Environment Canada
Environmental Protection Service

Environnement Canada
Service de la protection de l'environnement

GemEng Lightweight Fireproof Boom: Oil Containment Testing at OHMSETT

Canada

Technology Development
Report EPS 4-EP-83-5

Environmental Protection Programs Directorate
November 1983

ENVIRONMENTAL PROTECTION SERVICE REPORT SERIES

Technology Development Reports describe technical apparatus and procedures, and results of laboratory, pilot plant, demonstration or equipment evaluation studies. They provide a central source of information on the development and demonstration activities of the Environmental Protection Service.

Other categories in the EPS series include such groups as Regulations, Codes, and Protocols; Policy and Planning; Economic and Technical Review; Surveillance; Training Manuals; Briefs and Submission to Public Inquiries; and, Environmental Impact and Assessment.

Inquiries pertaining to Environmental Protection Service Reports should be directed to the Environmental Protection Service, Department of the Environment, Ottawa, Ontario, Canada, K1A 1C8.

GEMENG LIGHTWEIGHT FIREPROOF BOOM: OIL CONTAINMENT TESTING AT OHMSETT

by

Michael Borst
Mason & Hanger-Silas Mason Co., Inc.
Leonardo, New Jersey 07737

for the

Technical Services Branch
Environmental Protection Programs Directorate
Environmental Protection Service
Environment Canada

EPS 4-EP-83-5
November 1983

REVIEW NOTICE

This report has been reviewed by the Technical Services Branch, Environmental Protection Service, and approved for publication. Approval does not necessarily infer that the contents reflect the views and policies of the Environmental Protection Service. Mention of trade names or commercial products does not constitute endorsement for use.

Cat. No. En48-4/83-5
ISBN 0-662-52770-4
BEAUREGARD PRESS LIMITED

ABSTRACT

An oil containment boom developed by GemEng Ltd., of Toronto, Ontario, was tested at the Oil and Hazardous Materials Simulated Environmental Test Tank to assess its containment capabilities under fire, current, and wave conditions.

The oil loss rates at the tow speeds tested were lower than predicted. Although splashover did occur in 0.2 m x 1.4 m regular waves, the first-loss tow speed in calm water was 1.1 kn. That speed is approximately 10% higher than the normal as established by previous boom tests. The tests showed that the GemEng boom can be expected to have good durability under rough environmental conditions.

TABLE OF CONTENTS

		Page
ABSTRACT		i
LIST OF TABLES		iv
LIST OF FIGURES		v
1	INTRODUCTION	1
2	BOOM DESCRIPTION	2
3	TEST DESCRIPTION	5
3.1	Containment Testing	6
3.2	Fire Testing	6
3.3	Survival Testing	6
4	TEST RESULTS	7
4.1	Containment Testing	7
4.2	Fire Testing	11
4.3	Survival Testing	12
5	CONCLUSIONS	14
6	RECOMMENDATIONS	15
APPENDIX	UNITED STATES ENVIRONMENTAL PROTECTION AGENCY'S OIL AND HAZARDOUS MATERIALS SIMULATED ENVIRONMENTAL TEST TANK (OHMSETT)	17

LIST OF TABLES

Table		Page
1	PREDICTED CALM WATER LOSS RATES	7
2	MEASURED LOSS RATES FOR THE GEMENG BOOM	11
3	SUMMARY OF FIRE TESTS	12

LIST OF FIGURES

Figure		Page
1	DRAWING OF THE BOOM SECTION	3
2	DRAWING OF THE CABOOSE	4
3	TEST SET-UP	5
4	COMPARISON OF THE PRE-TEST PREDICTED LOSS RATES WITH THE MEASURED LOSS RATES AT TOW SPEEDS THROUGH 1.5 kn IN CALM WATER	7
5	ENTRAINMENT LOSS AT LOW SPEED TESTS	8
6	DRAINAGE LOSSES AT HIGHER SPEED TESTS	8
7	COMPARISON OF THE LOSS RATE FOR THE GEMENG BOOM IN WAVES AND IN CALM WATER	9
8	PULSED LOSSES IN WAVES	10
9	BOOM SPLASHOVER IN SHORT WAVE TESTS	10
10	BOOM UNDER FIRE DURING TEST 21R	13

1 INTRODUCTION

An oil boom intended as an inexpensive alternative for the containment of burning oil has been developed by a Canadian company. Several designs were investigated; the final design was tested by exposure to burning diesel fuel. With the capability to withstand heat exposure proven, the boom was shipped to the Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) in Leonardo, New Jersey. The U.S. Environmental Protection Agency's test facility was chosen to document the oil containment capabilities of the boom in an environmentally safe manner. A complete description of the OHMSETT facility can be found in the Appendix. As part of the OHMSETT tests, the boom was tow-tested with burning Murban crude oil. The boom was tested at high speed to determine whether it would submarine or plane; its ability to sustain exposure to a 0.63-m harbour chop for an extended period was also assessed. The combination of the fire, high speed, and wave exposure tests push the limit of non-destructive testing.

This report summarizes the results of the OHMSETT trials. The work was done under contract through the Canadian Department of Supply and Services for the Environmental Protection Service. It was undertaken by Mason & Hanger-Silas Mason Co., Inc. through Article XIX of Contract No. 68-03-3056 with the U.S. Environmental Protection Agency.

The Project Officer for the trials was R.A. Griffiths of the Oil and Hazardous Materials Spills Branch of the Municipal Environmental Research Laboratory, Edison, New Jersey.

