St. Braintree, Mass.	Polyurethane	20.3	2.74	0.8	10
3M Company 3M Center 53-4 St. Paul, Minn.	Polypropylene	20.3	2.43	1.6	13-25
Conwed Corp. 332 Minnesota St. St. Paul, Minn.	Vegetable fiber mat	20.3	3.05	1.6	15-22

The Coastal Services Inc. Absorbent Boom (Figure 4) consists of small pieces of polyurethane foam inside a cheesecloth, sausage-shaped bag. Two grommets at each end of the cylinder serve as attachment points for joining boom sections. Boom sections were tied together butt to butt with nylon parachute cord for testing. The covering bag is the only tension member.

The 3M Company Type 270 Sorbent Boom (Figure 5) is an open-weave polypropylene mesh bag filled with polypropylene fiber. The tension member consists of a 0.95-cm polypropylene rope connected by shackles and steel rings so that the boom ends overlap.

The Conwed Corporation Heavy Duty Sorbent Boom (Figure 6) is made of a vegetable fiber mat and a foam floatation strip sealed inside a polypropylene mesh bag. Steel rings and snaps connect sections so that the ends overlap. A 0.95-cm polypropylene rope is the tension member.

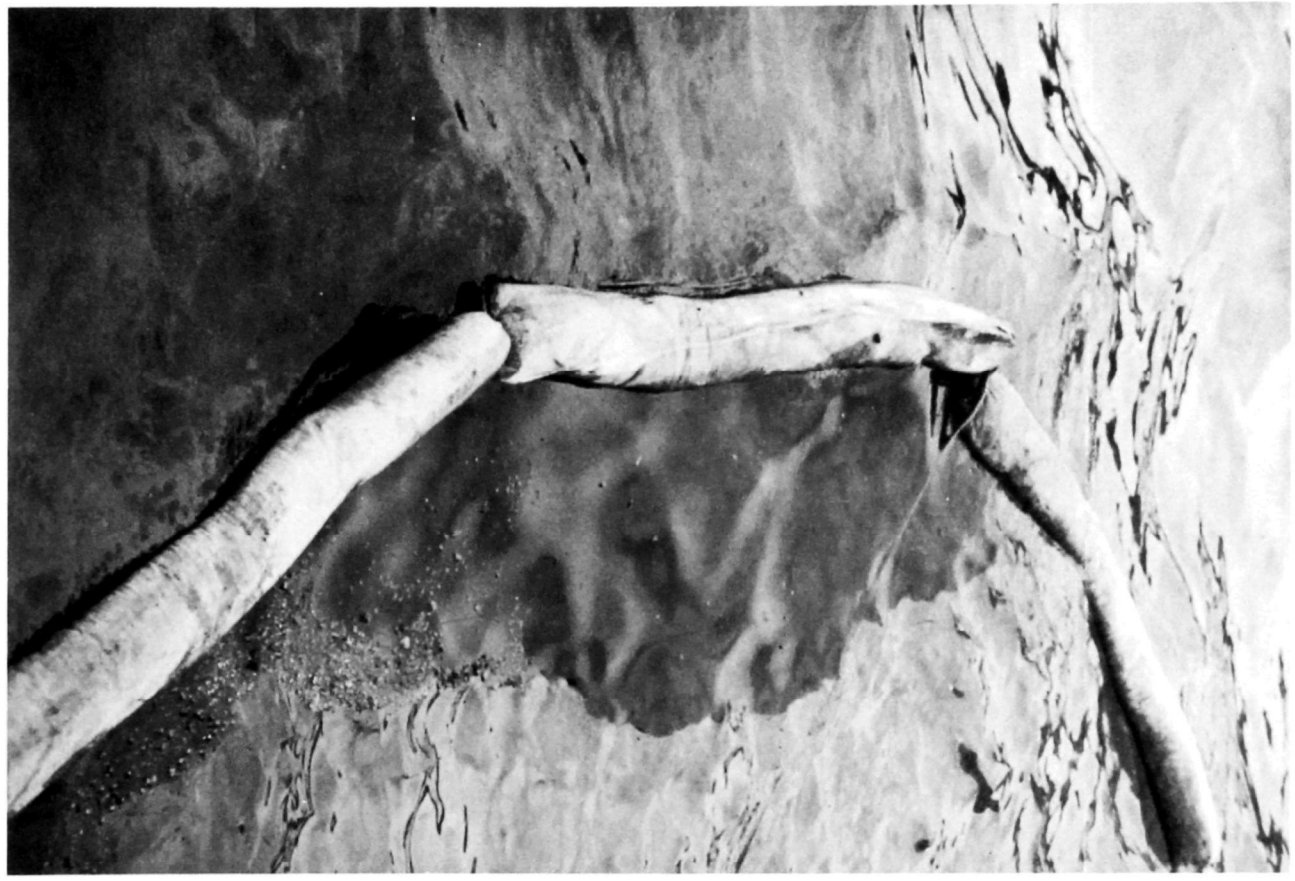

Figure 4. Coastal Services Inc. absorbent boom in 0.3-m HC wave near 0.3 m/s tow speed.

