Finding 5

Guidelines for the selection of in-situ burning equipment

Oil Spill Response Joint Industry Project

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About this report

In response to the *Deepwater Horizon* incident at the Macondo Prospect off the Gulf of Mexico In April 2010, the International Association of Oil and Gas Producers (OGP) formed the Global Industry Response Group (GIRG). This Group was tasked with identifying ways to prevent the recurrence of such an incident and to identify learning opportunities both with respect to the cause of, and response to, the incident. Part of this effort involved the formation of a subgroup on Oil Spill Response (OSR). This group was comprised of nominees from OGP member companies, from the IPIECA Oil Spill Working Group (OSWG), from Oil Spill Response Limited (OSRL), and from other industry organizations, associations and spill response cooperatives, as appropriate.

The OGP GIRG-OSR task force reported on its findings to both the OGP Management Committee and the IPIECA Executive Committee at a joint session in February 2011. While certain actions recommended by the GIRG-OSR report fell within the remit of existing organizations, it was recognized that the most efficient way to execute the resultant work was for the industry to establish a limited duration Joint Industry Project (JIP), governed by the funding companies.

This report addresses Finding 5 of the JIP project, which reviews selection criteria for equipment needed to conduct in-situ burn operations.

Introduction

Source: ©MediaBakery

In-situ burning (ISB) is a response technique that combusts vapours from slicks on a water or land surface and converts the hydrocarbon mixture into predominantly carbon dioxide and water with some particulates, or soot, which is then released into the atmosphere. ISB has been used on relatively small inland and inshore spills in North America since the late 1950s. ISB operations can be conducted on land, ice or other hard surfaces, or on water. Burning has also been of special interest with regard to oil spill response operations on or in sea ice where the ice can act as a barrier to corral the oil and maintain the minimum slick thickness.

All ISB operations require:

- sufficient fuel to generate an ignitable concentration of vapours, since it is the vapours that burn rather than the liquids;
- an ignition source to instigate the burn; and
- sufficient quantities of fuel (i.e. greater than 1–2 mm) to sustain a burn.

Larger and thicker slicks are more likely to present an ignitable concentration of vapours, and hence may be easier to ignite. On land, friction presented by the land surface slows down the lateral spreading and thinning of spilt oil, hence the occurrence of thicker slicks which are easier to ignite is more frequent. For oil spills on water, there are no natural boundaries to prevent spreading and thinning, and it may therefore be harder to ignite the spilt oil and thereafter to sustain a burn. In most cases where there is an interest in burning a slick on water, fire-resistant containment booms can provide this boundary. When towed by response vessels, such booms can be used not only to constrain spreading, but also to corral a slick into a smaller area and thereby to thicken it. Other ISB equipment that can influence burn efficiency includes igniters, ignition promoters, wicking agents and chemical herders.

How in-situ burning functions

In-situ burning removes surface oil by combusting hydrocarbon vapours released by a surface slick. To at least initiate combustion, the slick thickness must be a minimum of 1–2 mm to avoid excessive heat loss to the underlying water. Sustained burns can remove virtually all of the floating oil (Fingas, 2010). The type of oil and its state of weathering can also influence how effectively it will burn, but to a much lesser degree than the thickness of the slick. The ease, or conversely the difficulty, of igniting the hydrocarbon vapours is referred to as 'burnability'. Some light oils (e.g. gasoline) are highly evaporative and burn easily. Ignition of emulsified oil can be achieved, but due to the water content, a longer preheating time is needed, requiring the use of a high-intensity igniter and possibly a primer (Fingas, 2010).

Table 1 presents information on the removal of a variety of different oils by burning. The oil types are listed from the lightest to the heaviest (i.e. from gasoline to heavy oil). The potential effectiveness of the burn can be estimated by examining several characteristics, including:

- **burnability:** the relative ease or difficulty in igniting and sustaining the burn;
- **relative speed of flame spreading:** how quickly the flame will spread through the slick;
- **estimates of oil removal:** effectiveness of the burning of the product—this can also be described as the removal rate of the product from the surface of the water by burning;
- **burn rate:** the rate at which a slickness will be consumed;
- **sootiness of flame:** the amount of soot (i.e. dark smoke) that is likely to be produced; high levels of soot may indicate incomplete combustion or the chemical structure of the product being burned; and
- **relative ease of ignition:** a subjective measure of the likelihood of ignition. This characteristic can help to determine whether additional products (i.e. primers) may be needed to ignite the vapours; it can also determine the type of igniter needed based on the level of intensity of the burn (high versus low) and the length of the burn (long versus short) (see Table 4).

As shown in Table 1, the relative speed of flame spreading is quicker for finished products like gasoline, diesel and lighter crudes. The speed is slower for weathered or heavy products. However, it should be noted that a key factor for the effectiveness of a response option is its ability to encounter oil. For example, a fast-moving yet narrow response option might have the same overall encounter rate as a slower-moving, yet broader option.