The Scientific Authority was K.M. Meikle, Environmental Protection Service, Environment Canada.

2 BOOM DESCRIPTION

A lightweight fireproof oil containment boom (Figure 1) has been developed by GemEng Ltd. of Toronto, Ontario. The boom is constructed in discrete 1.2-m lengths, hexagonal in cross-section. The maximum diameter of the hexagon is 484 mm, and the minimum diameter is 420 mm. When floating, the boom has a freeboard of 280 mm and a draft of 440 mm. The center of the boom sections is hollow, giving the boom an annular cross-section. A 10-mm diameter steel cable runs through six sections to form a train that serves as the boom flotation and freeboard. A 300-mm skirt is fastened to the bottom hexagon face. A single skirt is connected along a six-section length of boom supported from aluminum angle. The bottom of the skirt is doubled over to wrap around a smaller diameter tension cable.

The end section of each train, the caboose, is built differently from the remaining sections and holds the mechanism for joining trains. It is constructed to the same dimensions as the other members of the train, but the top is hollowed out to give access to the turnbuckle and plate connectors (see Figure 2).

The boom is constructed of a Foamglas core surrounded by a 4-mm fibre-reinforced refractory cement skin. A 75-mm diameter galvanized steel tube is at the core of each boom section. The mating ends of boom sections are shaped to form a ball-and-socket joint. A silicon bead has been placed in the socket half of each joint. This shape allows for a random connection of the sections so long as the caboose is at the end of the train. The trains are joined together within the caboose to form the boom.

