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REPORT

Oil in Ice - JIP

Report no.: 27

Tests of Fire-Resistant Booms in Low Concentrations of Drift Ice - Field experiments May 2009.

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Preface

SINTEF has in cooperation with SL Ross Environmental Research Ltd and DF Dickins Associates LLC on behalf of the oil companies AGIP KCO, Chevron, ConocoPhillips, Shell, Statoil and Total initiated an extensive R&D program; *Joint industry program on oil spill contingency for Arctic and ice covered waters.* This program was a 3-year program initiated in September 2006 and finalized in December 2009.

The objectives of the program were;

- To improve our ability to protect the Arctic environment against oil spills.
- To provide improved basis for oil spill related decision-making:
- To advance the state-of-the-art in Arctic oil spill response.

The program consisted of the following projects:

- P 1: Fate and Behaviour of Oil Spills in Ice
- P 2: In Situ Burning of Oil Spills in Ice
- P 3: Mechanical Recovery of Oil Spills in Ice
- P 4: Use of Dispersants on Oil Spills in Ice
- P 5: Remote Sensing of Oil Spills in Ice
- P 6: Oil Spill Response Guide
- P 7: Program Administration
- P 8: Field Experiments, Large-Scale Field Experiments in the Barents Sea
- P 9: Oil Distribution and Bioavailability

The program has received additional financial support from the Norwegian Research Council related to technology development (ending December 2010) and financial in kind support from a number of cooperating partners that are presented below. This report presents results from one of the activities under this program.

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Funding Partners

Eni Agip KCO, ConocoPhillips, Chevron, Shell, Total, Statoil

R&D Partners

SL Ross, Dickins

Cooperating Partners

The Research Council of Norway, NOFO, alaska clean seas, UNIS, Kystverket, MMS, Oil Spill Recovery Institute Cordova, Alaska, Coastal Response Research Center at the University of New Hampshire

Test Report

JOINT INDUSTRY PROGRAM ON OIL IN ICE

Project 2: *In situ* Burning in Arctic and Ice-Covered Waters

Task 2.3 – Tests Of Fire-Resistant Boom In Low Concentrations Of Drift Ice: Field Experiments May 2009

Sponsors: Total, Statoil, ConocoPhillips, Shell, Chevron, AGIP KCO

Contractors: SINTEF Applied Chemistry
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Location: Svalbard.

Test Period: May 2009

March 20, 2010

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1. Introduction

A two-day test program was conducted in the Barents Sea in May 2009 to perform experiments related to *in situ* burning of oil in open drift ice. The tests were part of a broader program performed over a two-week period that included tests with skimmers, dispersants, and remote sensing systems, and studies of oil-in-ice behaviour. Preliminary tests were performed with the boom in 2008: these tests did not involve oil, but proved the feasibility of several operational aspects of fire-boom use in ice. In the 2009 test program, oil was collected in ice-affected waters and subsequently burned *in situ*.

1.1 Background

Field deployment tests of booms and skimmers in broken ice conditions in the Alaskan Beaufort Sea highlighted the severe limitations of conventional containment and recovery equipment in even trace concentrations of broken ice (Bronson et al. 2002). Even small amounts of brash ice concentrated by the containment booms severely affected the effective operation of skimming systems designed for use in ice-affected waters.

It is possible, however, that the accumulation of brash ice and small floes in the back of a fire-resistant containment boom would not curtail *in situ* burning of the oil sandwiched between the ice floes. Field tests (SL Ross and DF Dickins 1987) have shown that high concentrations of oil in brash/slush between floes can be ignited and burned efficiently. Research using laboratory-scale (40 cm diameter) and larger (ca. 2 m diameter) outdoor wave tank burns has shown that crude oil can be effectively burned *in situ* with either brash ice or frazil/slush (SL Ross et al. 2003). The research showed that the minimum ignitable thickness for fresh crude oil is doubled from 1 mm to 2 mm for burns on brash or slush ice but the minimum ignitable thickness for weathered crude remains the same at 3 mm; the burn rate for crude oil on open water is halved on frazil ice and halved again on brash ice (waves also reduce the burn rates on brash or frazil ice); and, the residue remaining from 3-mm slicks increases from 1 mm on water to 1.5 mm on frazil ice to 2 mm on brash ice.

