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A Guide to In-situ Burning of Oil Spills on Water, Shore, and Land

ARPEL ENVIRONMENTAL GUIDELINE

A Guide to In-situ Burning of Oil Spills on Water, Shore, and Land

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ARPEL Emergency Response Planning Working Group

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A Guide to In-situ Burning of Oil Spills on Water, Shore, and Land
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The Objectives of the ARPEL Emergency Response Planning Working Group are:

- To develop appropriate strategies to support industry's efforts to ensure a cost-effective response to emergencies both at the local and regional level.
- To promote the development of bilateral and regional cooperative agreements on emergency planning through joint government/industry cooperation.
- To provide guidance to assist industry's efforts in being proactive in the prevention of oil spills.

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1. INTRODUCTION

1.1. An Overview of In-situ Burning

This Guideline provides guidance on decision-making for in-situ burning of oil spills and practical advice on how to conduct burns. It contains a compilation of information and includes the scientific aspects of the burning process and its effects, examples from the extensive research into in-situ burns, and practical information about the procedures to be followed and equipment required for carrying out such a burn.

In-situ burning is recognized as a viable alternative to mechanical methods for cleaning up oil spills on water and in near shore areas, wetlands, and other land situations. When performed properly and under the right conditions, in-situ burning can rapidly reduce the volume of spilled oil and eliminate the need to collect, store, transport, and dispose of recovered oil. The response time to an oil spill can be shortened, thus reducing the chances that the oil will spread on the water surface and thereby protecting aquatic biota. Such rapid removal of oil can also prevent the oil from reaching shorelines, which are difficult to clean and where the greatest environmental damage caused by oil spills occurs.

While in-situ burning of oil spills has been tried over the past 30 years, it has only recently been accepted as an oil spill cleanup option in some countries. The lack of acceptance and implementation of burning as a cleanup option is largely because both the combustion products resulting from the burning of oil and the principles governing the combustibility of oil on water are poorly understood.

After an in-situ burn, by-products such as carbon dioxide, water, some smoke particulate, and unburned oil in the form of residue remain. Levels of emissions from the fire can now be forecast and safe distances downwind from the fire can be calculated. It may be necessary to contain the oil in order to carry out in-situ burning as the oil must be thick enough to burn - a minimum of 2 to 3 mm. Even if containment is required, however, in-situ burning requires less equipment and personnel than mechanical methods of oil spill cleanup.

The two essential physical concepts associated with burning are the minimum amount of vapors required above the oil slick, which is often simplified to a minimum thickness of about 2 to 3 mm, and the fixed burn rate. The burn rate is about 3.75 mm/min for a lighter crude oil and about 1 mm/min for heavier oil. Fuel, oxygen, and an ignition source are required. Fuel is provided by the vaporization of oil, which must be sufficient to yield a steady-state burning, that is one in which the amount of vaporization is about the same as that consumed by the fire. Once a light crude oil slick is burning, it burns at a rate of about 3.75 mm per minute, which means that the depth of the oil is reduced by 3.75 mm per minute. This rate is limited primarily by the amount of oxygen available. As a rule of thumb, the burn rate for light crude oil is about 5,000 L/m^2 day. Heavier oils burn at a rate of about 1,200 L/m^2 day.

The oil burn rate is a function of the area covered by the oil because of the physics of a burn, that is, the volume does not affect the amount burned in a given time, only the area burned. If not enough vapors are produced, either the fire will not start or it will be quickly extinguished. The amount of vapors produced depends on the amount of heat radiated back to the oil. If the oil slick is too thin, some of this heat is conducted to the water layer below it. Since most oils have about the same insulation factor, most slicks must be about 2 to 3 mm thick to be ignited and yield a steady-state burn. Once burning, the heat radiated back to the slick and the insulation is usually sufficient to allow burning down to about 1 mm of oil. If greater amounts of fuel are vaporized than can be burned, more soot is produced as a result of incomplete combustion, fuel droplets are released downwind, and small explosions, or fireballs, may occur.

Studies conducted in the last 10 years have shown that the type of oil is relatively unimportant in determining how an oil ignites and how efficiently it burns. Heavy oils, however, require longer heating times and a hotter flame to ignite than lighter oils. It has also been shown that heavier oils burn at a lower rate and at only about 70% efficiency.

It is uncertain whether oil that is completely emulsified with water can be ignited, although oil containing some emulsion can be ignited and burned. Burn efficiency is the initial volume of oil before burning, less the volume remaining as residue, divided by the initial volume of oil. Efficiency is largely a function of oil thickness.

The residue from burning oil is largely unburned oil with some lighter or more volatile products removed. When the fire stops, unburned oil is left which is simply too thin to sustain combustion. In addition to unburned oil, weathered oil is left that has been subjected to high heat. Finally, heavier particles are re-precipitated from the smoke plume back into the fire and thus become part of the residue. Highly efficient burns of some types of heavy crude oil may result in oil residue that sinks in sea water after cooling. Floating residue can be recovered using methods similar to those used for recovering very heavy oils. Small amounts of residue can be recovered by hand, using shovels and sorbents.

Fire-resistant containment booms may be needed to concentrate the oil to thicknesses that will burn well and efficiently. The types of these booms currently available include: water-cooled booms, stainless-steel booms, thermally resistant booms, and ceramic booms. Most fire-resistant booms, especially stainless-steel booms, require special handling because of their size and weight.

Fire-resistant booms are typically towed in a U-configuration by two boats or small ships. Oil is collected in the apex and ignited and the boom is towed so that oil continues to enter the boom. Tow speeds must be maintained below about 0.4 m/s (0.75 knots) to avoid oil loss. A 200-m boom will provide a maximum burn area of about 1,500 m^2. This burn area would remove oil at a maximum rate of 300 m^3/h. The rate for a typical crude would be about half of this and, for a heavier oil, could be as low as 1/4 of this.

As the U-configuration is difficult to maintain with two vessels towing, a tether line or cross bridle is often extended across the open end of the U to assist in maintaining the configuration. Concepts for deploying booms in other configurations as well as in diversionary mode are described. Possible techniques for using available materials and conventional booms are also discussed.

The types of ignition devices available for starting in-situ fires are outlined. The helitorch uses gelled fuel to ignite spills from a helicopter. Detailed procedures are given for fueling and deploying these devices. Several hand-deployable ignition devices have been built over the years, some of which can be made from readily available materials. For example, slicks have been ignited with fuel-soaked rags or sorbents, indicating that ignition is not usually difficult.

All burn operations must be conducted with safety in mind. Provisions must be made for good communications and backup measures. Burns should be monitored by aircraft whenever possible to provide early warning of heavy oil concentrations and other vital information such as movement of the smoke plume and problems with boom tows and other equipment. A backup method of monitoring burns is to use a larger ship, which provides a better view of the operations than smaller vessels. The tow vessels should be equipped with fire hoses or monitors to drive back oil or burning oil that get too close to the vessel. Burn crews must be trained in methods of escape, how to control unwanted fires, and how to extinguish fires.

The emissions from burning are discussed extensively in this manual. These emissions include particulate matter precipitating from the smoke plume, combustion gases, unburned hydrocarbons, organic compounds produced during the burning process, and the residue left at the site of the burning pool. Although consisting largely of carbon particles, soot particles contain a variety of absorbed and adsorbed chemicals.

1.2. How and When to Conduct Burns

There are several basic steps involved in burning oil spills at sea which are summarized in Figure 1. When an oil spill occurs, the situation is examined and analyzed for possible countermeasures. The type of oil, its thickness, and its state at the time burning could be applied are reviewed. The “prime rule of thumb” of in-situ burning is that oils will ignite if they are at least 2 to 3 mm thick. Although thinner oil slicks may burn, they will almost always burn when thicker than 2 or 3 mm.

The questions to be asked before deciding to use in-situ burning at a particular spill situation are outlined in Figure 2. If burning is possible and the response organization is prepared for burning, planning will then begin. A plan is formulated using pre-established scenarios, check lists, and safety procedures. In most cases, containment will be required either because the slick is already too thin to ignite or will become too thin within hours.

Next, personnel and equipment are transported to the site. In most cases, fire-resistant boom is deployed downwind of the spill and towing of the boom begins. When the oil collected in the boom is thick enough, it is ignited using a helitorch or a hand-deployed igniter. A close-up of a burn in progress is shown in Figure 3. The boom tow is resumed and continued until the fire is extinguished or the tow is stopped for operational reasons. The burning and progress of the tow are monitored by personnel in aircraft or on a larger ship from which an overview of the slick and conditions is possible. The monitoring crew can also direct the boom tow vessels toward slick concentrations upwind. During the burn, monitoring normally includes estimating the area of oil burning at specific time intervals so that the total amount burned can be estimated. The amount of residue is estimated in a similar manner. Particulate matter downwind might be monitored to record the possible exposure levels.

In theory, it has been proposed that a towed boom burn at sea can be stopped by releasing one end of the boom tow or by speeding up the tow so that oil is submerged under the water. Questions exist as to whether these two methods will extinguish a fully developed burn. If the burning stops because there is not enough oil in the boom, the tow can be resumed going downwind and then turning around into the wind before re-igniting. After the burn operation is finished, for the day or for the single burn, the burn residue must be removed from the boom. As the burn residue is very viscous, a heavy-oil skimmer may be required if there is a large amount of material. A small amount of residue can be removed by hand using shovels or sorbents.

Historically, many burns have been conducted on land, with fewer being conducted at sea. These burns and some of the lessons learned are summarized in Table 1. More lessons from these burns will be given throughout this guideline.

