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REPORT

Oil in Ice - JIP

Report no.: 5

Tests of Fire-Resistant Booms in Low Concentrations of Drift Ice - Field experiments May 2008.

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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 2008

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

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Location: Svalbard.

Test Period: May 2008

March 20, 2010

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1. INTRODUCTION

A one-day test program was conducted off Svalbard in May 2008 to perform tests 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 East of Hopen in the Barents Sea that included tests with three different skimmers, tests with chemical herding agents to facilitate *in situ* burning, and tests of a remote sensing system. The fire-boom tests did not involve oil. A subsequent test in 2009 includes the collection of oil followed by burning of the oil.

1.1 Background

Field deployment tests of booms and skimmers in broken ice conditions a few years ago 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 the smallest brash ice pieces concentrated by the containment booms severely impacted the effective operation of skimming systems designed for use in ice-infested 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 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 slightly reduce the burn rates on 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 is required to determine whether:

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

1.2 Objective and Goal

The overall objective of this portion of the field program was to determine whether fire-resistant containment boom can be used to aid in burning oil *in situ* in lower drift ice concentrations. The objective of the 2008 field tests was to investigate the operational use of a fire-resistant boom in low concentrations of drift ice. The 2008 program was used as a preliminary test in preparation for a large-scale test with oil, and a subsequent burn, in 2009.

More specifically, the goal of the work was to tow two 500-foot (150-metre) sections of fire-resistant boom through a field of 1 to 3/10^{ths} drift ice off Svalbard in May 2008, 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.

2. TEST PROCEDURES

2.1 Introduction

The original intention was to test the fire-resistant booms at the main test site, east of Hopen. However, deck space on the *RV Lance* was severely limited, so it was decided to do the boom tests at the conclusion of the test program. The fire booms were left in Longyearbyen and after the other tests were completed, the *RV Lance* returned to Longyearbyen, the skimmers and their ancillary equipment were removed from the boat, and the booms loaded onto the forward deck of *RV Lance*. As the boom tests did not involve oil, there was no need to return to the main test site, a two-day transit, so the tests were performed in Billefjord, approximately 20 km northeast of Longyearbyen. Even without the other test equipment there was insufficient space for the full complement of boom, and only 250 feet (75 metres) of the Elastec/American Marine boom and 500 feet (150 m) of the (smaller) AFTI boom were brought on board.

2.2 Equipment and Instrumentation

Two booms were acquired for the 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 (45-m) sections of conventional boom to be used as the leading arms of the U-configuration, and one 200-ft (60-m) 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 *RV Lance,* and the second by the rescue boat from *RV Lance,* a 100-HP fibreglass hull vessel with jet drive. The leading end of each towline was fitted with a load cell with direct digital readout.

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

2.3 Test Procedures

The intention was to tow the booms through ice fields of minimal concentration (trace to $1/10^{\text{ths}}$), manoeuvring to avoid large ice pieces. Within a reasonable transit time of Longyearbyen, an ice field of $7/10^{\text{ths}}$ concentration was found. At first, an attempt was made to clear a path through the field and create an area of lower concentration. This was unsuccessful so it was decided to make repeated passes along the outside edge of the ice field, each time capturing one or more discrete ice floes until the target ice concentration was reached.

For each of the two booms, the boom was towed in a U-configuration with a gap or sweep width of approximately 30 m. The boom was first towed through open water, then through a light ice condition, and the towing loads measured for each. Once approximately half the contained area of the boom was covered with ice, tow speed was maintained for approximately one minute to confirm a steady-state condition that would allow burning. Following this, the speed was gradually increased to determine the failure limit for the containment of the ice.

2.4 Tow Force Measurements

Tow forces were measured by load cells on each of the two towlines, with a direct digital readout of the load cells located on the forward deck of *RV Lance* and the rescue boat, respectively. The readings fluctuated due to the oscillation of the boom under tow and the elasticity of the towlines and the boom. To overcome this, spot readings were taken some 15 seconds apart and the results averaged. As the tow forces were measured, tow speed was recorded from the navigational display on the bridge of *RV Lance*.