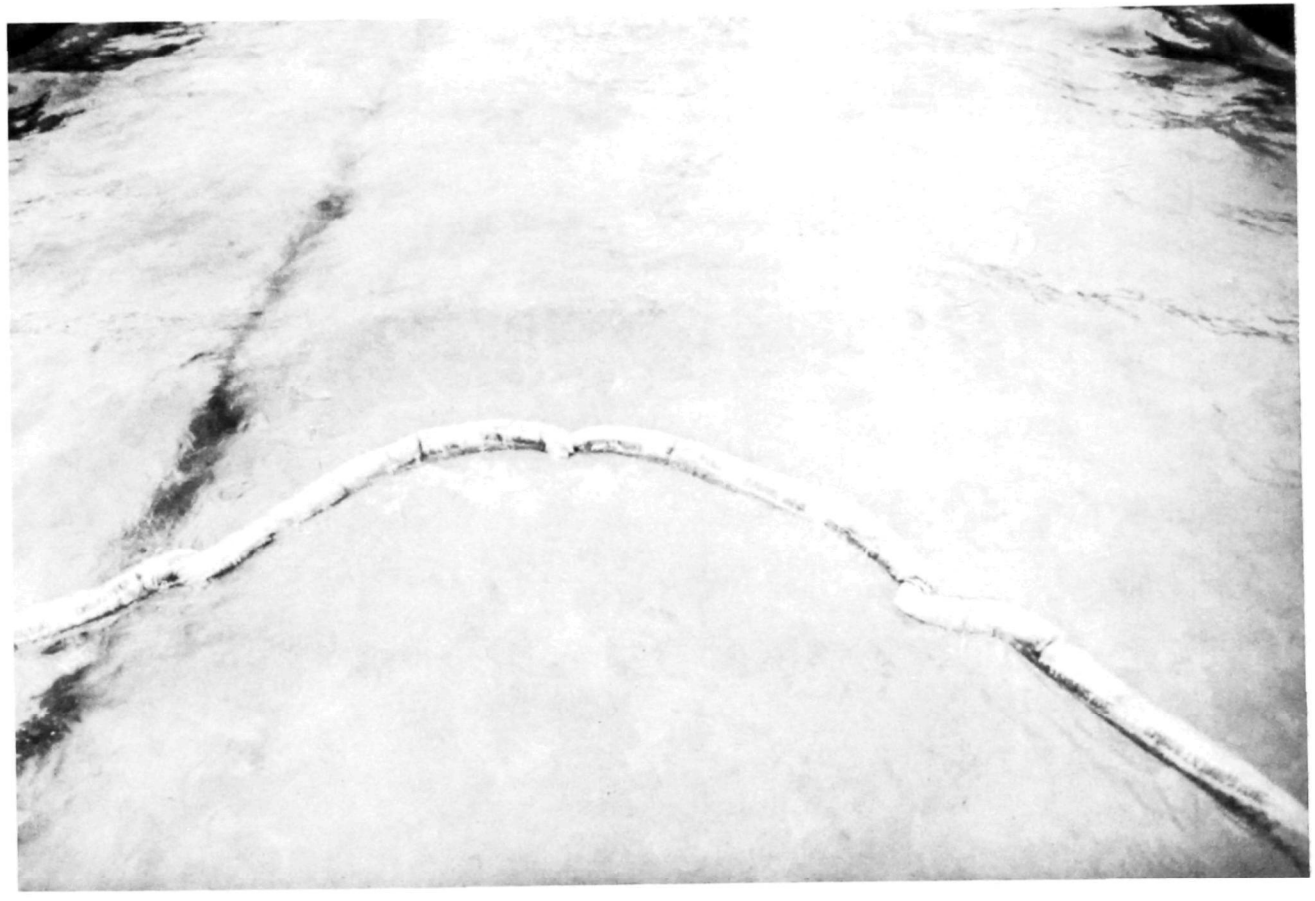

Figure 5. 3M Company Type 270 sorbent boom in 0.3-m HC wave near 0.3 m/s tow speed.

Figure 6. Conwed Corporation Heavy Duty Sorbent Boom in 0.3-m HC wave near 0.3 m/s tow speed.