Larger-scale testing was proposed to determine whether:

- Fire-resistant booms could operate in lower concentrations of drift ice without debilitating damage;
- Fire-resistant booms could collect operationally reasonable amounts of oil among lower concentrations of drift ice before exceeding their operational limits;
- Fire-resistant booms could concentrate oil spilled among low concentrations of drift ice to ignitable thicknesses; and
- The presence of collected ice in the apex of a fire-resistant boom prevents effective removal of the collected oil by *in situ* burning.

1.2 Objective

The overall objective of this portion of the field program was to determine whether fire-resistant containment boom could be used to aid in burning oil *in situ* in low drift ice concentrations. Tests were performed as part of FEX 2008 with the objective of investigating the operational use of a fire-resistant boom in low concentrations of drift ice, but without oil and without a burn. The 2008 tests proved the feasibility of the concept in preparation for a full-scale test with oil, and a subsequent burn, in 2009.

The goal of the 2008 tests was to tow two 500-foot sections of fire-resistant boom through a field of 1 to 3/10$^{\text{ths}}$ drift ice, to measure tow loads, monitor boom performance, document any damage to the boom caused by ice pieces, and, in general, to confirm the boom's suitability to the task prior to testing with oil.

The goal in the 2009 tests was to tow the same two sections of fire-resistant boom through a field of drift ice containing oil, and then burn the oil *in situ*.

1.3 Summary of 2008 Tests

The main objective of the tests in 2008 was to confirm that the booms could contain ice while under tow such that a "contain-and-burn" operation could be performed in light ice conditions. Ice was gathered by making sequential passes along the edge of a field of loosely consolidated drift ice. Initially, the towing vessels were operated at as low speed as possible to minimize any contact forces between the ice floes and boom as the ice entered the containment area. Once there was some confidence that the boom could contain the ice while underway, the tow speeds were gradually increased until containment failure occurred.

Two booms were tested: the Elastec/American Marine Boom (formerly known as the 3M Boom), and the AFTI PyroBoom. Each boom was able to contain ice at speeds in excess of the normal containment limits of oil, i.e., 0.7 to 1 knots.

A secondary objective of the tests was to measure the change in towing loads when ice was present in the contained area. This could be of concern if the tensile strength of the boom or towing gear were to be approached or exceeded.

The total loads on the booms when towed in open water were similar to the theoretical loads as calculated by empirical-based formula (World Catalog 2008). There was considerable scatter in the data, likely due to errors in taking only spot readings from the load cells, but also in part due to the typical variations in load due to stretch in the boom and tow lines, variation in the towed configuration, and variations in tow vessel spacing and direction. The total tow loads when ice was present within the containment area were on the order of double the loads experienced in open water.

Overall, the tests met the primary objective of confirming the suitability of the two fire-resistant booms for subsequent testing in the 2009 field program, with oil and an *in situ* burn. Both booms were able to contain a modest number of ice floes as would be encountered in a “collect-and-burn” operation in light ice concentrations.

Recommendations were made regarding the vessel requirements for the 2009 tests, specifically the need for greater deck space to allow the boom to be flaked out without twisting, and to allow all of the boom sections to be connected prior to entering the water, and that the vessel have some measure of speed control at the low speeds required for effective containment.

2. Test Equipment and Procedures

2.1 Fire-Resistant Booms and Rigging

The same booms used in the 2008 tests were used in the 2009 tests: the Elastec/American Marine Boom (formerly known as the 3M Boom) supplied by Alaska Clean Seas, and the AFTI PyroBoom supplied by Applied Fabrics International Inc. Both booms are intrinsically fire-resistant, as opposed to boom that uses ancillary equipment to supply coolant to the boom to achieve its fire resistance.

Detailed specifications on each boom are provided in Appendix A. Both booms are relatively heavy, compared with conventional booms of similar dimensions, due to their use of fire-resistant components. For example, for floatation, the Elastec boom uses rigid ceramic foam covered by two layers of stainless steel knitted mesh, a ceramic textile fabric and PVC outer cover. The AFTI boom uses stainless steel shell floats, filled with ceramic foam for redundancy. To save cost and overall weight, the AFTI system was supplied in two parts: two 150-ft sections of conventional boom to be used as the leading arms of the U-configuration, and one 200-ft section of fire-resistant boom to be used at the apex of the “U”.