Figure 1: Steps in In-situ Burning

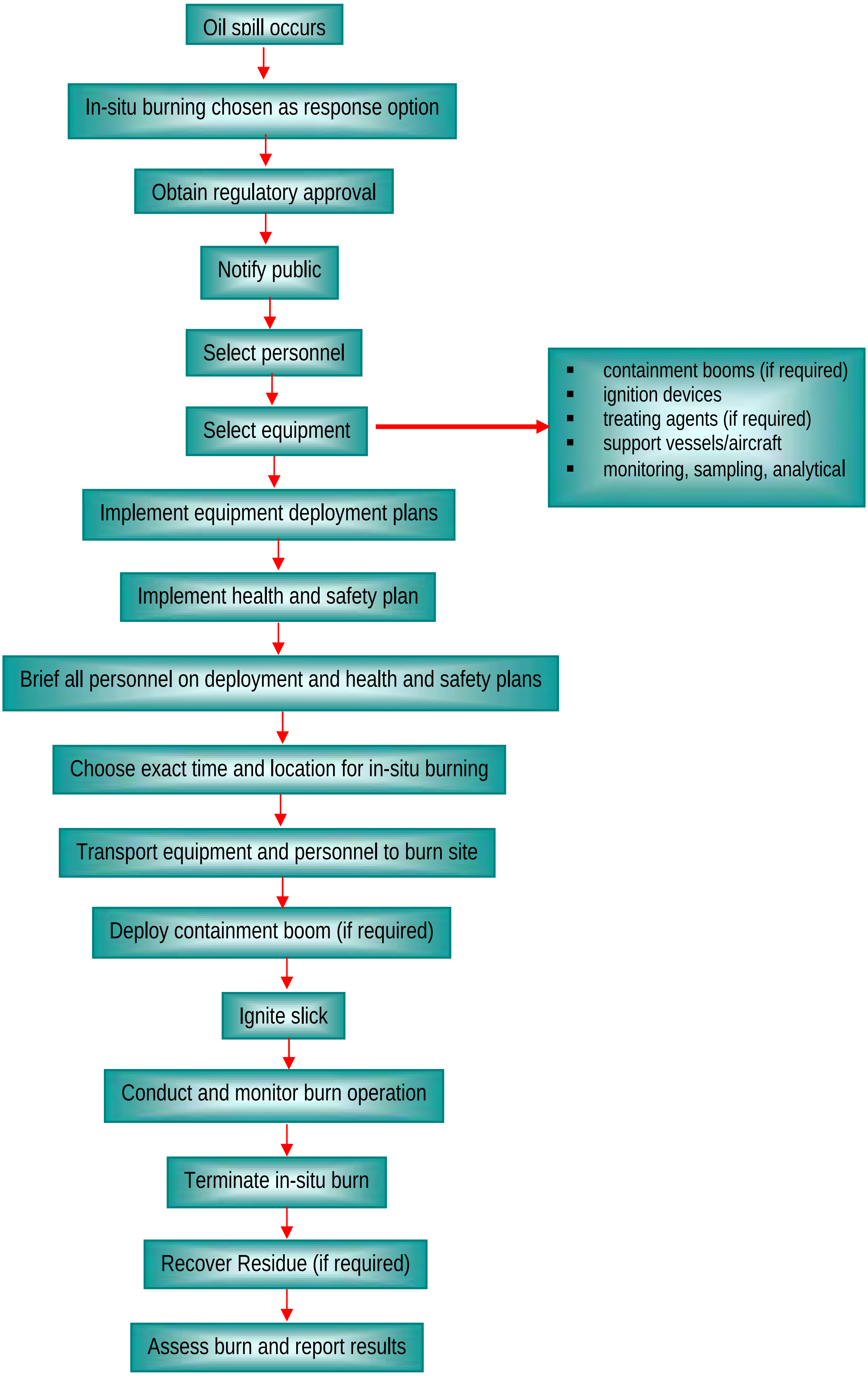


Figure 2: Decision Flow Chart for In-situ Burning

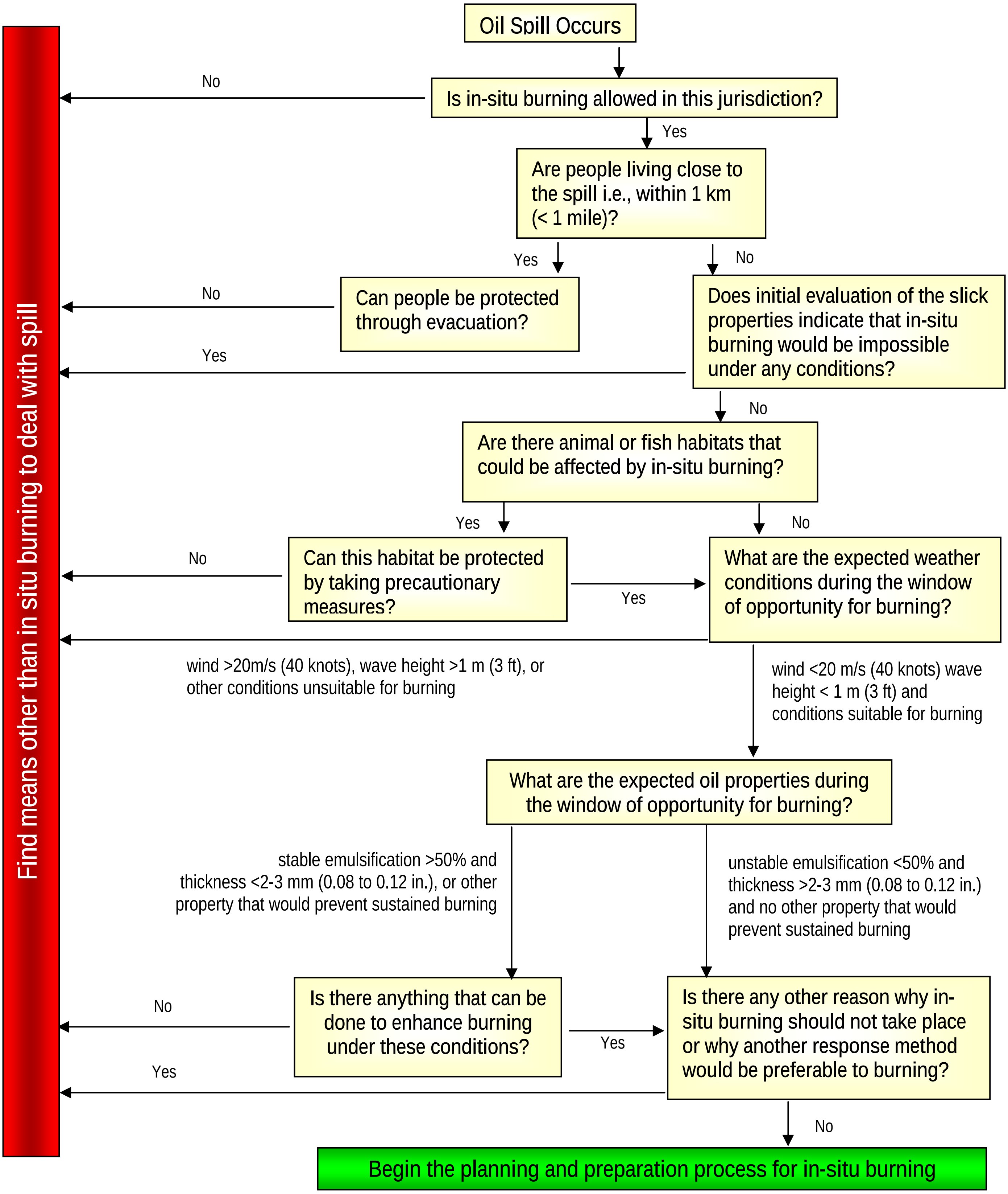


Figure 3 – Burn in Progress

2. ASSESSMENT OF FEASIBILITY OF BURNING

2.1. Burn Evaluation Process

When an oil spill occurs, information must be obtained on the spill location, weather conditions, and any other relevant conditions at the site. The planning and preparation for burning should have been completed beforehand. The checklist in Figure 1 and the decision tree in Figure 2 are used to decide if the burn is feasible.

The following steps should be taken:

- Review the plans and procedures already established.
- Consult with the regulatory agencies in the jurisdiction.
- Evaluate the location and the impact of smoke on humans and the environment.
- Decide if the oil is burnable both by type and thickness that would be achieved
- Evaluate the safety of any proposed burn.
- Evaluate the weather conditions and the opportunities for burning.
- Proceed if all conditions are met.

2.2. Areas Where Burning May Be Prohibited

Burning may be prohibited within a specified distance of human habitation, e.g., within 1 km and within a specified distance of the shoreline, petroleum-loading, production, or exploration facilities, or a nature preserve, bird colony, or national or state/provincial parks. Burning may also be prohibited in a marine park or preservation area and in areas designated as military target areas or former areas of munitions dumping.

Table 1: Some Historical Burns

Year	Country or Location	Description	Amount burned tons	Events	Lessons
1958	Canada	Mackenzie River, NWT	120	First record of use of in-situ burning, on river using log booms	In-situ burning possible with use of containment
1967	Britain	Torrey Canyon	800	Cargo tanks difficult to ignite with military devices	There may be limitations to burning
1969	Holland	Series of experiments	10	Igniter KONTAX tested, many slicks burned	Burning at sea is possible
1970	Canada	Arrow	50	Limited success burning in confined pools	Confinement may be necessary for burning
1970	Sweden	Othello / Katelysia	100	Oil burned among ice and in pools	Can burn oil contained by ice
1970	Canada	Deception Bay	100	Oil burned among ice and in pools	Can burn oil contained by ice
1975	Canada	Balaena Bay – experiment	40	Multiple slicks from under-ice oil ignited	Demonstrated ease of burning oil on ice
1976	U.S.A.	Argo Merchant	0	Tried to ignite thin slicks at sea	Not able to burn thin slicks on open sea

Year	Country or Location	Description	Amount burned tons	Events	Lessons
1976/82	Canada	Nipisi spills	~500	Two large spills in 1976 and 1982 were partially burned	Residue reduces potential for re-vegetation
1978/82	Canada	Series of experiments	<5	Studied many parameters of burning	Found limitation to burning was thickness
1978	U.S.A.	West Hackberry	<1000	Spill was burned accidentally	Burning was effective at removal
1979	Mid-Atlantic	Atlantic Express / Aegean Captain	>10,000	Uncontained oil burned at sea after accident	Uncontained slicks will burn at sea directly after spill
1979	Canada	Imperial St. Clair	<500	Burned oil in ice conditions	Can readily burn fuels amongst ice
1983	Canada	Edgar Jordain	200	Vessel containing fuels and nearby fuel ignited	Practical effectiveness of burning amongst ice
1984-5	U.S.A.	Beaufort Sea-experiment	5	Burning with various ice coverages tested	Burning with various ice coverages tested
1989	U.S.A	Exxon Valdez	30	A test burn performed using a fire-proof boom	One burn demonstrated practicality and easy
1990	Canada	British Columbia	<150	Tank battery overlow into bog	Bog flooding assisted in protecting plant life
1991	U.S.A	First step of Mobile experiments	50	Several test burns in newly constructed pan	Several physical findings and first emissions results
1992	U.S.A.	Chitipin Creek	200	Spill from pipeline burned using naphtha as igniter	Successful but residue hard to clean
1993	Canada	Newfoundland Offshore burn	100	Successful burn on full scale off shore	Hundreds of measurements, practicality demonstrated
1994	Russia	Kolva Pipeline Spills	>10,000	Large-scale burning over long period of time, mostly on land	Residue is problem, more control needed for efficiency
1994	Norway	Series of Spitzbergen burns	50	Large-scale burns of crude and emulsions	Large are of ignition results in burn of emulsions
1994	Norway	Series of Spitzbergen burns	100	Trial of uncontained burn	Uncontained burn largely burned
1996	Britain	Burn test	15	First containment burn test in Britain	Demonstrated practicality of technique
1997	U.S.A.	Louisiana spill	100	Pipeline spill	Condensate burned well and cleanly

2.3. Net Environmental Benefit Analysis and Scenarios

All decisions associated with spill response have inherent trade-offs. Net Environmental Benefit Analysis (NEBA) is a tool to assist decision makers in selecting the oil spill response option(s) or strategy that will result in the lowest overall negative impact on the environment. NEBA is best described as a "process" to gain consensus among stakeholders that considers and weighs the advantages and disadvantages of the different response options compared with the advantages and disadvantages of natural clean-up (no response) to arrive at a spill response decision that can result in the lowest overall environmental and socioeconomic impacts. An excellent reference on NEBA is the IPIECA Report Series Volume Ten – "Choosing Spill Response Options to Minimize Damage: *Net environmental Benefit Analysis"* which can be downloaded from the IPIECA website (www.ipieca.org).

Post spill decisions can be best made in a timely manner if based on pre-spill analysis, scientific work, consultations and agreements by the appropriate stakeholders long before the occurrence of an actual oil spill. For this reason, NEBA must be conducted as part of oil spill contingency planning. The response countermeasures that are generally evaluated in the NEBA process are:

- Mechanical (containment and recovery with booms & skimmers)
- Recovery by hand (rakes and shovels)
- Chemical Countermeasures (dispersant)
- In-situ Burning
- No response (natural clean-up)

There are a number of steps to take in order to develop an effective NEBA. These include:

- Gather detailed information on the local environment. The term "environment" includes both natural – such as mangroves, coral reefs, bird nesting areas, various types of beaches, etc. - and man-made – such as water intakes, wharfs, tourist facilities, etc. In fact, if one has not already been produced for the area, this is a great opportunity to develop a complete sensitivity map showing ALL environmentally (natural and man-made) sensitive sites. NOTE: Keep in mind that sensitivity's may change depending on the season. For example, migratory birds are obviously not a high priority when they are not present (although their nesting areas may be).
- Identify the products that could possibly be spilled that would threaten these sites. Included in this evaluation would be the predicted spread, thickness and oil movement and deposition, including weathering and chemical composition
- Once the above information is gathered each site needs to be prioritized as to its sensitivity and given a rating as to its recoverability. For example, mangroves may have a high sensitivity rating and a "slow" recovery rate if it is oiled while a sandy tourist beach may be relatively less sensitive and have a high recovery rate. The key here is to work very closely with all stakeholders, especially government officials.
- Consider all response strategies that could be used to respond to a spill of the various identified products.
- Again, working with stakeholders, develop predictions of how each of the identified response strategies will affect each of the identified sensitive areas. Using a mangrove swamp as an example, one could predict the mangroves will be significantly affected should no action take place or recovery is done by hand while there may be no to little affect if the oil is e.g. burnt or dispersed before it can interact with the mangroves.

- Once all this work is completed an evaluation of each of the response strategies and their predicted affects on each of the sensitive sites is done by comparing the advantages and disadvantages to the environment.
- Finally, using all of the information gathered the optimum response method can be identified.

