ALASKA CLEAN SEAS TEST AND EVALUATION OF FIRE CONTAINMENT BOOM

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ABSTRACT

Four fire containment booms have been tested and evaluated for their resistance to fire during 24-hr exposures to burning crude oil. Seven individual burn tests were conducted using FireGard Boom (Kepner Plastics Fabricators, Inc.), PYROBOOM (Globe International, Inc.), SWEPI Fire Containment Boom (Shell Western E&P Inc.), and 3M Fire Boom Blanket (3M/Ceramic Materials Department). Each boom was connected in a closed loop and placed within a steel tank 3 m (10 ft) on a side. Thermocouples were positioned within the booms and at various locations in the test tank. Cook Inlet crude oil was fed continuously to the center of each containment area at approximately 2.8 to 3.8 liters/min (3/4 to 1 gal/min) and ignited. The performance of each boom was documented on videotape, and temperature profiles were recorded for each thermocouple. The results of these tests are summarized along with an overall assessment of each system's physical and operational strengths and weaknesses. Included is a summary of several tests conducted to evaluate the oil-holding capacity and wave-riding characteristics of each boom. These tests were conducted with and without an oil simulant in waves up to 0.6 m (2 ft) in height and with currents of 0.2 to 0.6 m/sec (0.4 to 1.2 kt).

INTRODUCTION

This paper contains a summary of a much more extensive report prepared by Spiltec for Alaska Clean Seas (ACS), an oil-industry-sponsored oil spill response organization based in Anchorage, Alaska. The original report, Test and Evaluation of Fire Containment Boom (Spiltec, 1986), presents the results of one of several R&D efforts sponsored by ACS during 1985. Shell Western E&P Inc. (SWEPI) served as the ACS administrator during all phases of the project.

Four fire containment concepts were evaluated during the course of this project including:

- FireGard Boom -- A bottom-tensioned, reelable boom, manufactured by Kepner Plastics Fabricators, Inc., with two layers of fire-resistant fabric positioned over a coil and foam flotation system.

Environment Canada. Arctic and Marine Oilspill Program (AMOP) Technical Seminar, 9th. Proceedings. June 10-12, 1986, Edmonton, Alberta, Canada, Environment Canada, Ottawa, Ontario, 187-201 pp, 1986.

- PYROBOOM -- A fence boom manufactured by Globe International, Inc. and using external steel hemispherical floats. The above-water portion of the boom is protected by a wire-reinforced, specially coated refractory material, while the skirt of the boom is a conventional impermeable material weighted with lead discs.

- SWEPI Fire Containment Boom -- A bottom-tensioned, cylindrical-flotation boom, designed by Shell Western E&P Inc. (SWEPI), and manufactured by Fire Control, Inc., with multiple layers of fire-resistant, wicking fabric positioned over steel canisters for flotation. An additional sacrificial layer and a coarse wire-mesh barrier are used externally for abrasion resistance.

- 3M Fire Boom Blanket -- A multi-layered, fire-resistant blanket, provided by 3M/Ceramic Materials Department, for use as an add-on with most conventional types of boom for the containment of burning oil. The blanket is held in position by any number of fastening systems requiring installation of the fasteners to the support boom in advance.

Other existing fire-resistant booms were not included in this test program because they did not meet certain operational and financial constraints.

