The Use of In-Situ Burn Technology For the Control of Accidental Petroleum Fires on Water

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Abstract

Over the past 20 years many attempts have been made to contain burning oil on water with such barriers as air bubble and water-spray systems, high-temperature fabric booms, metal booms, water-cooled booms, and combinations of these devices. The development of such fire-resistant floating barriers (called "fire booms") and the associated techniques for the deliberate burning of spilled oil have exposed a new tool and improved response capability for marine fire fighters. Fire boom, if available on short notice, can significantly minimize, and in some cases prevent, the impact of a waterborne petroleum fire on people, equipment and facilities. Whether at sea, along shorelines, on rivers and lakes, or in ports and harbors, fire boom can be used to 1) contain and isolate a burning source of spillage; 2) enhance the use of fire-fighting foam; and 3) deflect burning oil away from vessels, docks and other sensitive resources. A properly deployed fire boom can help hold both the burning oil and the vapor-suppressant foam applied to that oil. The boom's freeboard and fire-resistant properties make it possible to build a proper foam thickness over the burning oil while keeping the foam from drifting away under the influence of wind and currents.

1.0 Introduction

Over the past two decades the oil spill response community has made significant efforts to develop equipment and procedures for the controlled "*in-situ*" burning of spilled oil on water (Buist et al., 1994; Fingas and Punt, 2000). Driven by the challenges associated with offshore drilling/production blowouts, tanker accidents and pipeline failures, technology has evolved to include the containment and rapid elimination of huge quantities of floating oil in place. The success of these efforts has revealed that the tools and techniques for such controlled "deliberate" burning could also be used for the control of "accidental" petroleum fires on water.

Known burn rates for fresh crude oils are typically around 3 to 4 millimeters of oil thickness per minute. A rule-of-thumb for fairly fresh oils involves approximately 200 liters per square meter per hour. Therefore, a burn area approximately 50 meters on a side could easily involve the elimination of about 500 cubic meters (or more than 3000 barrels) of oil per hour. With efficiencies of removal typically in excess of 95%, such burns can eliminate spilled oil faster and more efficiently than most other response options.

In order to achieve such high elimination rates, spilled oil must be kept at thicknesses that will sustain combustion. It is well known that at least a few millimeters are needed for most fresh oils, and that several centimeters, or more, are desirable. Minimum combustion thicknesses are often achieved at or near a spill source, particularly in very cold climates and in the presence of ice or other natural barriers. On open water or in fast-moving inland waters, however, spilled oil will often spread rapidly to thicknesses of a millimeter or less, making sustained

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combustion impossible. In such situations, containment of the oil with natural or manmade barriers is essential to conduct a controlled burn.

One of the most important "spin-offs" resulting from the development of deliberate controlled burn technology is the fire-resistant, floating barrier, or fire boom, that has proven to be effective in keeping oil thick enough to support sustained combustion. Such booms must have all of the usual sea-keeping and oil-containment characteristics of good conventional boom; however, they must also be capable of surviving temperatures often in excess of 1000 °C for extended periods of time. Special purpose booms involving high-temperature ceramics, stainless steel and water-cooled fabric covers have been used with a variety of burning petroleum products to demonstrate their utility under a wide range of environmental conditions (Walz, 1999; DeVitis *et al.*, 1999).

Marine and inland fire-fighting organizations are now able to expand their fire response capabilities because of the advancements recently achieved with fire boom. It is now recognized that if fire boom is staged at critical locations, it can be moved swiftly to 1) contain and isolate a burning source of spillage; 2) enhance the use of fire-fighting foam; and 3) deflect burning oil away from vessels, docks, and other sensitive resources. Without fire boom, it is often difficult or impossible to keep burning oil from reaching equipment, boats and other facilities, resulting in serious secondary fires. When waterborne fires occur in busy, inland waterways (e.g., Barges V822-V825, loaded with crude oil in the Upper Mississippi river, St. Louis, Missouri in 1983; and the tank vessel *Jupiter* loaded with gasoline in the Saginaw River, Bay City, Michigan in 1990)), burning oil can threaten bridges, hotels, restaurants and other sensitive resources with serious consequences.

Burning oil on water can now be contained and/or deflected with fire boom. More importantly, such boom now makes it possible to use conventional fire-fighting techniques and equipment more effectively. Where vapor-suppressant foams could not be applied effectively and kept from spreading out on water, they can now be contained along with the burning oil and allowed to build to an effective layer.

2.0 Modes of Use

There are many potential spill scenarios where fire boom could be used to help control the accidental spillage and combustion of oil on water. It is important to recognize that not all spill scenarios involving burning oil (or potentially ignitable oil) should be boomed. Depending upon the nature and location of the incident, and its distance from other sensitive facilities or resources, it may be advisable to encourage the transport and dispersion of flammable liquids away from the spill source. If the risks of fire or explosion are greater with burning oil at/or near the source than at locations downstream, the best course of action may involve the use of fire monitors, prop-wash, dispersants, and other measures to move oil and vapors away from the source as quickly as possible. There are spill situations where it is clearly better to avoid any concentration of spilled flammable material (ignited or unignited) at or around its source. To do so, in some cases, may actually prevent fire-control or spill-control personnel from accessing the source; such action may expose critical equipment or other petroleum storage units to excessive heat; and, the concentration of ignited or unignited product at the source may prevent the safe and effective relocation of the spill source.

