DOME PETROLEUM'S FIREPROOF BOOM - DEVELOPMENT AND TESTING TO DATE

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INTRODUCTION

In situ combustion of oil on water can be an effective countermeasures technique if the floating oil slick can be contained and thickened to burnable thicknesses.

Dome Petroleum has designed, built and tested a prototype section of a fireproof boom. It is constructed of 310 stainless steel flotation chambers of pentagonal cross-section with a "sail" to provide freeboard and a PVC-coated nylon skirt to ensure containment of floating oil. The combined draft and freeboard of the boom is 1.8 m.

The floatation chambers are connected with 321 stainless steel flexible connector sections to allow the boom to follow waves.

The boom has been successfully tow-tested in both straight line and catenary configurations in waves

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of 1 metre. A two hour burn of crude oil was conducted with the boom used to contain the burning oil also. Of the 1 545 litres of oil pumped into the area enclosed by the boom, 99.87% was combusted. The boom survived intact and there was no effect on the structural integrity of the boom sections.

The boom was subsequently tested at the OHMSETT facility where it demonstrated excellent stability in a catenary in two speeds up to 2.5 knots and waves 0.4 m high x 19 m long. The boom contained oil in all the test waves with the first loss occurring at a tow speed of 0.75 knots. Successful burns, with efficiencies estimated to be in excess of 90%, were accomplished in calm water with tow speeds of 0.3, 0.5, and 0.75 knots. Successful burns were also carried out in 0.2 and 0.4 m high x 19 m long swell. It was observed that the volume of residue left increased with increasing swell height, but the combustion was still as vigorous as the calm water runs. Burning in choppy, breaking waves was not very successful as the breaking waves extinguished the flames.

Future testing of the boom will consist of the construction of a further 60 m of the boom for offshore durability, containment and burning trials.

INTRODUCTION

The use of booms to contain and thicken oil so it can be burned in situ on a water surface has been investigated in several previous Canadian studies (Purves and Daoust, 1978; Roberts and Chu, 1978 and McAllister, 1979). Each proposed design, however, failed to be an operationally feasible device for one reason or another.

As a result of work on a "quickie" fireproof boom, Dome Petroleum decided to undertake a project to research, develop, construct and test a fireproof boom that has the following design criteria:

i. the ability to withstand flame temperatures of 980°C for extended periods of time in a salt-water environment and be reuseable;

ii. the ability to contain oil in a "U-shaped" configuration in a sea state 4 and survive a sea state 5;

iii. be as compact as possible and remain flexible down to -20°C and storable to -50°C;

iv. have good abrasion resistance so as to be able to withstand frequent handling and some contact with ice;

v. easily deployed, if possible manually, using standard rig supply vessels and easily towed at 2 knots; and

vi. have a tensile strength of at least 110 000 newtons.

This project, which commenced in the fall of 1979, has been funded by the Canadian Offshore Oilspill Research Association, an organization of oil companies with interests in Canada's offshore waters, and by AMOP who provided funding for a portion of the OHMSETT trials.

This paper deals with the development and design of a prototype section of fireproof boom, the results of the preliminary towing trials, the fire testing and subsequent OHMSETT trials and the conclusions and recommendations arising from the test programs to date. Proposed offshore tests are also reviewed.

BOOM DESIGN

In order to meet the design criteria an extensive search for suitable materials of ocnstruction was instituted, using Roberts and Chu (1978) as a starting point. It became apparent that there were very few materials that could meet the design requirements and that only two were relatively inexpensive; these being high chromium stainless steels, such as type 309 and 310 (Perry and Chilton, 1973) and a refractory blanket material manufactured by the Carborundum Company, "Fibrefrax L144" which is a cloth material woven with a Nichrome wire.

Using these materials a 12 m section of prototype boom was constructed, consisting of vented stainless steel flotation units of pentagonal cross-section with a "sail" to provide freeboard and a PVC coated nylon skirt underwater to provide draft (see Figure 1). To provide wave conformation, each 1.5 m long flotation unit was joined to a 0.75 m long flexible panel constructed of stainless mesh encased "Fibrefrax" blanket connected to a further section of PVC coated nylon skirt.