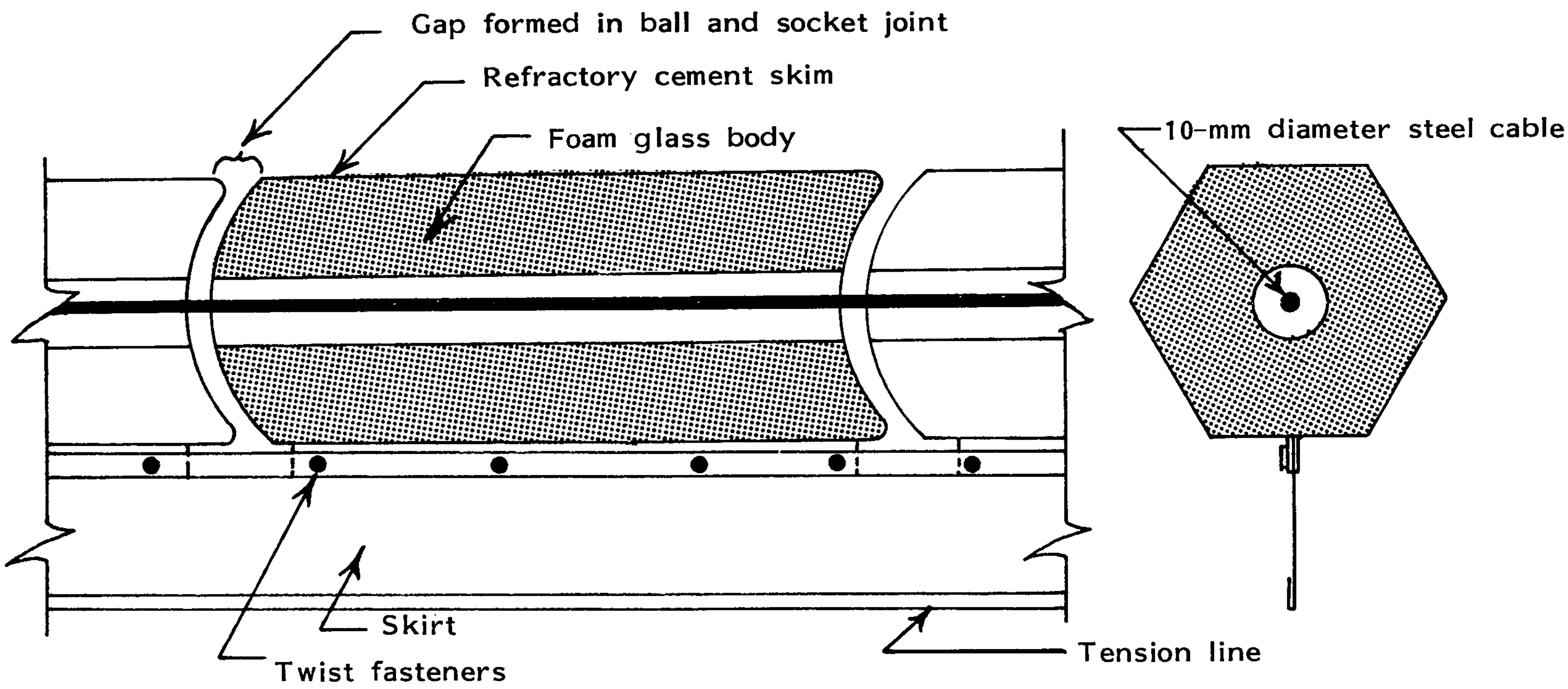


FIGURE 1 DRAWING OF THE BOOM SECTION

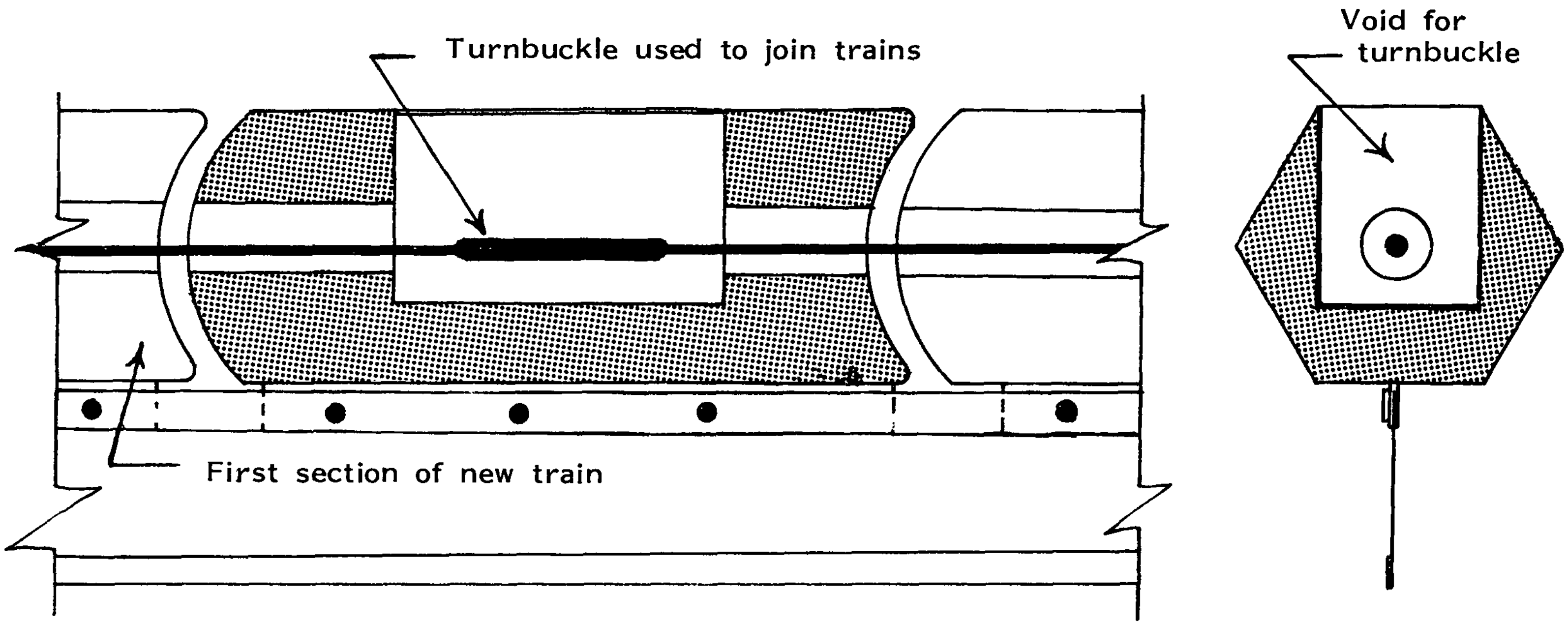


FIGURE 2 DRAWING OF THE CABOOSE

3 TEST DESCRIPTION

Three boom sections were joined together and a 4.6-m leader was connected to each end. The tow cables were connected to tow points 10.4 m apart on the main bridge. The main cable was connected at the waterline, and the skirt was connected 400 mm below the waterline. A tow-back cable was connected to the boom between the eighth and ninth boom sections, slightly west of the apex and midway along the train length (Figure 3).