As many spill response options as possible should be kept open and available on short notice. It is essential, therefore, to identify, study and evaluate potential spill and burn scenarios for a particular location in advance. Responsible personnel at petroleum handling facilities on or near water (i.e., platforms, vessels, docks, pipelines, storage tanks, etc.) should conduct a thorough risk assessment that includes the possibility of burning oil on water. Timing will obviously be of extreme importance in implementing an appropriate course of action to save lives, minimize damage to equipment and the environment, and bring the spill/fire under control.

The following accidental burn scenarios are provided as representative waterborne spill situations where fire boom could conceivably be used to mitigate the impacts of burning oil. The use of fire boom in such situations or similar spill scenarios should be determined on a case-by-case basis by qualified personnel on location.

2.1 Containment & Isolation at Dockside

Figures 1 and 2 illustrate two burn scenarios where fire boom is deployed around a burning source to prevent burning oil from spreading to other vessels and facilities nearby. In both examples, the boom is intended to contain burning oil and foam. In Figure 1, a boom may have been positioned prior to any spillage or prior to any ignition because of a very high risk of exposure to people and vessels/facilities immediately downstream. If possible, one or both ends of the boom (at the banks) should be releasable, as is the vessel-tended connection, should it be desirable to release the burning oil into a backup fire boom downstream. Such release may also be desired for the possible relocation of the fuel barge.

Figure 2 represents a similar fuel loading facility; however, the fire boom is maintained in a dynamic mode so that the boom-tending vessel can alter the size and shape of the oil/fire containment area. Should it be desirable, the containment area can be opened for greater oil-holding capacity, or it can be made smaller to reduce the volume of foam needed to cover the burning oil. As with the scenario in Figure 1, the tow line used by the boom-tending vessel should be of sufficient length (typically ~100 meters or more) to keep the vessel well upstream or out a safe distance from the fire.

2.2 Partial Containment & Deflection at Dockside

Depending on the rate of flow from the spill source, it may be unsafe or impractical to contain the burning oil at its source. As depicted in Figure 3, one or more ruptured pipelines are releasing enough oil to make containment impossible. It is also likely that swift currents, should they exist, would result in substantial entrainment of oil unless simply deflected. In this mode, the fire booms are used as multiple deflection booms to keep burning oil from moving toward docks, vessels and other facilities immediately downstream. With long towlines, continually submerged or wetted at the surface, burning oil could be deflected at each boom's seaward end, a safe distance away from the shore. Additional vessels with fire monitors (and/or foam and chemical dispersants) could be positioned to help deflect and extinguish the naturally thinning oil layer and keep it from moving toward shore.