As is apparent, it is difficult to conduct this process on the spur of the moment. It needs to be completed as part of the contingency planning process with the input from all of the key stakeholders including applicable government agencies. By working together all parties will have a much better understanding of what is at stake should a spill incident occur and how best to respond to that spill.

As no two oil spills are the same, it is helpful to look at several possible scenarios when developing response techniques for spill situations. The following burn specific spill scenarios and the suggested strategies for dealing with them are described in Appendix A: burning at sea, burning in a protected bay, burning on a river, burning in a salt marsh, and burning in an inter-tidal zone.

The strategies listed in Appendix A can best be implemented using specific tactics. These tactics are listed in Appendix C and each one is illustrated separately in Figures C1 to C9. Each of these tactics has specific advantages and limitations.

The well-known tactic of using towed fire boom to collect and burn oil directly in the boom is shown in the Figure C1. As with all booms, this technique has a relative current limitation of 0.4 m/s (0.7 knots) before oil is lost under or over the boom. This can be overcome on the open ocean by towing at the relative velocity, despite the surface current. This means that, if the actual current exceeds 0.4 m/s (0.7 knots), the boom tow could be slipping down current. Another limitation of this method is that the fire could propagate to the source of the oil or endanger the tow boats and their crew.

Collecting the oil separately, towing the boom away from a non-burning source, and then burning the oil are shown in Figure C2. This approach prevents the fire from spreading to the oil source. Another advantage is that the oil can be collected using a conventional boom and then transferred to a fire-resistant boom for actual burning. Since fire-resistant boom is more expensive and harder to deploy than conventional boom, this option has some practical and economic benefits.

The use of towed boom to burn and to separate the source from the fire and the use of fire-resistant boom to protect amenities are shown in Figure C3 and C4. Using anchored boom to burn oil is shown in Figure C5. This tactic poses no risk to tow boats and their crew. The boom may not maintain correct alignment with the wind and current, however, and the relative velocity of the surface current and the boom are also considerations. The use of anchored deflection boom to direct oil away from amenities or toward burn areas is shown in Figure C6. The burning of oil against shoreline is shown in Figure C7. This can only be done if there is no combustible material such as trees and buildings on the shoreline. In addition, highly adhesive oil residue may be left on the shoreline, which could be difficult to remove.

Oil can be contained in shallow water using a temporary steel boom as shown in Figure C8. The boom is constructed of corrugated steel sheets and metal stakes. As a portion of the corrugated steel is in the water, heat is dissipated and the sheet metal should remain intact long enough for the oil to be burned. It is important to stress that this method has not been extensively tested and backups should be in place in case of failure.

Finally, burning uncontained oil is shown in Figure C9. While this method is simple and economical, the oil must be thick enough to ignite and burn, which is rare for most uncontained spills of crude oil.

2.4. Burning in Special Locations

There is only limited experience in using burning in a variety of special locations. Summary information on the use of burning at locations other than on open waters using fire-resistant boom is provided in this section.

Several marsh burns have been conducted around the world, including recent well documented burns in Louisiana and Texas. These burns were mostly successful and provided important information on protecting the marsh plants and the best time of year to burn. The roots of marsh plants, which contain the propagation portion of the plants, are sensitive to heat. If burning is conducted at a dry time of year, such as in late summer, these roots will be killed Flooding is a useful technique for flushing oil out of a marsh while protecting the roots of marsh plants.

This can sometimes be accomplished by putting a berm across the drainage ditches or by pumping water into the high areas of the marsh. Care must be taken to use flood water of similar salinity to that normally in the marsh and to restore the natural drainage in the marsh after the flood. Several studies have been conducted on the depth of water that is best for minimizing damage. These studies have shown that the damage to Spartina and other marsh plants is negligible when the water depth is 10 cm over the roots and soil surface. The damage to the plants is measurable when the water is 2 cm deep and more severe when the water is 2 cm below the soil surface.

Often marshes cannot be flooded, however, and thus burning could be conducted when the marsh is wet such as in spring. If a marsh cannot be burned within about one month of oiling, there is usually no benefit to burning because the oil will already have penetrated and severely damaged most of the plant life. When burning in marshes, care must be taken to prevent damage to shrubs and trees that grow in the back and higher areas of the marsh. A fire-break must be available to prevent the fire from spreading outside the marsh and to ensure that wind will not drive the fire into nearby forested areas.

Burning can be conducted near-shore if there are no people in the area and there is no danger of the fire spreading to plants on the shore. As these two factors cannot always be guaranteed, near-shore burning is not often conducted. The exception to this is in the Arctic where these conditions often exist and where near-shore burning is practiced frequently. Such burns have been very successful, particularly if the oil is contained by the shoreline. If there is also an onshore wind, oil is concentrated against the shoreline.

When oil is stranded in tidal pools formed during low tide, igniting the oil from above using a helitorch or other air-deployable igniter and conducting a burn may be the only viable cleanup solution. It can be dangerous for response personnel to get to the spilled oil either from the shore or the water between tides and such attempts are not recommended. The window of opportunity for burning is quite narrow, however, because of the extreme fluctuations between outgoing and incoming tides. It is also difficult to predict the location of the oil pools and there may not be enough time to conduct aerial surveillance before burning operations. This type of in-situ burn operation would be useful for an oil spill in an area of extensive inter-tidal flats.

3. HOW TO APPLY BURNING

3.1. Burning Without Containment

Controlled burning of uncontained slicks is sometimes possible if the slick is thick enough and all other safety factors are considered. As it takes time to get containment booms to a site, if the oil slick is already fairly thick, it may be best to ignite and burn as much of the slick as possible as a first response and then bring in containment booms to thicken the remaining parts of the slick for a second burn. Uncontained oil can be ignited with a helitorch at the location where the oil is thickest. Such a technique is illustrated in Figure C9.

When burning an uncontained slick, personnel must ensure that there is no direct link between the oil to be burned and the source of the oil, e.g., the tanker or platform, to prevent the fire from spreading to the source. The safest and quickest option is to move the source away from the slick. In the case of a tanker spill, this can be done using a tug boat. When the spill originates from a platform or other fixed source, the portion of the slick that is to be burned should be moved away from the source and the oil slick around the source should be isolated using containment booms.

Several oil spills or blowouts have accidentally caught fire while uncontained and have burned well. While it is not known what conditions are best for burning uncontained oil, emulsified oil may stop or retard the spreading of uncontained oil while it burns. In a large burn, large volumes of air are drawn into the fire, which is referred to as a “fire storm”. This may provide enough force to prevent the oil from spreading. Oil from tankers has burned on the sea because oil is thick near the spill source. Such a burn is shown in Figure 4.

Figure 4: A burning tanker

In remote areas, natural barriers such as shorelines, offshore sand bars, or ice can sometimes be used to contain oil so that it can be burned. The shorelines must consist of cliffs, rocks, gravel, or sandy slopes to resist burning and there must be a safe distance between the burning oil and any combustible materials, such as wooden structures, forests, or grass cover. In populated areas, the weather conditions must be such that the smoke plume will drift offshore. Zones of convergence can also be used to contain oil. Local oceanographers must be consulted to determine the location of these zones. The local authorities (i.e. Coast Guard or similar organization) and fishermen are also familiar with currents in an area.

3.2. Oil Containment and Diversion Methods

An oil slick must be at least 2 to 3 mm thick in order to be ignited and continue to burn. Several methods for increasing the thickness of a slick to this level or to maintain a thickness at or above this level are discussed in this section.

The biggest concern with containment booms for in-situ burning is the ability of the boom's components to withstand heat for long periods of time. Very few fire-resistant booms are commercially available because the market is small and the cost of production is high. Fire-resistant booms cost considerably more than conventional booms. These booms often have been tested for fire resistance and for containment capability.

The different types of fire-resistant boom are water-cooled booms, stainless steel booms, thermally resistant booms, and ceramic booms. Fire-resistant booms require special handling, especially stainless steel booms, because of their size and weight. Thermally resistant booms look and handle like conventional booms, but are built of many layers of fire-resistant materials. The various types of fire-resistant boom are shown in Figure 5.

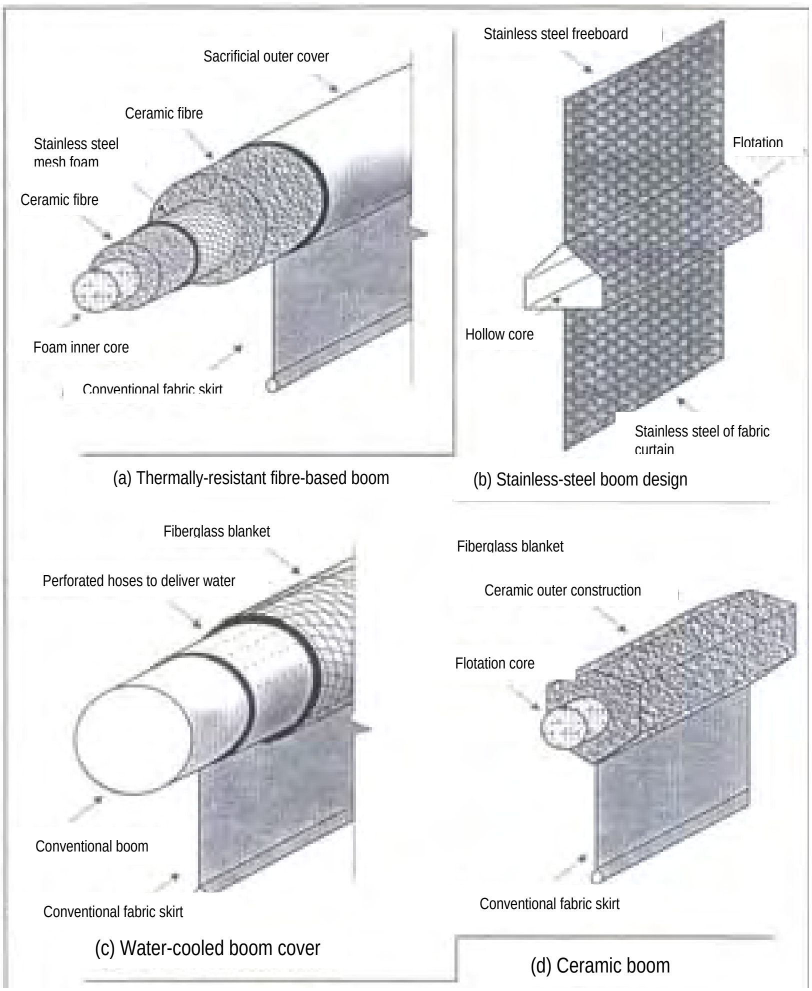
Conventional booms cannot usually be used to contain burning oil as the construction materials either burn or melt, compromising the boom's ability to contain the oil. It is often much quicker to get a conventional boom to a spill site, however, as they are much less expensive and very few fire-resistant booms are stockpiled at spill response depots.

Conventional booms can be used to corral a slick and contain it until a fire-resistant boom can be obtained. These booms can also be used to contain and thicken a slick to an acceptable burning thickness and then burn it, thus sacrificing the boom. The overall burn efficiency of this method is questionable, however, as the boom will not remain intact for very long once the oil is burning. When the boom fails, the slick could spread and quickly become too thin to sustain burning.

Logs or other floating material can sometimes be used as temporary booms. In narrow rivers, dams can be constructed across the upper layer of water to contain or divert the oil for burning.

The size of boom required for an in-situ burn depends on the amount of oil to be burned. Generally, the oil in the boom should fill no more than one third of the area of the catenary. If the boom is too long, it will be difficult to control and the stress on the boom may be too great. If the boom is too short, the catenary may not be large enough to contain the burned oil.

Figure 5: Fire-resistant Boom Designs
(Source: Fingas, M.F. and M. Punt, 2000)



In general, booms range from 150 to 300 m in length, with most commercial booms coming in standard lengths of 15 or 30 m. The relationship between the length of the boom and the area of oil that can be contained is shown in Figure 6. The overall height of the boom should be equal to the maximum expected wave height (short period waves, not swell) from peak to trough. Figure 7 shows a burn in a tow configuration.

An important factor when containing oil is the direction and speed at which the boom is being towed. The burn should be far enough from the tow vessels that it doesn't endanger the tow vessel or personnel onboard the vessel. However, unless the tow line is very short (only a few metres long), the heat from the fire should not be an issue. Also, since the boom is being towed upwind, the smoke from the burn should not reach the tow vessels. Figure 8 shows a burn from containment boom that was not headed directly into the wind.