A straight grade, naphthenic lubricating oil (Circo X Medium, Sun Oil Company) was used as the test fluid for this study. Test fluid properties are as follows:

Viscosity	$242 \times 10^{-6} m^2/s$ @ 22.7°C
	$38 \times 10^{-6} m^2/s$ @ 56.7°C
Specific gravity	0.928
Surface tension	$38.1 \times 10^{-3} N/m$
Interfacial tension	$7.6 \times 10^{-3} N/m$
	with OHMSETT tank water of 9 ppt salinity
Water and sediment	0.1%

SECTION 4

EXPERIMENTAL PROCEDURES

BOOM TOW TESTS

Boom sections were removed from their shipping containers and placed end to end on a concrete surface. Several new, dry sections were individually measured and weighed. Section ends were then fastened together, and the resulting 61-m boom was deployed on the test tank surface with ends connected to the towing bridge in a catenary configuration (Figure 7).

Tests were first conducted without oils to find the upper tow speed stability limit for each boom. After establishing the wave conditions (if any) on the tank surface, the boom was towed at increasing speed until the apex of the boom either submerged or planed. Tow speed was increased and decreased 0.05 m/s around the limit to reconfirm its magnitude.

Presumably, pretesting without oil could cause the booms to become water saturated. Oil encountering the boom sections would have to then displace this water, perhaps lowering the boom's capacity compared to dry boom sections. Ideally, in a spill situation, sorbent booms would be deployed onto the water in advance of the oil similar to procedure used in this test program. If the boom sections are deployed directly onto the oil slick, oil capacity may be higher.

Tow tests with oil were similar to stability tests. An oil slick equivalent to 25 percent of the boom's maximum recommended capacity, was placed on the tank surface. Then the boom was towed at increasing speed until failure, first in calm water and then in waves. Failure was observed to have occurred when oil loss was observed under, through, or over the boom sections. If other modes of oil loss were also observed, they were noted but not used to determine critical tow speed. Additional oil was then added to the slick to obtain 50, 75, 100, and 125 percent of the boom's recommended capacity. Both calm water and wave tests were conducted for each oil load level. Photographic documentation included 16 mm color movies and 35 mm black and white prints.

BOOM REGENERATION TESTS

A squeeze roller assembly was fabricated at OHMSETT to regenerate the sorbent booms (Figure 8), even though two of the booms were not advertised as being regenerable. The squeeze roller assembly was made