OBJECTIVES

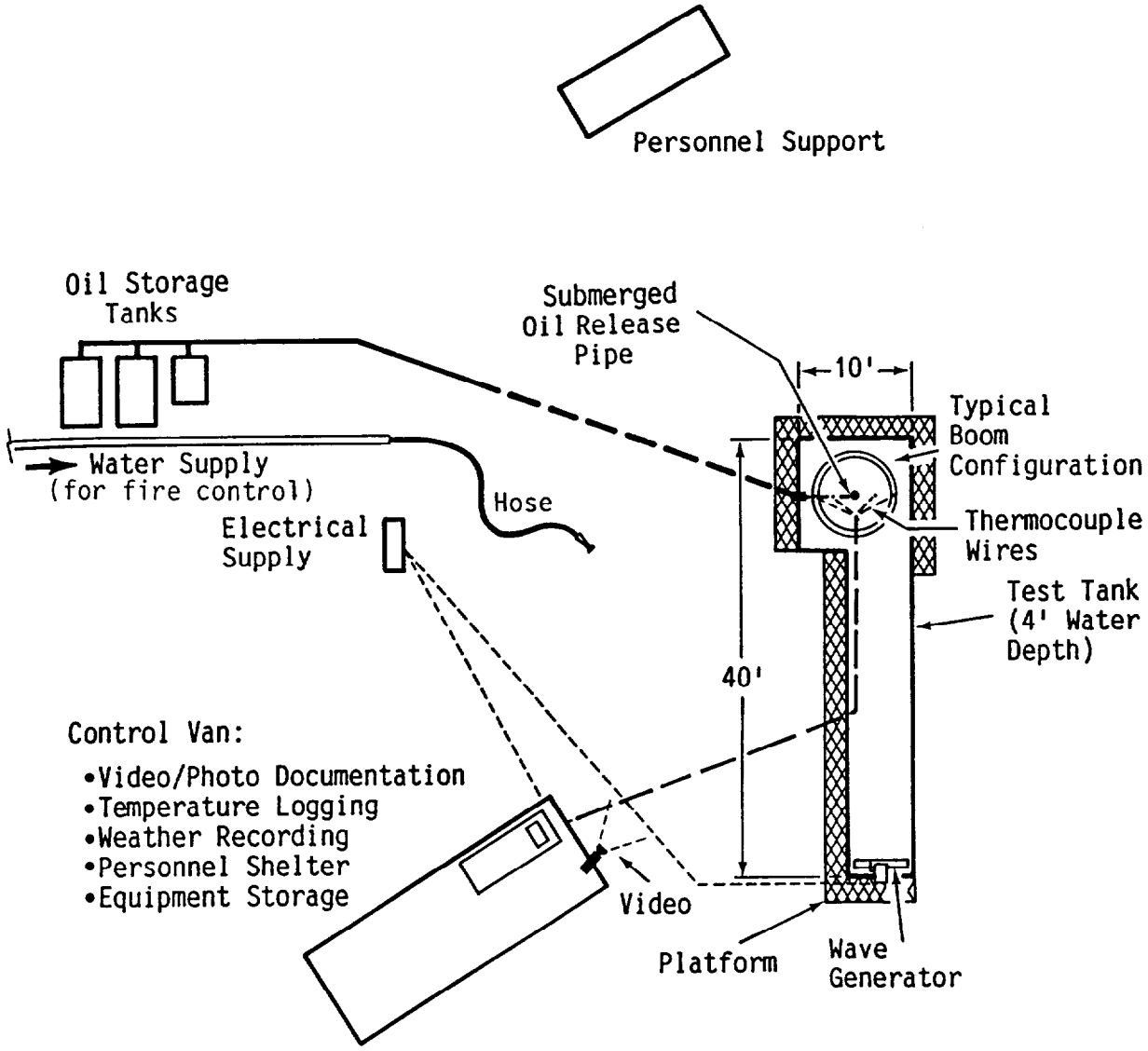
Several individual burn tests were conducted in a test tank at an onshore facility in Kenai, Alaska. The objective of these tests was to expose the above fire containment systems to burning crude oil for 24 hr. The survivability of each system was to be evaluated during each burn test; and qualitative assessments were to be made of such characteristics as flexibility, strength, weight, and ease of handling.

During separate wave-tank tests at Shell Oil Company's Westhollow Research Center in Houston, Texas, each of the above containment systems would then be exposed to a range of towing speeds and wave conditions. These tests (funded independently by SWEPI) would serve to evaluate the oil or oil-simulant holding characteristics and the wave-riding and tow-stability aspects of each system.

TEST FACILITIES AND PROCEDURES

Kenai Test Facilities

The test facilities for the fire containment boom burns were set up at the Kenai Community College's fire control training site in Kenai, Alaska (Figure 1). All tests carried out during this project were conducted with Cook Inlet crude oil (35° API) provided by SWEPI. All tests were also conducted in fresh water. Prior to each test, thermocouples were mounted on posts in the test tank so that each thermocouple could be positioned a few inches above the water surface at several locations within the burn region of each boom. In addition, project personnel worked with the manufacturer's representatives prior to each burn test to determine the desired locations for thermocouples on or within the boom to be tested.



Fire Containment Boom Test Facility

Location: Kenai Community College Fire Control Training Site, Kenai, Alaska

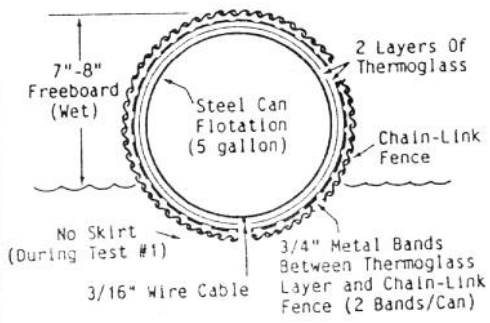
Test Tank: 40-ft long, 5-ft-high steel tank with 10 ft x 10 ft area for placement of boom.

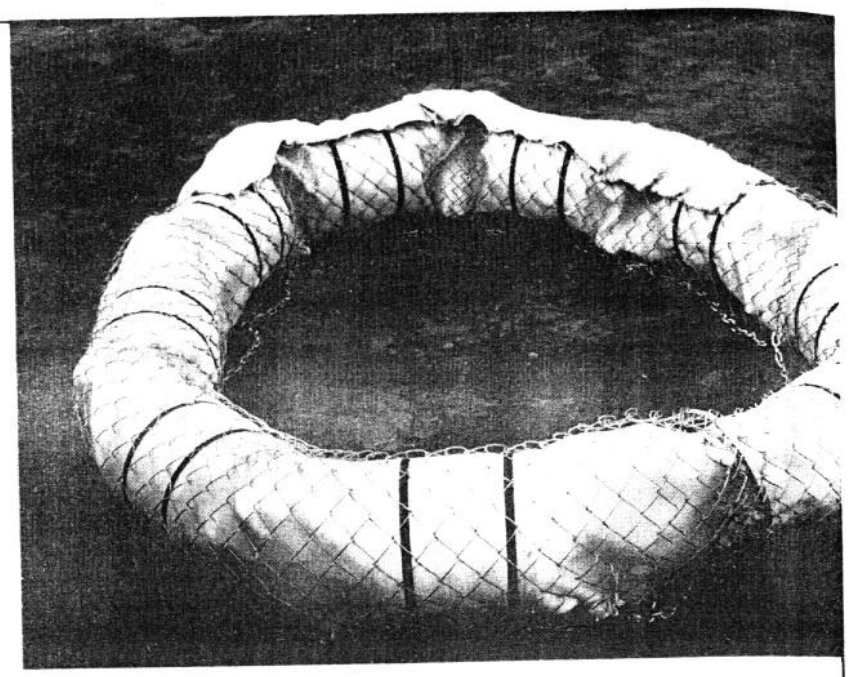
Oil Storage & Transfer: Two 500-gal containers plus one 300-gal container, elevated to provide 3/4 to 1 gal/min continuous gravity feed to test tank.