In general, tow lines from tow boats should be at least 75 m long. The boom must always be towed into the wind so that the smoke will go behind it. As tow speeds are measured relative to the current, the boom may have to be towed very slowly or even downwind to maintain a low enough speed relative to the current while towing into the wind. If the boom is towed too slowly, however, the burn will begin to move up towards the end of the boom.

In general, the boom must be towed at a speed of less than 0.4 m/s (0.7 knots) relative to the current in order to prevent the oil from splashing over the boom or becoming entrained beneath the boom. The towing speed may have to be increased periodically if the burn begins to fill more than two-thirds of the boom catenary. If contained oil does become entrained in the water column below the boom or splash over the boom, it will resurface or pool directly behind the apex of the boom. This oil could be reignited by burning oil inside the boom or by oil that splashes over the boom.

Another important factor in ensuring that the oil is properly contained for burning is the configuration of the boom. Booms can be towed in various configurations, depending on the equipment available and the weather and sea state conditions. The various conventional configurations for oil spill booms are shown in Figure 9.

The standard configuration is a length of fire-resistant boom connected with tow lines to two vessels at either end of the boom to tow the boom in a catenary or U shape, as shown in Figure 9 (a). Note: The addition of similar sized regular containment boom as leader boom on each end of the fire resistant boom can increase the encounter rate with the oil when towing in a U configuration. A tether line or cross bridle is often secured to each side of the boom several metres behind the towing vessels to ensure that the boom maintains the proper U shape, as shown in Figure 9 (b). This tether line or cross bridle is useful in maintaining the correct opening on the boom tow as well as preventing the accidental formation of the J configuration. The tether line can also be attached to the vessels as shown in Figure 9 (d). The advantage of this method is that boat operators can detach the tether line very quickly in case of an emergency.

When using the standard U configuration, it can be difficult to ensure that the two towing vessels maintain the same speed. To overcome this problem and to increase control over the boom configuration, three vessels can be used as shown in Figure 9 (c). One vessel tows the boom by pulling from the centre using tow lines at each end of the U, while the other two vessels pull outward from the ends of the boom to maintain the U shape.

Figure 6: Nomogram to Calculate Burn or Slick Area
(Source: Fingas, M.F. and M. Punt, 2000)

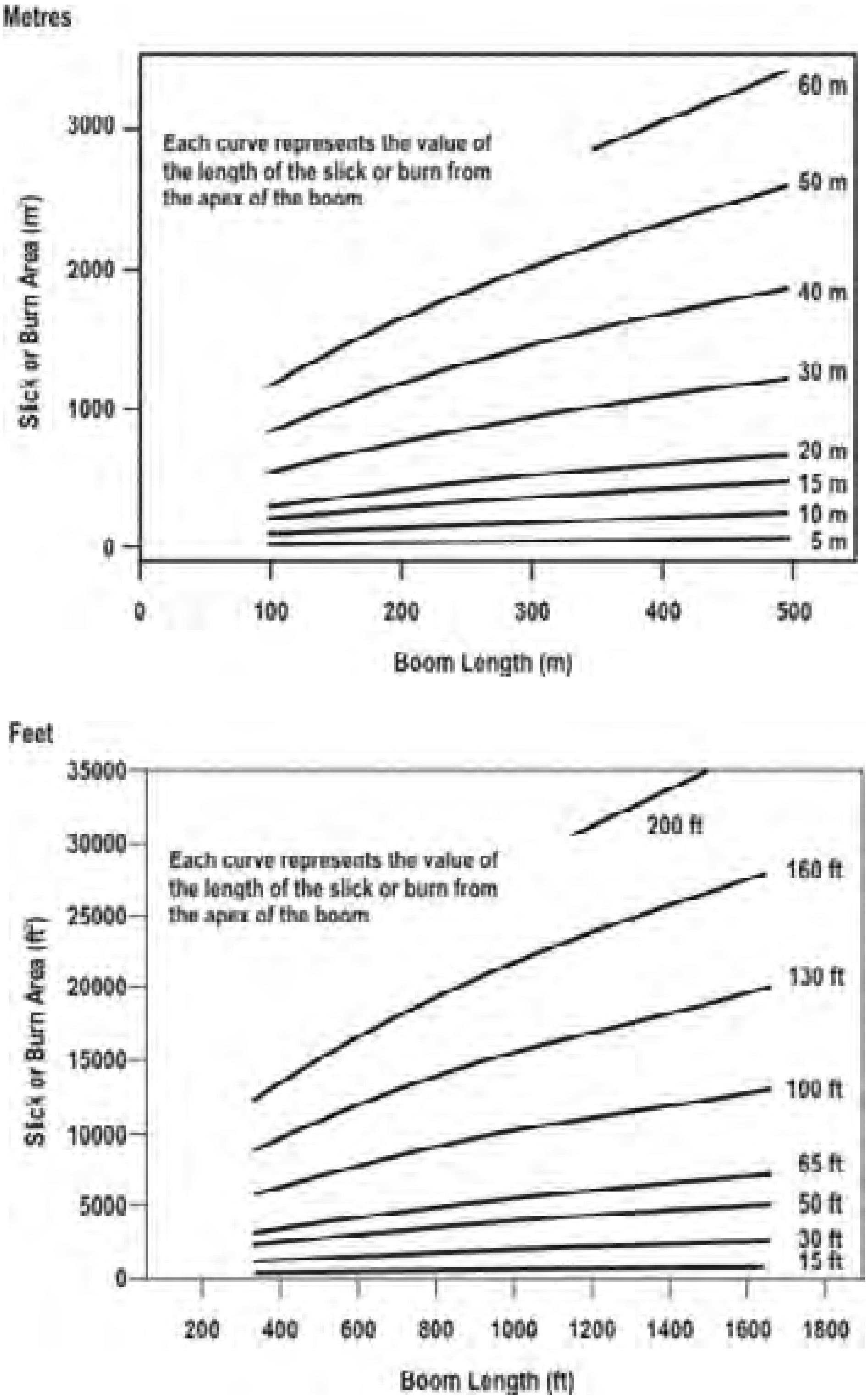
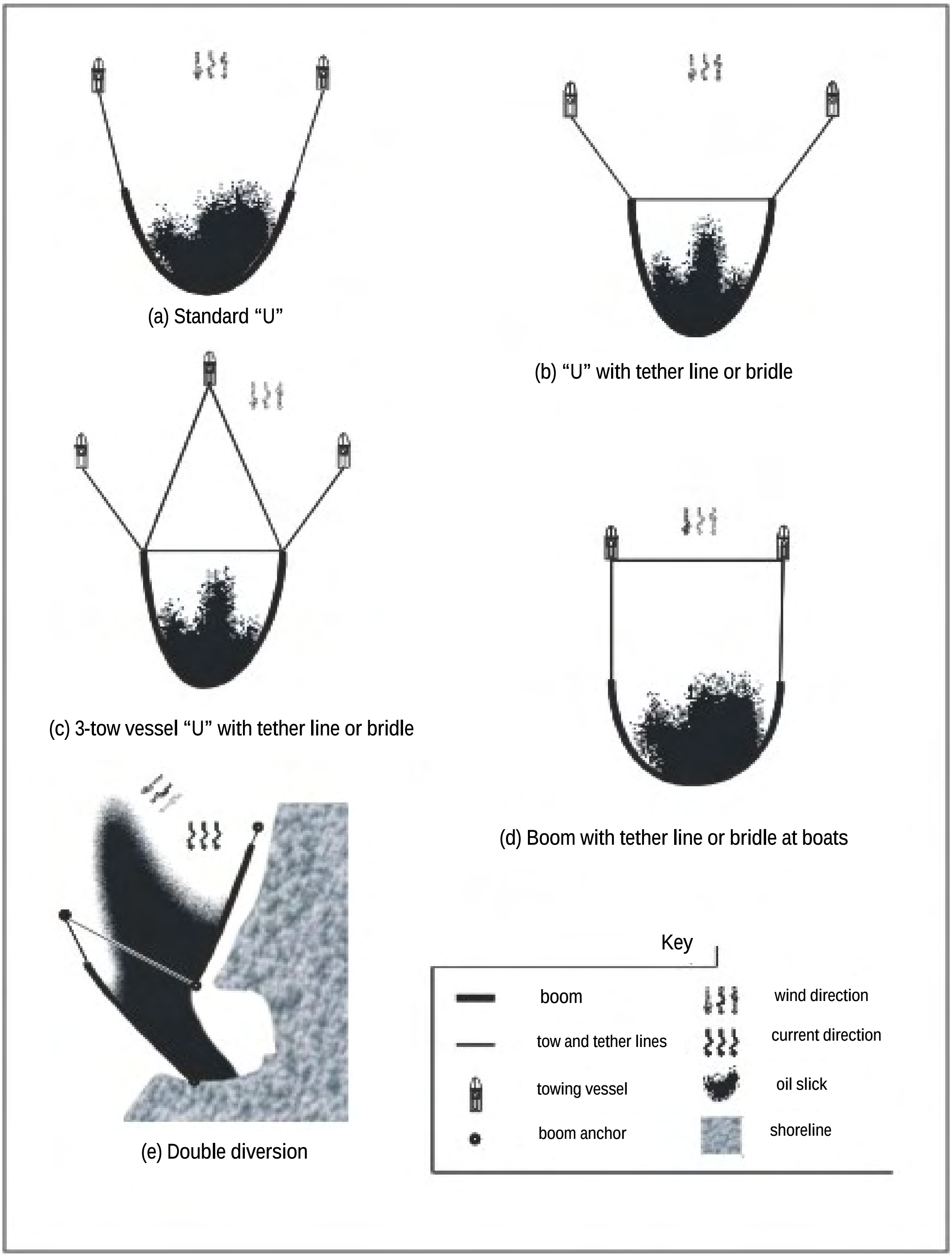


Figure 7: A test burn at sea using a fire-resistant boom for containment. *At the time this picture was taken, only oil at the rear of the slick is burning, as the forepart is too thin.*

Figure 8: A test burn at sea. *Note that the boom was incorrectly towed downwind and there is some leakage behind the boom*

Figure 9: Boom Configurations for In-Situ Burning
(Source: Fingas, M.F. and M. Punt, 2000)



If the oil is near shore, a boom or booms can be used to divert it to a calm area, such as a bay, where the oil can be burned. An example of this method using two booms is shown in Figure 9(e). Diversion booms must be positioned at an angle relative to the current that is large enough to divert the oil, but not too large that the current would cause the boom to fail. The boom must be held in place either by anchors, towing vessels, or lines secured to the shoreline.

In near-shore situations, anchors can be used to secure booms in a stationary position. It is important, however, that a proper anchor is used particularly in high currents to ensure that the boom will stay in place for the duration of the burn.

These configurations are also illustrated graphically in Figures C1 to C9 in Appendix C.

The following is a typical procedure for deploying boom in open water from a vessel using a standard U configuration:

- The deployment vessel is located far enough downwind from the oil to allow enough time to deploy the boom before approaching the oil.
- The deployment vessel aligns itself so that its bow is facing upwind.
- Before the first part of the boom is deployed from the deck, a tow line for the towing vessel is attached to the end.
- The boom is deployed off its stern so that the wind causes the boom to trail behind the vessel.
- When the last section is deployed, the end of the boom is attached with a tow line to the deployment vessel, which now becomes one of the towing vessels.
- The tow line at the other end of the boom is then attached to a second towing vessel.
- The second towing vessel heads upwind until the proper U configuration is formed.

If a tether line or cross bridle is used across the opening of the U [see Figures 9 (b), (c), and (d)], this line should be attached to the end of the boom or tow line closest to the deployment vessel before the last section is deployed. Once the U is formed, a third vessel will have to bring this line across to the other end of the boom or tow line and connect it. If, as is shown in Figure 9 (c), a third tow vessel is used for stability, the tow lines for this third vessel should also be attached as the boom is deployed and then attached to the third vessel, which then situates itself in-between and ahead of the other two tow vessels.

The method for deploying diversion barrier in a river is very different from deploying containment boom in a U configuration in the open ocean. The boom must be held in place at an angle relative to the current that is large enough to divert the oil, but not so large that the current would cause the boom to fail. The boom must therefore be secured in place either with lines to the shoreline or towing vessels, or by anchoring the boom on the river bottom. Unless the boom can be fixed to both shorelines, it is normally more secure to use anchors.