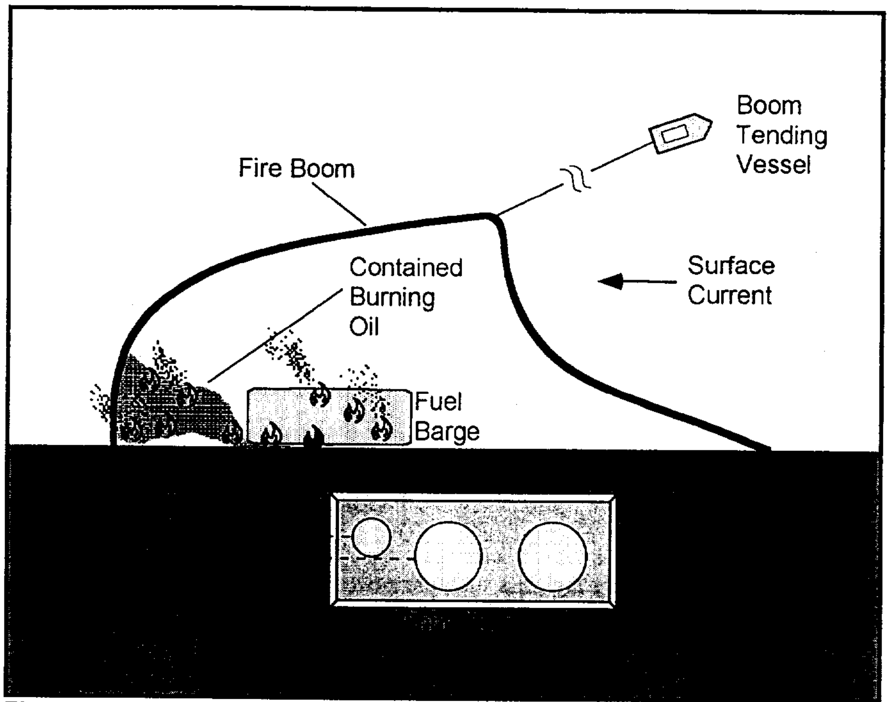

Figure 1 Containment of Burning Oil at Source – Fixed Configuration

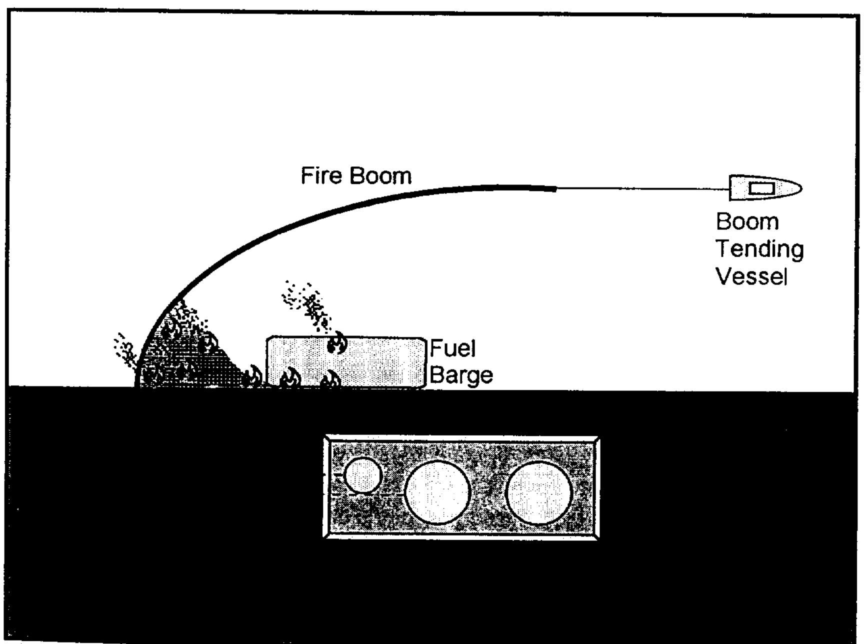

Figure 2 Containment of Burning Oil at Source – Dynamic Configuration

This scenario is one in which it would also be favorable to avoid immediate containment of the burning oil because of the need to save the damaged pier and other possible pipelines, and to minimize risk to the already disabled vessel that caused the accident.

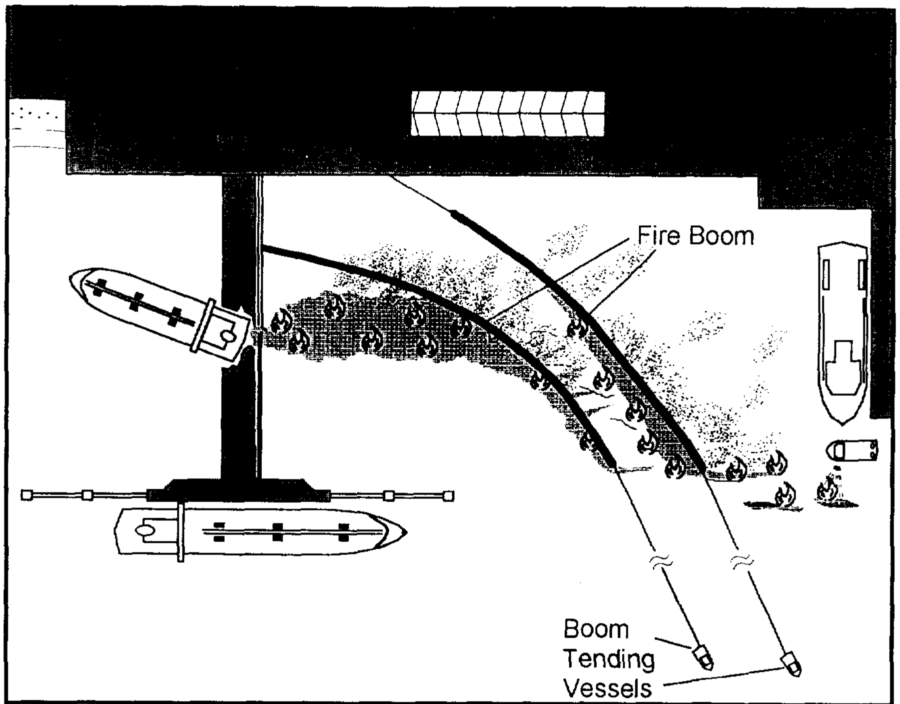

Figure 3 Partial Containment and Deflection of Burning Oil – Pipeline Rupture

In Figure 4, onsite conditions are such that containment of the burning oil at or near the source, would pose unnecessary risk to the vessel being fueled by the barge. A fire on the fuel barge has resulted in serious damage to the barge, and burning oil is drifting back toward a hotel and stores on creosote-soaked pilings. Pre-staged fire boom, if not deployed as a precautionary measure prior to fueling, could be deployed rapidly with the help of a line gun to minimize any exposure of the boom tending vessel(s) to oil/fire during deployment. Should there be enough fire boom to create a collection area (or "cusp") at the end of the boom, a contained burn at a safe distance from the dock could be used to hold and eliminate oil that would otherwise move off and contaminate other resources. If burning within the cusp is not used, vessels (as in Figure 3) could be used to extinguish any remaining fire. Where safe to do so, mechanical recovery systems could be positioned downstream and used to recover unburned oil and burn residue.