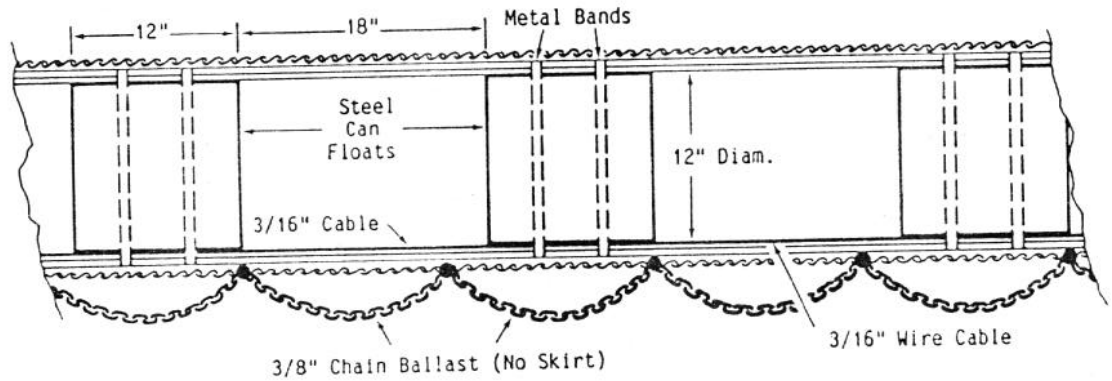
Oil: Fresh Cook Inlet crude oil (35° API)

Support Facilities & Equipment: As shown above.

FIGURE 1 KENAI TEST FACILITY







Abrasion Protection: Chain-link fence placed completely around upper, flotation portion of boom.

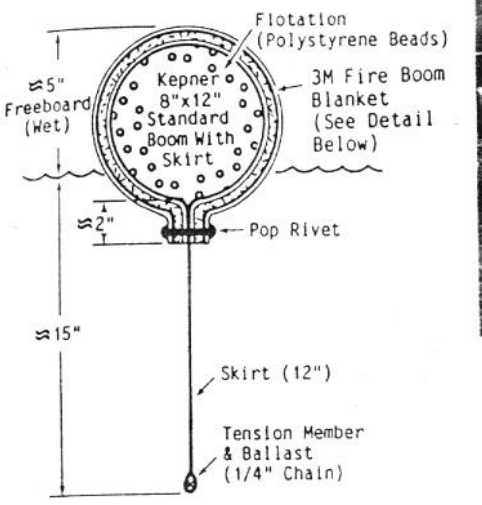
Fire Protection: Two layers of 70 oz. Thermoglass held adjacent to flotation cans with steel bands.

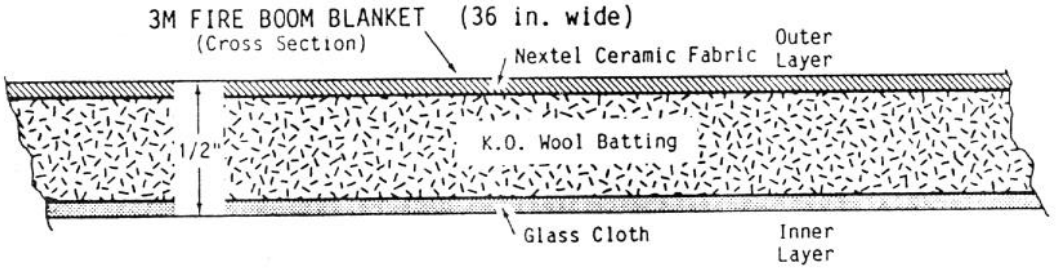
Flotation: 5-gal metal cans, 18 in. apart and attached to 3/16-in. cable.

Skirt: None used in this test.

Tension/Ballast: 3/16-in. cable for tension. Cable plus 3/8-in. chain connected to wire fence for ballast.

FIGURE 2 SWEPI FIRE CONTAINMENT BOOM WITH CHAIN-LINK OUTER COVER AND NO SKIRT (TEST NO. 1)





Outer Layer: #312 Nextel, open-mesh ceramic continuous-filament fabric by 3M, St. Paul, Minnesota. Fabric neoprene-coated.