For in-situ burning, it is recommended that oil be corralled to a minimum thickness of 1–2 mm for optimum ignition and sustained burn (Fingas, 1999). When products are corralled on land due to natural or man-made berms this can be less of an issue than for a spill on water where slicks have the potential to spread more rapidly. When a slick becomes too thin (~1 mm), the amount of heat retained by the slick, which enhances the generation of more vapours, is reduced as heat is transferred to the water layer below the slick. This will result in the burn being extinguished. Fire booms are used on water to thicken the slicks to a minimum thickness. As with a traditional containment boom, the encounter rate for a fire boom is dependent on:

(a) the speed at which the boom can be towed (WCOSRP, 2012) (i.e. tow speeds usually need to be maintained below about 0.4 m/s (0.75 knots) to avoid oil loss); and
(b) the sweep width (i.e. the distance between the openings in the boom).

Table 1 Surface oil removal by burning (modified from Fingas (2011); API gravity data from ADIOS v2.0.)

Oil type	Range of API gravity	Typical burnability	Relative speed of flame spreading	Estimates of oil removal (percent)	Burn Rate (mm/min)	Sootiness of flame	Relative ease of Ignition
Gasoline	58–74	very high	rapid	95–99	4–3.5	medium	very easy
Diesel fuel	35–40	high	moderate	90–98	3.5–2.9	very high	easy
Light crude	31	high	moderate	85–98	3.5	high	easy
Medium crude	22–31	moderate	moderate	80–95	3.5	medium	easy
Heavy crude	< 22	moderate	moderate	75–90	3	medium	medium
Weathered crude	n/a	low	slow	50–90	2.8–2	low	difficult, primer may be required
Crude with ice	22–31	low	slow	50–90	2	medium	difficult, primer may be required
Light fuel oil	17–28	low	slow	50–80	2.5	low	difficult, primer may be required
Heavy fuel oil	14–18	very low	slow	40–70	2.2	low	difficult, primer may be required
Waste oil	n/a	low	slow	30–60	2	medium	difficult, primer may be required
Emulsified oil	n/a	low	slow	30–60	2–1	low	difficult, primer may be required

Table 2 (see page 4) summarizes eleven burn operations and provides some details on the location, spill circumstance, habitat type, initial volume and the calculated burn effectiveness. As each operation has many variables, this table is only a guide to illustrate that oil removal efficiencies of 80 or 90% can be achieved with ISB.

Table 2 Synopsis of selected burn operations and their effectiveness

Name of incident	Oil type	Year	Location	Spill circumstance (source)	Habitat type	Initial spill volume	Burn effectiveness (%)	Description
Burmah Agate	Nigerian crude	1979	Offshore	Release from tanker	Open water	39750	46.7	The collision ruptured two storage tanks which resulted in explosions, the vessel continued to burn for two months (Kana *et al.*, 1981).
YUM II/ Zapoteca	Light crude oil	1987	Offshore	Offshore well blow out	Open water	6780	Up to 90%	Exploratory oil well, located approximately 20 miles northwest of Ciudad del Carmen (in Mexican waters), experienced a well blowout and fire. During the response the Mexican authorities conducted a prolonged six-day controlled burn at the well head, where an estimated 90% of the escaping hydrocarbon was burnt. When engineers involved in the well kill operations did not need access near the well, the escaping oil was re-ignited (NOAA, 1992).
Exxon Valdez	North slope crude	1989	Coastal bay	Release from tanker	Open water	55	98	Using a fire boom, a single burn continued for 1 hour 15 minutes resulting in 300 gallons of stiff, taffy-like burn residue (Allen, 1990).
Chiltipin Creek	Light crude oil	1992	Inland	Release from underground pipeline	Salt marsh	1182	80–85	Weathered a few days; fire was ignited using mineral spirits and burned for 21 hours. Marsh was covered by sticky residue that was collected over the following 15 days (Fingas, 2010).
Rockefeller Refuge	Condensate	1995	Inland	Release from pipeline	Brackish marsh	6	> 80	In a remote area with no access roads. The product had weathered for four days. Mechanical recovery was deemed to be damaging the marsh and ineffective. Only then was in-situ burning considered by state authorities even though it was mentioned early in the response (Fingas, 2010).
Lakehead pipeline spill (Ruffy Brook)	Bow River crude oil	2000	Inland	Release from pipeline	Freshwater marsh	8	80	Oil was released from a 34-inch pipeline. Mechanical recovery was deemed to be difficult to deploy and potentially damaging to the marsh, so in-situ burning was conducted. Residue (up to 1 cm thick) was collected by hand with no evidence that any residue sank (Michel *et al.*, 2003).
Northern Utah pipeline burn	Diesel fuel	2000	Upland	Release from pipeline	Salt flat and wetlands	100	75–80	Weathered for approximately 45 days prior to first burn. Helitorch system was used for first ignition of the most highly impacted 5 ha; drip torches were used for ignition of the lightly impacted 1.5 ha (Williams *et al.*, 2003).
Mosquito Bay	Condensate	2001	Inland	Release from pipeline	Brackish coastal marsh	79	99	Weathered 7–8 days prior to in-situ burning. Various controls and treatments were conducted (Michel *et al.*, 2003).
Bayou Tank Battery	Crude oil	2002	Inland	Release from tank battery	Marsh	24–50	90–98	Fresh oil was burned. Removal of burn residue proved difficult. (Fingas, 2010).
Chevron Empire Facility	Louisiana sweet crude	2005	Inland	Release from tank farm	Brackish coastal marsh	200	80-90%*	Percentage of removal of surface oiling was based on visual observations. Approximately 34,000 barrels were released into a secondary containment area and 200 barrels were released into an adjacent marsh (Merten *et al.*, 2008).
Deepwater Horizon	Louisiana sweet crude	2010	Offshore	Offshore well blow out	Open water	Continuous release	99	Approximately 400 controlled burns were conducted, removing an estimated 35–49 k m^3 (Mabile, 2012).