Each end of the booms was rigged with a towing bridle and a 90-metre (300-ft) polypropylene towing line. Once the boom was in the water, one towline was taken by the *KV Svalbard* (noted below), and the second by the rescue boat from the *Svalbard*, a 340-HP aluminum-hull vessel with jet drive.

The *Svalbard* is an icebreaking patrol vessel with the Norwegian Coast Guard. It served as the main vessel for FEX 2009, storing and transporting the boom to the site, and was the main towing, control, and observational platform for the operation. It has twin variable-pitch azimuthal drives and a bow thruster, which gave it excellent control at the low speeds required for effective booming operations.

2.2 Observational Equipment

During the tests, aerial photos and video were taken from a helicopter and from the deck of the *Svalbard*.

Speed-over-water (SOW), speed-over-ground (SOG), and wind speed were recorded from instrumentation aboard the *Svalbard*.

2.3 Overview of Test Procedures

The intention was to tow the booms through ice fields of low concentration (trace to $3/10^{ths}$), manoeuvring to avoid large ice pieces. As a precautionary measure, it was decided to avoid working in the loose ice at the edge of the pack, as this was thought to be more populated by seabirds and therefore presented a greater risk of oiling birds. Based on this, areas with the desired characteristics (i.e., relatively low ice concentration) were identified within the pack; these were surrounded by dense pack ice thought to be relatively free of marine birds.

Two ice fields were targeted for testing: a near open water condition with trace amounts of small ice pieces, and a denser field of brash in the range of $3/10^{ths}$ concentration. In each case the plan was to encounter and capture enough ice to cover approximately 20% of the boomed area, release oil into the boomed area, and then ignite and burn the oil. The intention was to perform all of these activities while proceeding slowly into the wind. Following the burn, any remaining residue would be collected with pre-weighed sorbents and measured to assist in estimating burn effectiveness.

The oil used in the tests was Troll crude (density 0.893 g/mL @ 15°C). It was stored in two 4 m^3 portable tanks on the aft deck of the *Svalbard*. Prior to discharge, the height was measured -from the upper surface of the oil to the top of the tank, and the volume of oil calculated using mathematical formula for the “percent full” for horizontal cylindrical tanks, then multiplying by the “total volumetric capacity” stamped on each tank.

3. Results

3.1 Deployment and Retrieval

Preparations for each of the two tests began with retrieving the boom from the ship's hold and flaking it out, with all connections made, on the heli-deck of the *Svalbard* (Figure 1). In the 2008 tests using the *Lance*, there was inadequate deck space to properly flake out the boom. As a result, when it was deployed, there were several twists in the boom that were difficult to remove. It was hoped that with more space the boom could be better staged and allow a smoother deployment.

The boom was then picked up in a single lift with the ship's crane and placed in the water. Care was taken in positioning the slings and in establishing the lengths of each of the slings such that the boom layout remained intact during the lift. As a result, the boom went into the water free of twists, greatly simplifying its subsequent use (Figure 2).

One of the *Svalbard*'s rescue boats took one end of the boom, towing it away from the ship to straighten it and confirm there were no twists. The rescue boat was a aluminum hull with 340-HP jet drive. The boat then brought the boom back towards the *Svalbard*, encircling a patch of ice pieces while en route. The two ends of the boom were then secured for towing, one end held by the rescue boat and one end by the *Svalbard*.

At the conclusion of each test, the boom was towed back to the *Svalbard* and visually inspected for damage while it lay in the water beside the ship. The boom was then retrieved to the *Svalbard* using the deck crane. The boom was lifted, section by section, inspected again, and bundled on the deck of the *Svalbard* for storage.

3.2 Test Narrative

3.2.1 Test #1: Elastec / American Marine Boom in Moderate Ice Coverage

At the start of the boom deployment operation, the *Svalbard* had been positioned at the downwind end of an area of loose drift ice, with the concentration varying from trace to 5/10^{ths}.