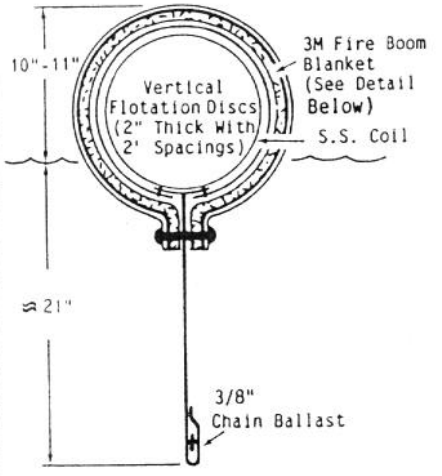
Middle Layer: K.O. Wool, ceramic batting (short staple fibers) by Babcock & Wilcox, Augusta, Georgia.

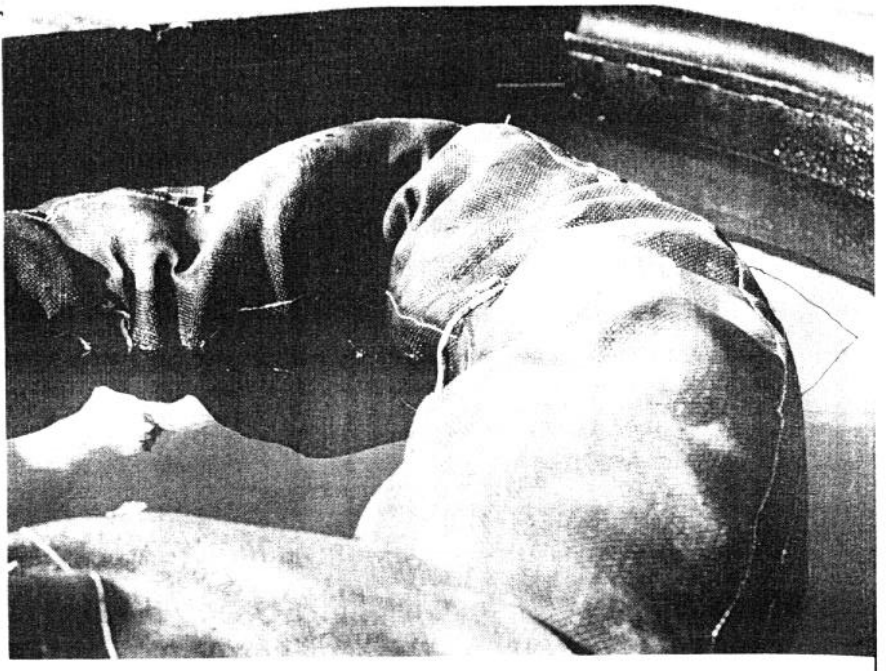
Inner Layer: Glass Cloth, Style 1583, fiberglass fabric by Schwabbel, White Plains, N.Y.

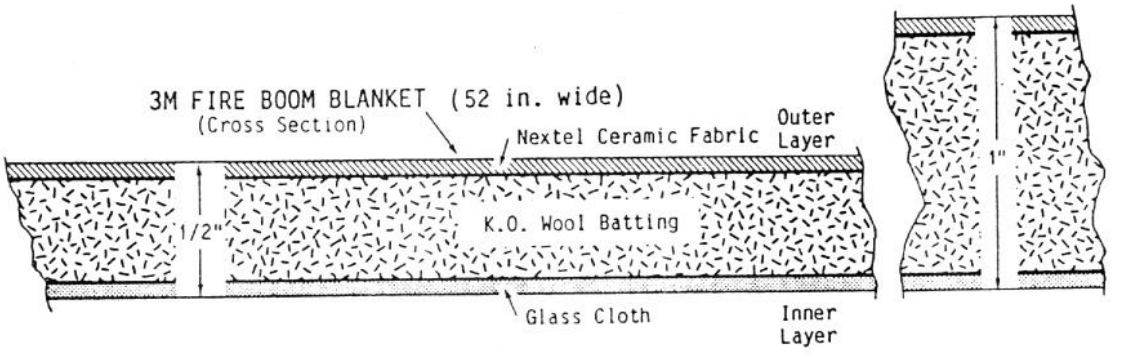
Connectors: Pop-rivets placed through blanket and skirt material every 12 inches.

Support Boom: Kepner Standard Boom with 8-in. flotation, 12-in. skirt, and polystyrene beads as filler. Fabric cover, 22-oz. PVC. Ballast, 1/4-in. chain. No connector plates used.

FIGURE 3 3M FIRE BOOM BLANKET OVER KEPNER 8" X 12" STANDARD BOOM, BEAD-FILLED (TEST NO. 2)







Outer Layer: #312 Nextel, open-mesh ceramic continuous-filament fabric by 3M, St. Paul, Minnesota. Fabric neoprene-coated.