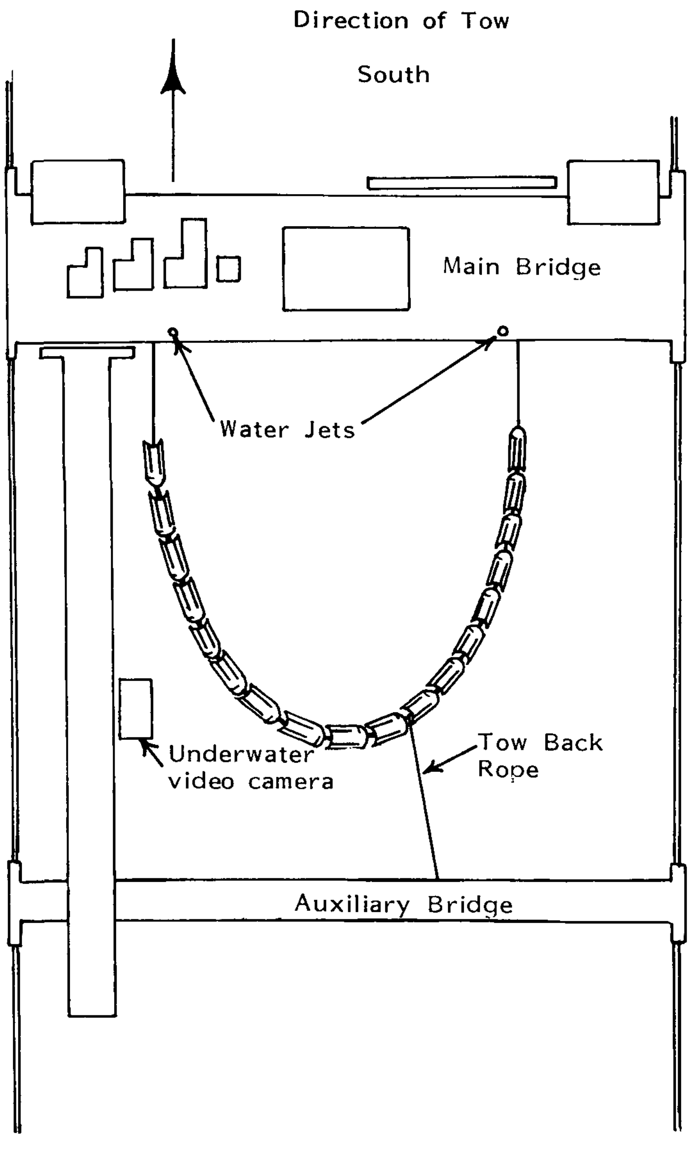


FIGURE 3 TEST SET-UP

3.1 Containment Testing

The boom was preloaded with 0.19 m^3 of Circo-X heavy oil and was brought to the designated test speed. Oil distribution began with first movement of the bridge. The time required to traverse a pre-marked distance of 30.5 m was measured after the bridge came to speed. When the boom had traversed 80% of the available tank length, the tow speed was reduced to 0.5 kn. The at-speed test time was measured as the elapsed time from reaching the desired test speed to the time of speed reduction to 0.5 kn.

After the tow speed was reduced to 0.5 kn, the trailing oil was forced past the auxiliary bridge boom, and the oil control system was implemented. The bridges were stopped and the auxiliary bridge boom lowered. The bridges were then returned to their starting positions at the north end of the test tank. The oil behind the auxiliary bridge boom was sandwiched between the auxiliary bridge boom and a 19.8-m length of MP boom that crossed the tank. This oil was then fire-hosed to the east side of the tank where it was collected using a Kaiser SWISS OELA III skimmer. The skimmer fluid was pumped to polypropylene barrels for measurement and sampling.

3.2 Fire Testing

The boom was preloaded with 76 L of Murban crude oil; four buckets of the oil were also placed on the main bridge. The boom was brought to 0.25 kn to begin the test. A 150-mm length of 150-mm diameter ethafoam flotation was wrapped with 3M sorbent 100 and secured with machinist wire to form a wick. The wick, soaked in oil and sprayed with an ether-based automotive starting fluid, was lit and placed on the water surface with a boat hook. The preload was then towed into the wick to ignite the oil. After the oil within the boom was burning, the test began. As the oil in the boom was depleted by the combustion, oil was added from the buckets on the main bridge to maintain the oil supply.

3.3 Survival Testing

The boom was towed by the main bridge at speeds up to 3.5 kn to determine the strength of the materials and any tendency to plane or submarine at higher tow speeds. The boom length was also exposed to a 0.63-m harbour chop for 45 minutes to determine whether the boom would survive heavy seas. It was recognized that this would not substitute for sea trials, but was intended to give an indication of capabilities.

4 TEST RESULTS

4.1 Containment Testing

The GemEng boom losses were predicted based on two other booms that have been tested with the same basic method and were made without regard for any loss other than under the skirt. These a priori estimates are listed in Table 1. It was felt that, if the GemEng boom loss rate compared closely with these loss rates, the boom had adequate oil containment capabilities. The calm water test results showed a first loss tow speed higher than predicted. At speeds above first loss, the loss rate was slightly below the predicted values (Figure 4). Tests run at the lower speeds showed entrainment as the loss mechanism (Figure 5). Higher speed tests showed both drainage (Figure 6) and entrainment losses.

TABLE 1 PREDICTED CALM WATER LOSS RATES

Tow Speed (kn)	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5
Loss Rate (m^3/h)	0.1	0.3	0.7	1.6	3.3	7.0	14.7	30.6	64.5	135.2

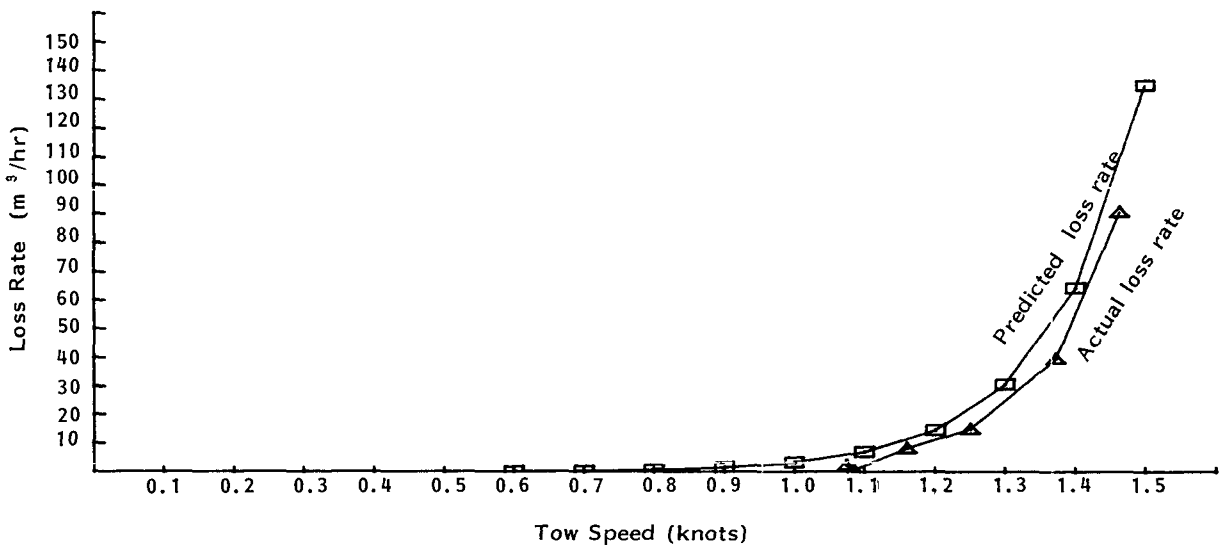


FIGURE 4 COMPARISON OF THE PRE-TEST PREDICTED LOSS RATES WITH THE MEASURED LOSS RATES AT TOW SPEEDS THROUGH 1.5 kn IN CALM WATER

