

## Fire Resistant Booms Tested in Flames at Ohmsett

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### ABSTRACT

An enhanced propane underwater bubbler system designed to allow the testing of fire-resistant booms in flames was installed at Ohmsett in the fall of 1998 by the Minerals Management Service (MMS) and the US Navy Supervisor of Salvage and Diving (SUPSALV). The test is based on a screening protocol for testing fire resistant booms in waves and flames developed for MMS and the Canadian Coast Guard (CCG). The cornerstone of the test is an underwater bubbler system to create air-enhanced propane flames that produce an average total heat flux to the surface of a candidate containment system in the range of 110 to 130 kW/m<sup>2</sup> and flame temperatures near the containment device on the order of 900°C. The candidate boom is stretched over the center of the bubbler, parallel to the long dimensions of the test tank, and tensioned to realistic towing forces. The fire exposure portion of the test involves three cycles of one hour of exposure to air-enhanced propane flames in waves, followed by a one-hour

cool-down period in waves alone, and conforms to ASTM F 2152-01.

Since the air-enhanced propane system was developed, 11 fire resistant boom systems have been tested. These include: three refractory fabric booms, one stainless steel boom, three water-cooled blanket prototypes, three reflective/insulating blanket prototypes, and one water-cooled boom. This paper summarizes the test methods used and the results.

## INTRODUCTION

*In situ* burning is gaining acceptance as an oil spill response tool for eliminating large quantities of spilled oil from the water surface. Many areas of North America have pre-approval, or expedited approval, for the use of *in situ* burning in response to oil spills. Contingency plans are incorporating the use of controlled burning of slicks as a response technique, and burn equipment packages, including fire boom, have been, and continue to be, staged for use. In addition to their use in spill response, fire booms are being proposed as a marine fire-fighting tool, to prevent the spread of burning slicks on water (Allen 2000).

The use of *in situ* burning as an operational technique presents responders and regulators with a difficult task: in order to assess the adequacy of given response equipment packages, the expected performance and survivability of the various components need to be evaluated. In the case of the fire boom, the expected operating environment is particularly challenging, involving simultaneous exposure to: salt water; the intense heat generated by burning oil slicks; the flexing action of ocean waves; and, the tension loads imposed by tow vessels .

Using appropriate, durable equipment is crucial; support for *in situ* burning as a viable oil spill cleanup option will be significantly diminished if the first real response fails due to poor fire boom performance. Determining the survivability of untested fire booms was identified as a

high priority by an international panel of oil spill experts at a recent workshop on *in situ* burning in New Orleans, LA (Laferriere 1998 in Walton and Jason 1998). To address this, MMS, the U.S. Coast Guard (USCG), CCG, SUPSALV, and others have supported testing of commercially available and prototype fire booms in realistic conditions.

This paper summarizes the results of several series of fire tests that have been conducted at Ohmsett since 1998. Complete, detailed descriptions of the test methods and results may be found in the various technical papers prepared for the projects ( McCourt et al. 1998, McCourt et al. 1999, Buist et al. 2001a and Buist et al 2001b).

## **SUMMARY OF TEST EQUIPMENT AND BOOMS**

The tests were carried out at Ohmsett using the air-enhanced propane fire test system, illustrated in Figure 1, as detailed in McCourt et al. 1999. There were minor modifications made to the equipment detailed in the 1999 paper: (1) a larger air compressor has been used (rated at 750 cfm); (2) the bubbler frame was welded into a stiff, bottom-founded structure (Figure 2), as opposed to an articulated, floating frame; and, (3) the air injection nozzles were modified to facilitate their movement up and down with waves.

Propane is supplied from two 10,500-gallon propane tankers located at the east side of the tank (Figure 3). The flow of propane to the underwater bubbler frame is controlled by a series of pressure regulators and valves also located at the east side of the tank (Figure 4). The flow of compressed air is controlled with two valves from the same location (also shown in Figure 4).

Instrumentation is installed to record various fire data (see McCourt et al. 1999 for specifics). The pressure, temperature and flow rate of the propane and air are recorded. Flame temperatures are measured with four Type K flame thermocouples. Two Total Heat Flux

Transducers (MEDTHERM model 64-20-1080-20) can be mounted to "look" at the flames across the test section of boom.