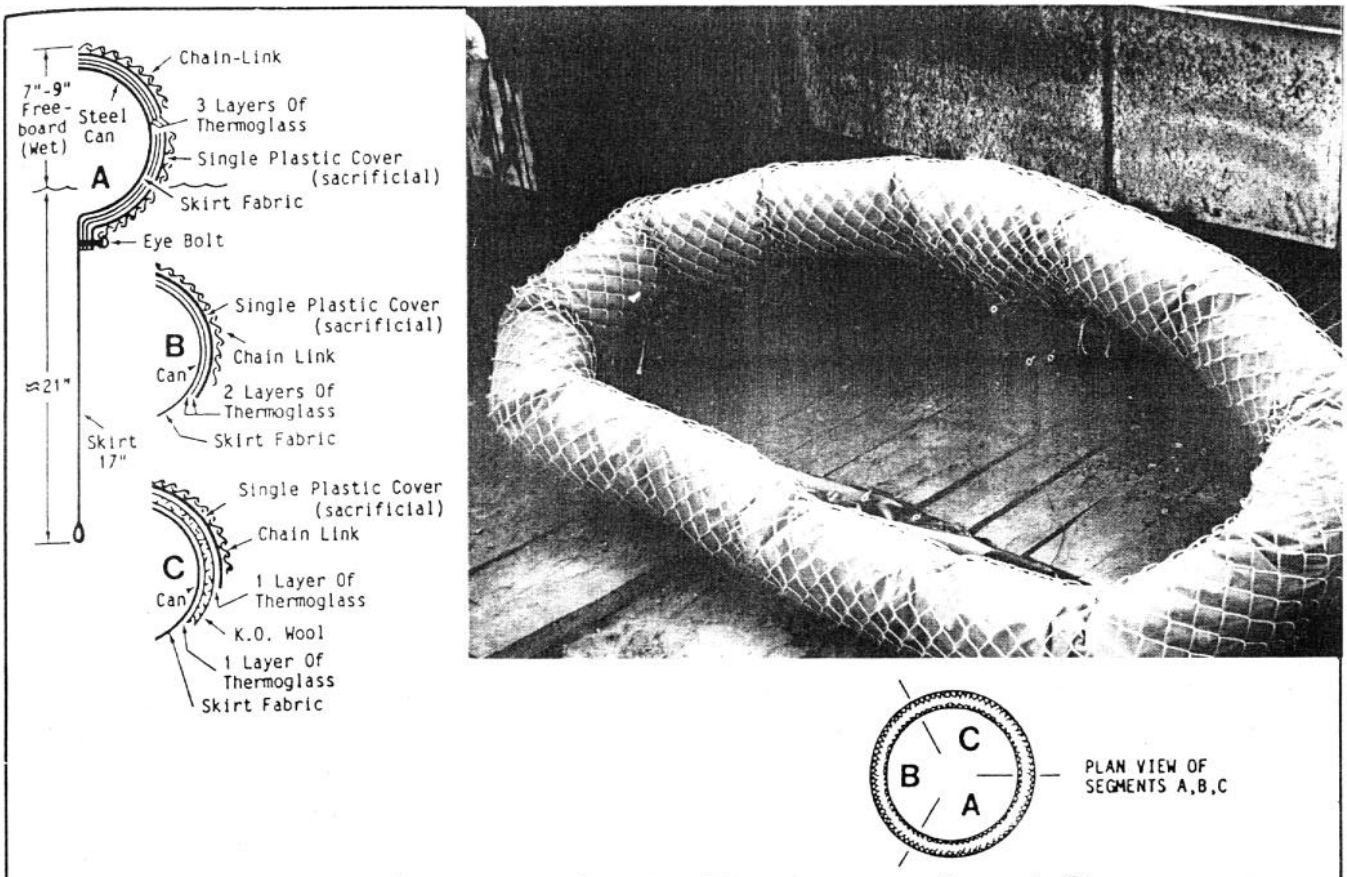
Middle Layer: K.O. Wool, ceramic batting (short staple fibers) by Babcock & Wilcox, Augusta, Georgia. Half of boom had 1/2-in. batting, and half had 1-in. batting.

Inner Layer: Glass Cloth, Style 1583, fiberglass fabric by Schwabbel, White Plains, N.Y.

Connectors: Pop-rivets placed through blanket and skirt material every 12 inches.

Support Boom: Kepner Compactible Boom with 14-in. flotation, 18-in. skirt, and PVC-fabric-covered coils. Flotation provided by air inside covered coils, plus 2-in. thick polyurethane foam discs spaced 2 ft apart. Ballast, 3/8-in. chain. No connector plates used.

FIGURE 6 3M FIRE BOOM BLANKET OVER KEPNER 14" X 18" COMPACTIBLE BOOM (TEST NO. 5)



Abrasion Protection: chain-link fence connected to eyebolts beneath flotation on each side of skirt (all 3 segments). Plastic (sacrificial) cover beneath outer fence material.