Equipment used in ISB operations

The number of different types of equipment used for a burn will depend on the circumstances of a spill and the scale of an intended burn. Small-scale burns will require less equipment than larger burns. In general:

- For spills on land, where there is natural friction from surface soils, plants and plant material which constrains slick movement, and when a slick is thick enough for ignitable vapour concentrations, there may only be a need for an igniter and fire control equipment.
- For spills on land where there is a slope or porous soils, trenching equipment or shovels can be used to provide a 'basin' in which to collect spilled oil to generate ignitable vapour concentrations. An igniter and a means for fire control will then be required.
- For spills on water, where there is no lateral boundary to constrain slick movement or thinning, equipment will be needed to provide that boundary. Typically, such equipment will consist of a floating boom (i.e. a fire boom) designed to tolerate the high temperatures during a burn. Additionally, boom towing vessels, igniters and a means for fire control will be required.

For larger burns, there may also be a requirement or expectation for air quality monitoring. However, since the equipment used in this process does not influence a burn's ability to remove surface oil it is not addressed in this report.

Fire-resistant containment boom

Similarly to conventional boom, a fire boom is deployed between two vessels to contain and/or corral the oil on a water surface. As oil is corralled into a more confined area within a boom, the thickness of the slick will be increased which, in turn, facilitates initial and sustained ignition of the oil by reducing heat loss to the underlying water.

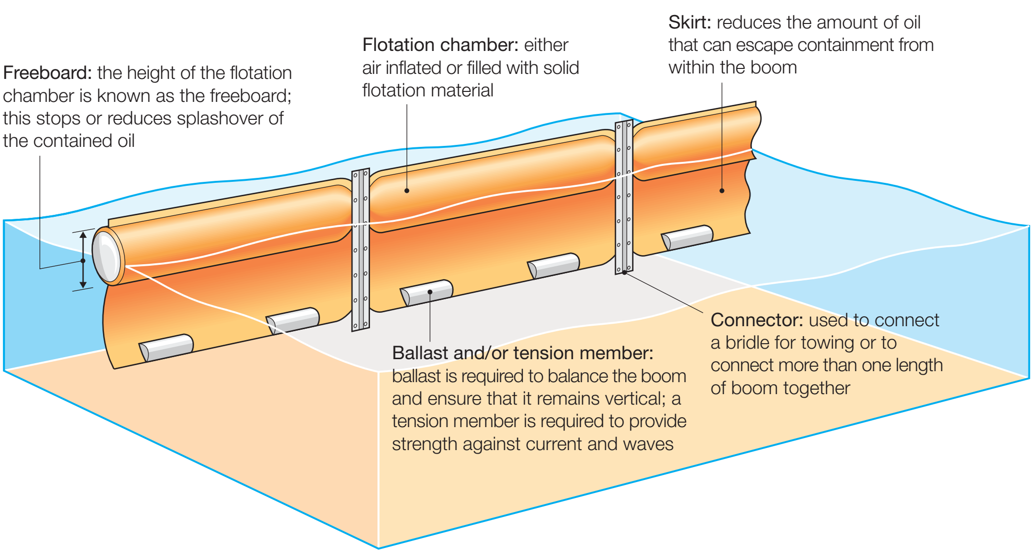
A fire boom's resistance to heat is achieved through either:

- the use of coolants (e.g. pumping water onto the surface of the boom during the burn, or wicking water into the boom surface material), as is the case with an 'actively-cooled fire resistant boom'; or
- the use of fire-resistant materials in its construction so that the boom is 'intrinsically fire resistant'.

Although all fire booms are designed to be fire resistant, it is expected that their integrity will eventually be reduced through repeated burns, and that they will therefore have a finite life once deployed. Before each use, it is important to ensure that boom integrity is sufficient to last through the burn operation, and to contain residues after the burn. A boom should also remain sufficiently intact so that it can be recovered for disposal after the burn.

The design principles of a fire boom are the same as those for a conventional boom (used for on-water oil containment and recovery) and the same descriptors for components can be applied (see Figure 1, overleaf).

Figure 1 The component parts of an oil containment boom



Below left: the Hydro-Fire® boom is a water-cooled, reelable fire boom consisting of individual inflated segments with redundant water cooling and filtering systems.

Below right: the PyroBoom® is a fence-type boom consisting of a silicone-coated refractory barrier supported by stainless steel floats filled with glass foam.

It is important to note that there are some important differences between a fire boom and a conventional boom. Fire booms tend to be heavier because the materials used in their construction are likely to be heavier than those used in the construction of a conventional boom (Potter, 2010). The additional weight makes fire booms more prone to failure in higher weather/wave conditions than conventional booms. A fire boom requires careful handling when being deployed and recovered to prevent damage (WCOSRP, 2012).