Figure 1: AFTI boom carefully flaked out on heli-deck

Figure 2: Deployment of AFTI boom

The intention was to tow the boom into the wind and through this area. However, during the period that the boom was deployed and the ice gathered, the surrounding ice converged significantly such that the intended track was 3 to 5/10^{ths} coverage (Figure 3). Consideration was given to moving to an alternative test area, but it was decided to proceed with a slight modification to the towing setup. The original intention was to tow the boom with one tow line from the starboard stern of the *Svalbard*, with the rescue boat holding the second line approximately 30 metres away from the *Svalbard*, level with the stern. Instead, the tow line held by the *Svalbard* was passed from starboard to port, and the rescue boat re-positioned closer to the *Svalbard*, approximately 10 metres off the stern. With the beam of the *Svalbard* approximately 20 metres, this maintained a boom opening of approximately 30 metres as originally planned, but it gave the rescue boat the option of moving astern of the *Svalbard* should it need to avoid large ice floes. As well, a procedure was worked out with the helmsman in which the *Svalbard* would occasionally use its bow thruster to push ice floes away from the intended track while the ship moved forward. The port azimuthal drive was also used to push ice away: it was alternately directed port or starboard, with the starboard drive maintaining the forward thrust throughout the tow.

With the boom in a U-shape and ice filling its apex (Figure 4), Troll crude oil was discharged into the boom. Initially only 200 litres was discharged to confirm that the oil would flow into the boomed area and be contained. In fact, approximately 50 litres escaped containment, so the 100-metre long towlines were brought in half way to reduce the likelihood of oil losses. The balance of the 4 m^3 was discharged without loss.

After the towlines were let out to their full length, the “ignition boat”, a second rescue boat from the *Svalbard*, moved to a position between the leading ends of the boom and placed several igniters in the water upstream of the contained oil and ice. The igniters were gelled gasoline contained in zipper-locked plastic bags. The igniters drifted back into the oil, and the oil was soon completely afire (Figures 5, 6).

The ensuing burn lasted approximately 25 minutes. After the main fire, a small area was re-ignited and burned for an additional 13 minutes. Following the burn, pre-weighed sorbent pads

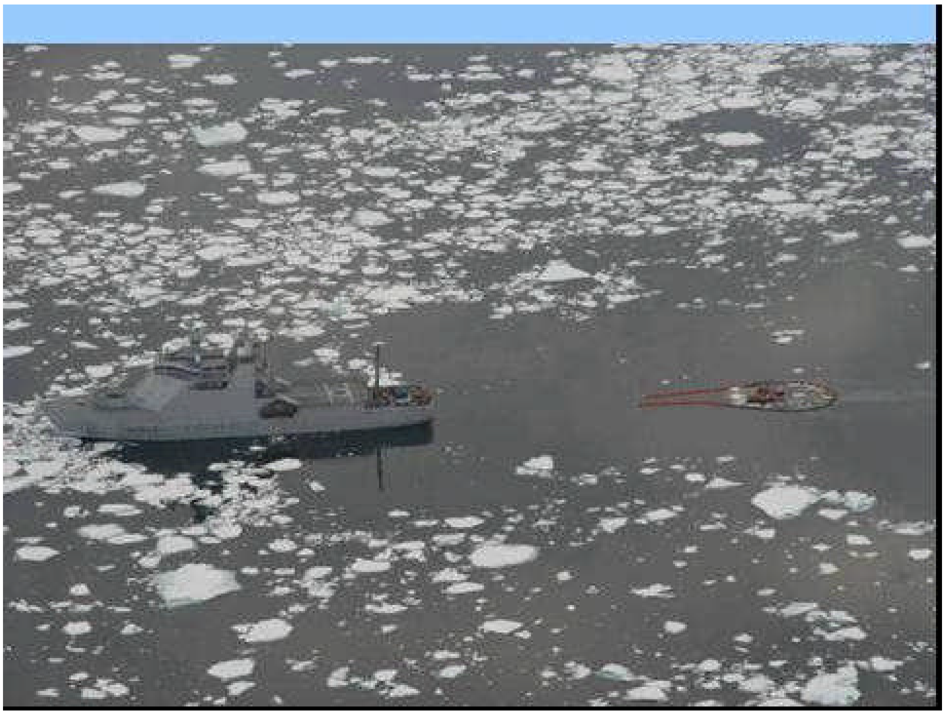

Figure 3: Ice conditions Test #1

Figure 4: Ice collection, Test #1

Figure 5: Early stage of burn, Test #1

Figure 6: Fully engaged burn, Test #1

were used to recover much of the residue. Peat moss was broadcast over the remaining residue and the ice/residue mixture released. The boom was observed to be in good condition and could have been used in a subsequent burn.