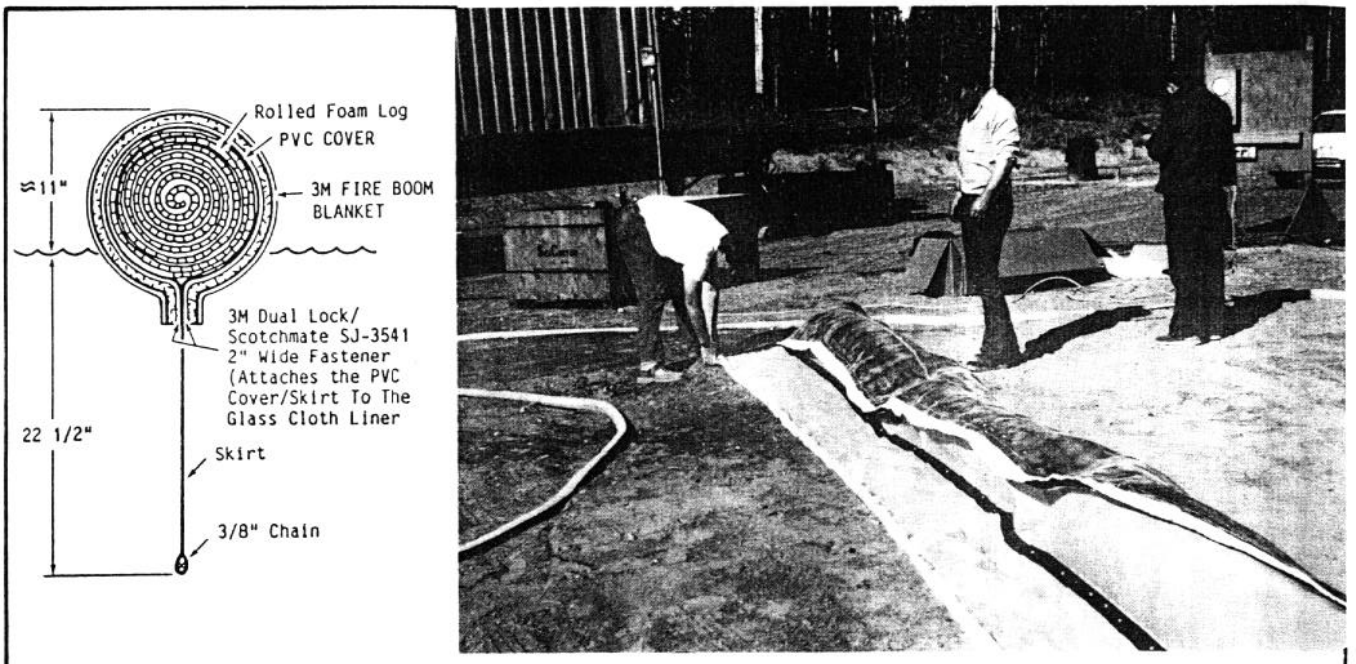
Fire Protection: Segment A: Three layers of 70-oz. Thermoglass. Segment B: Two layers of 70-oz. Thermoglass. Segment C: 1/2-in. K.O. Wool (see Fig. 3, Test 2) between two layers of 70-oz. Thermoglass.

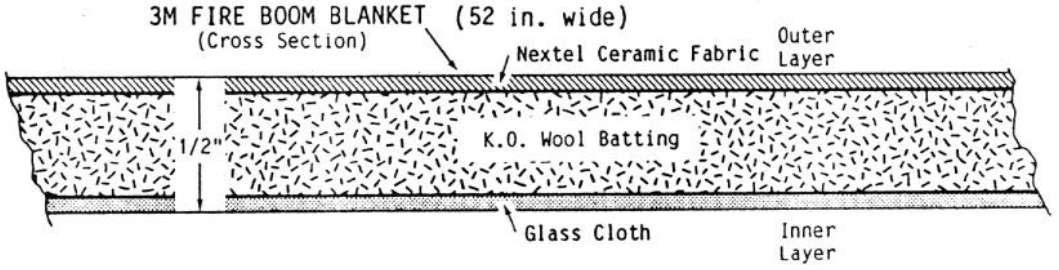
Flotation: 5-gal steel cans, 6 in. apart attached with steel bands directly to 3/16-in cable.

Skirt: 17-in. PVC skirt continuing up and around flotation cans.

Tension/Ballast: 3/16-in. cable for tension. 9/32-in chain for tension and ballast.

FIGURE 7 SWEPI FIRE CONTAINMENT BOOM WITH THREE EXPERIMENTAL TEST SEGMENTS INCLUDING SKIRT (TEST NO. 6)





Outer Layer: #312 Nextel, open-mesh ceramic continuous-filament fabric by 3M, St. Paul, Minnesota. Fabric neoprene-coated. One 7½-ft side of boom covered with light-gauge, woven stainless-steel mesh for experimental purposes.

Middle Layer: K.O. Wool, ceramic batting (short staple fibers) by Babcock & Wilcox, Augusta, Georgia.

Inner Layer: Glass Cloth, Style 1583, fiberglass fabric by Schwabbel, White Plains, N.Y.

Connectors: 2-in.-wide strips of 3M Dual Lock/Scotchmate (SJ-3541) fasteners (half of fastener strip glued to PVC cover beneath flotation, other half glued to inner glass-cloth liner of blanket). Fastener strips run full length of boom.

Support Boom: Kepner Standard Boom with 14-in. flotation, 18-in. skirt, and PVC-covered, rolled foam log for flotation. Ballast, 3/8-in. chain. Connector plates, standard Kepner extruded aluminum plates, shortened to fit under blanket.