3. RESULTS

3.1 Deployment and Retrieval

The capabilities of *RV Lance* limited the methods available for deployment and retrieval. The preferred method of deployment would have been to flake the boom out on the aft deck and ease it into the water over the stern, with the load gradually taken by a second towing vessel. As the aft deck of *RV Lance* is covered by the heli-deck, the booms could not be crane-lifted to that location. Instead, the booms were loaded onto the foredeck, between the lower deck hatch, crane, and other fixtures. Given the limited space available on the foredeck, only 250 feet (75 metres) of the Elastec/American Marine boom and 500 feet (150 metres) of the (smaller) AFTI boom could be stowed on board.

Both the Elastec boom and the fire-resistant portion of the AFTI boom were too heavy to be manually lifted over the deck rails on each side of the foredeck so the deck crane was used. Each 50-foot (15-metre) section of boom was flaked back and forth, and two slings were positioned under the bundled boom. The boom was then lifted from the deck and placed in the water. Once all sections were in the water, they were joined together. With the Elastec boom, joining the boom sections took some time, as the connectors were difficult to align. With the AFTI boom, the connectors were much easier to join, the boom being much lighter and easier to manhandle together. However, when the AFTI boom was bundled together on the deck, several twists were introduced into the boom, and these had to be removed once the boom was in the water. In all, the 250 feet (75 m) of Elastec boom required about one-half hour to deploy and make ready for use, and the 500 feet (150 m) of AFTI boom required about one hour.

At the conclusion of the tests, each boom was towed to a position alongside *RV Lance* and retrieved using the deck crane as the boom was too heavy to manually lift from the water and over the side deck rails. With the AFTI boom, the crane hook was attached to a lifting eye located at each section connector. With the Elastec boom, a sling was placed under the boom in the water, and the crane used to lift the boom to the deck several segments at a time (Figure 1).