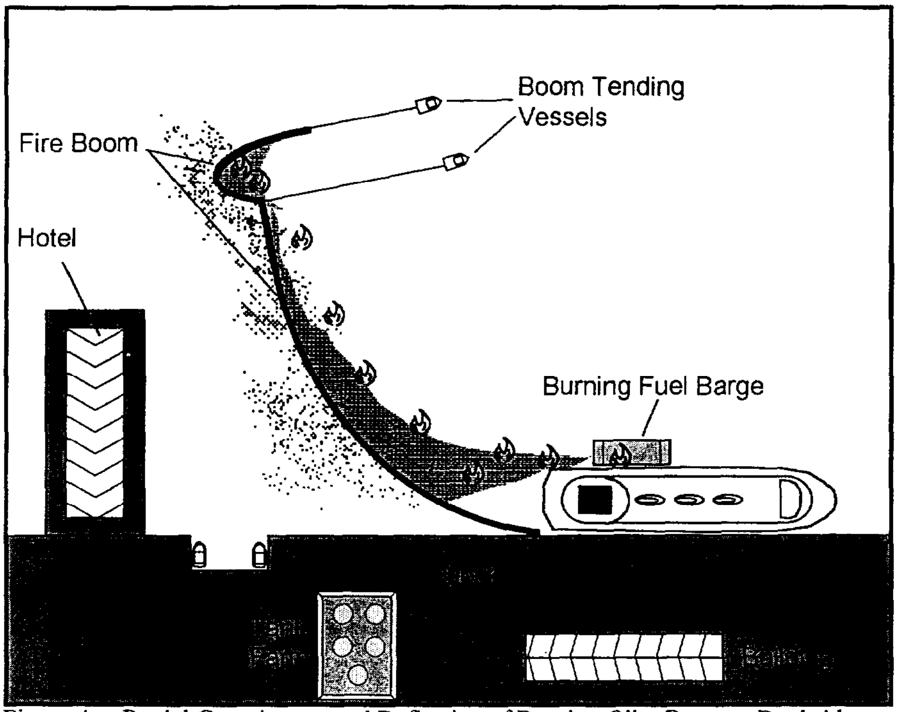

Figure 4 Partial Containment and Deflection of Burning Oil – Barge at Dockside

2.3 Deflection to Shoreline

Some accidents involve the rupture of fuel tanks and/or cargo holds during vessel groundings. In some cases, the vessel and its cargo are accidentally ignited (e.g., the *Pacific Glory* off the Isle of Wight, England in 1970 and the *Puerto Rican* off San Francisco Bay in 1984); while in other cases, a decision is made to deliberately burn the oil onboard (e.g., the *New Carissa* off Oregon in 1999). Sometimes, such groundings occur along shorelines that are extremely rocky, involve steep mountains or cliffs, and/or cannot be reached safely by land or by sea. In Figure 5 a spill scenario is illustrated where oil from a grounded vessel is on fire and moving in a light surf alongshore. In this case, there are no facilities to be protected; however, as oil moves in the littoral drift and out of the protected lee of the vessel and rocky point, the oil drops below its combustion thickness, becomes emulsified, and moves on to contaminate extensive portions of the shoreline.

This is a situation where protection of the environment (and not people/facilities) could result from the deflection of burning oil to a suitable location for "enhanced" combustion. The same shoreline deflection system could have been used had there been a risk of exposure to vessels or facilities downstream; however, in this example, the intent is simply to minimize environmental impact.