Tension members, consisting of 9.5 mm diameter stainless steel cables were added to ensure no tension

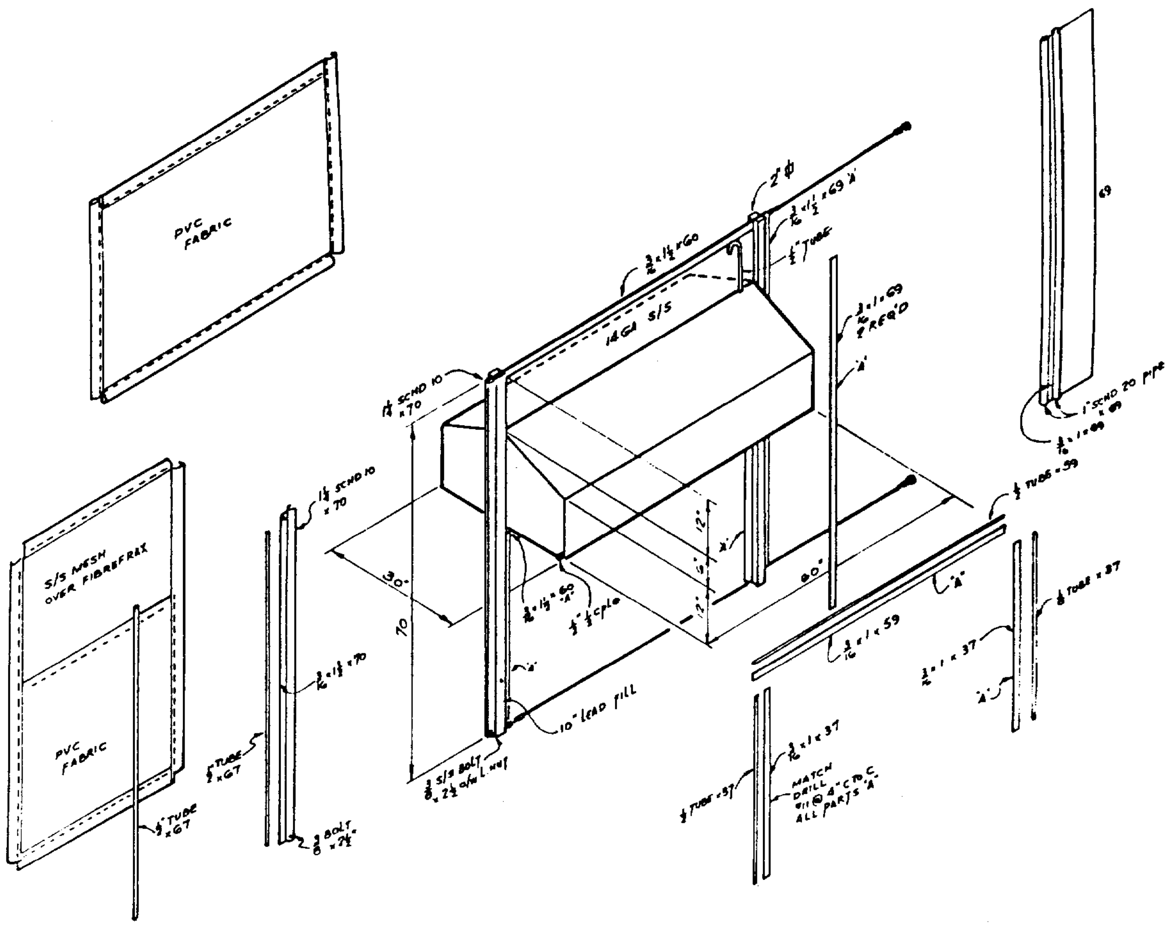


FIGURE 1 FIREPROOF BOOM FOR DOME PETROLEUM

loads were placed on the flexible panels. The overall height of the boom was 1.77 m, with 0.66 m being the freeboard in calm water.

Each section of the boom was connected by means of a sliding joiner. These joiners fit inside slotted pipes fastened to both the free end of a flexible panel and the end of the next flotation unit.

TOWING TRIALS

Following successful static flotation trials that confirmed the stability of the flotation units, the boom was tow-tested in both straight line and catenary configurations. The straight line tests revealed that the boom could be successfully towed at speeds up to 5 knots, but that at this speed the prop wash tended to deflect the first section of the boom. A significant bow wave was set up by the first section which resulted in a high drag force on the boom as well. It was concluded that for an operational model a towing paravane should be included.

The catenary towing trials were held in a short, choppy sea with wave heights of approximately 1 m and a wind speed of 30 km/h. The boom conformed well to the waves, demonstrated excellent stability and was only overtopped once by a small amount of spray from a breaking wave.

Following these trials it was discovered that the "Fibrefrax" material had been seriously eroded by the action of the waves and it was concluded that the flexible panels, as originally designed, would not contain oil.