At the end of the burn, some small oil droplets were observed surfacing directly downdrift of the boom, creating a rainbow sheen. A survey of the test area revealed only sheen and a few lightly stained floe edges.

3.2.2 Test #2: AFTI Boom in Light Ice Coverage

The second test was intended for a less dense area of ice near the edge of the pack. An area was identified with a mixture of trace ice and open water. A total of 500 feet of boom was used, consisting of 200 feet of AFTI fire-resistant boom, and 300 feet of Applied Fabrics GlobeBoom, a conventional containment boom. The two 150-foot sections of conventional boom were used as the leading ends of the deployment to save on weight and cost. The fire-resistant boom formed the apex of the U-shape, where the fire would be located.

Following deployment, the boom was positioned in a U-shape and towed approximately 1 kilometre in a downwind direction to the intended starting position, collecting ice pieces along the way (Figure 7). Unfortunately, too much ice was gathered – it filled approximately 50% of the boom, and almost 100% of the area contained by the fire-resistant boom – so some had to be released. The first attempt to do this involved towing the boom at approximately 1.5 knots, but this did not lose any of the ice. The contained area was then opened, and one of the rescue boats nudged ice pieces out with its bow.

The boom was then towed back to the intended starting position, but by this time, the ice had opened significantly and there was little ice to be encountered during the tow, as had been intended. A course was set into the wind, essentially through open water.

With the towlines shortened to lessen the drift of oil, 4 m^3 of oil was discharged into the contained area. Several igniters were placed upwind of the oil and allowed to drift back to the slick.

Figure 7: Ice collection, Test #2

Ignition proceeded, but not as energetically as in the first burn (Figure 8). Compared with Test #1, the ice pieces in this test were smaller and therefore packed together more densely. As well, there was more slush ice in the mix. As a result, the burn area was not as great, at any particular time, as in the first test, and the burn took much longer, a total of 2-½ hours. Throughout the burn, the boom was subjected to wind waves and swell. Slowing the tow speed and allowing the ice to spread out somewhat could have accelerated the fire, however each time this was attempted, the boom began to swing away from the direction of the tow, presumably due to the effect of currents. This caused the burn area to approach the portions of the boom that were not fire-resistant, and rather than risk losing control of the fire, it was decided to proceed as originally intended, at a speed through water of approximately 0.3 knots. An example of a more vigourous period of burning, in the latter stages when the tow speed was slowed briefly, is shown in Figure 9.

Figure 8: Test #2 burn

Figure 9: Vigourous burn in latter stages of Test #2

After the burn, a small amount of thick oil was observed directly behind the apex of the boom in an area 1 metre wide by 4 metres long. Large oil droplets were observed surfacing in the area.

At the conclusion of the burn, sorbent pads, rakes and shovels were used to recover much of the residue, which was more viscous than in the first burn. Peat moss was broadcast over the remaining residue and the ice/residue mixture released. The boom was observed to be in good condition and could have been used in a subsequent burn.

The much longer burn time in this test is consistent with the results in SL Ross et al. 2003 regarding the effects of brash and frazil ice and waves in reducing burn rates and increasing the amount of residue after extinction.

3.3 Estimate of Burn Effectiveness

Burn effectiveness is expressed as the percentage of oil that is removed from the water through burning, and is measured by comparing the amount of oil that is remaining after the burn to that originally spilled. In a laboratory setting, it is also possible to estimate the amount burned by multiplying the burn rate by the burn area; however, in these tests it was impossible to estimate the burn area at any given time due to the presence of ice floes within the contained burn area.