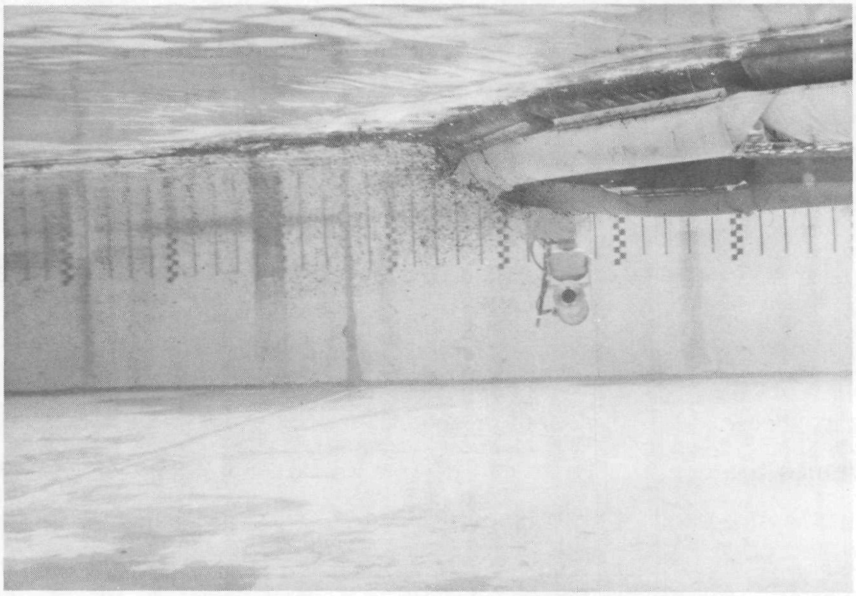


FIGURE 5 ENTRAINMENT LOSS AT LOW SPEED TESTS
This underwater photograph was taken during test 3 run at 1.075 kn. The loss rate was determined to be 2.3 m^3/h.

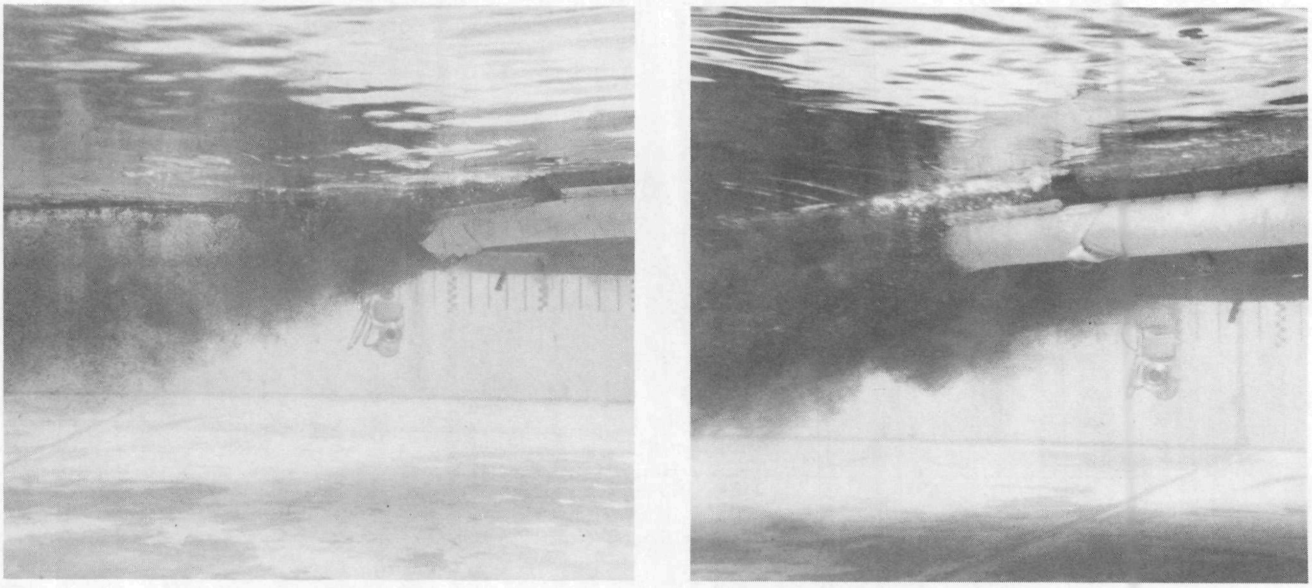


FIGURE 6 DRAINAGE LOSSES AT HIGHER SPEED TESTS
When towed at the limits of this testing, both entrainment and drainage became apparent.

The losses in wave conditions were greater than in calm water (Figure 7). In these tests, the losses tended to come in pulses, produced as the boom began to climb an oncoming wave. An example of this pulsed loss is shown in Figure 8. In the shortest wave tested, the boom suffered splashover as well as under-boom losses. This was the only wave that caused splashover (see Figure 9). The loss rates for the wave and calm water tests are listed in Table 2.