Source: Elastec/American Marine

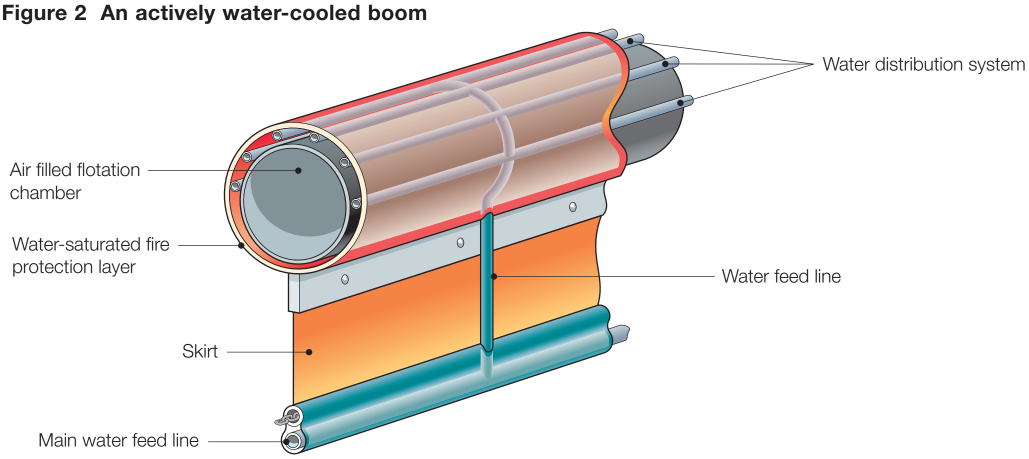
Source: Al Allen/Spiltec

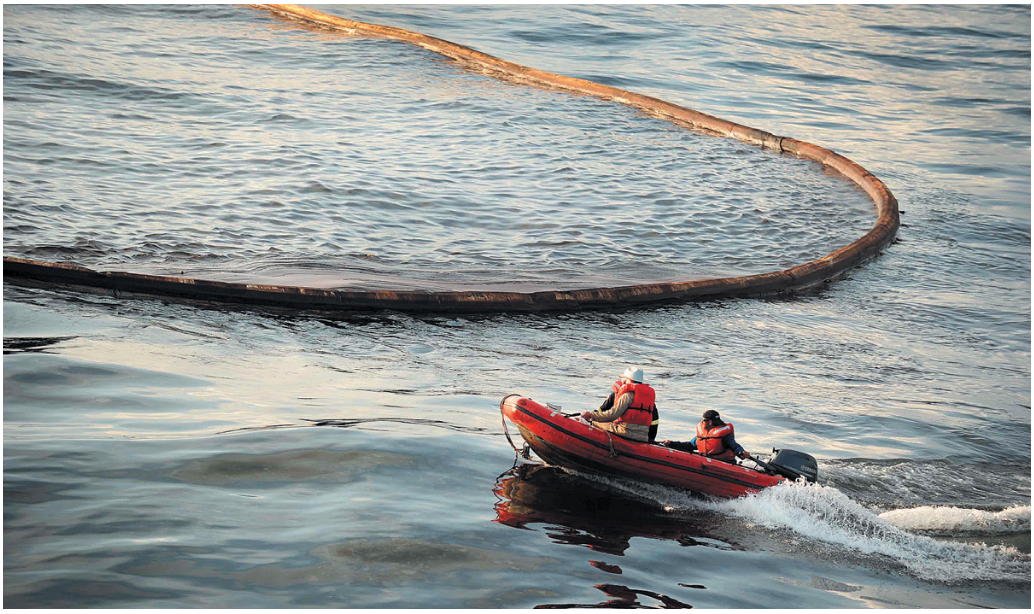
Design options for fire booms

Inflated fire boom/actively water-cooled systems

An actively water-cooled inflated fire boom (Figure 2) incorporates a cooling system that uses water pumps and a protective jacket. This system sits over the boom inflation chamber and distributes water across the exposed surface of the boom to provide cooling. The boom can be stored on a powered reel giving the combined benefits of requiring less storage space, making it easier to transport, and allowing for ease of deployment and retrieval from the vessel. This system requires advanced training due to the ancillary support equipment (i.e. air pumps, water pumps).

Figure 2 An actively water-cooled boom





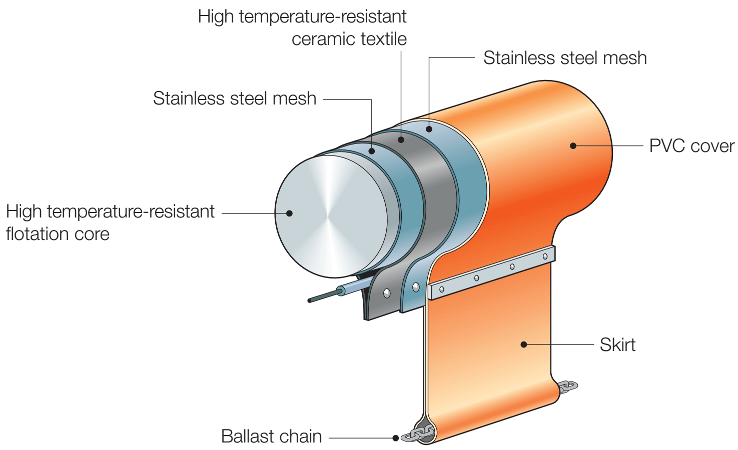
Source: U.S. Coast Guard/Petty Officer 2nd Justin E. Stumberg

Inspecting a fire boom prior to conducting a controlled burn in the Gulf of Mexico (May, 2010).