FLEXIBLE PANEL REDESIGN

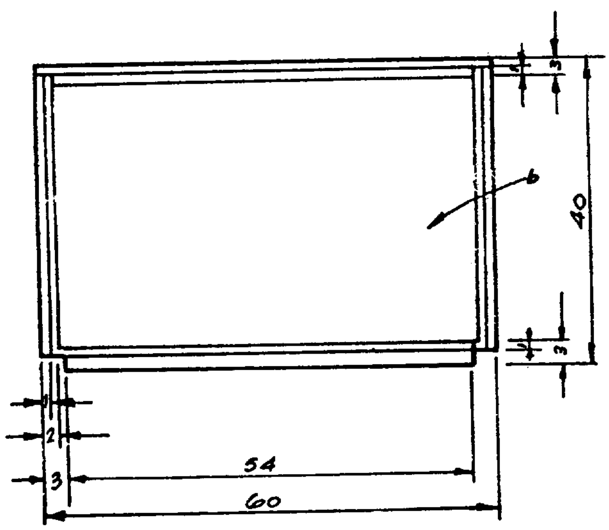
Following a further investigation of suitable construction materials, it was decided that the flexible panels should be built from a thin gauge (0.4 mm) type 321 stainless steel sheet that had been corrugated to provide the required flexibility (see Figure 2). These panels were fitted to the boom and a second towing trial confirmed that they did have the required flexibility and durability. Each boom section as redesigned, has a weight of approximately 125 kg, a gross buoyancy of approximately 440 kg and a buoyance to weight ratio of 3.5:1.

BURNING TRIALS

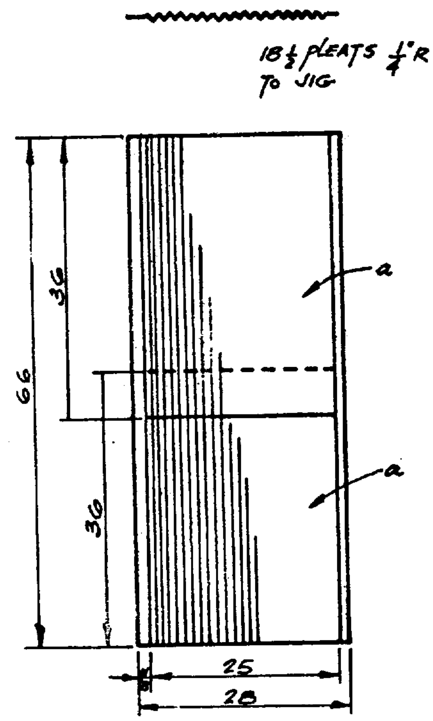
In order to confirm that the design of the boom and the materials selected would withstand the temperatures of a crude oil fire; that no corrosion problems would occur and to investigate the continuous combustion of crude oil on water, a burning trial was held December 12, 1980 near Port Mellon, B.C.

The boom, with the redesigned flexible panels, was connected in a circle and secured inside an area encircled by 0.9 m inshore boom and fender logs, as shown in Figure 3.

Thermocouples were mounted at various locations on one section of the boom and monitored from a barge,