Oil for the test burns was stored in a horizontal cylindrical deck tank positioned on the aft deck of the *Svalbard*. The amount of oil available for burning was estimated by measuring the volume in the deck tank prior to and after discharge. The amount of oil remaining on the water after the burn was estimated by weighing the recovered residue, and modifying this number with a visual estimate of the percentage of burn residue that was actually recovered. Prior to the recovery of burn residue, a visual estimate was made of the area and thickness of the residue, and this was used for comparison.

3.3.1 Test #1: Elastec / American Marine Boom in Moderate Ice Coverage

Based on tank measurements before and after discharge, the total amount of oil released into the boom was 4.384 m^3, or 3,915 kg.

Prior to its recovery, a visual estimate was made of the residue within the boom. There were eight patches of residue, with a total area of 25 m^2, estimated to be 2 mm thick, and one 5-mm thick patch 0.2 m^2 in area, equating to an estimated residue volume of 51 litres. It was visually estimated that 80% of the residue was recovered by rakes and sorbent pads. The total weight of collected residue was 68.4 kg of residue collected; factoring in the 80% indicates that there had been a total of 85 kg of residue.

Based on this the estimated burn effectiveness was 98%.

3.3.2 Test #2: AFTI Boom in Light Ice Coverage

Based on tank measurements before and after discharge, the total amount of oil released into the boom was 4.192 m^3, or 3,743 kg.

Prior to its recovery, a visual estimate was made of the residue. There were two main patches of residue, each with an area of 5 m^2, estimated to be 5 and 10 mm thick respectively, equating to an estimated residue volume of 75 litres. It was visually estimated that 50% of the residue was recovered by rakes and sorbent pads. The total weight of collected residue was 210.1 kg of residue collected; factoring in the 50% indicates that there had been a total of 420.2 kg of residue.

Based on this the estimated burn effectiveness was 89%.

4. Conclusions

The primary objective of the tests was to determine whether fire-resistant booms could be used to collect and contain oil in low concentrations of drift ice for burning *in situ*. This was accomplished with two different booms, the Elastec/American Marine (aka 3M) fire boom and the Applied Fabrics Technologies (AFTI) PyroBoom. The booms were tested in two different ice conditions: the former in a field of 3 to 5/10$^{\text{ths}}$ ice, and the latter in trace ice conditions.

Both booms were deployed and retrieved with a minimum of difficulty from the *Svalbard* using its deck crane. The ample space on the heli-deck was advantageous for the pre-deployment staging of the boom, but any clear deck space of sufficient dimensions would have been adequate.

The speed control and manoeuvrability of the *Svalbard*, with its variable-pitch propellers and bow thrusters, was advantageous in navigating through the ice and in towing the boom at low speed without significant loss of oil. In the moderate ice condition, the azimuthal-drive of the ship and its bow thrusters were also very useful in deflecting ice away from the containment area as the ship and boom moved through the ice field.

Both booms proved to be suitable to the task, and were able to contain a modest number of ice floes as would be encountered in a “collect-and-burn” operation in light ice concentrations.

In each test, a high percentage of the oil was removed through *in situ* burning, some 98% in the first test and 89% in the second. The burn in the second test was less effective and took much longer due to the presence of more densely packed brash and frazil ice and due to the presence of waves.

In summary, it is feasible to use fire-resistant booms in light drift ice to collect oil and ice for *in situ* burning. This technique should have excellent applicability for spills in trace to 3/10ths ice concentration.

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Appendix A:

Fire Resistant Boom Specifications

Elastec Fireboom

Note: This boom is not currently being marketed; it was last produced by Elastec/American Marine, Carmi, Illinois. It was formerly known as the 3M boom after the company that originally developed it.