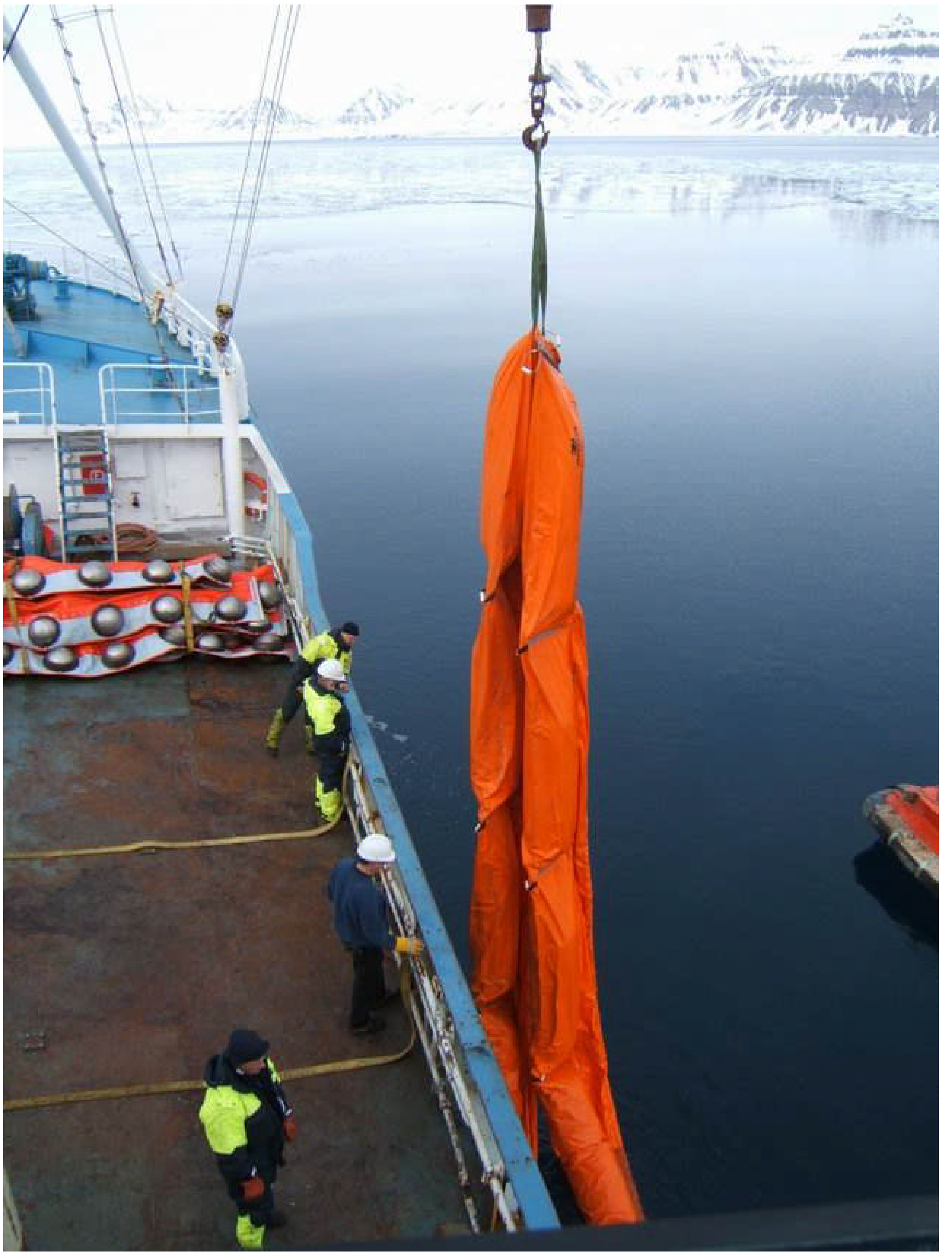

Figure 1: Retrieving Elastec boom

Figure 2: Gathering ice along edge of pack

3.2 Containment of Ice

The main objective of the tow tests was to confirm that the boom 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 the loosely consolidated drift ice (Figure 2). 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.

The AFTI boom was able to contain ice in this manner up to a speed of 1.5 knots, at which speed the containment failed with the boom riding up over the ice (Figure 3). The Elastec boom contained ice floes at tow speeds to 1.5 knots. Greater speeds were not possible due to the limited power of jet boat used as the towing vessel. Nonetheless, in each case, the boom

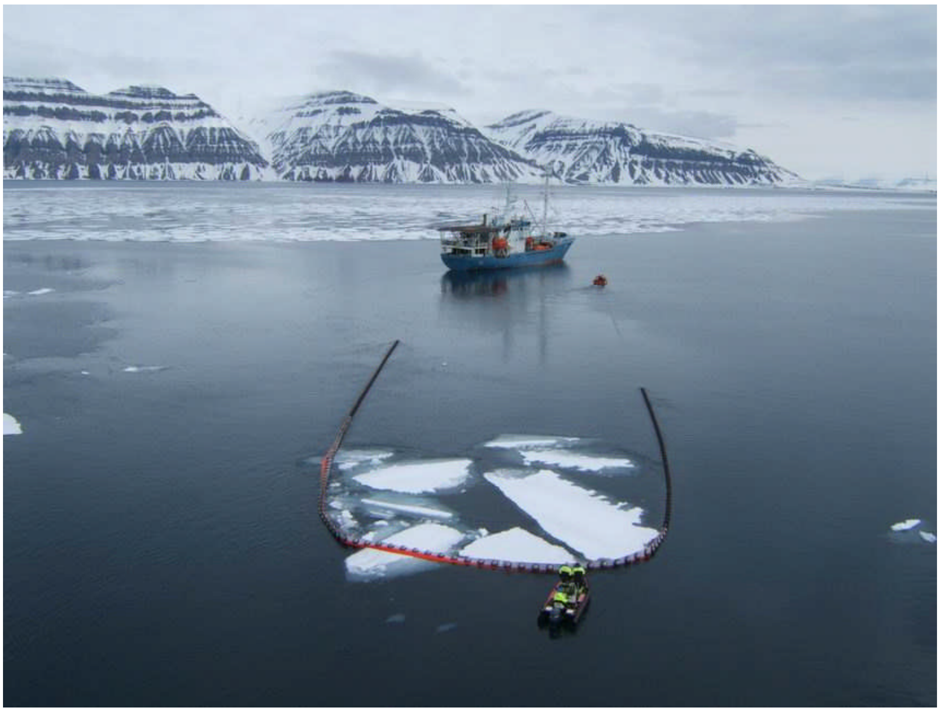

Figure 3: AFTI boom overriding ice floes at 1.5 knots

was able to contain ice at speeds in excess of the normal containment limits of oil, i.e., 0.7 to 1 knots (Figures 4 and 5).