FIGURE 8 3M FIRE BOOM BLANKET OVER KEPNER 14" X 18" STANDARD BOOM, ROLLED FOAM LOG (TEST NO. 7)

original project report available from ACS, Anchorage, Alaska (Spiltec, 1986). Table 1, however, presents a summary of the results from both the Houston wave and current tests and the Kenai burn tests. It is recognized that some of the assessments made are subjective, therefore relying upon the judgement of personnel conducting the tests and preparing the text of this report. Every effort has been made to present the results of the tests as fairly and as accurately as possible, while avoiding the very natural tendency to make comparisons between the containment systems. Any meaningful comparison would have to reflect the different performance objectives and the modes of use for which each system might be selected, as well as storage and individual cost considerations.

For example, a particular containment system might involve materials that are highly resistant to abrasion; however, such characteristics may not be necessary if the system is never expected to be exposed to ice, debris, or frequent rough handling. Under another set of conditions, a potential user may need a system that must be deployed and recovered frequently with a very low probability of ever being needed for the containment of fire. The durability and ease of handling in this case would represent important characteristics against which the system's resistance to fire would have to be weighed. These and many other factors, such as the expected duration of any fire and the seas under which containment would be required, help emphasize the fact that no one system is necessarily best for all potential fire containment situations.

Because of the many operational considerations that go beyond the oil containment and fire resistance characteristics of a boom, Table 2 is provided as a summary of other considerations pertinent to each of the containment systems as tested. One must keep in mind that the assessments contained in Tables 1 and 2 are based on the specific containment system(s) provided by each manufacturer. In some cases, the manufacturer is capable of providing variations on the size, shape, and/or material used in their particular product. In at least three of the four fire containment systems reported on here, the manufacturers have already indicated that modifications are underway to improve their respective products.

In conclusion, the results of this project suggest that:

- Existing commercially available fire containment systems do exist with the potential of containing burning oil for at least 24 hr;
- Such systems are sufficiently durable and portable to be transported to and deployed at the scene of an offshore or nearshore spill quickly and efficiently; and
- These same systems can be expected to contain oil at least as effectively as most conventional open-ocean booms under waves and current conditions typically attempted with mechanical containment devices.

REFERENCE

Spiltec, 1986. Test and Evaluation of Fire Containment Boom. Prepared under contract to Shell Western E&P Inc., for Alaska Clean Seas, Anchorage, AK.

TABLE 1

BOOM PERFORMANCE SUMMARY

ACS KENAI 24-HOUR BURN TESTS

CRITERIA	FIRECARD	PYROBOOM	SWEPI		FIRE BOOM BLANKET		
	TEST 3 (2 fabric layers on coil)	TEST 4 (single-layer fence boom)	TEST 1 (2 layers, no skirt)	TEST 6 (3-segment experimental test)	TEST 2 (on 8" x 12" solid-fill boom)	TEST 5 (on 14" x 18" coil boom)	TEST 7 (on 14" x 18" solid-fill boom)
OIL CONTAINMENT							
24-hour Burn Test (static test)	No loss of oil	No loss of oil	No loss of oil	No loss of oil	No loss of oil	Lost oil (malfunction) in support boom)	Minor loss of oil (less than 1 gal)
PERFORMANCE DURING BURN							
External Surfaces	Noticeable loss of resistance to abrasion. Fully capable of containing burning oil, though dry and brittle on upper surfaces.	Rapid deterioration of upper refractory material. Baked silicon rubber coating flakes off with minimal abrasion. Strength retained by wire structure. Still impermeable from 4" to 5" above water-line down.	No visible damage. Fabric continually wet and flexible. Slight increase in stiffness due to burn residue buildup. Slight reduction in fabric abrasion resistance. No damage to chain link fencing.	No visible damage in any of the 3 experimental segments. All surfaces wet and flexible. Usual thin buildup of burn residue and slight reduction in fabric abrasion resistance. No damage to chain link fencing.	No visible damage. Slight decrease in resistance to abrasion. Fabric continually wet and flexible. Slight buildup of burn residue.	No visible damage up to point of termination (about 1 hr. burn time).	Significant discoloration and localized brittleness over one 2- to 3-ft section of boom. All other surfaces in excellent condition (wet and flexible).
Internal Components	Second layer also less resistant to abrasion. Fabric impermeable to oil flow at water line, though dry and easily punctured above water line.	N.A.	Second layer of fabric oil-stained in places, though wet, flexible and in excellent condition. No significant reduction in abrasion resistance.	Second layer of Segment B discolored and slightly brittle. Middle K.O. Wool layer in Segment C of questionable value (oil-saturated and unstable consistency). Segment A with 3 layers in excellent condition.	K.O. Wool in good condition, though mushy and easily torn/displaced if exposed or worked excessively. Glass cloth inner liner in excellent condition.	Unsuccessful alteration of coils in Kepner Boom caused mechanical failure of support for blanket.	Same as Test No. 2, except for thermal stress in localized region mentioned above.
Flotation/Freeboard	Fabric-wrapped foam flotation in excellent condition. No loss of freeboard.	Steel shells and foam glass filler in excellent condition though foam was brittle and cracked. No loss of freeboard.	Steel flotation cans undamaged. No loss of freeboard.	All flotation cans undamaged (no loss of freeboard). Slight damage to skirt material around cans in Segments B and C. No thermal stress on skirt material in Segment A (3 layers).	Kepner Boom as support flotation in excellent condition. No signs of thermal stress.	Rapid loss of flotation and freeboard.	Melt-down of 2- to 3-ft of Kepner boom. Reduction in freeboard from 11" to 3". Remaining portion of Kepner boom like new (no reduction in freeboard).
Continued Burn Potential (under similar, static test conditions)	Good	Good	Good to Excellent	Excellent for Segment A Good for Segment B Fair for Segment C	Excellent	None	Of questionable value (1 to 2 hr at most)
Reusability	Highly unlikely. Coil/flotation components could be reused.	Highly unlikely. Flotation system and skirt would be reused.	Highly unlikely. Flotation system could be reused.	Possible for 2nd and 3rd layer of Segment A. All chain-link barrier and flotation system could be reused.	Highly unlikely for blanket. Kepner Boom was oil stained but definitely reusable.	None	None
Recovery	Relatively light and easy to recover. Easy to remove fabric covers.	Relatively light and easy to handle. Handles easily attached for deployment or recovery.	Difficult. Water-saturated fabric quite heavy.	Difficult. Water-saturated fabric quite heavy.	Difficult. Water-saturated fabric quite heavy.	Difficult. Water- and oil-saturated and damaged.	Difficult. Water-saturated and damaged.