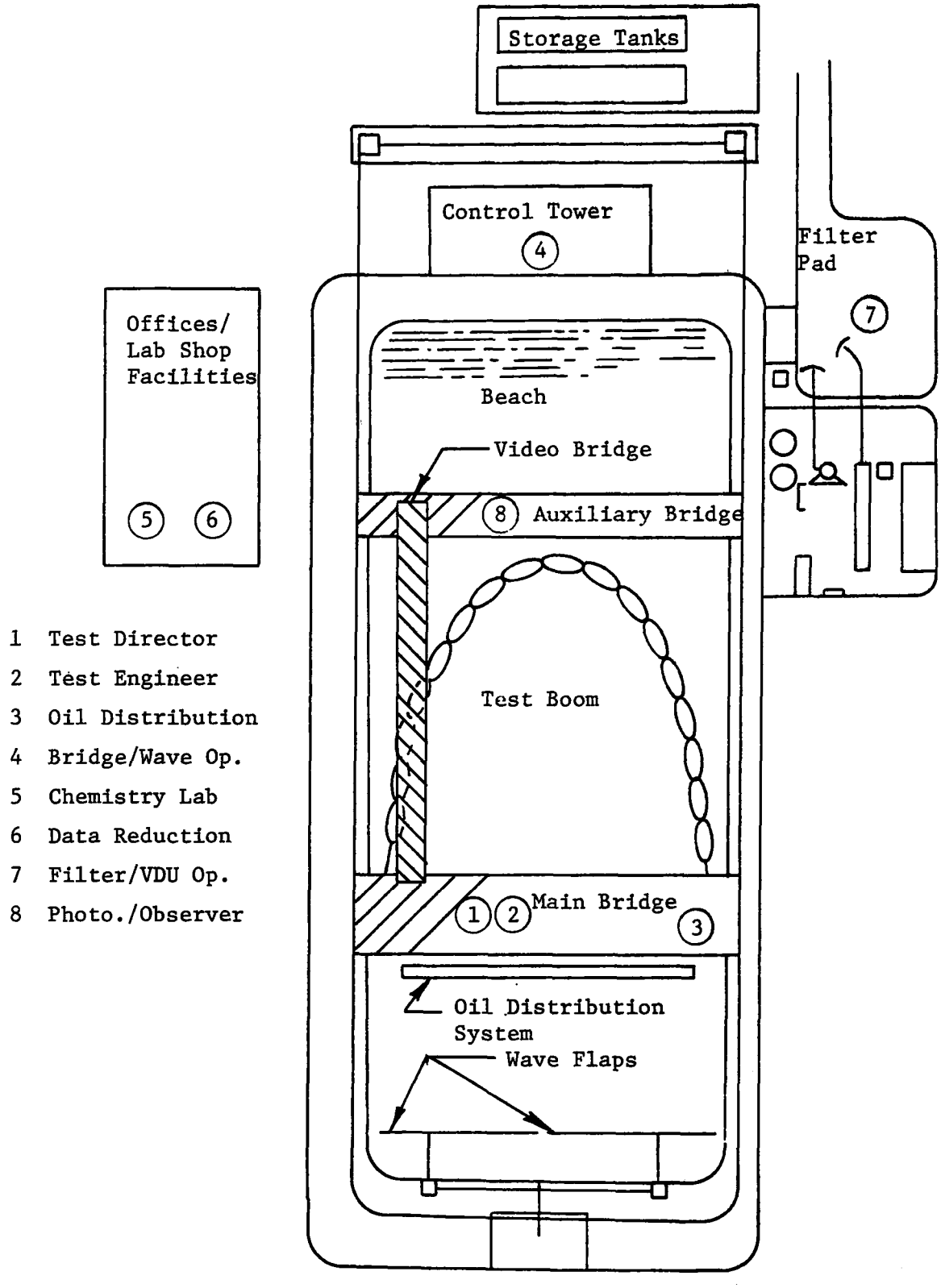

Figure 7. Layout of test tank and sorbent booms.

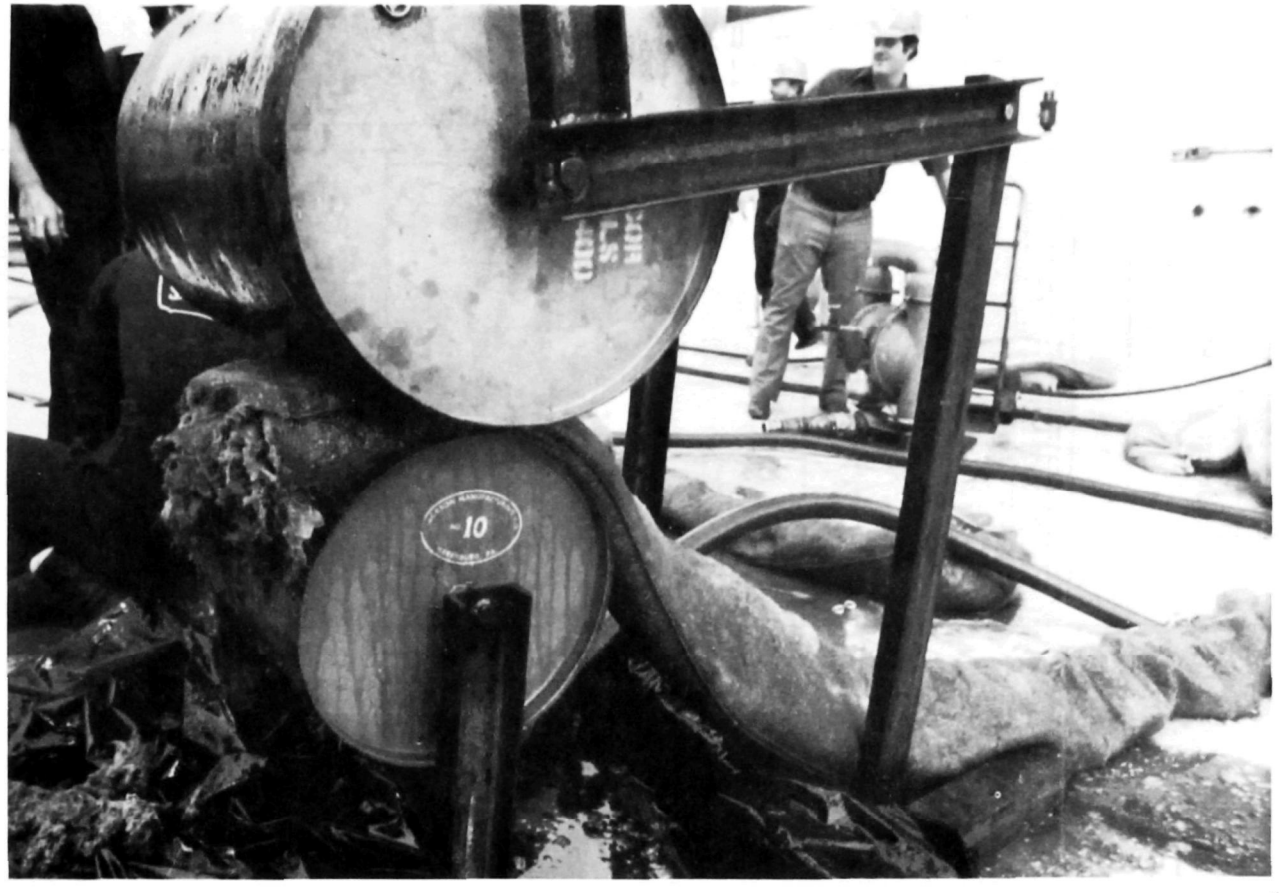

Figure 8. Failure of OHMSETT boom regenerator.