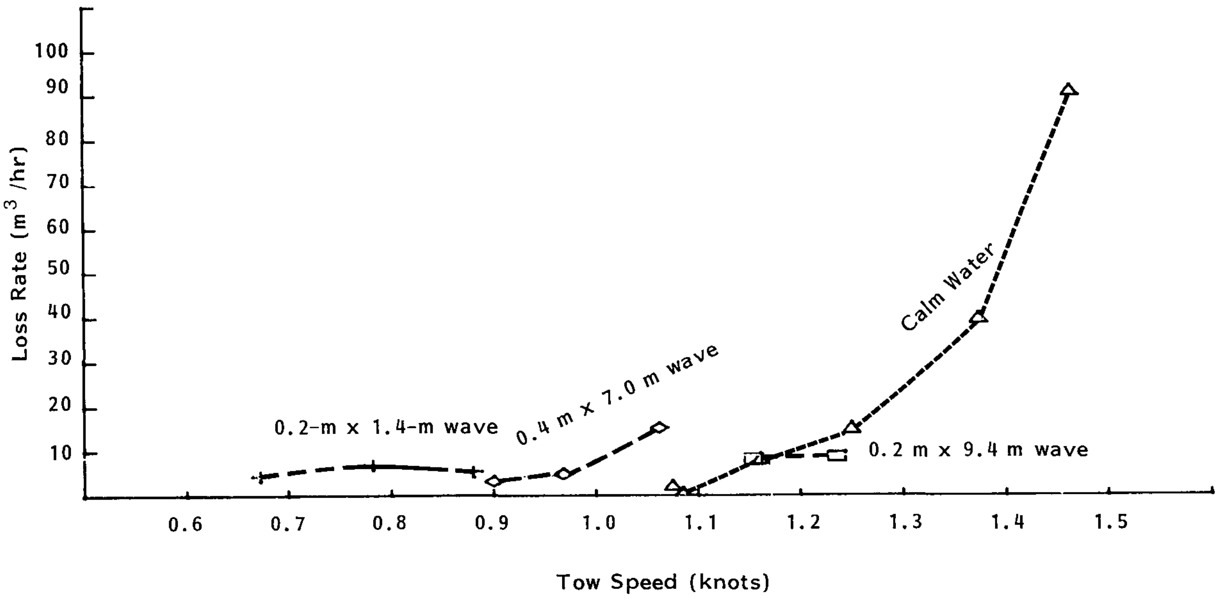


FIGURE 7 COMPARISON OF THE LOSS RATE FOR THE GEMENG BOOM IN WAVES AND IN CALM WATER. Note that the second point in the regular wave (0.2 x 9.4 m) is below the calm water loss rate.

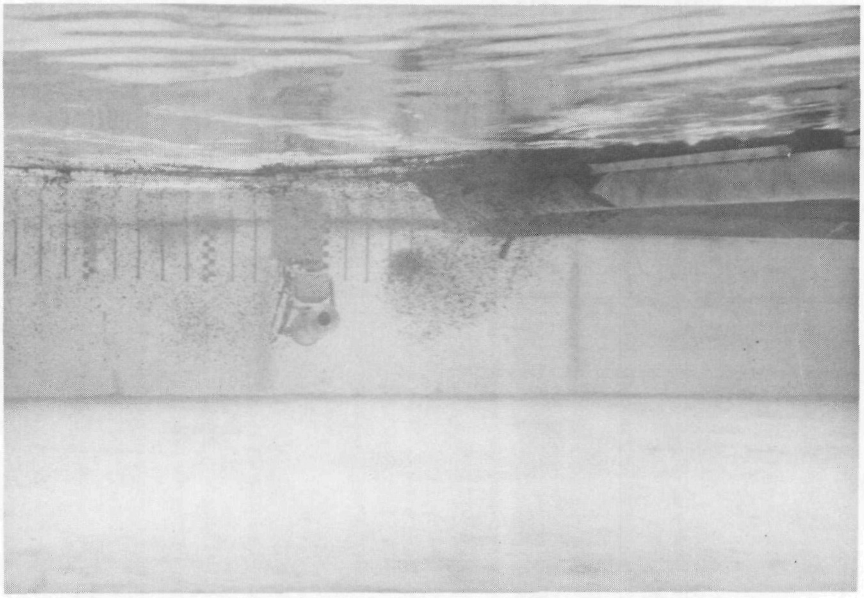


FIGURE 8 PULSED LOSSES IN WAVES
This underwater photograph was taken during test 13. The boom is being towed into a regular wave (0.4 m x 7.0 m), which is not readily apparent in the photograph. The loss rate was measured at 3.1 m^3/h. Notice the oil pulse immediately behind the boom apex.