Readings of the percent full, pressure and temperature gauges on the two propane tankers are taken periodically. These are used to verify the propane flow meter readings. Calibration data for the various instruments may be found in the various technical reports.

### **Candidate Fire Booms**

The following fire boom systems have been tested using the air-enhanced propane flame system:

- Alaska Clean Seas SWEPI Fire Boom, a refractory fabric boom specifically designed for use in broken ice.
- Applied Fabric Technologies, Inc. stainless steel Pocket Boom.
- three Applied Fabric Technologies, Inc. prototype reflective/insulating blankets tested on conventional, US Navy offshore boom.
- Elastec/American Marine Fire Boom (originally 3M Fire Boom) - the version tested was the one deployed at the Newfoundland Offshore Burn Experiment (NOBE - Environment Canada 1993, Raloff 1993) which was used as one method of benchmarking the test protocol.
- Elastec/American Marine Hydro Fire Boom, a water-cooled type.
- Elastec/American Marine prototype water-cooled fire protection blanket, tested on conventional, US Navy offshore boom.
- Environmental Marine Technology & Associates water-cooled fire protection blanket prototype, tested on conventional, US Navy offshore boom.
- Oil Stop, Inc. prototype water-cooled fire protection blanket, tested on conventional,

US Navy offshore boom.

- Oil Stop, Inc. Auto Boom Fire Model, an air-inflated refractory fabric boom.

## **THE OHMSETT ENHANCED-PROPANE TEST PROTOCOL**

The fire booms were exposed to the full, four-stage test protocol described below. The prototype water-cooled booms and fire protection blankets were subjected to a modified test in either waves or calm conditions and flames, with no pre- or post- burn stress testing or oil containment testing. The purpose of these tests was strictly to assess their ability to survive flames. The reflective/insulating blankets were placed beside the propane fire, and exposed to radiant heat only in calm conditions.

### **Pre-burn Wave Stress Test**

This test involves stressing a section of the candidate fire boom under realistic tension loads for a period of two hours in large waves. The boom is installed longitudinally in the tank and tensioned by a winch. The tension load imposed is to simulate that expected for a 150 m (500 ft) length of the candidate boom deployed in a "U" configuration at sea in 1 m (3 ft) high waves in a 0.75 knot current (or sweeping speed), nominally 1100 N (250 lbf). The tension is measured by a 4000-lb. load cell mounted on the south end of the test section of boom. The longitudinal stresses in the boom and the wave characteristics are monitored using the Ohmsett data acquisition system. Waves of approximately 0.4 m (16 in) height with short periods are generated in the tank (a 27-cpm harbour chop using a 4.5-in wave maker stroke) and used to accelerate axial bending and flexing of the test boom and its components, as would happen to a real boom over a much longer time period.

After the test any sacrificial coverings are carefully removed so that the underlying fire

resistant components can be non-destructively examined. Particular attention is paid to the appearance of the refractory material and structural members.

### **Test in Waves and Flames**

In general, the plan for this portion of the protocol is to subject the candidate section of boom to three cycles of flame of one hour duration, interspersed by two cycles of one hour of wave action with no flame, as specified in the ASTM F 2152-01 fire boom test protocol. The boom is approximately centered over the propane bubbler frame so the middle 4 to 5 m (13 to 16 feet) would be covered by flame and is tensioned to 1,100 N (250 lbf). Flames are generated along both sides of the middle of the candidate boom (Figure 5). The width of the flames on each side of the boom is approximately 1.2 m (4 ft). The instrument stalk holding the ignitor and the optional thermocouples is positioned as near as possible to the flame center, without interfering with the motion of the fire boom. Once the flames have been established, waves (approximately 0.3 m [12 inches] high with a wave length of 18 m [60 ft.]) are generated at the south end of the test basin (with the wave generator operating at 27 cpm with a 4.5-inch stroke and the wave beaches raised), simulating Sea State 2. At the end of a one-hour burn, the propane and compressed air flow are shut down and the boom is visually inspected. The waves continue for a further hour, then the system is reignited.