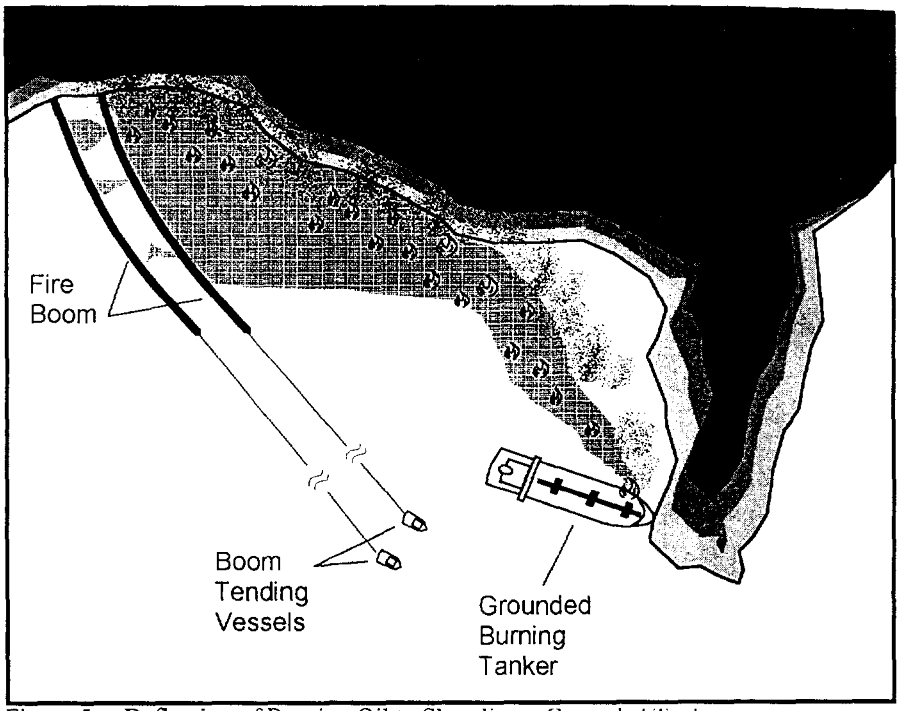

Figure 5 Deflection of Burning Oil to Shoreline – Grounded Tanker

If fire boom could be taken ashore safely with the boom-tending vessels, one or more booms could be anchored in the relatively calm lee-side of the vessel and held in a deflection mode for the duration of the burn. For a long-duration burn, arrangements would have to be made for the relief of personnel and the refueling of the boom-tending vessels. Should it be necessary, fire boom could be deployed by helicopter, setting the boom's shore-side end and anchor first, and then swinging seaward with the rest of the boom, dropping it for recovery by one of the vessels. The aerial deployment of boom can be conducted safely, and is an excellent way to set boom in difficult-to-reach locations.

Figure 6 involves a similar mode for deflecting burning oil; however, in this case, the burning oil is moving away from a damaged and burning, river-pipeline crossing. The burning oil is threatening vessels, marinas and other facilities downstream. In this scenario, fire boom has been deployed across the river to deflect the burning oil to lower currents in the river, and to a less sensitive portion of the river's banks. Secondary containment would normally be set up downstream of the primary fire boom for assured extinguishment and recovery of unburned oil and burn residue.

2.4 Exclusion of Burning Oil

Figure 7 is representative of a number of potential spills where burning oil could move quickly to threaten marinas, hotels, shopping areas and other public and private facilities. In this situation, fire boom had not been in place during the fuel

