S & T COMMITTEE
THE EFFICACY OF FIRE RESISTANT CONTAINMENT BOOMS
A Response Tool for In Situ Burning of Oil

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SUMMARY

The purpose of this fact sheet is to provide information on fire resistant containment booms to Regional Response Teams (RRTs) and On-Scene Coordinators (OSCs) to use in developing plans for *in situ* burning. Most response plans for *in situ* burning at sea call for the use of fire resistant boom to contain the oil and maintain slick thickness dauring the burn. Due to the limited window of opportunity to burn an oil spill, equipment needs to be pre-staged, particularly in regions where *in situ* burning has been pre-approved. Fire boom containment systems do exist and have been used in experimental and accidental burning situations. However, previous tests on fire booms have shown that current systems need improvements in performance, handling, and durability. In order for *in situ* burning to reach its full potential as an effective response tool, new concepts and material combinations must be developed for fire resistant booms.

BACKGROUND

Although, the first instance of *in situ* burning occurred during the TORREY CANYON in 1967, fire resistant containment booms were not developed until the 1980's. Various burn tests were conducted throughout the '70's and early '80's which evaluated the burning of oil in different environments. Based on these tests, it was determined that several different factors affect the feasibility of *in situ* burning, including the oil type, the slick thickness, the weathering of the oil, and the sea state (See NRT Fact Sheet, Aug. 1992). Development of fire containment booms began after it was determined that an oil slick must be at least 2 to 3 mm thick to achieve a sufficient burn rate. In order to maintain this thickness, a fire resistant containment boom was necessary.

The development of reliable fire resistant containment booms has been hindered by lack of public acceptance of *in situ* burning as a response tool. Public concerns over air emissions from *in situ* burning of a spill have not only inhibited the development of contingency plans for the use of *in situ* burning, but also have deterred development of better technologies with which to conduct effective burns. With the passage of the Oil Pollution Act and increasing pressure to explore alternative response technologies, there have been increased research efforts addressing many concerns associated with non–mechanical response technologies, including *in situ* burning. As a consequence, there has been gradual acceptance of this technology by RRTs and OSCs and inclusion of *in situ* burning in contingency plans. This regional activity has led to a closer evaluation of this technology in meeting operational expectations, including the survivability and at–sea capabilities of fire resistant booms.

STATUS OF CURRENT TECHNOLOGY

Since the 1980's, various fire resistant containment booms and products have been developed and tested. Most fire boom designs have similar characteristics to non-fire booms, such as inflatable or foam flotation chambers, skirt ballast chains, and standard end connectors. Three different types of fire resistant booms are currently available: thermally resistant fabric booms, stainless steel booms and water cooled booms. Fire booms are primarily constructed of either metals or refractory fibers. Those made of metals usually have metal flotation chambers of spherical, cylindrical, or rectangular shape. Due to the high temperatures and the presence of sea water, metals such as stainless steel or certain alloys of aluminum or copper are chosen because of their resistance to heat and corrosion. The most commonly used metal is stainless steel; it is highly resistant to oxidation and has rupture strengths ranging from 1.5 to 4.5 kilopounds per square inch (ksi) at 1800°F.

Fire resistant booms constructed of refractory fibers use "hot side" materials and are used for applications where flexibility is necessary. Fabrics for these booms are limited to inorganic fibers composed of silica, alumina, zirconia, and boron. These fibers can withstand temperatures ranging from 1800 to 2300°F.

To reduce the surface temperatures of the boom, most fire resistant booms use a process known as "wicking"— the adsorption of evaporated water from the ocean. Some booms also have heat conduction paths and materials which promote rapid transfer of heat to submerged parts of the boom. This heat transfer and/or cooling is essential since temperatures from tank tests have shown that peak temperatures consistently reach 2000°F.

Water cooled booms utilize water supplied through an external manifold with a filter system to continually "soak" the fabric during *in situ* burning operations.

Although some fire resistant booms are stored on reels, many fire resistant booms are stored in containers, requiring more time and personnel for deployment and recovery operations. Most fire resistant booms are made of expensive materials which can easily be damaged during deployment and recovery procedures, making deployment for training purposes a risky and possibly expensive endeavor.

Based on past burn experiences, 500 to 1,000 feet of fire resistant boom is needed to form a "U" configuration for containment. Recent tank tests at the National Oil Spill Response Test Facility (OHMSETT) in Leonardo, New Jersey have shown that oil can be contained in fire resistant booms up to towing speeds of 1.3 knots. Fire resistant booms at OHMSETT all yielded results comparable with non-fire booms, specifically all fire resistant booms were able to contain pre-load volumes of oil at 0.85 knots and above in calm water.