Solid flotation fire boom (intrinsically fire resistant)

A solid flotation fire boom (Figure 3) relies upon fire-resistant materials to maintain integrity during exposure to high temperatures during the burn. Solid flotation booms do not require support systems such as blowers or water pumps, simplifying their maintenance and deployment. The rigid nature of such booms precludes the use of reels, hence this system requires more storage space. Typically, this type of boom is shipped in containers or on pallets. It may be stored in containers or open trays, or 'flaked out' on the deck of the deployment vessel. The deployment and retrieval of this type of system will rely on manpower and the vessel's crane, if available.

Figure 3 Solid flotation fire boom (intrinsically fire resistant boom)



Contracted vessels pulling a fire resistant oil boom during a controlled burn in the Gulf of Mexico.

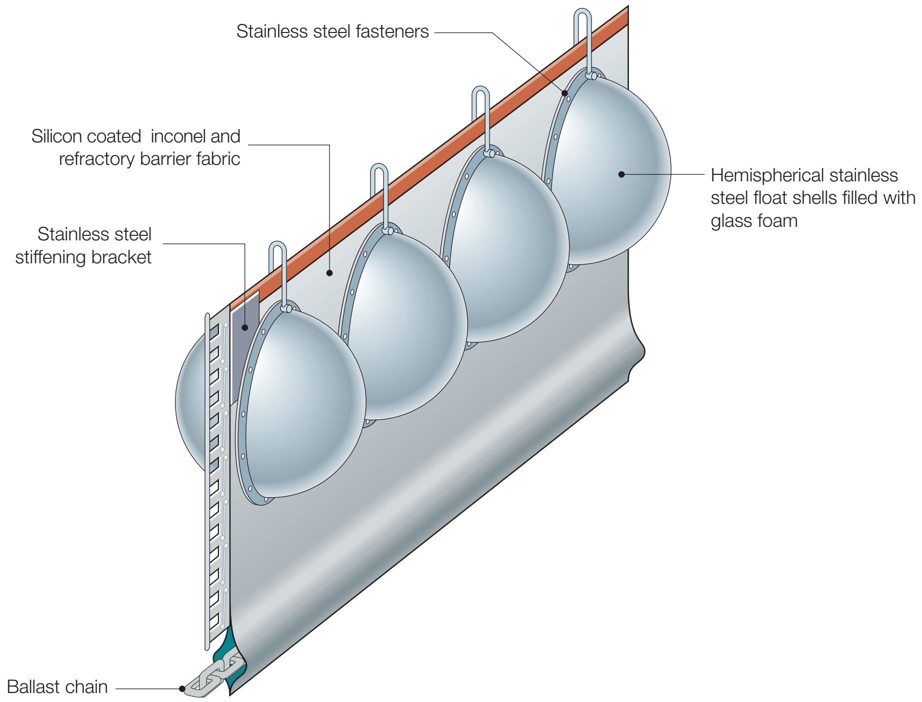
Source: U.S. Coast Guard/Petty Officer 3rd Class Justin Stumberg

Solid flotation fire boom with stainless steel hemispheres (intrinsically fire resistant)

A solid flotation fire boom with stainless steel hemispheres is constructed on the same premise as the solid flotation boom, i.e. it uses flotation material which is designed to withstand exposure to high temperatures. However, in this case, the flotation material is placed within stainless steel hemispheres and affixed to heat resistant material which forms the barrier for the spilled oil.

As with the solid flotation fire boom illustrated in Figure 2, solid flotation fire booms with stainless steel hemispheres have considerable bulk due to their design and method of construction, making them a challenge to transport and store. However, it is possible to recondition this type of boom in the field, as component parts are easily fitted using shackles and eyebolts. The system can be deployed rapidly due to the fact that there is minimal need for ancillary equipment.

Figure 4 Solid flotation fire boom with stainless steel hemispheres (intrinsically fire resistant)



Evaluation of boom performance during an in-situ burn

This document reports findings on the efficiency of fire booms from studies of, and practical experience in, the use of fire booms during oil spills, insofar as that information is available. Although a number of small trials have been conducted, it is difficult to replicate true field conditions using small or even mesoscale field trials.

A number of large-scale evaluations of fire booms have been carried out (DeVitis *et al*., 1997, 1999; Walz, 1999) which aimed to determine the types of fire booms that performed best in varying conditions. Observations were focused on the level of degradation of a boom subsequent to a burn. Fire booms which shared the same design principles showed marked differences in their level of degradation after a burn, suggesting that it is not reliable to make generalized assumptions that one particular boom design is necessarily more durable than another, or that the construction materials or a specific manufacturer's approach to the design have a greater bearing on performance. Anecdotal information indicates that some fire booms can fail after just a few burns whereas others have sustained 12 or more burns before requiring repairs or replacement.