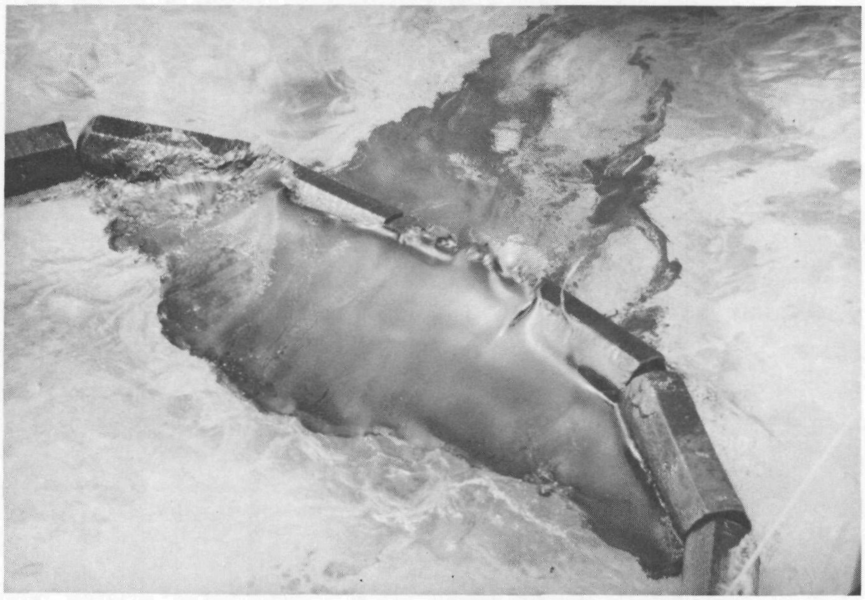


FIGURE 9 BOOM SPLASHOVER IN SHORT WAVE TESTS
This photograph, taken during test 18, shows the GemEng boom being towed at 0.782 kn into a regular wave (0.2 m x 1.4 m). Notice the splashover. This was the only wave which caused splashover.

TABLE 2 MEASURED LOSS RATES FOR THE GEMENG BOOM

Test No.	Tow Speed (kn)	Loss Rate (m^3/h)
	Calm Water, First Loss: 1.1 kn	
3	1.075	2.3
3R	1.085	0.7
4	1.161	8.2
5	1.250	15.0
6	1.373	39.8
7	1.463	90.8
	0.2 m x 9.4 m Regular Wave, First Loss: 1.1 kn	
9	1.154	8.0
10	1.235	8.6
	0.4 m x 7.0 m Regular Wave, First Loss: 0.9 kn	
13	0.900	3.1
14	0.968	4.8
15	1.062	15.1
	0.2 m x 1.4 m Regular Wave, First Loss: 0.7 kn	
17	0.672	4.4
18	0.782	6.8
19	0.880	5.3

4.2 Fire Testing

A total of three fire tests were run (see Table 3). The boom successfully withstood the exposure to fire. The surface of the boom spalled and cracked but was serviceable after the exposure. The boom contained the burning oil completely on the lower speed runs.

During the high speed fire test, the Murban crude oil was entrained and lost by the boom. The entrainment on the high speed tests looked about the same as the tests with the Circo oil. Burning oil was also lost through the ball and socket joints. This oil continued to burn close to the rear boom face (within about 1 metre). When resurfacing entrained oil encountered this oil, it too was ignited. Figure 10 shows the boom during the second fire test.

TABLE 3 SUMMARY OF FIRE TESTS

Test No.	Tow Speed (kn)	Burn Duration (min:s)	Wind Direction	Wind Speed (kn)	Air Temp (°C)	Water Temp (°C)
21	0.50	4:21	N	2-3	15	23
21R	0.25	7:25	SE	1-2	14	23
22	1.25	1:44	W	1-2	15	23

The fire in these burns was more intense than previously experienced during testing at OHMSETT; a large fire vortex formed in the 0.5-kn and 0.25-kn tests. It is speculated that the fire was more intense than in the previous tests because of the higher ambient temperatures. This would make more of the lighter ends within the Murban crude oil vaporize and stimulate combustion.

4.3 Survival Testing

When the boom was towed through 3.5 kn, the water rose against the face of the boom. At 3.5 kn, the water began to trickle over the top of the boom until suddenly the boom "popped up" and rode at the same level as in the slower speed tests.

During the 45-minute exposure to the 0.63-m harbour chop, the boom rode the wave well in both tow directions. The individual boom components slid along the 10-mm cable, colliding with each other. Some deterioration occurred at the ball-and-socket connections. The damage to the sections where the boom was connected to the tow back cable was more pronounced than at the other points.

During the testing, the skirt tore and several support angle lengths became separated from the flotation. The caboose sections tended to rotate about the 10-mm control cable despite the weights added to prevent this. A few sockets lost the silicone bead applied to them.

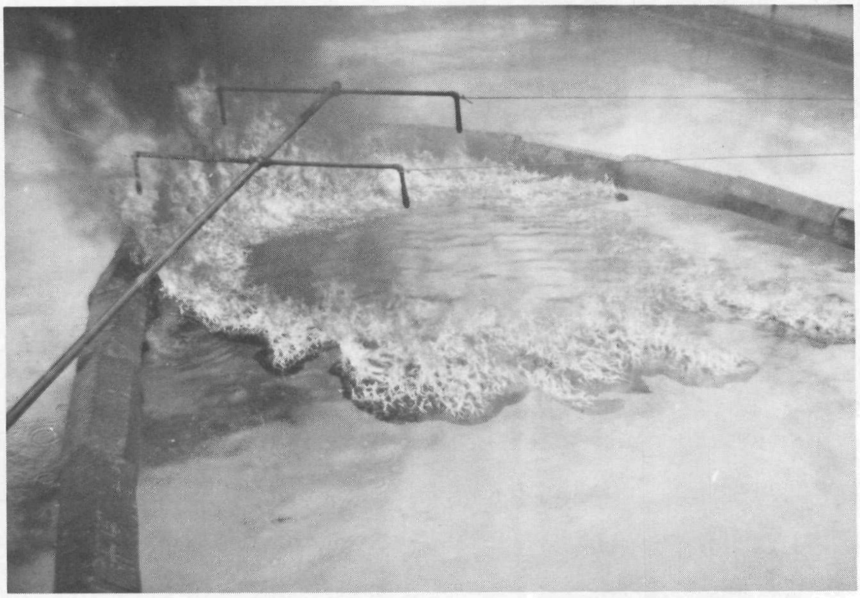


FIGURE 10 GEMENG BOOM UNDER FIRE DURING TEST 21R
The boom is being towed at 0.25 kn in calm water. The circular flames in the foreground resulted from the ignition of a bucketful of Murban crude oil added during the test. This was the longest test run with burning oil, lasting 7 min 25 s.