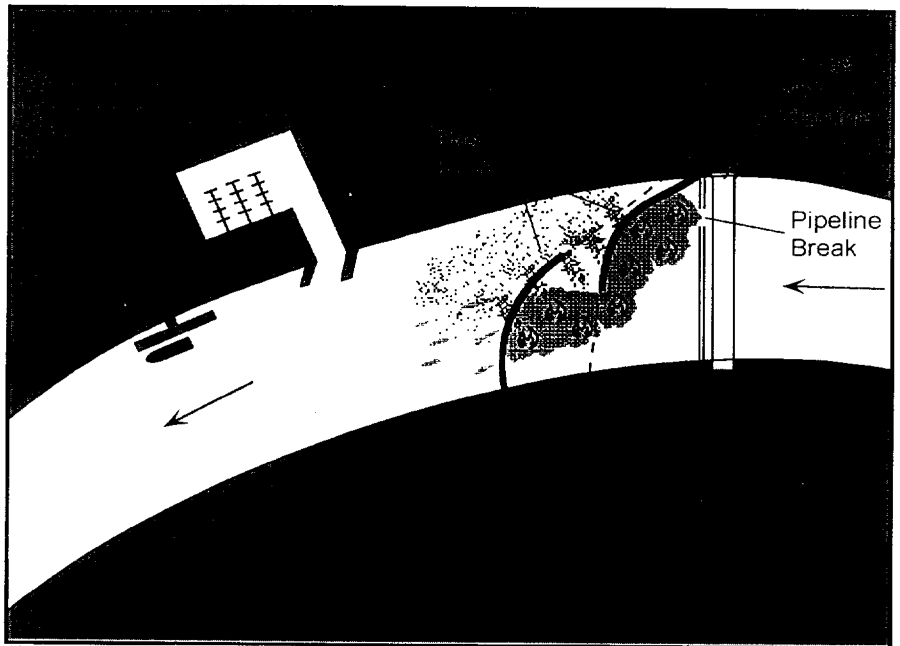

Figure 6 Deflection of Burning Oil to River Bank – Pipeline Crossing

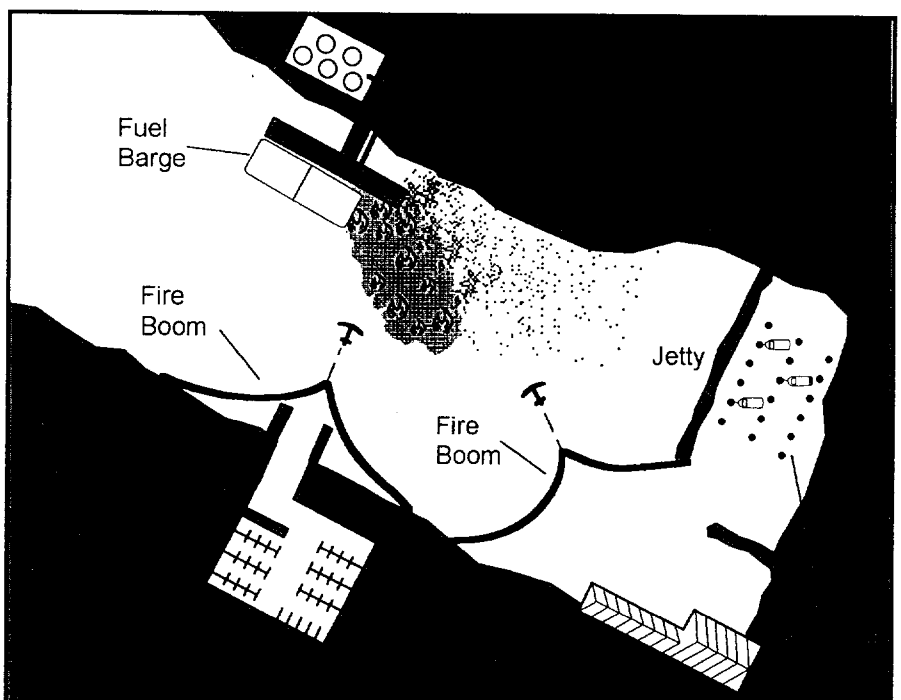

Figure 7 Exclusion Booming Between Shoreline Facilities and Burning Barge

loading operation, and boom was either unavailable or not safe to deploy at the spill site. Instead, fire boom has been staged at key locations where it can be positioned rapidly at pre-planned sites to keep burning oil from entering sensitive areas. The fire boom in this example is secured to shoreline anchor points and to pre-set anchor and buoy assemblies. Should burning oil reach the fire boom, it is likely that the buoys would be destroyed – a very small price for the protection of people, boats, and high-value shoreline property.

In burn situations involving exclusion booming, the objectives may simply be to hold the oil in place until it burns out, to deflect the burning oil to a less sensitive area, or to guide and concentrate the burning oil at a preplanned site for extinguishment. Depending on the nature and size of the spill/burn, the exclusion of burning oil from sensitive resources may be the only safe and practical option available.

2.5 Containment and Control Away from Shore

There are times when accidental petroleum fires occur at distances well offshore. Such fires may result from vessel accidents, blowouts, pipeline failures, etc. When they do, there may be a low risk of fire exposure to people and facilities at the shoreline; however, there may still be considerable risk to vessels, drilling platforms, and other offshore structures. Figure 8 is one such example where an oil and gas blowout is producing a heavy concentration of burning oil at and immediately downstream of the platform. Without the containment of the burning oil, nearby platforms and other fixed facilities could be exposed.

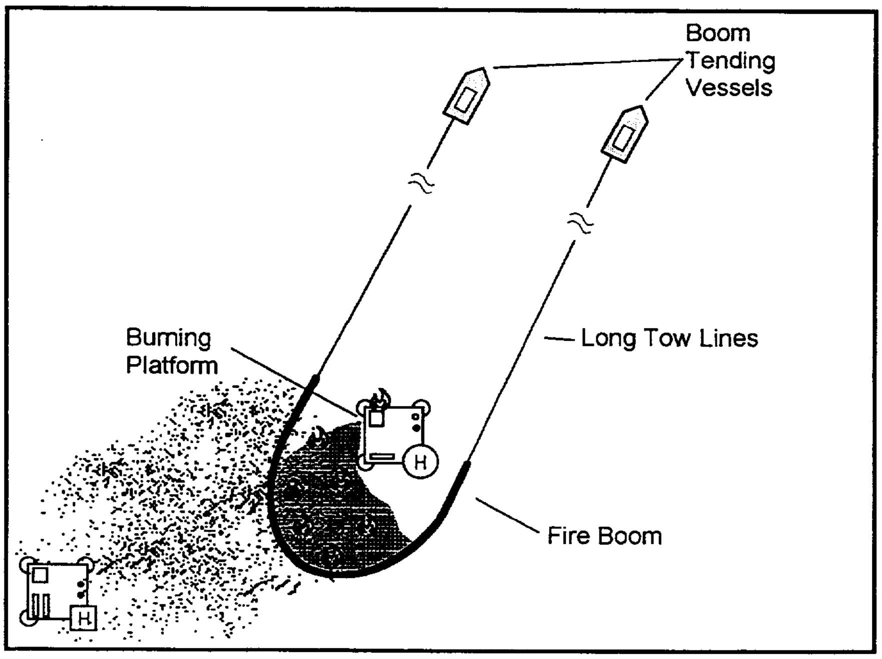

Figure 8 Containment and Control of Burning Oil in Open Water – Blowout

By positioning fire boom in a dynamic mode, boom-tending vessels are able to control the size of the burn area, and to maintain the boom's orientation in response to changing wind, wave and current conditions. Should the surface currents (over the ground) exceed 1 knot, oil entrainment beneath the fire boom would become excessive, precluding the possible use of a "station-keeping" mode of operation. The boom towing boats would then have to relocate downstream and work in a gradual drift backward (over the ground) as they maintain a heading into the current. This mode of collection would normally be performed with oil passing unignited between the towing vessels for safety reasons. And, if the oil had already self-extinguished, this drift mode of response would not be needed to protect other facilities from burning oil. This approach, however, could still be used for the collection and re-ignition of oil at a safe location for the controlled elimination of spillage.