Several types of fire booms tested in the above-mentioned large-scale evaluations are not readily available today; it may therefore be useful to reflect on the experiences gained from the response to the *Deepwater Horizon* incident at the Macondo Prospect in 2010. A number of ISB operations were carried out during this incident and a variety of different types of fire booms were utilized. The observations concluded that, in general, actively water-cooled booms were able to withstand more burns than those of an intrinsically fire-resistant design. It was noted that the build-up of burn residue on solid flotation fire booms appears to extend the life of this type of boom. It was also suggested that inflatable water cooled booms are better able to withstand the forces that the boom is subjected to when being towed or deployed over a longer period of time, as well as to survive the excesses of temperature during a burn (Mabile, 2010).

Table 3 General guidance for selecting an appropriate fire boom

Factors		Actively water-cooled systems	Intrinsically fire-resistant systems	
		Inflated fire boom	Solid flotation fire boom	Solid flotation fire boom with stainless steel hemispheres
Storage space on deck	Limited space required (reels)	✓		
	Clear deck space required (flaked/zig-zagged)	✓	✓	✓
Deployment time	Ongoing operations, deployment time less important	✓		
	Small short-term operation		✓	✓
Deployment team	Training required	✓✓	✓	✓
	General oil spill response workers, or leveraged from locally available resources		✓	✓

It should be noted that manufacturers have since improved their fire boom design and/or the materials used in the construction of new fire booms, in accordance with the lessons learned from the Macondo incident (Mabile, 2010).

Igniters

Several ignition devices or methods have been developed to serve as the source of ignition. Many devices or methods used are modifications of ignition devices used for other purposes including the wildfire service (Fingas, 2010). Before most oils will reach their flashpoint and ignite the vapours, an ignition device must provide a source of heat to warm the surrounding oil; such a device provides a flame that will ultimately initiate a burn. Once burning, sufficient vapours will generally evaporate from a slick to sustain combustion with no further requirement for external ignition. The temperature at which this occurs is known as the fire point. (ASTM Standard F1990-07).

How easy it is to achieve ignition will depend upon:

- the concentration of petroleum hydrocarbon vapours, and whether that concentration is high enough to ignite;
- the oil type and state of weathering:
  - lighter oil requires much less heating than heavier fractions;
  - emulsions (> 20–40% water), particularly stable emulsions, generally require significant preheating and possibly the addition of an ignition promoter (see the Appendix) (Fingas, 2010); and
- the ability of an igniter to provide a source of heat for sufficient time to heat the vapours and bring them to ignition.

Igniters range from highly specialized pieces of equipment to simple devices that can be manufactured on site from commonly available component parts. Deciding on the most appropriate igniter is dependent on the deployment platforms available, the operating environment, the type of product to be burned, and the extent and duration of the operation (i.e. the expectation of a single burn compared to several days or weeks of burn operations).

Simple ignition devices

To provide an ignition source for spills on land, propane/butane torches, weed burners and rags/sorbent pads soaked in fuel have been used as ignition devices (ASTM Standard F1990-07). These devices are relatively unsophisticated and it is therefore unlikely that they will incorporate safety mechanisms such as those described in the ASTM Standard F1990-07, for example a delay mechanism between activation of the igniter and combustion, or a mechanism to guard against accidental activation.

To provide an ignition source for spills on water, floating handheld igniters (see page 12) can be manufactured from readily available components. During the Macondo incident, such devices were initially made from filling a 500-ml plastic jug with a mixture of diesel fuel and gelling agent, and securing a marine flare to the outside.

Right: example of a floating hand-held igniter using a marine flare, diesel fuel and a gelling agent; these are a simple solution to providing an ignition source for spills on water, and can be manufactured from readily available components.

Source: Elastec/American Marine

Two benefits of floating handheld igniters during the Macondo spill were that:

- component parts could be stockpiled prior to deployment, reducing the risk of accidental ignition; and
- they were easily deployed from small vessels which were capable of manoeuvring in close quarters (Allen *et al*., 2011).

Similarly, when conducting the test burns reported by SINTEF, the burns were ignited using devices manufactured from gelled gasoline contained in sealable plastic bags; the sealed bags were ignited before being released into the corralled oil from a designated 'ignition boat' (Potter, 2010).

Drip torch

Drip torches are commonly used on land for prescribed burning during wildfire control and land management. These igniters consist of a canister to hold fuel (generally a mixture of diesel and gasoline) with a looped metal spout that runs past an igniter. As the fuel is 'poured' out it is ignited and drops to the ground.

Right: examples of hand-held drip torches

Source: ©Forestry Suppliers Inc.

Source: ©firehistory.asu.edu

Terra torch

Terra torches are mobile flame throwers that can propel gelled fuel 15 to 30 metres (50 to 100 feet) from a handheld wand. Gelled fuel is a combination of a gelling agent and a petroleum fuel such as diesel, gasoline or aviation fuel (NWCG, 2011). The range of the flame generated and the amount of fuel that can be held will vary between the different models that are available, and between different manufacturers' products. These devices are most useful for igniting thicker slicks, because the force of the flame can push thinner slicks away (Fingas, 2010).

Source: National Wildfire Coordinating Group

The terra torch can be hand held or mounted on a vehicle, and has the advantage of being able to facilitate ignition in areas that may otherwise be difficult to access.