from 7.6-cm channel iron and two 34.3-cm diameter by 45.7-cm long lawn rollers. The top roller was filled with 0.25 m^3 of water and weighed approximately 250 kg. Upon completion of the towing tests, those sections of each sorbent boom judged to be the most highly saturated were gravity drained (mostly water drained out), weighed and then pulled through the squeeze rollers. The fluid recovered was analyzed to determine the percent of recoverable oil. The weight of the dry boom was subtracted from the weight of the saturated boom to determine the weight of fluid picked up. Some of this fluid could not be wrung out of the boom; a portion of this represents spilled oil that could be picked up from the water surface but that could not be recovered in a reusable state.

SECTION 5

RESULTS AND DISCUSSION

No-oil-loss tow speeds for all three booms varied little during this test program as shown by Tables 2 through 4.

The Coastal Services Inc. Absorbent Boom was stable at tow speeds up to 1.78 m/s in calm water and 0.51 m/s in a 0.3-m HC wave. For tests where oil volumes of 25 to 125 percent of manufacturer-recommended boom capacity were used, the calm water, no-oil-loss tow speeds ranged from 0.30 m/s at 25 percent capacity down to 0.15 m/s at 100 percent capacity. In the 0.3-m HC wave, no-oil-loss tow speeds near 0.12 m/s were observed for all oil volumes. Wet weight of the section judged most saturated (11.58 kg/m) less the boom's dry weight (0.83 kg/m) is the weight of fluid sorbed by the boom (10.75 kg/m). If the percent of oil in the regenerated (squeezed out) fluid (weight) is also representative of all the sorbed fluid, then the boom picked up a total of about 1.72 kg/m of oil.

The 3M Company Type 270 Sorbent Boom was stable at tow speeds up to 1.22 m/s in calm water and 0.76 m/s in the 0.3-m HC wave. Calm water tests with oil revealed the no-oil-loss tow speed maximum to be 0.25 m/s at all oil capacities. No-oil-loss maximum tow speed declined to 0.15 m/s in the 0.3-m HC wave at all oil capacities. Wet weight (>18.44 kg/m) less boom dry weight (1.49 kg/m) equals >16.95 kg/m of sorbed fluid. The sorbed fluid times the percent of oil in the regenerated fluid (30 percent) yields >5.08 kg/m oil picked up by the boom.

The Conwed Corp. Heavy Duty Sorbent Boom was stable at tow speeds up to 1.22 m/s in calm water and 0.71 m/s in the 0.3-m HC wave. The maximum no-oil-loss speed is about 0.22 m/s at all oil capacities in calm water. The 0.3-m HC wave and oil produced a maximum no-oil-loss tow speed ranging from 0.10 m/s with an oil volume at 75 percent of rated boom capacity to 0.25 m/s at 50 percent of rated boom capacity. Wet weight (14.86 kg/m) less boom dry weight (1.56 kg/m) equals 13.30 kg/m of sorbed fluid. The sorbed fluid times the percent of oil in the regenerated fluid (50 percent) yields about 6.65 kg/m oil picked up by the boom.

When any boom was saturated, boom failure occured near 0 m/s tow speed. Typically, failure took the form of droplet shedding from the oil slick in the 0.3-m HC wave (Figure 9) and oil passing under the boom in calm water (Figure 10). Visual observation revealed no apparent

TABLE 2. COASTAL SERVICES INC. ABSORBENT BOOM RESULTS

Test no.	Type of wave	Oil quantity m^3	Oil quantity % of capacity	Maximum no-oil-loss tow speed (m/s)	Type of failure	Comments
1A	Calm	0	—	(1.78)	Boom submersion	Stability (no oil)
2A	0.3-m HC	0	—	(0.51)	Splashover	Stability (no oil)
3A	Calm	0.15	25	0.30	Loss under boom	Loss at section ends occurs at 0.05 m/s
4A	0.3-m HC	0.15	25	0.10	Loss under boom	"
5A	Calm	0.30	50	0.20	Loss under boom	"
6A	0.3-m HC	0.30	50	0.10	Droplet shedding from slick	"
7A	Calm	0.45	75	0.15	Loss under boom	"
8A	0.3-m HC	0.45	75	0.10	Droplet shedding	"
9A	Calm	0.60	100	0.15	Loss under boom	"
10A	0.3-m HC	0.60	100	0.15	Droplet shedding	"
11A	Calm	0.75	125	0.20	Loss under boom	"
12A	0.3-m HC	0.75	125	0.15	Loss under boom	"