PART D BOTTOM PANEL
1 REQ'D



PART B - CONNECTION PANE
1 REQ'D

FIGURE 2 FIREPROOF BOOM PROTOTYPE - FLEXIBLE PANEL DETAILS

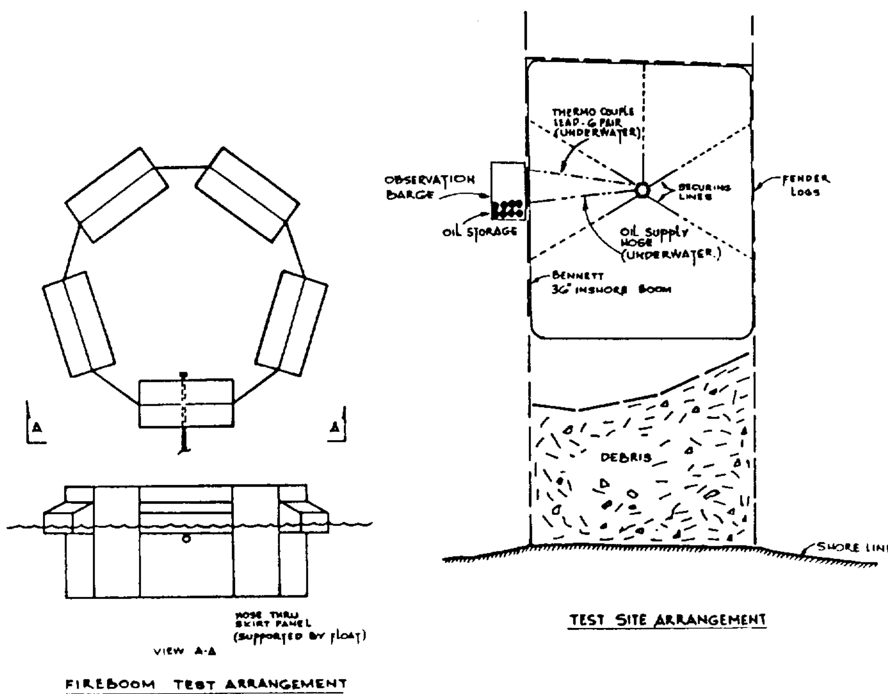


FIGURE 3 FIREPROOF BOOM PROTOTYPE - TEST ARRANGEMENT

edges of the boom and in the air space above it, rather than immediately above the slick.

The thermocouples located in the water below the fire (No.'s 1 and 2 on Figure 4) indicated that although some heat was being transferred to the water it was not raising the water temperature appreciably, even 4 cm below the burning slick. Presumably much of the heat transferred into the water column was being absorbed in boiling off a thin surface layer of water. This was evidenced by observations of some droplet carryover during the combustion, normally caused by boiling, and the fact that during gusts of wind that bent the flame over the side of the boom; the surface water in close proximity to the fame could be observed boiling.

During the trial, a small fire was observed burning outside of the boom. The source of this leak was later determined to be a gap at the waterline in the stitch welding and not a failure of the boom caused by the burning.

The smoke plume generated by the burn rose vertically to a height of approximately 300 m and then dispersed horizontally with visible smoke disappearing within 2-3 km downwind.

When the fire had extinguished itself the boom was examined and found to be in good structural condition. Some of the sheet metal was slightly warped and the exposed surfaces were covered with droplets of a hard asphaltic residue caused by the aforementioned droplet carryover. On removal from the water no further damage was observed and the boom was considered ready for immediate re-use.

OHMSETT TRIALS

Following the burn trails the prototype boom was tested at the U.S. Environmental Protection Agency Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) facility to further confirm its towing and stability characteristics, define its oil containment characteristics in controlled wave and current conditions, and investigate the effects of waves and currents on in situ combustion.

Two oils were utilized for the testing, a Circo 4X light oil (specific gravity = 0.9, viscosity = 11 mPa.s @ 22°C) for the containment trials and Murban crude oil (specific gravity = 0.85, viscosity = 9 mPa.s @ 14°C for the in-situ combustion trials.

The test matrix and the preliminary results obtained from the program are summarized in Table 1.

As can be seen from Table 1 the boom exhibited excellent stability in all the wave conditions tested and was found to contain oil at speeds up to 0.4 m/s (0.75 knots). At this speed a vortex formed between adjacent flotation units that drew small quantities of oil beneath the skirts. The anomalous containment of oil by the boom at up to 1.25 m/s tow speeds observed in Runs 3R, 4 and 19 was presumably due to the small volumes of oil used in these runs.

TABLE 1 TEST MATRIX AND PRELIMINARY RESULTS

Test No.	Tow Speed (m/s)	Wave Type	Wave Height X Length(m)	Oil (Amount)	Remarks
1	0.25 - 1.0	calm	-	-	- stable in catenary, no rolling
2	0.25 - 1	swell	0.4 x 19	-	- stable, good wave conformance, no rolling
3	0.25 - 5.0	calm	-	Circo 75 1	- first loss at 0.4 m/s at vortex between floats
3R	0.25 - 1.25	calm	-	Circo 38 1	- required 1.25 m/s to flush oil, at lower speeds oil not touching boom
4	0.25 - 1.0	swell	0.4 x 19	Circo 75 1	- first loss at 1 m/s, oil held out from boom by float backwash
7	0.25 - 1.0	harbour chop	0.2	"	- first loss at 0.4 m/s, oil dispersed by turbulence in catenary
8	0.25	calm	-	Murban 38 1	- intense burn for 5 min, estimated greater than 90% efficiency
9	0.15	calm	-	"	- intense burn for 5 min 51 s, estimated same efficiency as 8
10	0.35	calm	-	"	- flames had some difficulty spreading upwind, intense burn after for 4 min, 43 s
11	0.25	harbour chop	0.2	"	- no ignition of oil, igniter pushing oil away by bobbing
11R	0.25	harbour chop	0.2	"	- no ignition of oil
18	0.25	swell	0.2 x 19	"	- ignited in calm condition, intense burn for 3 min, 39 s, more residue than 7, 8 and 9