During a burn, the fire resistant boom material may not be able to withstand towing. Prior to burning, the fire resistant materials have high tensile strengths. After burning, most materials become brittle and may not be able to withstand higher tow forces.

RESEARCH AND DEVELOPMENT EFFORTS

The first *in situ* burn which used booms for containing an oil slick was in 1980 at Port Melon, British Columbia. This was a static test of a stainless steel fire boom using Redwater crude oil. The boom was further tested at the test facility in 1981. Further static and wave tank tests were performed in 1983 at Prudhoe Bay. These were the first tests to focus on the performance and use of fire resistant booms.

From 1981 to 1992, various *in situ* burn tests were performed utilizing fire containment booms. Most tests were concerned with the chemistry and physics of the burn, particularly the emissions produced from burning oil. The most significant test focusing on booms was done in 1986 in Alaska. A series of seven 24 hour burns were performed, testing four fire containment concepts. The survivability of booms was evaluated based on flexibility, strength, weight, and ease of handling after the burn. Temperature measurements for the flames ranged from 1200 - 1750°F. Surface temperatures on the fire side of the boom ranged from 250 -1000°F for the various booms tested. Tow tests were also performed on each boom at a tank facility to evaluate wave performance, tow stability, and oil containment capacity. Results from these tests indicate that the critical tow speed for most of the booms was approximately 1.2 knots, after which drainage failure occurred.

The Newfoundland Offshore Burn Experiment (NOBE) in 1993, which did not focus on fire containment booms, produced some unexpected results affecting boom development. First, the burn produced sustained surface temperatures that were higher than previous open pit and tank tests. Secondly, the peak temperatures which were experienced occurred at higher points on the floatation chamber of the boom. In general, sea conditions took a much larger toll on the fire containment boom than was expected from previous tank tests.

Fire boom evaluations using propane were conducted in 1996 and 1997, by S.L. Ross Environmental Research Ltd., sponsored by the U.S. Minerals Management Service (MMS) and the Canadian Coast Guard. The propane test evaluations were conducted in a wave tank located at the Canadian Hydraulic Centre, National Research Council of Canada in Ottawa. The wave tank was constructed of concrete and was 120 m long by 60 m wide by 3.3 m deep. A pneumatic wave maker at one end of the tank was used to generate waves up to 0.6 m. The fuel used was commercial propane. Liquid propane from a storage tank was heated to create gaseous propane and piped to an underwater bubbling system. Flames were applied to both sides of the fire boom to simulate the exposure observed in liquid hydrocarbon fires. In the 1996 tests, propane alone was used. In the 1997 tests, compressed air was injected into the flames through nozzles located around the boom. The heat flux measured in the 1997 tests with air enhanced propane were comparable to those measured in the diesel fuel fires.

Fire boom test evaluations, using diesel fuel were conducted in 1997 and 1998, by the National Institute of Standards and Technology (NIST), and sponsored by the U.S. Coast Guard Research and Development Center and MMS. The test evaluations were conducted in a wave tank designed specifically for evaluating fire resistant containment boom, located at the U.S. Coast Guard Fire and Safety Test Detachment facility on Little Sand Island in Mobile Bay, Alabama. The wave tank was constructed of steel and was 30.5 m long by 9.1 m wide by 1.5 m deep. A wave maker at one end of the tank was used to generate waves up to 0.3 m. The wave tank was designed to accommodate a nominal 15 m boom section, forming a circle approximately 5 m in diameter. The test cycle consisted of three one-hour burning periods with two one-hour cool down periods between the burning periods. Waves were run throughout the entire test cycle.

In 1997, five booms were evaluated and in 1998, six booms were evaluated. Test results have been submitted to the American Society of Testing and Materials (ASTM) F-20 Committee for use in developing the Standard Guide for In Situ Burning of Oil Spills on Water: Fire-Resistant Containment Boom. The tests also provided information to the boom manufacturers on the performance of their product. Four of the six booms evaluated in 1998, were shipped to the OHMSETT facility for post-burn oil containment and tow tests based on ASTM suggestions. In general, there was some degradation of materials in all booms. Further, it appears that many booms had not reached a steady-state condition in terms of degradation. That is, for many booms, if they had been subjected to further fire exposure, further material degradation would have taken place. Since the principal purpose of these tests was to evaluate the test protocol, the booms were not rated as passing or failing.