A backup boom can be placed 200 to 300 m behind the burn to contain any oil that has been entrained or has splashed over a fire-resistant boom during the burn. A conventional boom that is not fire-resistant can be used as any burning stray oil would be extinguished on its own or by the fire-extinguishing vessel before it reaches this boom.

It has also been found that oil escaping from the fire-resistant boom will usually pool directly behind the boom because of eddies formed in this area. This oil usually remains in this area for some time and therefore can become reignited or remain lit. If this oil escapes, it will spread and become too thin to sustain burning and can be safely collected in the backup boom.

3.3. Ignition Devices

A variety of ignition devices or methods, both commercial and noncommercial, have been used to ignite oil slicks, although the methods of igniting oil on water have not been well documented. Many of the methods used are modifications of ignition devices used for other purposes.

In general, an ignition device must meet two basic criteria in order to be effective. It must apply sufficient heat to produce enough oil vapors to ignite the oil and then keep it burning and it must be safe to use. Safety issues to be considered when operating ignition devices are outlined later.

The most sophisticated commercial devices used today for igniting oil slicks are the helitorch igniters. These are helicopter-slung devices that dispense packets or globules of burning, gelled fuel and produce an 800°C flame that lasts up to 6 minutes. This type of igniter was designed for the forestry industry and is used extensively for forest fire management.

Two helitorch systems suitable for igniting in-situ burns are the Simplex Helitorch manufactured by Simplex Manufacturing of Portland, Oregon and the Universal Drip Torch available from Universal Helicopters of Deer Lake, Newfoundland or Canadian Helicopters of Prince George, British Columbia. The Simplex Helitorch was used effectively during the NOBE in-situ burn exercise off the coast of Newfoundland in 1993 as shown in Figure 10.

Figure 10: A Helitorch in operation. *In general, an ignition device must meet two basic criteria in order to be effective. It must apply sufficient heat to produce enough oil vapors to ignite the oil and then keep it burning and it must be safe to use. The most sophisticated commercial devices used today for igniting oil slicks are the helitorch igniters. These are helicopter-slung devices that dispense packets or globules of burning, gelled fuel and produce an 800 ˚C flame that lasts up to 6 minutes.*

While the two units are assembled differently, they operate in a similar way. Both have a 205-L fuel barrel connected to a fuel pumping and ignition system. The fuel used in the helitorch system is a mixture of a powdered gelling agent with either gasoline, jet fuel, or a diesel/gas mixture. SureFire, an aluminum soap is the most commonly used gelling agent. Alumagel is another type of gelling agent that was used to make Napalm for military purposes. It is currently available only through military surplus. The SureFire powder is more readily available and gels faster than Alumagel. An improved version of SureFire gel, known as SureFire II, is now available. SureFire and SureFire II are available from Simplex Manufacturing in Portland, Oregon.

Simple ignition methods such as oil-soaked paper, rags, or sorbent have been used to ignite oil at actual and test spills. For example, gelled fuel in a plastic bag was used to ignite some of the oil from the *Exxon Valdez* spill. The bag was ignited, thrown towards the slick from a boat, and floated into the slick. It should be noted that diesel oil is preferable to gasoline for soaking materials or as a base for the gelled fuels in hand-held igniters because diesel burns slower, making it safer and supplying more pre-heat to the slick.

A variety of hand-held igniters have been devised for igniting oil slicks. These are meant to be thrown into a slick from a vessel or helicopter. These devices often have delayed ignition switches to allow enough time to throw the igniter and, if required, allow it to float into the slick. These igniters use solid propellants, gelled fuel, gelled kerosene cubes, reactive chemical compositions, or a combination of these, and burn for 30 seconds to 10 minutes at temperatures from 1,000 to 2,500°C. Several hand-held igniters have been built, some of which are improvised devices which can be made on the scene. Such devices should be partially prepared in advance.

Heavy fuels can be ignited by applying a primer, such as diesel fuel, to the heavy oil and then igniting with a hand-held igniter.

3.4. Treating Agents

In general, as a burn becomes hotter and thus more efficient, the emissions from the burn are reduced. Work has been done to investigate the use of chemical additives to enhance burning. While there are a number of agents that can be used, none of these is readily available or has proven effective. Agents include emulsion breakers, ferrocene, combustion promoters, and sorbents.

Emulsion breakers and inhibitors are formulated to break water-in-oil emulsions or to prevent them from forming. They have not been used extensively in field trails, however, and rarely in actual spills.

3.5. Support Vessels/Aircraft

Vessels and aircraft play an important role in a successful in-situ burn operation. Vessels are required to bring equipment and personnel to the burn site, tow booms, and carry monitoring equipment. Barges and small boats may also be required for standby fire safety operations, monitoring, recovering residue, and storing equipment and residual oil. Tug boats may be required if a tanker must be moved away from the burn area.

Enough vessels must be available to transport and deploy the length of containment boom required at the burn site. The vessels must have a large enough deck to carry the boom as well as any equipment and materials required for handling the boom. They must also be able to move steadily at a slow speed [<0.5 m/s (1 knot)] and have bow-thrusters for easy maneuvering and to quickly move in reverse if required. When containment booms are used in open water, two vessels are required to carry, deploy, recover, and tow each end of the boom, depending on the boom configuration used.

For safety reasons, any vessels used in a burn operation must be large and stable enough to carry the necessary equipment in all possible sea states including storm conditions. A vessel with an onboard crane and one or more tugger winches is recommended for handling equipment on deck and for recovering oil from the water. Separate, smaller tow vessels can be used to tow the boom.

Fixed wing aircraft and/or helicopters may also be required to perform surveillance of the spill site, carry monitoring equipment, and perform ignition and extinguishing operations. For safety reasons, twin-engine helicopters are recommended for helitorch operations. If a single-engine helicopter must be used, it should be equipped with floats to allow emergency landing on the water. This is not a requirement for twin-engine helicopters. When using more powerful twin- engine helicopters in ignition operations, however, the oil must be ignited from high enough above the slick to ensure that the down draft from the helicopter does not extinguish the burn.

3.6. Monitoring, Sampling, and Analysis

Monitoring emissions during an in-situ burn operation provides continuous feedback as to whether the burn is progressing properly and safely. A well planned monitoring program during which data are recorded before, during, and after a burn will also help answer any questions that come up after a burn operation is completed. It is generally recommended that, if possible, the following sampling and monitoring be performed for any in-situ burn operation:

- real-time monitoring of PM-10 particulate matter in the smoke;
- real-time monitoring of volatile organic compound (VOCs) in the smoke;
- soot sampling for analysis for organic compounds and polyaromatic hydrocarbons (PAHs); and
- residue sampling for analysis for organic compounds and PAHs.

If it is determined that burning can be done safely and will likely result in the least overall environmental impact, operations should not be delayed because of monitoring and sampling activities.

In general, real-time monitoring of emissions should be performed downwind of the fire and at a point closest to populated areas. Studies of the emissions from in-situ oil burns indicate that the main public health concern is particulate matter in the smoke plume as this is the first emission that normally exceeds recommended health concern levels.

For monitoring of particulate matter, it is generally accepted that the concentration of small respirable particles with a diameter of 10 µm or less (PM-10) should be less than 150 $\mu g/m^3$ for a 24-hour period. A new PM-2.5 standard of 65 $\mu g/m^3$ for a 24-hour period has been proposed. The second emission of concern is polyaromatic hydrocarbons or PAHs on the particulate matter. Volatile organic carbons or VOCs are a tertiary concern.

Visual monitoring is not as effective as monitoring using instruments. Obviously, gases and light concentrations of particulate matter cannot be seen. The trajectory of the smoke plume can be observed, however, and its passage over land, population centres, and other points of concern can be noted, timed, and recorded. This information is necessary if there is ever a question of exposure to emissions after an in-situ burn incident. The prime areas of deposition should be surveyed after a burn to check for soot deposits. If soot is found, it should be sampled for possible analysis if necessary.

3.7. Final Recovery of Residue

The oil residue left after a burn is usually a heavy, tar-like material which is very viscous and adhesive, similar to a highly weathered oil. The greater the burn efficiency, the higher the density and viscosity of the residue. The burn residue from some types of oil may sink in the water column. This behaviour should be determined in advance for common crude and bunker oils being transported in the area of concern. Figure 11 shows a burn residue that is dense but did not sink.

The decision to recover the residue mechanically or leave it to break down biologically depends on the total volume of the residue, whether the residue is dense enough to sink, and where it is expected to go if left alone. Other considerations include the immediate availability of equipment and personnel who may be deployed in other recovery efforts.

Residue is best recovered using a vessel with low freeboard that provides easy access to the water surface. A sea truck or landing craft used in conventional oil spill response is ideal for this purpose. The amount of residue that can be recovered will depend on the displacement of the vessel and the size of the tank and other equipment that can be safely carried on the deck. Depending on sea conditions and the dimensions and displacement of the sea truck, such a vessel could carry an estimated 1 to 5 tons of residue.

Recovering burn residue is simplified if the recovery vessel can be operated from a shore base. The vessel can be launched from shore and the recovered residue can be removed using a vacuum truck on shore. If the residue is too viscous to remove using vacuum devices, it can be removed manually. When conducting a burn on the open ocean, launching and retrieving a boat to recover residue can be difficult. Unless the burn site is within a reasonable distance of shore, the residue recovery vessel must be deployed from one of the larger vessels towing the fire boom. This vessel must be equipped with a suitably sized crane to launch and retrieve the residue boat and have enough tankage or deck space to hold the recovered residue. Figure 12 shows the manual recovery of burn residue.

Transferring the recovered residue to a larger vessel could be difficult, especially if the larger ship has a high freeboard. The residue tanks should therefore be carried on the ship with the lowest transfer height. Residual oil can also be collected in a backup boom and recovered using sorbents or skimmers suitable for use with heavy oil. Depending on the volume, the residue can be recovered or transferred using either a vacuum suction system or a submersible pump such as the Desmi DOP-250 or it can be manually transferred with shovels and buckets.

Residual oil can also be collected in a backup containment boom and recovered manually using sorbents, shovels and rakes or mechanically with skimmers and suction systems suitable for use with heavy oil.

3.8. Equipment Availability

Depending on the jurisdiction, equipment for an in-situ burn response operation can be obtained by prior agreement from various organizations including the Marine Spill Response Corporation (MSRC), Clean Harbors Environmental Services, Inc., Clean Caribbean and Americas (formerly Clean Caribbean Cooperative), Clean Bay Incorporated, National Response Corporation, Marine Pollution Control, and FOSS Environmental & Infrastructure in the United States. Some of these organizations are able to assist for a fee or can lease equipment and operators (for further details on industry's cooperatives of oil spill response equipment, see *International Oil Industry Spill Response Resources: Tier 3 Centres,* IPIECA/ITOPF, 1999).

Figure 11: This is the residue remaining from a 50-ton burn at sea. *The oil residue is from a light to medium crude oil. The residue is relatively heavy which is shown by the small amount of water on top of the residue. The fire-resistant boom is an older technology, with a mesh covered with a fire-resistant material.*

Figure 12: Cleaning up the residue from a crude oil burn. *The residue is quite adhesive and difficult to deal with. In this case, about 0.01% of the oil burned remained as a residue.*

3.9. Equipment Checklist

Before starting any in-situ burn response operation, it must be ensured that all the required equipment is available. To assist in determining the type and specifications of the equipment that may be required for a burn operation, a Burn Equipment Checklist is provided in Appendix B.

In the United States, the National Oceanic and Atmospheric Administration (NOAA) has developed a service called Spill Tools which consists of computer-based tools and learning aids designed to help both government and private organizations to gain access to information for developing plans for possible spills. Specifically, the in-situ burn calculator provides oil spill planners and responders with calculations for estimating time and fire boom lengths required for burning oil in either a single release (batch) or a continuous release of oil. This calculator depends on the knowledge of oil slick thicknesses or source release rates. The calculator permits rapid computation for a range of conditions for a burn scenario which should provide some realistic solutions. The model can assist in selecting and staging appropriate equipment.

The in-situ burn calculator is available through the *"Aids for Oil Spill Responders"* link from http://response.restoration.noaa.gov/index.html.