TABLE 3. 3M COMPANY TYPE 270 SORBENT BOOM RESULTS

Test no.	Type of wave	Oil quantity m^3	Oil quantity % of capacity	Maximum no-oil-loss tow speed (m/s)	Type of failure	Comments
1B	Calm	0	--	(1.22)	Boom submersion	Stability (no oil)
2B	0.3-m HC	0	--	(0.76)	Splashover	Stability (no oil)
3B	Calm	0.60	25	0.20	Loss under boom	
4B	0.3-m HC	0.65	25	0.15	Loss under boom	
5B	Calm	1.21	50	0.25	Loss under boom	
6B	0.3-m HC	1.21	50	0.20	Droplet shedding under boom	Creases developed in boom sections and oil loss occurred at creases
7B	Calm	1.82	75	0.25	Loss under boom	Loss at creases occurred at 0.15 m/s
8B	0.3-m HC	1.82	75	0.15	Droplet shedding	
9B	Calm	2.42	100	0.25	Droplet shedding	Loss at creases occurred at 0.51 m/s
10B	0.3-m HC	2.42	100	0	Splashover	Some boom sections saturated and almost submerged

TABLE 4. CONWED CORPORATION HEAVY DUTY SORBENT BOOM RESULTS

Test no.	Type of wave	Oil quantity m^3	Oil quantity % of capacity	Maximum no-oil-loss tow speed (m/s)	Type of failure	Comments
1C	Calm	0	--	(1.22)	Boom submersion	Stability (no oil)
2C	0.3-m HC	0	--	(0.71)	Splashover	Stability (no oil)
3C	Calm	0.53	25	0.20	Loss under boom	Loss at section ends occurred at 0.10 m/s
4C	0.3-m HC	0.53	25	0.25	Loss under boom	Loss at section ends occurred at 0.20 m/s
5C	Calm	1.06	50	0.25	Loss under boom	
6C	0.3-m HC	1.06	50	0.20	Loss under boom	Apex of boom was becoming saturated
8C	0.3-m HC	1.59	75	0.10	Splashover	Apex of boom became saturated and nearly submerged