### **Post-Burn Wave Stress Test**

This test involves stressing fire boom candidates that passed the fire test again in larger, steeper waves for a period of two hours. The boom is re-tensioned to take up any slack. The longitudinal stresses in the boom and the wave characteristics are monitored. Waves approximately 0.4 m (16 in.) high with short periods are generated in the tank.

## **Static Thick Oil Containment Tests**

Fire boom models that successfully pass the post-burn wave stress test are subjected to a static, thick oil containment test. This final test involves assessing the capability of the candidate boom to contain thick slicks of low viscosity oil (a blend of JP-5 and diesel has been used), simulating a full-scale layer of burning oil in the pocket of a boom under tow. A section of the boom, consisting of at least the 4.6 m (15 feet) that were exposed to the propane flames is connected in a circle. Measured quantities of the low-viscosity oil are poured onto the water surface inside the circle and the boom is examined for leakage after each volume increment is added. Oil is added until significant leakage is noted. The thickness contained and the location and apparent reason for the leakage is recorded.

## **SUMMARY OF RESULTS**

Table 1 summarizes the results of the tests of the 11 fire boom systems/components. The ACS SWEPI boom passed all tests; however, due to its low freeboard it was constantly over-washed by the waves, which probably greatly affected its performance in the fire test. Wave action would likely not be present in its intended operating environment of broken ice conditions. The loss of oil, after reaching a 56-mm depth in the Thick Oil Containment Test was determined to be by drainage failure due to the boom being full to the bottom.

The AFTI Pocket Boom passed the Burn Test with only minor heat damage. It was not subjected to the Pre-Burn Stress Test since it had been tow tested and fire tested several times prior to being exposed to the air-enhanced propane test protocol (SL Ross 1999, Buist et al. 2001a). The boom was also not put through the Post-Burn Stress Test because the vulnerable connector sections were tested to failure in a subsequent, alternate test. It was not subjected to

the Thick Oil Containment Tests because it's post-burn containment performance had been previously determined in a different Ohmsett test series (SL Ross 1999).

The AFTI prototype reflective blanket tests involved placing a 50-foot section of US Navy boom covered with a blanket in a semi-circle beside the propane fire to expose it to radiant heat. Thermocouples measured the temperature of the underlying boom fabric. A successful test was defined as one where the boom fabric temperature did not exceed 280°F after ten minutes. The test boom was moved closer to the fire after each successful test. The best reflective blanket was #3, which prevented overheating of the underlying boom when placed 10 feet from the fire, the second best was #1 and the third best was #2 (SL Ross 2000, Buist et al. 2001b).

The Elastec/American Marine Fire Boom was tested in Ottawa during the development of the protocols, and was used as a benchmark for the test. A section of this boom that was used at NOBE was exposed to the air-enhanced propane test and deteriorated in the same manner and time as the boom exposed to the crude oil fire offshore (SL Ross 1997, McCourt et al. 1998).

The Elastec/American Marine Hydro Fire Boom passed the burn test portion of the protocol, but was not put through the Pre-Burn, Post-Burn or Thick Oil portions. The boom was exposed to waves only during the third hour of burn testing: the first two hours were completed in calm conditions. It was noted during the burn tests that the boom had a tendency to roll over in waves due to the weight of the water in the protective cover.

The Elastec/American Marine water-cooled blanket failed after 2 hrs 46 minutes exposure to flames. These tests were conducted in calm conditions for the first one-hour burn, in waves for the second hour and in calm conditions for the first 30 minutes of the third burn. The blanket had failed at the connection between adjacent blankets, allowing the underlying boom to melt and deflate. Again, it was noted during the burn tests that the boom had a tendency to roll over in



waves due to the weight of the water in the blanket.

The Environmental Marine Technology & Associates water-cooled blanket failed after 8 minutes exposure to flames in waves. A hot spot caused the cover to burn through to the underlying boom fabric, melting it and causing the flotation chamber to deflate. The failure was related to water distribution to the blanket which was hampered by a loose water coupling and using only four water distribution hoses.