4. POST-BURN ACTIONS

4.1. Follow-up Monitoring

The site must be surveyed immediately after the burn to ensure that no burning materials remain in the area. This could include thick patches of escaped oil, parts of the boom, or burning organic matter. After this immediate surveillance, the residue should be recovered quickly before it sinks. Areas where residue may have sunk should be carefully documented as this could adversely affect the benthic environment. The area should be surveyed and the amount of unburned oil remaining should be estimated. This value and the amount of residue are important in estimating the overall mass balance.

Analysis of particulate matter, PAHs, and VOCs at the downwind locations should be completed if these are sampled and these results included in the final burn report. In the case of the VOCs, a background sample must be collected on a day when burning is not taking place and when the wind is blowing in a similar direction as on the day of the burn.

A report on the actions taken during the burn should be prepared at this time to ensure that others can learn from the burn and that a good record remains if there are any questions on efficiency or other issues.

4.2. Estimating Burn Efficiency

Burn efficiency is measured as the percentage of oil removed compared to the amount of residue left after the burn. The burn efficiency, E, can be calculated by the following equation, where v_{oi} is the initial volume of oil to be burned and v_{of} is the volume of residual oil remaining after burning:

$$E = \frac{V_{oi} - V_{of}}{V_{oi}}$$

In this equation, the initial volume of oil, $v_{oi,}$ can be estimated in a number of ways. If the spill source is known, as in the case of a vessel or coastal storage depot, the volume spilled can be estimated from the tank size and the amount of oil remaining in the tank. In the case of an off-shore rig, the pumping rate can be used to estimate the initial volume. If the source is unknown or the volume of oil released from the source cannot be estimated, the volume of the slick can be estimated either visually using objects of known dimensions, e.g., response vessel or containment boom, or using timed overflights, aerial photographs, or remote sensing devices. This area, together with an estimate of the average thickness of the oil, performed either visually by taking samples or by remote sensing, can then be used to estimate the volume of the slick.

It should be noted that this equation does not take into account the volume of oil lost through soot produced from the burn, which is a small amount and difficult to measure, or any residue that has sunk or cannot be collected.

If the residue remains afloat, it can be recovered either by skimmers or sorbents. The volume of residual oil remaining after burning, v_{of}, can be estimated by measuring the volume or weight recovered. If the residue cannot be recovered, the volume of the residue slick can be measured by estimating its area and thickness, in the same way described for estimating the initial volume of oil. The volume of any tar balls in the residue should also be taken into account.

If some or all of the residue sinks, which is rare, the amount of oil that burned (v_{oi} - v_{of}) can be estimated using the fact that, for most oils and conditions, a light oil burns at a rate of 3 to 4 mm/min, generally taken at 3.75 mm/min. Heavy oils burn at a rate of about 1 mm/min. The amount burned can be estimated using this range, the area of the slick on fire, and the total time of the burn.

Research has shown that burn efficiency depends primarily on the thickness of the slick. Regardless of the initial thickness of the oil, the final thickness will be in the order of 1 to 2 mm. As such, much greater burn efficiency is achieved when burning a 20-mm thick slick than a 2-mm thick slick. The burn efficiency also depends on the flame-contact probability. This is a random parameter that can be controlled by proper containment, but is also affected by wind speed and direction. The burn efficiency can be reduced if the thickness of the slick is inconsistent, i.e., the flame reaches patches that are too thin to sustain burning or if the slick is not continuous. Heavier oils will typically burn to only about 70% efficiency as fractions of oil are present that do not vaporize from the slick at the temperatures attained by typical pool burns.

4.3. Burn Rate

It is generally accepted that a crude oil slick burns at a slick thickness reduction rate of 3 to 4 mm/min, generally taken at 3.75 mm/min. This range translates to about 5000 $L/m^2 \cdot day$. During the final stages of burning when the slick becomes very thin or for heavy oils such as Bunker C, the rate decreases to about 1 mm/min, with a reduction factor about 1200 $L/m^2 \cdot day$.

5. HEALTH AND SAFETY PRECAUTIONS DURING BURNING

5.1. Worker Health and Safety Precautions

To protect the health and safety of workers involved with in-situ burning, a thorough health and safety plan must be established and well understood by all personnel involved before the operation begins. As with any operation in which health and safety are issues, workers are responsible for their own safety and that of their co-workers. To assist in developing health and safety plans for in-situ burning, much of the information required can be obtained from firefighting associations.

Once the burn operation begins, the burn must be closely monitored so that response personnel can determine whether the burn situation must be reassessed, the plan needs to be modified, or the burn must be controlled or terminated. Surveillance of the burn area should be arranged to provide such essential information to the tow operators as the thickness and frequency of slicks in the path of the boom tow or containment area, the precise direction of the smoke plume, the area of oil burning, and whether this is increasing or decreasing.

Two surveillance tactics should be considered - aerial surveillance and surveillance from a larger vessel. The increased visibility from aircraft, particularly helicopters, ensures the safety of the burn operation. However, a larger vessel not only provides a good view of the tow operation from the surface but can also be equipped with extra fire monitors for firefighting capability. This vessel also provides a means of rescue if one of the tow vessels fails.

Any potential difficulties in a burn operation, such as encountering thick burnable slicks that could burn out of control, should be anticipated and avoided. The fire could propagate ahead of the tow vessels or to amenities that can be burned. Other difficulties that should be avoided are the loss of significant amounts of burning oil behind the boom. These burning patches could also cause problems downwind. This can be avoided by having an extra fire-resistant boom downwind to catch any burning patches or vessels with fire monitors to extinguish them.

Flames spread very rapidly through vapors - as fast as 100 m/s or 200 knots. If burning a highly volatile oil such as a fresh, very light crude, gasoline, or mixtures of these in other oils, vapour flame spread could occur and cause serious injury. This is referred to as vapour flashback. This can only be avoided by carefully assessing the properties and characteristics of the oil to be burned. If burning these very light mixtures, it must be ensured that no people are in the area. These circumstances are rare because normally the volatile fraction of the oil has been removed by the time responders reach an oil spill. In any case, all burn personnel should be familiar with the hazards and with the difference between the speed of flames spreading on a pool and through a vapour cloud.

Burning should not be attempted on a slick that could flash back to the source of the spill such as a tanker or towards populated areas. This can usually be prevented by removing or isolating the source from the part of the slick to be burned or separating manageable sections of the slick with containment booms and burning these sections within the boom well away from the main source of the slick. In tanker spills, the source can be moved away using tug boats which can be brought to the site more quickly than containment booms. When this is not possible, containment booms can be used to isolate the main part of the slick from the source. Precautions must also be taken to prevent the fire from spreading to nearby combustible material such as grass cover, trees, docks, buildings, and operational vessels.

Perhaps the best way to prevent unwanted or uncontrollable burns is to boom off a manageable section of oil from a large slick and pull it well away from the main slick or other combustible material before igniting it. This oil can be collected using conventional booms and then transferred to fire-resistant booms in an area where it is safe to burn. If oil is close to shore, deflection booms can be used to deflect oil toward a calm area such as a bay where it can be safely burned. Exclusion booms could be used to keep oil away from areas where it is not wanted.

A number of techniques can be applied to prevent secondary fires, fire spreading to unwanted areas, and flashback of the fire to workers. If a boom is used, it must be towed properly. It is important to recognize that a boom fails when towed at a speed faster than about 0.4 m/s (0.8 knots) and that the boom should always be towed into the wind. On most oil slicks, flames will not spread across an oil slick at a rate faster than about 0.2 m/s (0.4 knots). Thus, in a typical situation in which the boom is steadily towed at least at the flame-spreading speed, flames will not reach the boom tow vessels, even at low winds. Caution should be taken, however, because winds can change rapidly. Burns should not be conducted if the tow boats are actually in thick oil or could pass through it.

Operators of a boom tow should be knowledgeable about how to control the area of the burn by increasing or decreasing the tow speed. At excessive tow speeds, the oil will be lost through the boom apex as a result of boom failure, entrainment under the boom, or loss over the top of the boom. At a towing speed that is too slow, the oil, and therefore the fire, will slowly spread to the boom opening, towards the towing vessels. The movement of oil back and forth in the boom is also influenced by the amount of oil encountered. If more oil is encountered than can be burned in the area of the boom, measures will have to be taken to prevent the fire from spreading towards the tow vessels. If no safe action is possible, the fire may have to be extinguished or the boom tow dropped.

Once the oil is burning, extinguishment may not always be straightforward or easy. Several tow control methods have been proposed to extinguish the fire within a towed fire-resistant boom. The first method is to release one end of the boom tow and let the oil spread until it is too thin to burn. Secondly, if the tow speed is increased to greater than containment velocities (0.4 m/s or 0.8 knots), oil will submerge under the boom and the fire is often extinguished. Since these methods have not been thoroughly tested in a fully developed towed boom burn scenario, questions still exist as to their actual effectiveness. Another suggested method is to slow down the towing rate thereby reducing the encounter rate.

It is recommended that fire extinguishing equipment be available during the burn. One dedicated fire extinguishing equipment vessel should be positioned beside the boom containing the burn. During burn operations at sea, those who must be near the burn such as the tow-boat operators can be protected by ensuring that fire monitors of sufficient capacity are available. These monitors can be left on to ensure they are ready if needed. Extra fire monitors and experienced crews should be available on the surveillance vessel to assist if a fire spreads. The fire can also be extinguished by using a firefighting foam made for liquid fuel fires and, if available, aircraft with water-bombing capabilities. To ensure safety, at least two of these extinguishing methods should be ready at a burn site. When burning is done close to shore, fire trucks and crews can be stationed at strategic points on land to fight unwanted secondary fires.

When booms are being moved and recovered, personnel should avoid cables under tension such as the boom towing lines or tugger winch cables when in use. Personnel should also avoid standing in the coil or bight of a rope or cable lying on deck, which could tighten around a leg or foot and drag a person overboard.

Crane operations onboard ships are particularly dangerous as the roll of the ship may cause the load to swing like a pendulum on the crane wire. Anything being lifted by crane should have two handling lines attached to control the load. Only the crane operator, the signal person, and the two persons holding the load control lines should be involved in the operation. All other personnel should stay well away from the load while it is being lifted. The signal person is in charge of the operation. All personnel must maintain visual contact during the work. Hand signals should be reviewed and understood before operations begin.

Communications between the vessel bridge and the deck supervisor should be clear. Hand signals should be understood by all participants. It is recommended that a trained spill response team leader should supervise the entire operation from a safety point of view to detect any unsafe situations as they arise.

Recovering the boom after the burn has been completed is difficult and extremely messy work as the boom is usually waterlogged and covered with a tar-like residue. Workers should wear rain gear with neoprene gloves, rubber boots, and eye goggles. Cuffs should be taped with duct tape. Appropriate decontamination materials are also required for cleaning personnel after the work is completed. Sorbent materials, rags, paper and fabric towels, citrus cleaners, soap and warm water, hand cream, garbage bags, and containers should all be available onboard the vessel. Any cleaning materials used should be collected after the burn for proper disposal.

The following are some general safety issues that relate to ignition devices.

The operators must fully understand the operational and safety instructions for the specific device being used. This includes understanding the safe operating procedures, training requirements, disposal requirements for spent igniters, and requirements for retrieving and handling igniters that misfire. The device should be protected against accidental activation.

- Hand-held igniters should have a delay mechanism that postpones the ignition of the device for at least 10 seconds from the time of activation. This delay allows time to activate and throw the device and for it to float into the slick. For helitorch systems, specific helicopter safety precautions must be followed, as well as the specific precautions for helitorch systems.
- Any device deployed from a helicopter should not require the use of open flames or sparks within the aircraft.

Crews in vessels involved in tow operations are in danger of being exposed to fire or flames if the fire moves up the boom. This could occur if thick patches of oil are encountered and the flame spreads along this thicker patch. The flame velocity is about 0.02 to 0.16 m/s (0.04 to 0.3 knots). The flames would not spread towards the tow vessels if the boom is moving at a speed of at least 0.4 m/s (0.8 knots) in an upwind direction. Because winds can change rapidly, however, this fact should not be taken as an assurance of safety. In highly variable winds, caution must be taken to ensure that thick concentrations of oil are not encountered at low boom-tow speeds.