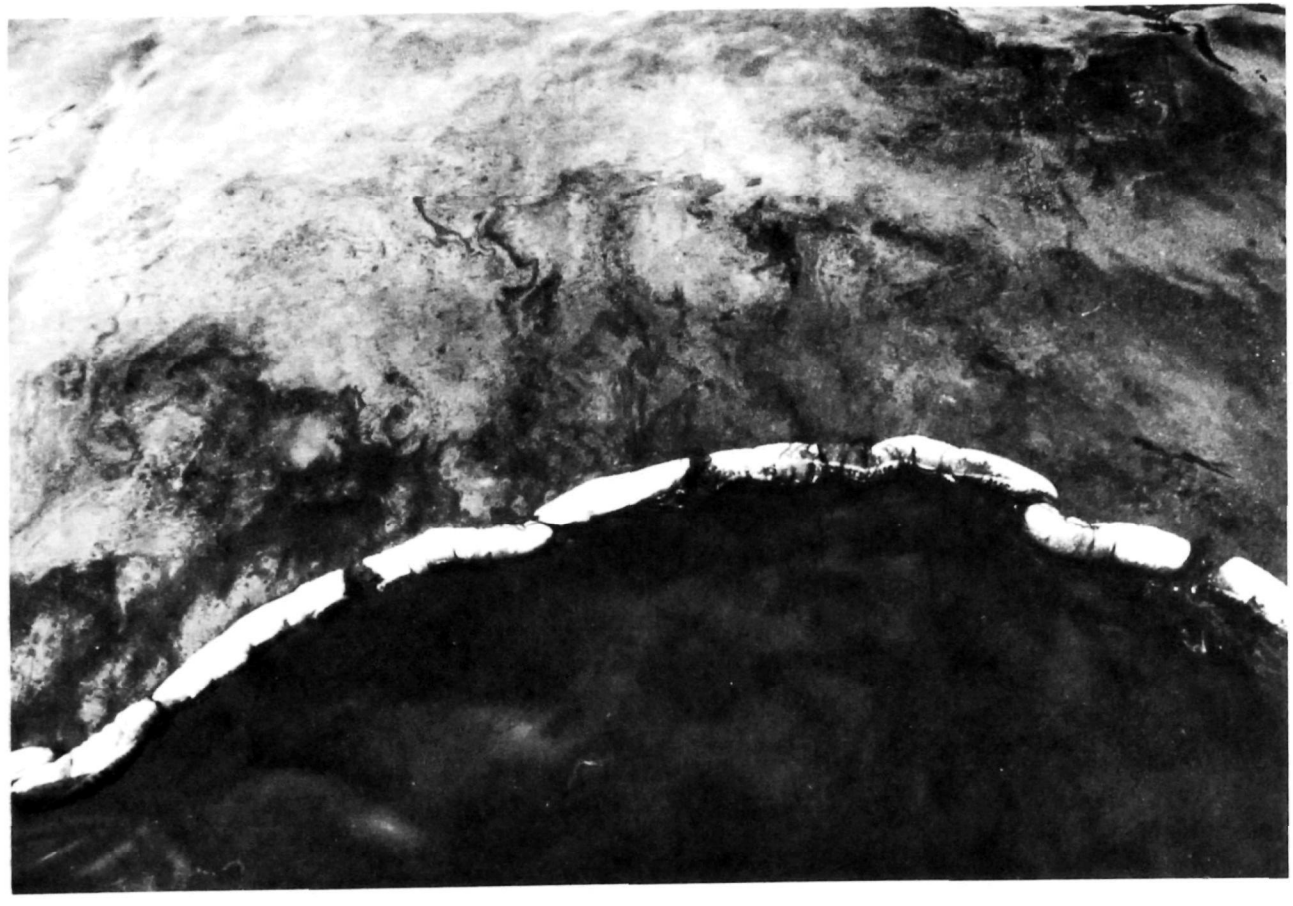

Figure 9. Oil lost from droplet shedding in the 0.3-m HC wave near 0.3 m/s tow speed.

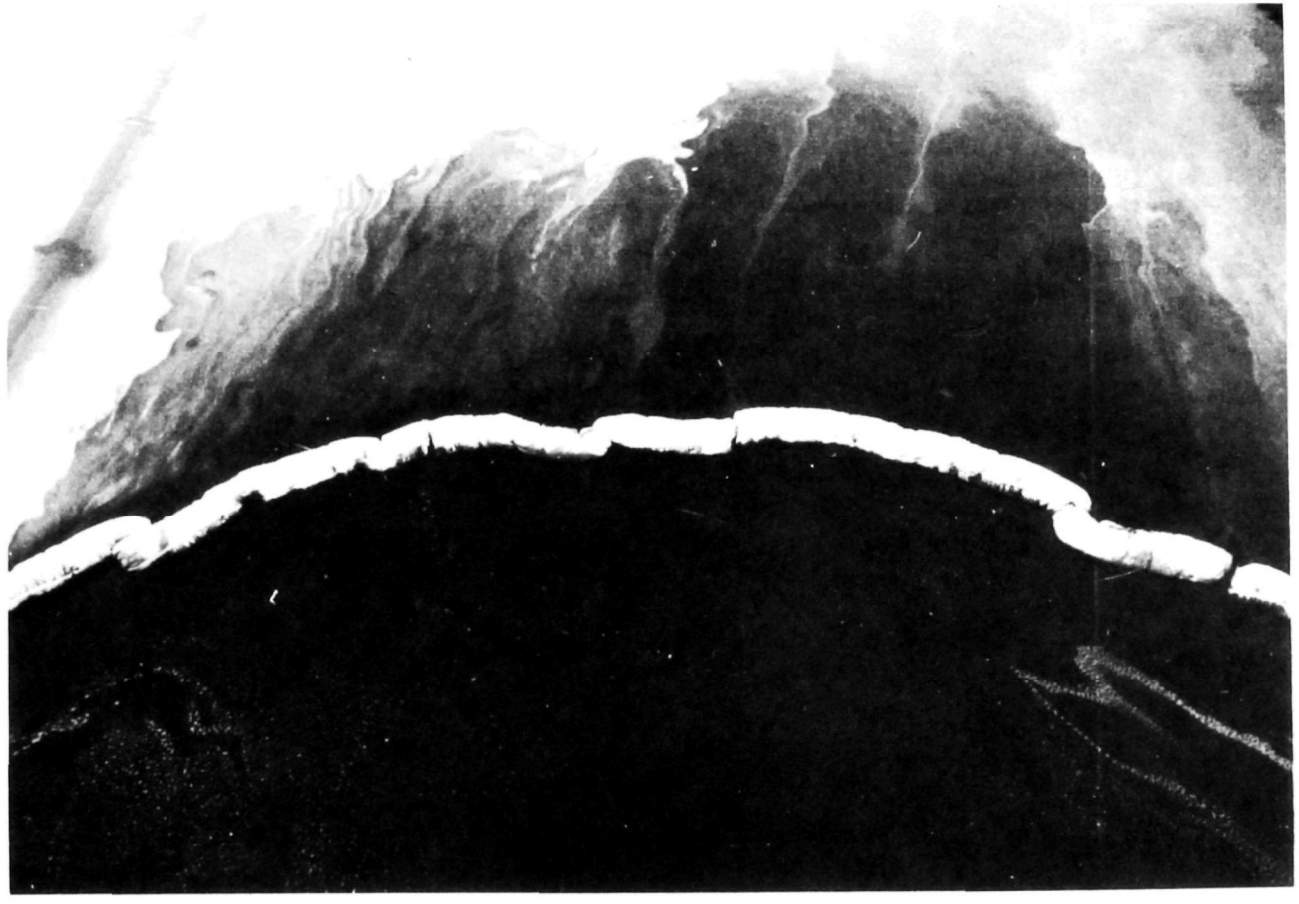

Figure 10. Oil lost under the boom in calm water near 0.35 m/s tow speed.

washing of oil from the sorbent when the boom was being towed; whatever was sorbed stayed sorbed.