The Oil Stop, Inc. water-cooled blanket passed two series of burn tests (it was evaluated in 1998 and again in 2000). In 1998 all three one-hour burns were done in waves; in 2000 only the second hour of exposure to flames was in waves. As with the other water-cooled blankets, it was noted that the boom had a tendency to roll over in waves due to the weight of the cooling water.

The Oil Stop, Inc. Auto Boom Fire Model showed some signs of cracking of its outer stainless steel mesh cover after the Pre-Burn Stress Test. After the first hour's burn many more cracks in the mesh were noted and it was observed that the underlying refractory felt mat was beginning to degrade. It was necessary during the first hour to increase the rate of the air blower in order to keep the boom fully inflated. During the one hour cool down in waves alone, it was also necessary to increase the blower rate. At the beginning of the second burn, it was necessary to set the blower at full speed in order to counteract the far end of the boom sagging. Fourteen minutes into the second hour the far end of the boom was being over-washed by the waves and 24 minutes into the second burn, the far end of the boom sank and the test was terminated. A large hole had been worn into the top of the boom.

## **CONCLUSIONS**

The Ohmsett air-enhanced propane fire protocol has been used to safely and successfully

test 11 fire boom systems. These include: three refractory fabric booms, one stainless steel boom, three water-cooled blanket prototypes, three reflective/insulating blanket prototypes, and one water-cooled boom. Based on these tests, it can be concluded that:

- well designed stainless steel fire boom can survive a large number of operational burns at sea;
- well designed water-cooled booms can survive a large number of operational burns at sea, but can become top-heavy and roll on their side;
- refractory fabric fire booms, depending on design, will likely survive one to four operational burns at sea before requiring replacement;
- well designed water-cooled blankets can protect underlying US Navy boom for several operational burns at sea, but will render the boom top heavy and highly susceptible to rolling over on to their side; and,
- reflective/insulating blankets can provide short-term protection to underlying booms exposed only to radiant heat loads experienced near an *in situ* burn.

## **ACKNOWLEDGEMENTS**

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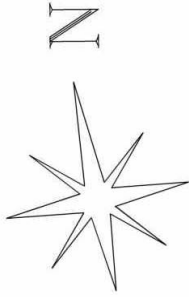
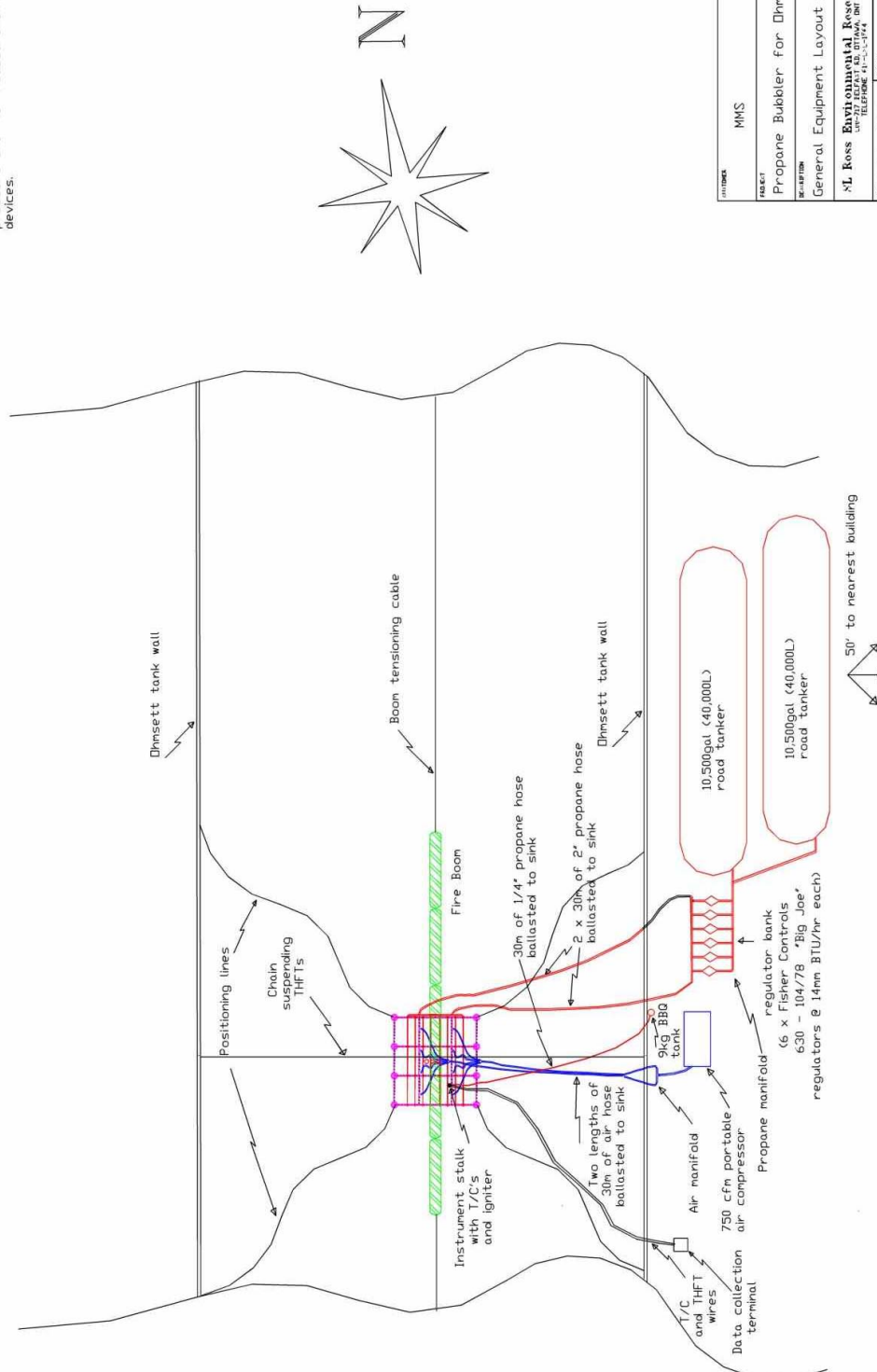
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Note:

1. Air manifold c/w temperature, pressure and pneumatic flow measurement devices.
2. Propane manifold c/w temperature, pressure and flow measurement devices.

Figure 1



MMS	
PROJECT	Propane Bubbler for Dimsett
DATE	2010-07-08
General Equipment Layout at Tank	
XL Ross Environmental Research Ltd	
200-2222 JAVANUP RD, WILLOWDALE, ONT	
TEL: 416-754-1111 FAX: 416-754-1144	
DATE	2010-07-08
SCALE	AS SHOWN
DESIGNER	JDM
REV	P8D-Site

A	REV	DATE	BY	REVISION

FILE: 2010 JAVANUP-1 - ALUMINUM.BUBBLER.MXD

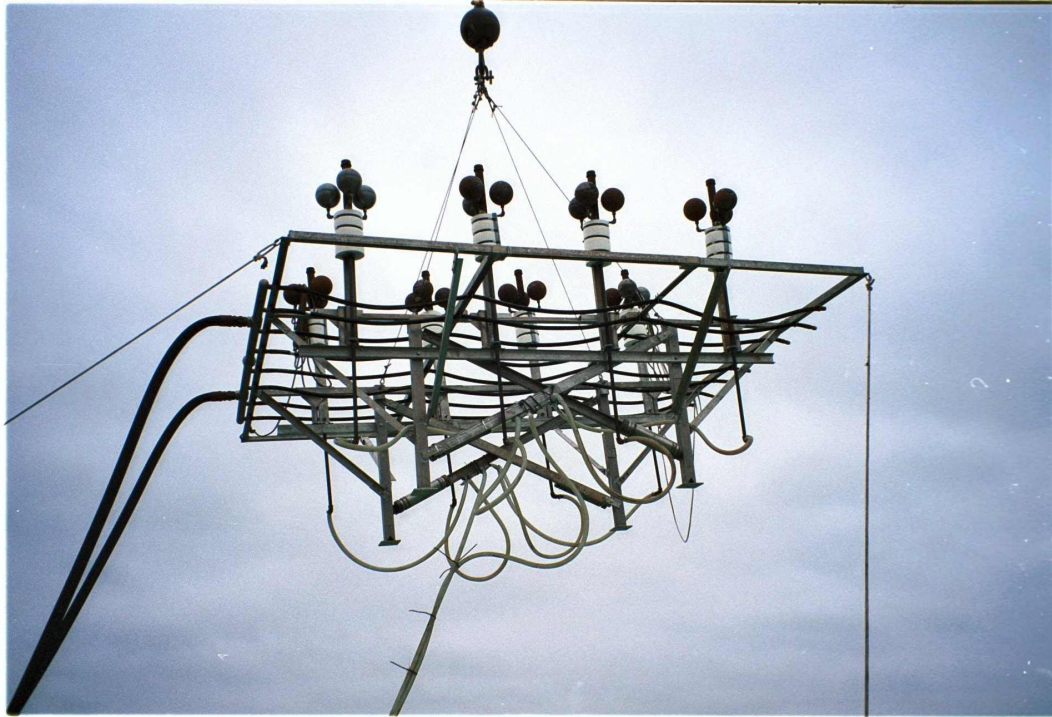


Figure 2. Propane bubbler frame being lowered into tank. Note compressed air stand pipes.



Figure 3. Propane road tankers parked at east side of tank.



Figure 4. Propane regulators and compressed air control valves.



Figure 5. Boom undergoing burn test in waves.

**Table 1. Summary of Fire Boom System/Component Test Results**

Name	Type	Test Results					Thick Oil Test	Comments
		Pre-Burn Stress	1 <sup>st</sup> hr	2 <sup>nd</sup> hr	3 <sup>rd</sup> hr	Post-Burn Stress		
ACS SWEPI <sup>1</sup>	Refractory	Pass	Pass	Pass	Pass	Pass	56 mm	Waves overwashed boom during burns 56 mm filled boom to bottom
AFTI Pocket Boom <sup>2</sup>	Steel	Not Done	Pass	Pass	Pass	Not Done	Not Done	Some minor cracks in top of connectors after third burn
AFTI Reflective Blanket #1 <sup>3</sup>	Al-Zetex w felt	Not Done	Second best-12 feet from fire			Not Done	Not Done	Prevented boom from heating to > 280°F for 10 minutes