5.2. Public Health and Safety Precautions

The public should not be exposed to emissions exceeding the recommended human health concern levels. The most concern would be the exposure to particulates greater than 150 $\mu g/m^3$ over a 24-hour period. This can be determined by using the formulae provided in the literature (see Section 6 for further information) to calculate minimum safe burn distances and by monitoring the particulate levels.

It is important to note that atmospheric inversions can occur that will increase ground-level concentrations to high levels and that the smoke plume itself might drop to ground level at higher elevations further inland. Monitoring must be done to ensure that this does not occur. If there is the potential of this occurring, the burn should not be started. If a burn is already started and the plume drops to ground level, the situation should be immediately assessed to determine whether the burn should be stopped, people evacuated, and/or whether the plume could drop again. Any people who may be affected by the burning, even if only remotely, must be briefed so that they are aware of the activity and the possible need to evacuate the area on short notice.

If burning near land, enough personnel must be available on land, in good communications with the burn command vessel. The land-based personnel will monitor the smoke plume and stay in contact with local weather officials to be informed of any potential changes that could cause the plume to directly affect people on the ground.

If burning against or very near the shore, additional precautions must be taken to ensure that the fire does not spread from the oil to other combustible material. The fire should be monitored from shore by personnel with the ability to put out any potential fires. Trees and other combustibles near the shore might be wetted down as an extra precaution.

5.3. Establishing Safety Zones

An important part of the safety program for an in-situ burn operation is establishing minimal safety zones. This has been accomplished in several ways including the use of values that are larger than the measured hazardous distances and by the use of smoke plume modeling.

Smoke dispersion modeling has been used frequently in the past decade to establish safe zones and obtain permits for large industrial sources. Specialized models have been developed that can also be applied to in-situ burning. Although models are not intended to replace monitoring, they provide an important tool for assessing the impact of smoke both before and after a burn.

Calculations using historical data can provide a guide to safe distances. Table 2 provides safe distances calculated by these methods.

Table 2 – Safe Distances for Exposure to Particulate Matter

Safe Distances in Kilometers		
Burn Area (m^2)	Crude Oil	Diesel Fuel
50	0.02	0.03
100	0.03	0.06
150	0.04	0.1
250	0.08	0.3
400	0.25	2.1
500	0.5	7
750	3.1	>50
1000	19	>100

6. DOCUMENTS FOR FURTHER GUIDANCE

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APPENDIX A - SPECIFIC SPILL SCENARIOS AND BURNING STRATEGIES

Scenario 1 Burning at sea	Strategy
Location: At sea Position: Offshore Proximity of Oil to Source: A large slick of oil well away from the source without any trail leading back to the source Condition of Oil: The oil in the centre of the slick is more than 3 mm thick and is not emulsified Weather and Sea State: Calm conditions	General Verify wind and current direction to ensure that burning the slick will not affect people, property, or environmentally sensitive areas. As a first response, as much of the slick as possible can be burned without using containment. This will require a helicopter with a helitorch. Several ignition points may be required to burn all parts of the slick that are burnable. Depending on the size of the slick and distance from land, a ship stationed near the slick may be required to refuel the helicopter and helitorch. Once the slick will no longer burn, containment can be used to further thicken the remaining oil and attempt to burn it again. Containment Configuration For the second stage of burning, ideally a fire-resistant boom should be used in the U configuration towed by two vessels. If a fire-resistant boom is not available, a conventional boom can be used with the understanding that the boom would be sacrificed and that its containment ability will be severely limited as the burn proceeds. Depending on the amount of oil to be burned, manageable sections of the slick (about 1/3 of the boom's U area) should be carved off from the main slick using the boom and transported away from the slick for burning. The slick should be approached from downwind and the boom should be towed into the wind during burning. Protection Aircraft overflights should be carried out to ensure that burning is under control and that sensitive areas are not being affected. A standby boat should be nearby for helicopter rescue. Aircraft with extinguishing foam or water-bombing capability should be available. During containment operation, towing vessels should have water spray guns ready to protect them from flames. Accident Response During containment operation, tow vessels disconnect boom towing lines and sail away upwind from the burning oil or they should speed up to entrain oil, thus reducing slick thickness and extinguishing the burn. Notice of a floating hazard is filed to ships in the area. Aircraft with extinguishing foam or water-bombing capability fly over burn.

Scenario 2 Burning at sea	Strategy
Location: At sea **Position:** Offshore **Proximity of Oil to Source:** A large slick of oil with a trail leading back to the tanker from which it was spilled. **Condition of Oil:** The oil in the centre of the slick is more than 3 mm thick and is not emulsified **Weather and Sea State:** Calm conditions	**General** As a first response, send tugs out to the site to move the tanker away from the main part of the slick. Surround the tanker with containment boom to prevent further seepage from the area and fully separate the vessel from the main slick. Water cannons can be used to separate any sheen connecting the tanker to the main part of the slick. Verify wind and current direction to ensure that burning the slick will not affect people, property, or environmentally sensitive areas. As much of the slick as possible can be burned without using containment. A helitorch should be used for ignition. Several ignition points may be required to burn all parts of the slick that are burnable. Depending on size of slick and distance from land, a ship stationed near the slick may be required to refuel the helicopter and helitorch. Once the slick will no longer burn, containment can be use to further thicken the remaining oil and attempt to burn the slick again. **Containment Configuration** For the second stage of burning, ideally a fire-resistant boom should be used in the U configuration towed by two vessels. If a fire-resistant boom is not available, a conventional boom can be used, with the understanding that the boom will be sacrificed and that its containment ability will be severely limited as the burn proceeds. Depending on the amount of oil to be burned, manageable sections of the slick (about a third of the U area) should be carved off from the main slick using the boom and transported away from the slick for burning. The slick should be approached from downwind and during burning, the boom should be towed into the wind. **Protection** Aircraft overflights should be carried out to ensure that burning is under control and that sensitive areas are not being affected. Vessels with water sprayers can be situated around the tanker to prevent any flames from reaching it. A standby boat should be situated nearby for helicopter rescue. Aircraft with extinguishing foam or water-bombing capability should be available. During containment operation, towing vessels should be equipped with water spray guns to protect vessels from flames. **Accident Response** During containment operation, tow vessels should disconnect boom towing lines and sail upwind from the burning oil or they should speed up to entrain oil, thus reducing slick thickness and extinguishing the burn. Notice of a floating hazard is filed to ships in the area. Aircraft with extinguishing foam and/or water-bombing capability fly over burn.

Scenario 3 Burning at sea	Strategy
Location: At sea Position: Offshore Proximity of Oil to Source: A large slick of oil well away from the source without any trail leading back to the source Condition of Oil: The oil in the slick is less than 2 mm thick and some parts of the slick are emulsified Weather and Sea State: Winds approximately 15 m/s (30 knots) and waves occasionally greater than 1 m	General An emulsion breaking treating agent should be applied to the parts of the slick that have stable emulsions. Verify wind and current direction to ensure that burning the slick will not affect people, property, or environmentally sensitive areas. Using containment boom with an overall height of at least 1 m, small sections of the slick should be pulled away from the main slick and burned. Monitor wave heights and try to burn during times when waves are less than 1 m or, if possible, tow contained portion to an area where waves are less than 1 m high. Ideally, a helicopter with a helitorch would be required to burn the contained oil. Depending on the size of the slick and distance from land, a ship stationed near the slick may be required to refuel the helicopter and helitorch. Containment Configuration Because several burns will have to take place, a fire-resistant boom in the U configuration towed by two vessels should be used. Manageable sections of the slick (about a third of the U area) should be carved off from the main slick using the boom and transported away from the slick for burning. The slick should be approached from the downwind side and boom should be towed into the wind during burning. Protection Aircraft overflights should be carried out to ensure that burning is under control and that sensitive areas are not being affected. A standby boat should be nearby for helicopter rescue. Aircraft with extinguishing foam or water-bombing capability should be available. Towing vessels should have water spray guns to protect vessels from flames. Accident Response During containment operation, tow vessels disconnect boom towing lines and sail away upwind from the burning oil or they should speed up to entrain oil, thus reducing slick thickness and extinguishing the burn. Notice of a floating hazard is filed to ships in the area. Aircraft with extinguishing foam and/or water-bombing capability fly over burn.

Scenario 4 Burning in protected bay	Strategy
Location: Protected bay Position: Near shore, close to a small populated area Proximity of Oil to Source: Well away from the source without any trail leading back to the source Condition of Oil: Slick less than 2 mm thick Weather and Sea State: Calm conditions	General If the shoreline around the bay is too sensitive to allow for burning, the oil should be pulled out of the bay using containment boom and burned away from the shoreline. A helitorch can be used for igniting the burn. If combustible materials are well away from the edge of the shoreline or the shoreline can be protected, the oil can be burned within the bay using the shoreline and/or containment booms to concentrate and contain the oil for burning. A helitorch can be used for ignition, but if accuracy is a concern, hand-held igniters should be used, thrown from a boat and allowed to float into the slick. Verify wind and current direction to ensure that burning the slick would not affect people, property, or environmentally sensitive areas. Containment Configuration If oil is to be burned outside the bay, booms should be used in a U configuration to bring the oil out of the bay and away from the shoreline for burning. If possible, the burning should take place within a fire-resistant boom and the slick should be lighted with a helitorch. Boom should be towed into the wind during burning. If burning is to take place in the bay, boom should be used in a diversion mode to direct the oil towards a calm part of the bay to concentrate it for burning. The slick can be lighted with either a helitorch or an igniter thrown into the slick from a vessel. Protection Aircraft overflights should be carried out to ensure that burning is under control and that sensitive areas are not being affected. A standby boat should be nearby for helicopter rescue, if a helitorch is being used. Aircraft with extinguishing foam or water-bombing capability should be available. For offshore burning, towing vessels should be equipped with water spray guns to protect vessels from flames. Within the bay, burning should take place at low tide if possible and the shoreline should be soaked with water before and during the burn. Water sprayers can be located on shore to divert flames from shoreline. If possible, fire trucks should be placed on the shoreline in case flames reach combustible material on the shoreline. Accident Response For offshore burning, tow vessels disconnect boom towing lines and sail upwind from the burning oil or they should speed up to entrain oil, thus reducing slick thickness and extinguishing the burn. Notice of a floating hazard is filed to ships in the area. Aircraft with extinguishing foam and/or water-bombing capability fly over burn and fire trucks are available on the shoreline.

Scenario 5 Burning on river	Strategy
Location: River Position: Near shore, away from amenities and populated areas Proximity of Oil to Source: Distant - no trail back to the source Condition of Oil: Slick less than 2 mm thick Weather and Sea State: Calm conditions, current more than 0.5 m/s (knots)	General Before burning can take place, the oil should be diverted to a calm part of the river (slow current area, a point or bay area) where the shoreline is free of combustible materials or can be protected from the flame. Both the shoreline and containment booms should be used to concentrate and contain the oil for burning. A helitorch can be used for ignition, but if accuracy is a concern, hand-held igniters should be used, thrown from a boat and allowed to float into the slick. Verify wind and current direction to ensure that burning the slick will not affect people, property, or environmentally sensitive areas. Containment Configuration Boom should be used in a diversion mode to direct the oil towards a calm part of the river to concentrate it for burning. If containment boom is required during the burning phase, a fire-resistant boom should be used when possible. Protection Aircraft overflights should be carried out to ensure that burning is under control and that sensitive areas are not being affected. Aircraft with extinguishing foam or water bombs should be available. The shoreline should be soaked with water before and during the burn. Water sprayers can be located on shore to divert flames from shoreline. If possible, fire trucks should be available on the shoreline in case flames reach combustible material on shore. Accident Response Aircraft with extinguishing foam and/or water-bombing capability should fly over burn and fire trucks should be available on shore.