3.3 Towing Forces

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.

Tow loads imposed on a boom are proportional to the draft of the boom, the sweep width, and the towing velocity squared. The draft of each boom was assumed to be constant through the tests. The sweep width varied somewhat through the tests; therefore, for comparison purposes, the measured tow forces had to be normalized to a constant sweep width of 30 metres.

Tow loads for the two booms are shown in Figures 8 and 9. The total load on the boom

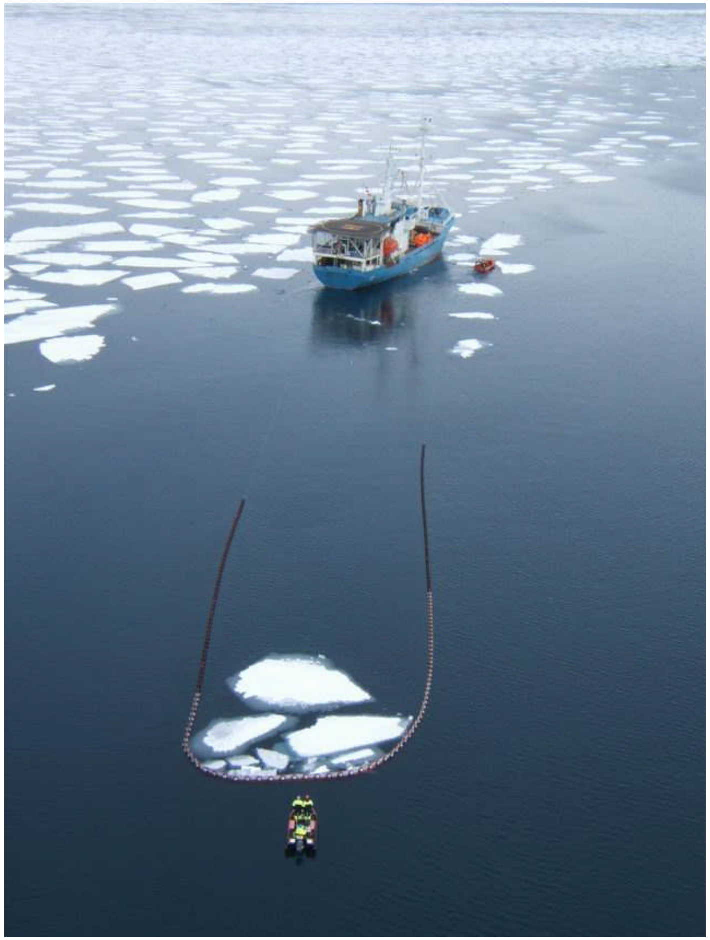

Figure 4: Applied Fabrics boom under tow with ice

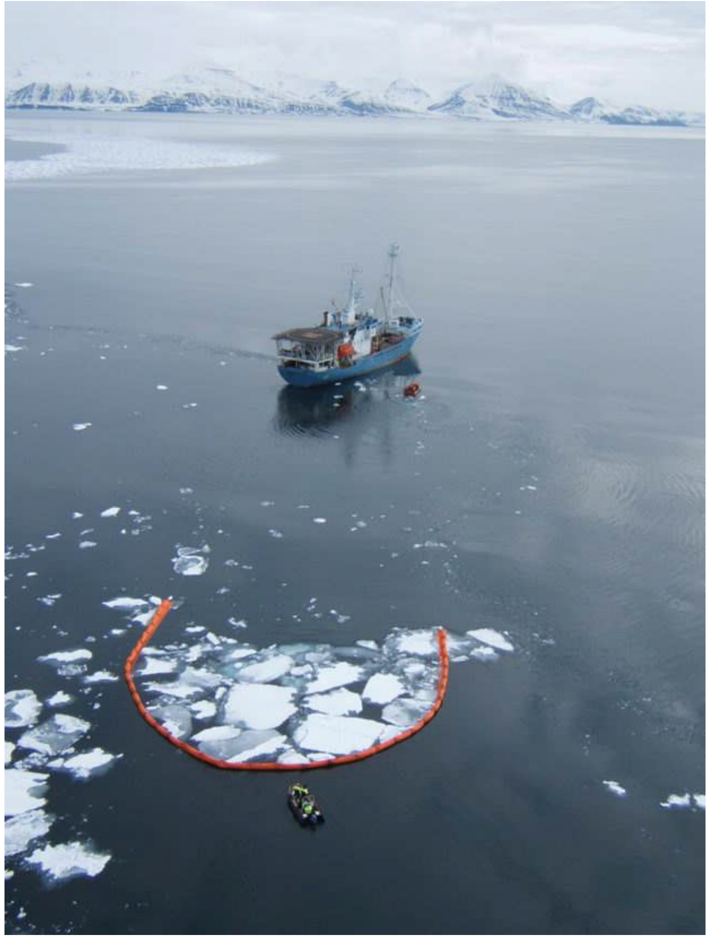

Figure 5: Elastec boom under tow with ice

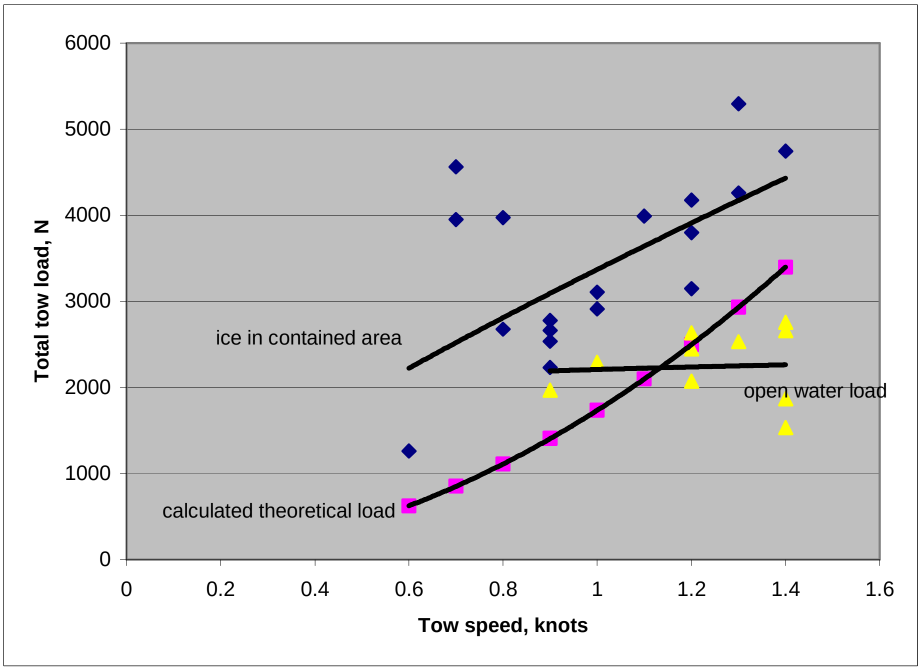

Figure 6: Tow loads on AFTI boom

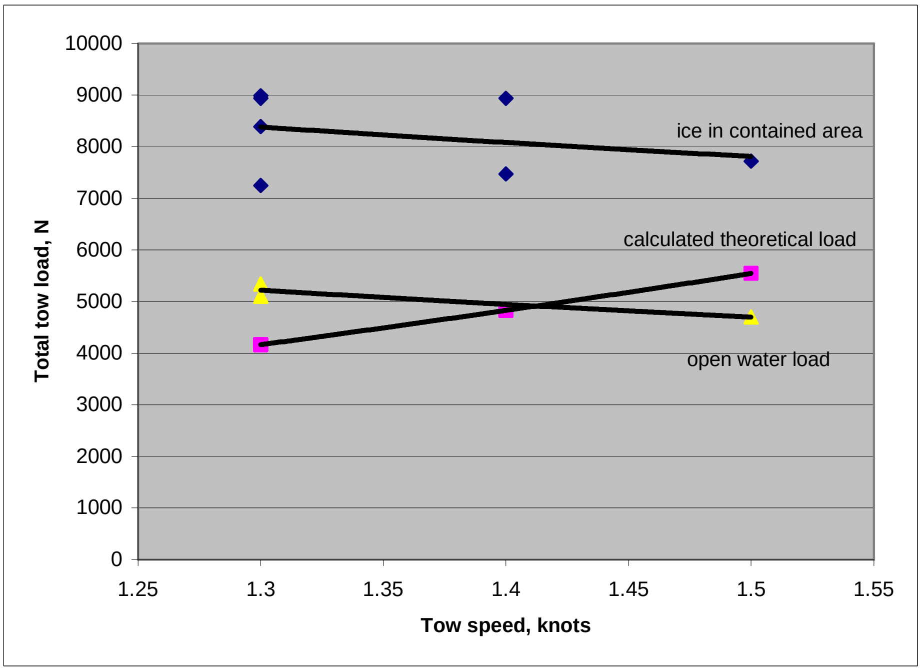

Figure 7: Tow loads on Elastec boom

when towed in open water is similar to the theoretical loads as calculated by empirical-based formula (World Catalog 2008). There is 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.

4. CONCLUSIONS AND RECOMMENDATIONS

The primary objective of the tests was to confirm 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 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.