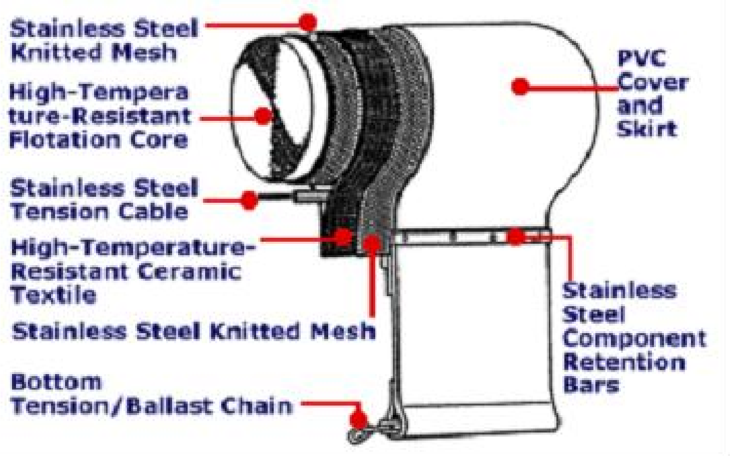

Figure A-1. Elastec Fireboom Design

The boom consists of flotation sections made of rigid ceramic foam. The floatation elements are covered by two layers of stainless steel knitted mesh, a ceramic textile fabric and a PVC outer cover (Figure A-1). The outer cover is designed to protect the inner layers from abrasion during handling and deployment and, not being fire-resistant, will melt away when exposed to fire.
The PVC material also extends below the floats to form the skirt. A stainless steel tension cable provides strength immediately below the floatation element, and a chain along the bottom of the skirt provides additional tensile strength and ballast. Various models are available (Table A-1); the 42-inch model (highlighted) was used in the tests described in this report.

Table A-1. American Marine Fireboom Dimensions

Manufacturer	Elastec/American Marine		
Model	American Marine Fireboom		
Type	Intrinsically Fire Resistant		
Height (in.)	20	30	42
Freeboard (in.)	5.5	9	15
Draft (in.)	14.5	21	27
Section length (ft)	50		
End connectors	ASTM		
Weight (lb/ft)	5.1	8.4	15.3
Storage volume (ft^3/ft)	0.7	1.4	3.2

Summary of Testing

Testing was conducted at the National Response Center (NRC) Outdoor Maneuvering Basin in Ottawa with propane burners (orange cover removed).

Various versions of this boom have been tested many times over the last 20 years. Based on field tests at the Newfoundland Offshore Burn Experiment (NOBE) and flame testing in waves in accordance with ASTM F2152-01, it is expected that boom sections exposed to flames would require replacement after three to four individual burns (McCourt, et al., 1998).

Manufacturer Information

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Applied Fabrics (AFTI) PyroBoom®

Figure A-2. Applied Fabrics PyroBoom®

PyroBoom® has been demonstrated to maintain its effectiveness and structural continuity even after exposure to a 2400°F fire for up to 24 hours. PyroBoom® is a solid flotation barrier that combines a wire reinforced refractory fabric for the above surface barrier with conventional GlobeBoom® fabric for the skirt. The glass foam filled, steel hemispheres are mechanically attached to the barrier. The modular construction allows for easy salvage, maintenance and repair in the field.

Operationally, has been demonstrated to maintain freeboard and stability when towed in a "U" configuration at speeds up to 3 knots. The high strength and impact resistant materials allow for rough handling and continued flexing under load. No special handling equipment is required other than the lifting and tugging hardware normally found on OSRV's. Handles, lift and tow points and bridle attachments are all included in the normal PyroBoom® layout.

PyroBoom® can be furnished in a "burn-kit". This kit consists of a standard GlobeBoom® guide-boom, a PyroBoom® "U" configuration sweep assembly with wire cross bridles and a steel storage kit with retrieval windlass. The whole system can also be stored on a reel, if desired, with a total deck footprint of about 9' x 20' for either configuration.

Table A-2. Applied Fabrics PyroBoom® Dimensions

Manufacturer	Applied Fabrics
Model	PyroBoom®
Type	Intrinsically Fire Resistant
Height (in.)	30
Freeboard (in.)	11
Draft (in.)	19
Section length (ft)	50
End connectors	ASTM
Weight (lb/ft)	8.5
Storage volume (ft^3/ft)	1.89

Summary of Testing

AFTI's PyroBoom® has been subjected to a variety of tests over the past 20 years. Based on testing for the State of Alaska in the 1980's, PyroBoom® was able to survive a 24-hour continuous burn and be salvaged for reuse. More recent testing (late 1990's) at Ohmsett and the USCG facility in Mobile has used the ASTM fire-boom test protocol which subjects a boom to three alternating one-hour periods of fire exposure and wave exposure, and the boom passed theses tests.

Manufacturer Information

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