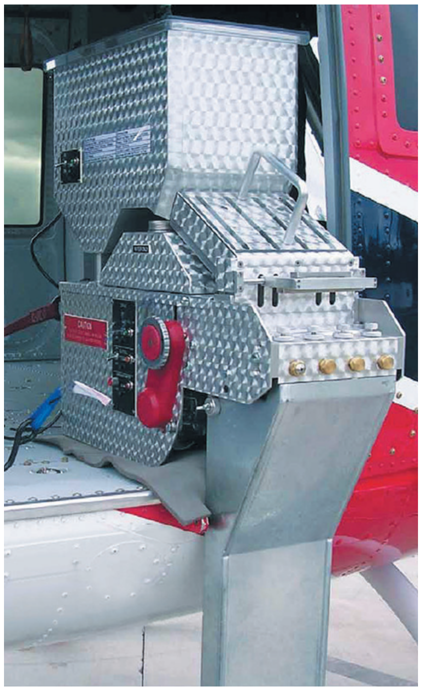
Flare/fusee

Flares can be used to generate the heat necessary to begin the ignition process. These igniters are lightweight, small and portable. Once activated, they can burn for approximately three to five minutes. They are better suited to small- and medium-scale operations, and are readily available at low cost. Typically, marine flares are used for on-water operations as they are waterproof and will float on water.

Source: ©Hansson Pyrotech

Plastic sphere dispenser

Plastic sphere dispensers (PSDs) propel plastic spheres filled with potassium permanganate into the desired burn zone. Prior to launching, the dispenser injects the sphere with glycol which reacts with the potassium permanganate causing a combustion reaction. Dispensers/launchers can be designed to be mounted on vessels, all-terrain vehicles (ATVs) or helicopters. This is a traditional technology in the 'prescribed burn/wildfire management sector', however there have been some advances made to the traditional designs. One such change includes the use of smaller plastic spheres, which enables a larger number of spheres to be carried in the hopper of the launcher, and creates less drag during free fall, resulting in a higher drop velocity and thus greater accuracy. After a 20–40 second delayed ignition as the potassium permanganate and glycol react, a sustained flame lasts for approximately two minutes.



Source: SEI Industries

Helitorch system

The helitorch system has been used in the past for the successful ignition of corralled oil. It was designed for use in the forestry industry and has been used extensively (Fingas, 2010). The helitorch is underslung from a helicopter and comprises a storage drum containing gelled fuel (typically gasoline or diesel), a pump and motor assembly, and electronically-fired propane jets. In operation, the gelled fuel is pumped as required to the ignition tip where propane jets ignite the fuel. The resulting stream of burning fuel is targeted to land in the slick (Buist *et al.*, 1999).

Source: U.S. Forest Service

A number of practical considerations should be mentioned with regard to using the helitorch system, the most obvious of which are the additional training requirements for crews deploying the device, and the approval/permissions that need to be obtained before use. Additional operational considerations such as weather limitations, the identification of safe landing and take-off points, and flight crew hours also need to be considered.

Operational considerations for determining a suitable ignition device

Each incident will present a range of characteristics that should be considered when determining which ignition device(s) should be used. Table 4 illustrates key operational considerations that influence that decision-making process. For example, an ISB operation on open water precludes the use of drip or terra torches. Another key consideration would be the window of ignition and intensity of the initial burn that is required for ignition, based on the type of oil that has been spilt.

Table 4 Summary of ignition devices and their characteristics

	Ignition devices											
	Simple floating igniter	Drip torch		Terra torch			Flare/fusee	Plastic sphere devices (PSD)				Helitorch
	Handheld	Handheld	ATV	Aircraft	ATV	Vessel	Handheld	Aircraft	ATV	Handheld	Vessel	Aircraft
Location:												
Open water	✓						✓	✓		✓	✓	✓
Terrestrial		✓	✓	✓	✓		✓	✓	✓	✓		✓
Burn characteristics required:												
Short Window of Ignition				✓	✓							✓
Long Window of Ignition	✓	✓	✓				✓	✓	✓	✓	✓	
Low intensity burn	✓	✓	✓				✓	✓	✓	✓	✓	
High intensity burn				✓	✓							✓
Cost:												
Low	✓	✓	✓				✓					
Medium					✓			✓	✓	✓	✓	
High				✓								✓

Source: Modified from Howard and Steber, 2013

Summary

In-situ burning is a useful response technique due to the high efficiencies that can be achieved, especially in marsh and inland environments. ISB has broad applicability in a number of environments with relatively minimal logistical requirements. This consideration has made it a favourable response option for most environments, even for oil in or on ice.

As well as determining the most suitable ISB equipment for use in a particular response, it is important to consider the location of the incident, the local weather, the personnel and the equipment assets that will be available to the operation. For example, when conducting a burn on water, an important planning and operational consideration is the provision of aerial surveillance support to ensure that the maximum efficiency of the burn operation is achieved. As with traditional containment and recovery operations, vessels involved in ISB operations can generally determine the thickness and consistency (i.e., potential burnability) of the oil in their immediate vicinity but considerably less so for oil lying further out on the horizon. Therefore, aerial surveillance support for ISB operations is critical for directing the vessels into the thicker, more burnable, patches of floating oil thus greatly increasing the overall efficiency of this technique.