AFTI Reflective Blanket #2 <sup>3</sup>	SS mesh	Not Done	Third best-16 feet from fire			Not Done	Not Done	Boom temp exceeded 280°F, some discoloration of blanket surface
AFTI Reflective Blanket #3 <sup>3</sup>	Al-Zetex	Not Done	Best-10 feet from fire			Not Done	Not Done	Prevented boom from heating to > 280°F for 10 minutes
E/AM Fire Boom <sup>4</sup>	Refractory	Pass	Pass	Marginal	Fail	N/A	Failed after 4 hr	tests conducted in Ottawa, holes in fabric after 2 hr, significant abrasion after 3 hr
E/AM Hydro Fire Boom <sup>5</sup>	Water cooled	Not Done	Pass	Pass	Pass	Not Done	Not Done	Fire tests only. Difficulty keeping boom from rolling over when wet
E/AM Blanket <sup>3</sup>	Water cooled	Not Done	Pass	Pass	Fail @ 46 min	Not Done	Not Done	Failed at connector. Underlying boom section holed and deflated
EMTA Blanket <sup>5</sup>	Water cooled	Not Done	Fail @ 8 min	-	-	Not Done	Not Done	Hot spot burned through to underlying boom
Oil Stop Blanket <sup>3,5</sup>	Water cooled	Not Done	Pass	Pass	Pass	Not Done	Not Done	Passed both test series (1998 and 2000). Boom rolled over when wet.
Oil Stop Auto Boom Fire Model <sup>1</sup>	Refractory	Pass	Pass	Fail @ 24 min	-	Not Done	Not Done	Some cracking after pre-burn test, more cracks after first burn, sank during second.

<sup>1</sup> Buist et al. 2001a

<sup>2</sup> SL Ross 1999

<sup>3</sup> SL Ross 2000

<sup>4</sup> McCourt et al 1998

<sup>5</sup> Stahovec et al. 1999