Test No.	Tow Speed (m/s)	Wave Type	Wave Height X Length(m)	Oil (Amount)	Remarks
14	0.25	swell	0.4 x 19	"	- ignited in calm, intense burn for 2 min, 29 s, more residue than 18
15	0.25	swell	0.4 x 19	"	- ignited in waves, intense burn for 2 min, 54 s, approx. same residue as 14
16	0.36 x 0.5	swell	0.4 x 19	"	- ignited in waves, intense burn for 2 min at 0.35 m/s, poor burn for 1 min, 59 s, at 0.5 m/s
19	0.35 - 1	calm	-	"	- intense burn for 3 min, 10 s, no difference in burning with increased speed
11R'	0.25	harbour chop	0.2	"	- successful ignition, poor flame spread, poor combustion, extinguished by break wave
20	0.25	calm	-	"	- emulsified oil from 11R successfully burned for 7 min, 10 s
21	0.25 - 0.75	calm	-	Circo 3800 l	- first loss at 0.4 m/s through vortex, extensive loss by entrainment at 0.5 m/s
21L	0.25 - 1	harbour chop	0.6 m	-	- durability trial - survived well, excellent stability - minor damage to skirt observed on removal

Runs 8, 9, 10 and 19 showed that, in calm conditions the combustion was not adversely affected by increased tow speed up to 1 m/s. However, it is probable that had larger volumes of oil been used, at speeds exceeding 0.5 m/s the combustion efficiency would be reduced due to entrainment of the oil beneath the boom. A comparison of runs 8, 18, 14, 15 shows that increasing swell height did not affect the ability to ignite the slick or the intensity of the resulting in situ combustion. However it was observed that the amount of residue left increased with increasing swell height. This was a function of the relatively small volumes of oil used in these trials and is not expected to seriously affect overall combustion efficiencies on a large-scale.

The results of runs 15 and 16 illustrate that in the swell wave condition the intensity of the burn was not affected until the tow speed reached 0.5 m/s (1 knot) at which point it was drastically reduced, presumably by the turbulence set up inside the catenary by the small waves reflected off the boom at this speed.

Of the three runs done in harbour chop (11, 11R and 11R') ignition was only achieved once (11R') by increasing the oil volume and using two igniters. The flame spread was slow and the combustion poor. Before the entire surface area of the slick was ignited a breaking wave extinguished the flames.

Upon removal of the boom the only damage observed to have occurred was the loss of six rivets which resulted in the slight bending of one of the skirt holding rods, and some wear on the upper flexible panel tension cable securing points.

FUTURE TESTING

At the time of writing it was proposed that an additional 60 m of boom be constructed, with some minor design changes (principally reinforcing the tension cable securing points and using larger rivets) and tested offshore. The purpose of this testing would be to fully evaluate the boom's performance with respect to towing, stability, structural integrity and containment in Sea States 1 to 5 and evaluate ignition and in situ combustion of crude oil in Sea States 4 to 5. Operational guidelines with respect to deployment, recovery, maintenance and storage will also be developed.

CONCLUSIONS

1. The boom as now constructed has met the design criteria. It has a total height of approximately 1.8 m and each 2.25 m long section, consisting of a stainless steel flotation unit and stainless steel flexible panel, weighs 125 kg, has a gross buoyance of 440 kg and a buoyance to weight ratio of 3.5:1.

2. The boom has demonstrated excellent stability in both straight line and catenary configuration tow tests at speeds up to 5 knots in Sea States up to 3.

3. A successful calm water stationary burn trial was held during which time approximately 1543 of 1545 litres of crude

oil pumped were burned off over a 2 hour period resulting in a 99.87% efficiency. Although the boom was exposed to flame temperatures in excess of 900°C during these trials it suffered no structural damage.

4. The boom can contain oil in swell and harbour chop at current speeds of up to 0.4 m/s.

5. The boom can thicken and contain burning oil in calm water and in swells of 0.4 m height x 19 m length at current speeds of up to 0.4 m/s.

6. In-situ burning of crude oil, in the harbour chop conditions and with the oil volumes tested, was not very successful; however, with larger quantities of oil it maybe possible.

RECOMMENDATIONS

1. The boom should be tested offshore to fully evaluate the boom's performance with respect to towing, stability, structural integrity and containment in Sea States 1 to 5 and to evaluate the feasibility of in situ combustion of oil in Sea States 4 to 5.

2. The flexible panel tension cable securing points should be reinforced.

3. Larger rivets should be used to secure the skirt material.

4. A paravane should be utilized to reduce drag during straight line tows.

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