SWEPI HOUSTON WAVE TANK TESTS

CRITERIA	FIRECARD	PYROBOOM	SWEPI	FIRE BOOM BLANKET
OIL CONTAINMENT				
Houston Wave Tank (2-ft waves/ 0.4 kt current; (some tests conducted with oil simulant)	Very minor oil loss. Good towing and wave riding characteristics to greater than 1 kt.	Some oil loss. Above 0.7 kt, significant oil loss. Above 0.8 kt, boom unstable.	Very minor oil loss Good towing and wave riding characteristics to greater than 1 kt.	Very minor oil loss Blanket does not reduce oil containability of support boom. Blanket does reduce freeboard of support boom (2" to 3" reduction with Kepner 14" x 18" Standard Boom). No noticeable reduction in wave-riding or towing characteristics.

TABLE 2

FIRE CONTAINMENT BOOM ASSESSMENT: OTHER CONSIDERATIONS

CONSIDERATION	FIREGARD	PYROBOOM	SWEPI	FIRE BOOM BLANKET
Pre-burn Resistance to Abrasion	Thermotex refractory outer cover provides tough, smooth surface. Continuous contours minimize tendency for snagging.	Stainless steel floats are highly resistant to abrasion, offering some protection to fabric as well. Coated refractory material with inconel wire provides good abrasion and puncture resistance. External floats may increase potential for snagging.	Uncoated Thermoglass layers are protected by sacrificial plastic cover and rugged chain-link fence barrier. Though strong and resistant to abrasion, fence material may increase potential for snagging.	Neoprene-coated Nextel outer fabric provides durable, smooth surface. Continuous contours minimize tendency for snagging.
Ease of Handling (& Weight)	Lightweight and easy to deploy, operate and recover. (Open Harbor, as tested = 3.3 lb/ft, dry)	Moderately heavy. Convenient handles for ease in deployment and recovery. Irregular surface can make handling awkward in some situations. (Weight, as tested = 7.5 lb/ft, dry)	Moderately heavy. Chain-link barrier can be used for handling during deployment and recovery. (Weight, as tested with 3 layers = 7 lb/ft, dry; 11 lb/ft, wet)	Relatively light. Blanket can be attached easily with grommets or with 3M Dual Lock/Scotchmate fasteners. Boom must be prepared with fastening system in advance. (Blanket weight 52" wide = 2.8 lb/ft, dry; 22.4 lb/ft, wet).
Tensile Strength	20,000 lb (function primarily of bottom tension member)	Total tensile strength is approximately 46,000 lb.	20,000 lb. (function primarily of bottom tension member)	Blanket does not provide significant additional tensile strength (depends on boom used).
Compactibility	4:1	0	0	0
Storage	Normally store on reel. Keep dry and covered. 0.18 ft^3/ft of length.	200 to 220 ft^3/100 ft of length. Estimate: 250 ft per 8'x10' reel or 1000 ft per 40'x8'x8' van. Keep covered.	Estimate: 600 ft per 40'x8'x8' van. Keep dry and covered.	12 ft^2/25 ft length (52" wide blanket only). 1,000 ft per 40'x8'x8' van with Kepner 14"x18" boom.
Maintenance & Repair	Low maintenance; easily repaired since protective layers are removeable. Replacement covers available from manufacturer. Coil and flotation reusable.	Floats, connectors and all below-water materials are reusable. Pre-punched refractory material available in rolls from manufacturer @ 20% to 25% total boom cost.	Floats, connectors and below-water parts reusable. Thermoglass and other protective layers commercially available. Fabrication and field maintenance personnel available from manufacturer in Alaska.	If damaged, return to manufacturer. If used, dispose of in accordance with federal/state regulations. Not reusable if wetted.
Estimated Cost (FOB factory 12/85)	$200,000/1,000 ft (without reel)	$165,000/1,000 ft	$125,000/1,000 ft	$157,000/1,000 ft (blanket only)