Regeneration of used boom sections was only partially successful with the unit employed. As each section was pulled through the squeeze rollers, the sorbent would bunch up at one end, creating a large plug in the sausage-shaped boom cover. When this plug approached the squeeze roller, the boom cover tore (Figures 8 and 11). The sorbent spilled out, and the boom section became useless.

Boom handling proved to be very easy compared to most conventional containment booms. Sorbent boom sections tested were light and not restrictively bulky. End connections on the 3M and Conwed booms proved convenient and strong enough to withstand towing at 1.78 m/s. The Coastal Services boom end connections were tied together with rope and did not provide for overlap as the 3M and Conwed booms did. During testing, one set of Coastal Services boom end connections failed when the grommet eyes tore out of the cloth cover (Figure 12).

Figure 11. Bag breakage of boom pulled through squeeze roller regenerator.

Figure 12. Grommet failure at Coastal Services Inc. absorbent boom attachment point.

APPENDIX A

OHMSETT TEST FACILITY

Figure A-1. OHMSETT Test Facility.

GENERAL

The U.S. Environmental Protection Agency is operating an Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) located in Leonardo, New Jersey (Figure A-1). This facility provides an environmentally safe place to conduct testing and development of devices and techniques for the control of oil and hazardous material spills.

The primary feature of the facility is a pile-supported, concrete tank with a water surface 203 metres long by 20 metres wide and with a water depth of 2.4 metres. The tank can be filled with fresh or salt water. The tank is spanned by a bridge capable of exerting a force up to 151 kilonewtons, towing floating equipment at speeds to 3 metres/second

for at least 45 seconds. Slower speeds yield longer test runs. The towing bridge is equipped to lay oil or hazardous materials on the surface of the water several metres ahead of the device being tested, so that reproducible thicknesses and widths of the test fluids can be achieved with minimum interference by wind.

The principal systems of the tank include a wave generator and beach, and a filter system. The wave generator and absorber beach have capabilities of producing regular waves to 0.7 metre high and to 28.0 metres long, as well as a series to 1.2 metres high reflecting, complex waves meant to simulate the water surface of a harbor or the sea. The tank water is clarified by recirculation through a 0.13 cubic metre/second diatomaceous earth filter system to permit full use of a sophisticated underwater photography and video imagery system, and to remove the hydrocarbons that enter the tank water as a result of testing. The towing bridge has a built-in skimming barrier which can move oil onto the North end of the tank for cleanup and recycling.

When the tank must be emptied for maintenance purposes, the entire water volume, of 9842 cubic metres is filtered and treated until it meets all applicable State and Federal water quality standards before being discharged. Additional specialized treatment may be used whenever hazardous materials are used for tests. One such device is a trailer-mounted carbon treatment unit for removing organic materials from the water.

Testing at the facility is served from a 650 square metres building adjacent to the tank. This building houses offices, a quality control laboratory (which is very important since test fluids and tank water are both recycled), a small machine shop, and an equipment preparation area.

This government-owned, contractor-operated facility is available for testing purposes on a cost-reimbursable basis. The operating contractor, Mason & Hanger-Silas Mason Co., Inc., provides a permanent staff of fourteen multi-disciplinary personnel. The U.S. Environmental Protection Agency provides expertise in the area of spill control technology, and overall project direction.

For additional information, contact: John S. Farlow, OHMSETT Project Officer, U.S. Environmental Protection Agency, Research and Development, IERL-Ci, Edison, New Jersey 08817, 201-321-6631.

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16. ABSTRACT

Performance tests on three commercially available sorbent booms were conducted at the U. S. Environmental Protection Agency's Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) test facility. Test variables included wave condition, tow speed, and quantity of oil encountered. The maximum no-oil-loss containment two speed was determined for each wave and oil quantity test condition.

The no-oil-loss tow speed in calm water was consistently near 0.25 m/s, but in a 0.3-m harbor chop wave, this figure decreased to between 0.05 and 0.1 m/s. In the 0.3-m harbor chop wave, the failure mode was typically droplet shedding from the contained oil slick, whereas in calm water, the oil slick passed under the booms. No sorbed oil appeared to wash out of the booms when they were towed.

When saturated boom sections were wrung out, the recovered fluid weighed from 9.5 to 14 times boom dry weight and was 16 to 50 percent oil.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Performance tests Booms (equipment) Sorbents Water Pollution Oils	Spilled oil cleanup Sorbent oil booms Sorbent regeneration	68D

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