5 CONCLUSIONS

The GemEng boom contains oil within the same general capabilities as the non-fireproof booms tested for loss rate. The loss rate for the boom is within the estimated limits of the projected loss rate. The limited number of booms having undergone similar testing does not provide the statistical confidence to state that the slightly lower loss rates are significant, but the loss rate was lower than predicted throughout the tow speed range tested. The increase in first-loss tow speed to 1.1 kn from the traditional 0.75-kn range is, however, significant.

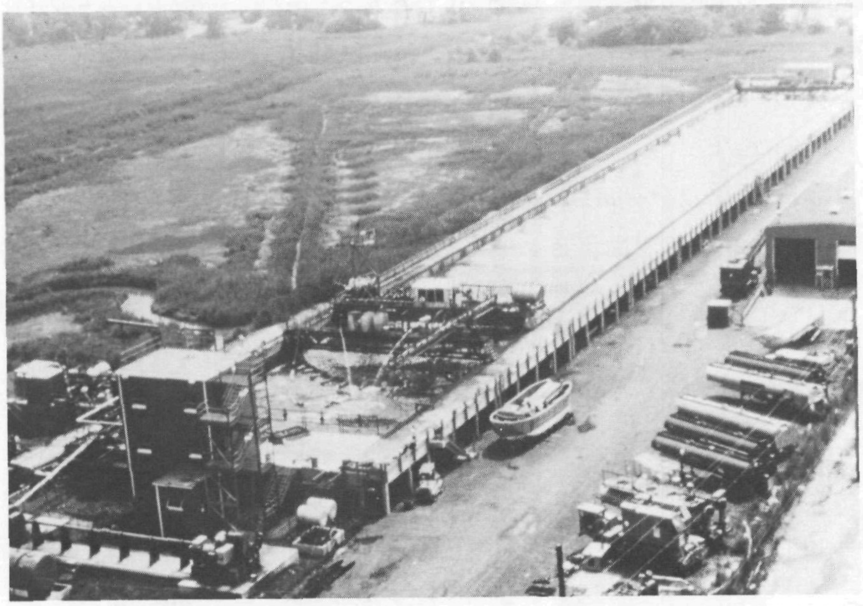
The intentionally abusive testing demonstrates that the boom can be expected to withstand some rough environmental conditions without complete deterioration. The damage incurred suggests, however, that immediate reuse of the boom after exposure should not be anticipated. Salvage of components of the boom can be expected. After the tests, the boom was returned to the manufacturer who reported that the damaged sections were readily repaired.

Despite the sudden pop-up that the boom demonstrated when towed at 3.5 kn, it is expected that the boom will submarine when used in high relative current applications. The cause of the resurfacing is not known, but is believed to be either a plastic deformation of the lower tension member or tearing of the skirt. Either will cause the total drag and thus the downward component force to decrease.

6 RECOMMENDATIONS

- The 75-mm diameter galvanized steel serving as a buffer in the center hole should be of slightly heavier gauge, as these were overly deformed and torn on several of the sections.
- The seal on the skin at both ends should be strengthened.
- The stainless steel twist fasteners should be replaced, as the lubricating nature of oil defeats the friction holding power of the fastener.
- The aluminum angle (40 mm x 40 mm x 3 mm) attached to the flotation with molly bolts should have a length of metal plate placed parallel within the boom to distribute rather than concentrate the forces at these three points.
- The connector boom sections (cabooses) are much more fragile than the standard boom sections. The integrity of these pieces must be improved. The center of mass of these sections must be moved below the center of buoyancy so that they float right-side-up without the need to add exterior weights as was done for this testing.
- The silicone bead used to seal the ball-and-socket joint needs to be enlarged and more securely fastened to the socket.
- A higher-tensile-strength skirt material should be used to replace the current material. The skirt tension member should be larger in diameter.

APPENDIX UNITED STATES ENVIRONMENTAL PROTECTION AGENCY'S OIL AND HAZARDOUS MATERIALS SIMULATED ENVIRONMENTAL TEST TANK (OHMSETT)



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

The primary feature of the facility is a pile-supported, concrete tank with a water surface 203-m long by 20-m wide and with a water depth of 2.4 m. The tank can be filled with fresh or salt water. The tank is spanned by a bridge capable of exerting a horizontal force up to 151 kilonewtons while towing floating equipment at speeds to 3.3 m/s (6.5 kn) for at least 40 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 slicks can be achieved with minimum interference by wind.

The principal systems of the tank include a wave generator, a beach, and a filter system. The wave generator and absorber beach can produce regular waves to 0.6 m high and 45 m long, as well as a series of 0.7 m high reflecting, complex waves meant to simulate the water surface of the harbour. The tank water is clarified by recirculation through a 268 m^3/h 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 oil barrier which is used to skim oil to the north end of the tank for cleanup and recycling.

When the tank must be emptied for maintenance purposes, the entire water volume of 9800 m^3 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.

Testing at the facility is served from a 650-m^2 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 21 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: Richard A. Griffiths, OHMSETT Project Officer, U.S. Environmental Protection Agency, Research and Development, MERL, Edison, New Jersey 08837. Telephone: 201-321-6629.