In Figure 9, a similar open-water burn is contained; however, in this example, the source is a ruptured subsea pipeline that could have been impacted by the dragging of an anchor or by the erosion of bottom sediments beneath the pipeline. Accidentally ignited (by the vessel assumed to have dragged the anchor in this scenario), the surfacing plume of gas and oil has the potential to expose nearby drilling and production rigs to burning oil. As in Figure 8, if currents are sufficiently low (typically a knot or less), it might be possible to operate in a station-keeping mode with the fire boom around the surfacing plume. With guidance from an aerial

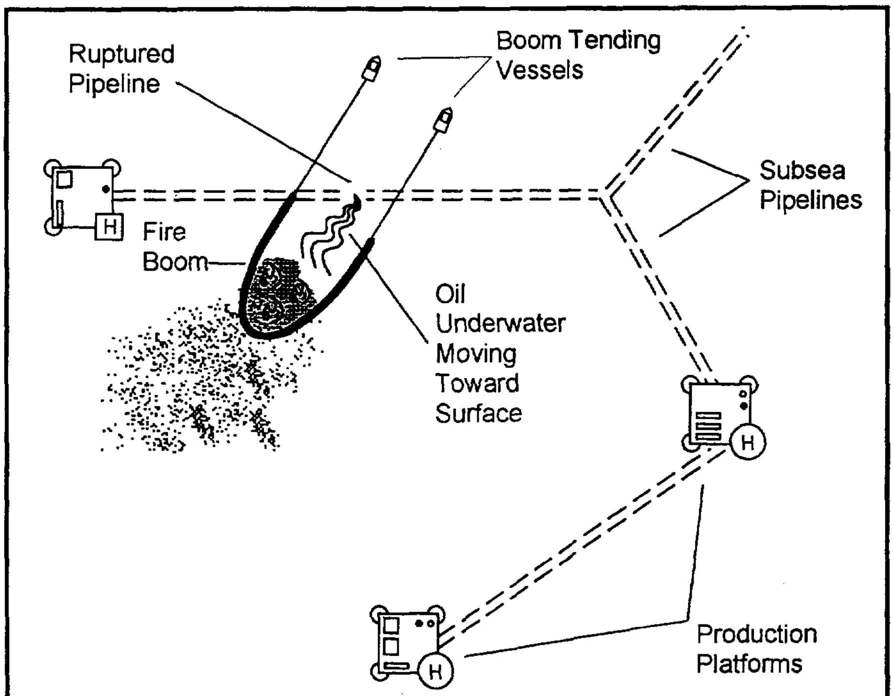

Figure 9 Containment and Control of Burning Oil in Open Water – Subsea Pipeline

spotter and/or observers on a nearby platform or vessel, the fire boom could be positioned to intercept all or a portion of the surfacing oil.

If a decision is made to continue burning (likely eliminating a vast majority of the oil), the light provided by the burning oil and gas could help the vessel captains to maintain a proper position, possibly even during darkness and/or limited fog conditions. As in the previous scenario, currents in excess of a knot would force the boom tending vessels to drift slowly (relative to the ground) while maintaining a heading into the current. Should it still be necessary to protect nearby rigs from burning oil, the boom-towing vessels could orient the fire boom to simply deflect the oil away from any exposed facility.

3.0 Operational Considerations

Unlike the deliberate use of controlled burning following an oil spill, the use of fire boom for accidental waterborne fires is an effort more in line with emergency fire fighting than with the control of spilled oil alone. Under most conditions, such emergency response to burning oil will not involve the degree of scrutiny, government and public reaction, and permission gathering often associated with the deliberate combustion of spilled oil. If spilled oil that is already burning threatens people, equipment and/or facilities, the immediate goal is to save lives while minimizing impacts to all resources, including the environment. The following information addresses some of the most important issues involving a decision to contain burning oil.

3.1 Safety

Fire-fighting activities, including the containment of an accidental waterborne fire, are, and should remain, the business of qualified fire fighters. The safety of personnel at or on the spill source, those being protected downstream or downwind, and those conducting the fire emergency response, should always be the single most important objective. The acquisition and staging of fire boom at any location should involve a thorough assessment of the risks and benefits associated with the deployment or non-deployment of fire boom, the full range of potential impacts (e.g., fire, smoke, unignited vapors, etc.), and the perceived impacts and reactions of private industry, government and the general public. As with forest fires, containment of a spreading fire is almost always the desired goal. The differences involving a waterborne fire, fed by an ongoing source of flammable liquid, however, must be considered carefully, and used to develop safe, meaningful and timely response options.