Two separate fire resistant boom test evaluations, using air-enhanced propane were conducted in the fall of 1998, by MAR INC. and S.L. Ross Environmental Research Ltd. The first test was conducted October 23-29, 1998 and was sponsored by MMS and the U.S. Navy Supervisor of

Salvage (SUPSALV). Three candidate fire protection systems were tested and evaluated. Each consisted of a water-cooled blanket designed to be draped over existing U.S. Navy USS-42HB Oil Boom to protect its exposure to an in situ oil fire. Each 55-foot long blanket was water-cooled using tank water supplied through an external manifold with a filter system, flow meter, and control valve. The second fire boom evaluation was conducted on November 24, 1998 and was sponsored by MMS. A prototype stainless steel Pocket Boom was tested and evaluated using the air-enhanced propane system. The Pocket Boom was a redesign of the Dome Boom originally developed as a high strength, offshore system for use in Arctic seas. A consortium of eleven different Federal agencies and private industry companies sponsored the re-engineering of the Dome Boom to reintroduce its size, weight, cost and ease of boom handling.

Both tests were conducted at the OHMSETT facility in Leonardo, New Jersey. The above ground concrete wave tank was 203 m long by 20 m wide by 3.3 m deep. A hydraulic wave maker at one end of the tank was used to generate waves up to 0.6 m. The fuel used was commercial propane. Liquid propane from a storage tank was heated to create gaseous propane and piped to an underwater bubbling system. Flames were applied to both sides of the fire boom to stimulate the exposure observed in liquid hydrocarbon fires. The test cycle consisted of three one-hour burning periods with two one-hour cool down periods between the burning periods. Waves were run throughout the entire test cycle.

Overall, the test protocol and its application were considered successful with both diesel fuel and air-enhanced propane. The propane fuel test method appears promising for future use, particularly since very little visible smoke is produced and it can be routinely used at the OHMSETT facility. Based on the results of recent testing, several issues have been identified for further consideration.

1. Does the fire size and duration coupled with wave action represent a realistic thermal and mechanical exposure? Although it is based largely on subjective observations, the fire and wave exposures used in both the diesel fuel and propane tests appear to provide a reasonable representation of actual *in situ* burn conditions. However, at present, there is not adequate data available to compare a test performance to performance in an actual at-sea burn.

2. How does wind speed and direction affect thermal exposure to boom? The impacts of wind speed and direction on the thermal exposure are difficult to quantify.

3. Should replicate tests be required? When evaluating a test method it is usually desirable to conduct multiple tests with the same product to determine if the method is repeatable. Production of prototype fire booms are expensive to manufacture and tests are expensive to conduct.

4. What evaluation criteria should be applied to the booms at the end of the test? The criteria for evaluating a boom is one of the most difficult and sensitive issues. It is unlikely that a numerical rating could be developed for these tests so a pass or fail criteria may be the best option.

PROTOCOLS AND STANDARDS

Oil spill planners and responders need to know the expected performance of fire resistant oil spill containment booms. The ASTM F-20 Committee has developed the draft Standard Guide for In Situ Burning of Oil Spills on Water: Fire Resistant Containment Boom. The draft standard could be considered a guideline since it does not provide all of the specific details necessary to conduct an evaluation of fire resistant booms. It does provide, however, some general performance requirements related to the collection and burning of oil. Since it is a draft document under development, the standards continue to be revised. The draft dated February 14, 1997 was used to develop the test protocol. The draft guide states that fire resistant booms should be able to withstand oil fires on calm or turbulent, fresh or salt water. Minimum requirements should include the following:

1. Performance and survival in temperatures up to 1300C.

2. The test cycle should consist of three one-hour burning periods with two one-hour cool down periods between the burning periods. Waves should be run throughout the entire test cycle. Wave characteristics have not been specified.

3. Maintain a positive freeboard.

4. Maintain a post-burn buoyancy to weight ratio of 15:1.

5. The boom should maintain adequate floatation during the fire exposure and contain a layer of oil 10 nm to 20 nm in thickness without loss.

It should be noted that in regions where pre-approval plans allow burning beyond state waters, which would classify the operating conditions as open waters, ASTM standards for other oil containment booms can also apply to fire boom selection. (These standards are listed in the references.)

RESEARCH AND DEVELOPMENT NEEDS

In November 2-4, 1998, MMS sponsored a second In Situ Burning of Oil Spills workshop, to review the current state of knowledge of in situ burning and to prioritize future research efforts to improve the use of *in situ* burning. During the workshop, concerns were raised over the current fire boom technology. The following research was suggested to improve the status of fire boom technology:

1. Continue performance testing of fire resistant oil spill containment booms.

2. Standardize boom testing through development of ASTM standards.

3. Improve durability, transportability and deployment.

4. Develop fire resistant boom for use in rivers.

5. Conduct large spill response exercises with real oil.

Although fire resistant booms are still not as robust and desirable so as to withstand multiple burns in diverse environmental conditions, significant advances are being made to develop standardized testing procedures that will reflect these requirements and allow valid comparisons of different booms to be made.

REFERENCES

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