Although a great deal of information has been available on the efficiencies of equipment used for in-situ burning in marshland and inland environments, it was not until the Macondo incident that the importance of in-situ burning on water was realized. The ISB operations undertaken during the Macondo incident provided useful information on the relative performance of different types of fire-resistant booms available at the time of the incident. However, it should be noted that some manufacturers have since modified the materials and design of their products. It is important to recognize that every incident will be different, and that the same items of specialized ISB equipment may demonstrate different levels of performance according to the circumstances in which they are deployed. Appropriate response techniques should always be determined with consideration given to local and national regulations, as well as to the specific incident characteristics.

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Selected websites

The following selected websites contain additional information on in-situ burning (this list is not comprehensive):

Arctic Response Technology Oil Spill Preparedness JIP. (2013). www.arcticresponsetechnology.org

DESMI-AFTI, Inc. www.appliedfabric.com

Elastec-American Marine. www.elastec.com

International Oil Spill Conference. www.ioscproceedings.org

National Wildfire Coordinating Group www.nwcg.gov

Orion Safety Signals www.orionsignals.com

SEI Industries, Ltd. www.sei-ind.com

The Federal Interagency Solutions Group. 2010. Oil Budget Calculator; Deepwater Horizon. Technical Documentation. Search Term ‘oil budget’. www.restorethegulf.org

Appendix: Additional specialized ISB equipment

Materials can be added to the slick to increase the efficiency of the burn or extend the window of opportunity for the technique. These additional items are summarized below.

Primers (also known as ignition promoters)

Primers are substances (usually combustible liquids) that are added to spilt oil to increase its ignitability or to promote the spread of the flame over the surface of the slick, thereby increasing the efficiency of the burn (Buist *et al.*, 1999). To achieve the maximum benefit of adding an additional substance to the slick it is important that the primer is evenly distributed throughout the surface of the slick. Products with diesel and kerosene are favoured as they are more stable than highly refined products (Buist *et al.*, 1999).

Wicking agents (also known as combustion promoters)

Wicking agents reduce the minimum burn thickness and increase the efficiency of the burn (Fingas, 2010). Wicking agents used in the past include peat moss and a variety of sorbent materials. These agents act as a wick or an insulator between the slick and the water, or a combination of both (Buist *et al.*, 1999). During the *Raphael* spill (Finland, 1968) 300 bales of peat moss soaked in diesel were used as a wicking agent; it is estimated that ISB operations achieved oil removal efficiencies of 80–95% (Buist *et al.*, 1999).

Smoke suppressors

Unlike ignition promoters and wicking agents, smoke suppressors do not act to achieve a greater efficacy of the ISB operation but are applied to the slick to reduce the amount of soot that is produced during a burn. It may be desirable to consider adding such substances to a slick to reduce the particulate matter for either environmental or health reasons. A number of products have been trialled over the past few decades but the most commonly used substance for oil spill response operations is ferrocene. Ferrocene has long been used as a smoke suppressor by way of its addition to some heating oils to reduce the particulates produced when combusted; adding 1–2% by weight of ferrocene to the oil can result in a soot reduction of up to 70% (Moir *et al.*, 1993). The application of ferrocene does, however, present operational challenges—it is a solid at room temperature (Moir *et al.*, 1993) and is denser than both oil and water (Fingas, 2010). However, work has been undertaken to develop a ferrocene substance which can be sprayed as a liquid (Moir *et al.*, 1993).

Herders

Although the performance of herders is not discussed in this document, an increasing amount of research is being undertaken into the use of chemical herders, especially in the context of oil spill response operations in ice-affected waters. Herders can be applied to the area around the slick which forces the slick into a smaller area countering the oils' natural tendency to spread as thinly as possible. The result is a thicker layer of oil on the waters' surface, the herder in effect removing the need for a fire boom. Current research into the use of herders in oil spill response operations is focused mainly on their use in ice-affected waters. Although fire booms can be deployed successfully in icy waters (Potter, S., 2010), this is a relatively complex operation; the use of herders as an alternative would be more efficient and would reduce the complexity of the operation.

Two herder products are currently listed on the United States National Contingency Plan (NCP) *Product Schedule* maintained by the US Environmental Protection Agency (US EPA, 2014). These can be applied at low dosages, at or below freezing conditions. In the *Product Schedule*, these herders are classified as 'surface collecting agents' (US EPA, 2014).

Glossary

Burnability	The ease at which a product will ignite.
Burn efficiency	A measure of the efficiency of a burn as determined by the amount of residue or product that remains after a burn has been extinguished compared to the estimated amount at the onset of the burn.
Critical tow speed	The tow speed at which the boom physically failed due to structural failure or submerging.
Encounter rate	The rate that a boom or skimming device corrals the product.
Fire point	The temperature at which the fuel will burn for at least five seconds after ignition by an open flame.
Fire-resistant containment boom	A boom manufactured with fire-resistant materials to maintain integrity during exposure to high temperatures during an in-situ burn.
Igniter	A device designed to provide a heat source to a material and increase its temperature to fire point.
In-situ burning (ISB)	A response technique that combusts vapours from slicks on a water or land surface and converts the hydrocarbon mixture into predominantly CO_2 and water, which is then released into the atmosphere.
Slick thickness	The amount of oil relative to its depth. Depending on fuel type and its evaporation rate, minimal oil thickness should be 2–3 mm to ensure continued burning.
Weathering	The natural processes whereby the physical and chemical properties of oil change after a spill.

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