3.2 Training

The concentration of oil that could become ignited or is already burning at or near its spill source, is an action that must be anticipated, planned for and practiced. As with all emergency response programs, the success of a response under actual emergency conditions is strongly tied to the experience and readiness of those required to implement the response. When the spillage and potential combustion of oil are involved, there are unique precautions and procedures that must be followed. Personnel responsible for the planning, management and implementation of those procedures must be familiar with the locations, the environmental conditions and the resources available to carry out a safe and effective response. This best be accomplished by practicing those procedures until as many different scenarios as possible become familiar and workable. Realistic training also reveals where and when certain pieces of equipment may not be available or fail to meet expectations.

Recent field exercises in the Gulf of Mexico by the U.S. Coast Guard and other response organizations have involved the full-scale deployment and use of water-cooled fire boom and an aerial ignition system (summary reports and videos are currently in preparation). These exercises, involving a broad range of environmental conditions, have provided valuable hands-on experience for vessel and aerial support personnel. These realistic field efforts have also allowed for the evaluation and refinement of many command and control functions. It is this kind of full-scale, real-world training (preferably with burning oil) that should be used for the training of personnel responsible for the control of accidental waterborne fires as well.

3.3 Equipment and Procedures

The most important tool for the containment of waterborne petroleum fires is fire boom. There are several different types of fire booms, some consisting of high-temperature ceramic materials, some with stainless steel or other metal components, and some with combinations of these materials. During the last few years, important advancements have been made to improve the basic design and the materials for fire booms (Allen, 1999; Buist *et al.*, 1994; Fingas and Punt, 2000). The most promising concepts involve modifications of some earlier metal booms (to make them lighter and easier to handle), and totally new approaches incorporating "water-cooled" outer fabrics with a continuous feed of ambient water. Numerous laboratory, meso-scale and full-scale tests with these booms reveal that there are now lighter, stronger, heat-resistant booms that can survive long exposures to burning oil (Allen, 1999; DeVitas *et al*,1999; and Walz, 1999). The water-cooled system, with air-filled flotation chambers, can be stored on reels for easy deployment and recovery; it can incorporate solid-filled flotation to shorten the deployment time; and it can be reused over and over again for training and/or actual burns.

Fast and efficient booming of an accidental waterborne fire is clearly tied to the selection of the right fire boom. Equally important is the staging of that boom at the site(s) most likely to need containment and or protection. When a petroleum fire breaks out, there may only be a few minutes during which the fire boom must be deployed and secured to shoreline anchor points, dock slide-posts, anchor/buoy assemblies and/or boom-tending vessels. It is critical that these activities be designed and practiced to avoid placing response personnel and equipment in "harm's way". Pre-set boom anchor points should be placed so that they can be accessed quickly and safely. Boom-tending vessels should be capable of pulling out fire boom while avoiding any significant risk of exposure to burning oil. And, where necessary, line guns should be used to pass tow lines across potentially dangerous exposure areas.

Response plans and training activities for the potential use of fire boom must also be developed in light of other emergency response efforts. It is important, for example, that the containment of burning oil at or near a source not interfere with the evacuation of personnel from that vessel or facility. Safe and effective containment of a fire must include a careful assessment of access routes for moving people away from the source, if necessary; and, for moving source-control specialists and/or fire fighters to the source, if needed.

Other emergency response efforts might include the deliberate ignition of the source to avoid the formation of large vapor clouds. Such vapor concentrations could result in a massive fire or explosion, or they could threaten downwind activities or population centers. The placement of fire boom should be coordinated with such deliberate ignitions to limit the spread of burning oil while safeguarding personnel at the time of ignition.

Another response activity might include the intent to move the spill source (ignited or unignited) to a new location where it can be contained, ignited, lightered or repaired under improved, or at least safer, conditions. Such measures may be especially important should there be any doubt about the presence of other hazardous waste materials and/or products that could pose additional risks in the presence of water and/or fire. The type and amount of fire boom and logistical support to carry out such operations should be anticipated and used to acquire appropriate inventories of equipment, and to identify personnel requirements.

4.0 Summary

The efforts of many people and the support of numerous organizations over the past two decades have led to the development and refinement of equipment and techniques for the controlled burning of oil on water. With the initial intentions aimed at the deliberate ignition and elimination of spilled oil, it is now evident that a most important "spin-off" of these efforts involves a new level of control for accidental waterborne fires as well. The development of lighter, stronger, long-lasting fire booms, coupled with the experience of handling such booms, has provided the petroleum industry and all flammable liquid-product handlers with a unique way to deal with fires on water. These advancements will give fire fighters and spill responders additional tools for the control of oil fires in open-water, nearshore and inland waterways.

5.0 References

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