The fire-resistant booms used in these tests, like all fire-resistant booms, are very heavy relative to conventional booms of similar dimensions and are somewhat fragile compared with conventional offshore boom. It would be advantageous in future tests to have a clear open stern deck on the deployment vessel 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.

Oil is lost past a containment boom if the tow speed exceeds about ¾ knots (0.39 m/s). This will require the use of vessels with some measure of speed control at low speeds, and cannot be accomplished by simply "clutching" in and out, as was done with *RV Lance* in these tests. Likewise, the jet boat that was used as the second towing vessel was barely adequate to tow the boom at the required speeds, and would have had difficulty if a greater length of boom had been used.

5. REFERENCES

Bronson, M., E. Thompson, F. McAdams, and J. McHale. 2002. Ice effects on a barge-based oil spill response systems in the Alaskan Beaufort Sea. Proceedings of the Twenty-fifth Arctic and Marine Oilspill Program Technical Seminar, Environment Canada, Ottawa, pp 1253-1269

McCourt, J., I. Buist, B. Pratte, W. Jamieson, and J. Mullin. 1998. Continued development of a test for fire booms in waves and flames. Twenty-first Arctic and Marine Oilspill Program Technical Seminar Proceedings. Ottawa, Canada. p. 505-528.

SL Ross Environmental Research Limited, DF Dickins Associates, and Alaska Clean Seas. 2003. Tests to determine the limits to *in situ* burning of thin oil slicks in broken ice. Report prepared for Minerals Management Service and ExxonMobil Upstream Research. MMS. Herndon, VA.

SL Ross Environmental Research Limited and DF Dickins Associates. 1987. Field research spills to investigate the physical and chemical fate of oil in pack ice. Environmental Studies Research Funds, Publication No. 062. ESRF, Ottawa.

World Catalog of Oil Spill Response Products, Ninth Edition. 2008. Published by SL Ross Environmental Research Ltd., S. Potter, Editor. Ottawa.

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.

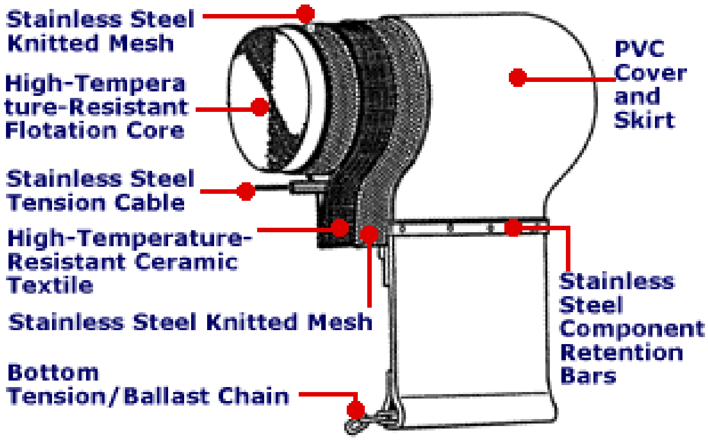

Figure A-1. Elastec Fireboom Design

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 foot print of about 9 x 20 feet (3 by 6 metres) 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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