Scenario 6 Burning in salt marshes	Strategy
Location: Salt marshes	**General** An emulsion breaking treating agent should be applied to the parts of the slick that have stable emulsions.
Position: Near shore, away from amenities and populated areas	Verify wind and current direction to ensure that burning the slick will not affect people, property, or environmentally sensitive areas. A helitorch should be used to ignite the oil in area of concern.
Proximity of Oil to Source: Distant - no trail back to the source	Depending on the size of slick and the distance from land, a ship may have to be stationed near the slick to refuel the helicopter and helitorch. **Containment Configuration** Containment boom should not be required as the melt pools should act as natural containment.
Condition of Oil: More than 3 mm thick and emulsification that has remained stable over several days	Water spray can be used to push oil to one side of the pool during the burn to keep the thickness at a burnable level. **Protection** Aircraft overflights should be carried out to ensure that burning is under control and that sensitive areas are not being affected.
Weather and Sea State: Calm conditions, wind speeds approximately 20 m/s (40 knots)	Standby boat should be nearby for helicopter rescue. Aircraft with extinguishing foam or water-bombing capability should be available. **Accident Response** Aircraft with extinguishing foam and/or water-bombing capability fly over burn.

<table>
<tr><th>Scenario 7
Burning in inter-tidal zone</th><th>Strategy</th></tr>
<tr><td>Location: Inter-tidal zone

Position: Near shore

Proximity of Oil to Source: Well away from the source without any trail leading back to the source

Condition of Oil: The oil in the slick is less than 2 mm thick

Weather and Sea State: Calm conditions</td><td>General
If possible, install temporary sheet metal boom or fire-resistant boom in shallow waters and initiate burn.
If the shoreline is too sensitive to allow for burning or the containment boom is too close to populated or sensitive areas, the oil should be pulled away from the area using containment boom and burned away from the shoreline. A helitorch can be used for igniting the burn.
If combustible materials are well away from the edge of the shoreline or the shoreline can be protected, the oil can be burned against the shore using the shoreline and/or containment booms to concentrate and contain the oil for burning. A helitorch can be used for ignition, but if accuracy is a concern, hand-held igniters should be used, thrown from a boat and allowed to float into the slick.
Verify wind and current direction to ensure that burning the slick would not affect people, property, or environmentally sensitive areas.

Containment Configuration
If oil is to be burned away from the area, booms should be used in a U configuration to bring the oil away from the shoreline for burning. If possible, the burning should take place within a fire-resistant boom and the slick should be lighted with a helitorch. Boom should be towed into the wind during burning.
If burning is to take place in the area, boom should be used in a diversion mode to direct the oil towards a calm area to concentrate it for burning. The slick can be lighted with either a helitorch or an igniter thrown into the slick from a vessel.

Protection
Aircraft overflights should be carried out to ensure that burning is under control and that sensitive areas are not being affected.
A standby boat should be nearby for helicopter rescue, if a helitorch is being used.
Aircraft with extinguishing foam or water-bombing capability should be available.
For offshore burning, towing vessels should be equipped with water spray guns to protect vessels from flames.
Burning should take place at low tide if possible and the shoreline should be soaked with water before and during the burn. Water sprayers can be located on shore to divert flames from shoreline.
If possible, fire trucks should be placed on the shoreline in case of flames reaching combustible material on the shoreline.

Accident Response
For offshore burning, tow vessels disconnect boom towing lines and sail upwind from the burning oil or they should speed up to entrain oil, thus reducing slick thickness and extinguishing the burn.
Notice of a floating hazard is filed to ships in the area.
Aircraft with extinguishing foam and/or water-bombing capability fly over burn and fire trucks are available on the shoreline.</td></tr>
</table>

APPENDIX B – BURN EQUIPMENT CHECKLIST

Vessels and Aircraft

- ❑ Tow vessels
- ❑ Command vessel
- ❑ Surveillance aircraft
- ❑ Helicopter for igniter

Safety Equipment

- ❑ Fire pump for each tow boat
- ❑ Fire hoses
- ❑ Fire nozzles
- ❑ Fire extinguishers
- ❑ First aid kits
- ❑ Fire blankets for tow boats
- ❑ Extra radios

Containment Equipment

- ❑ Full length of fire resistant boom
- ❑ Extra lengths
- ❑ Towing paravanes
- ❑ Towing cables
- ❑ Bridles
- ❑ Attachment shackles
- ❑ Anchors – if needed
- ❑ Equipment for backup boom if needed

Ignition Equipment

- ❑ Hand-held igniters
- ❑ Helitorch and accessories

Residue Cleanup Equipment

- ❑ Sorbents
- ❑ Shovels or bailers
- ❑ Drums or other recovery collection containers
- ❑ Heavy oil skimmer – if necessary
- ❑ Pumps and hoses for skimmer

General Supplies

- ❑ Burn plan
- ❑ Safety plan
- ❑ Radios
- ❑ Contact lists

Monitoring Equipment

- ❑ Portable monitors
- ❑ PAH Sampling pump/filters
- ❑ Summa canister
- ❑ Recording notebook, pens

Personal Protection Equipment

- ❑ Respirators
- ❑ Boots, gloves
- ❑ Special clothing
- ❑ Duct tape for sealing
- ❑ Goggles

Helitorch Equipment

- ❑ Helitorch unit
- ❑ Helicopter connecting harness
- ❑ Fuel gellant
- ❑ Fuel mixture
- ❑ Fire extinguishers
- ❑ Hard hat
- ❑ Gloves
- ❑ Goggles
- ❑ Protective clothing
- ❑ Safety boots
- ❑ Respirators
- ❑ Propane bottle

Personal Cleanup Equipment

- ❑ Sorbents, rags, towels
- ❑ Citrus cleaner
- ❑ Garbage bags
- ❑ Soap, warm water
- ❑ Extra clothing

APPENDIX C – TACTICS USED TO DEAL WITH OIL IN VARIOUS SITUATIONS

Figure Number	*Tactic*	*Application*
C1	Towed boom – burn in tow	Burning source Separation between source and oil Source separated
C2	Towed boom – collected and burn	Non-burning source Oil near habitation or sensitive areas
C3	Boom used to burn and to separate source	Non-burning sources
C4	Boom used to protect amenities	Burning or non-burning sources
C5	Anchored boom	River, estuaries, or shallow water Oil over subsurface sources or blowouts
C6	Deflection boom	Oil deflected away from amenities Oil deflected to burn area
C7	Burning against shoreline	Remote shoreline with no hazards
C8	Temporary steel boom	Oil can be contained in shallows
C9	Uncontained burning	Oil is thick enough to burn

Source: Fingas, M.F. and M. Punt, 2000

Figure C1: Use of Towed Boom to Burn of Oil Directly

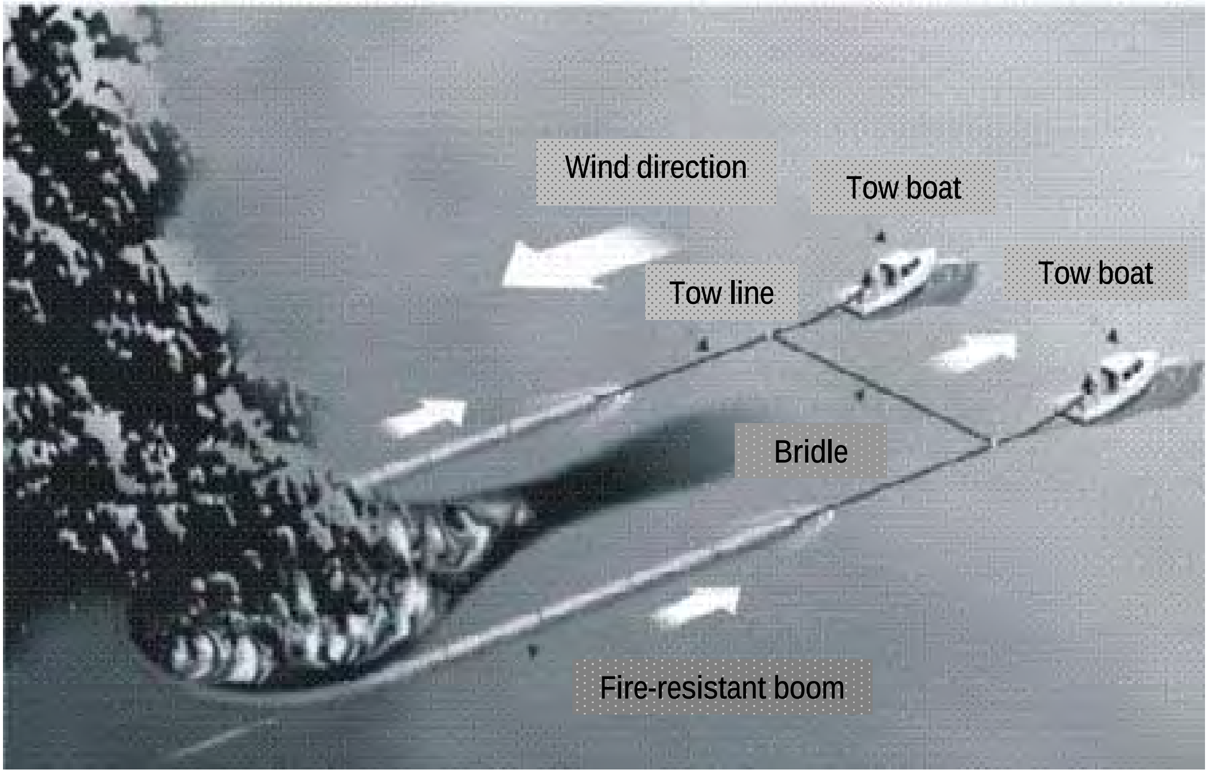


Figure C2: Use of Towed Boom to Collect and Burn Oil

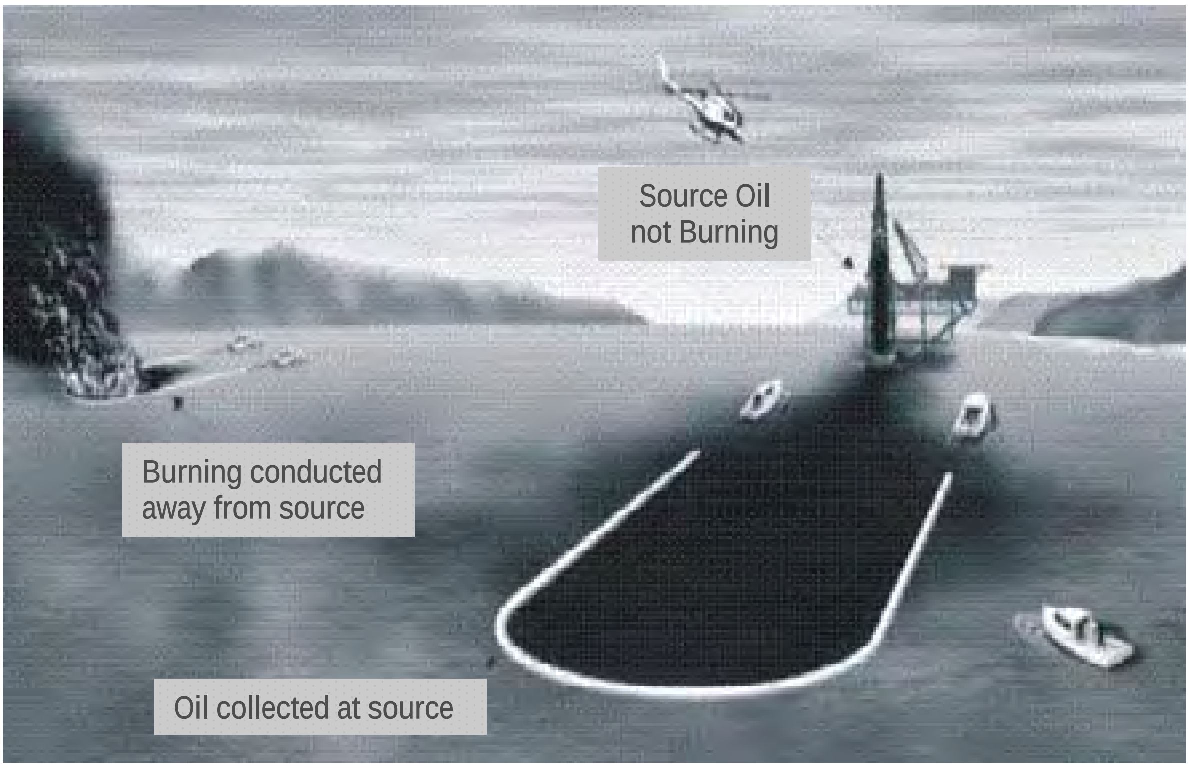


Figure C3: Use of Towed Boom to Burn and to Separate Source from Fire

Figure C4: Use of Fire-resistant Boom to Protect Amenities

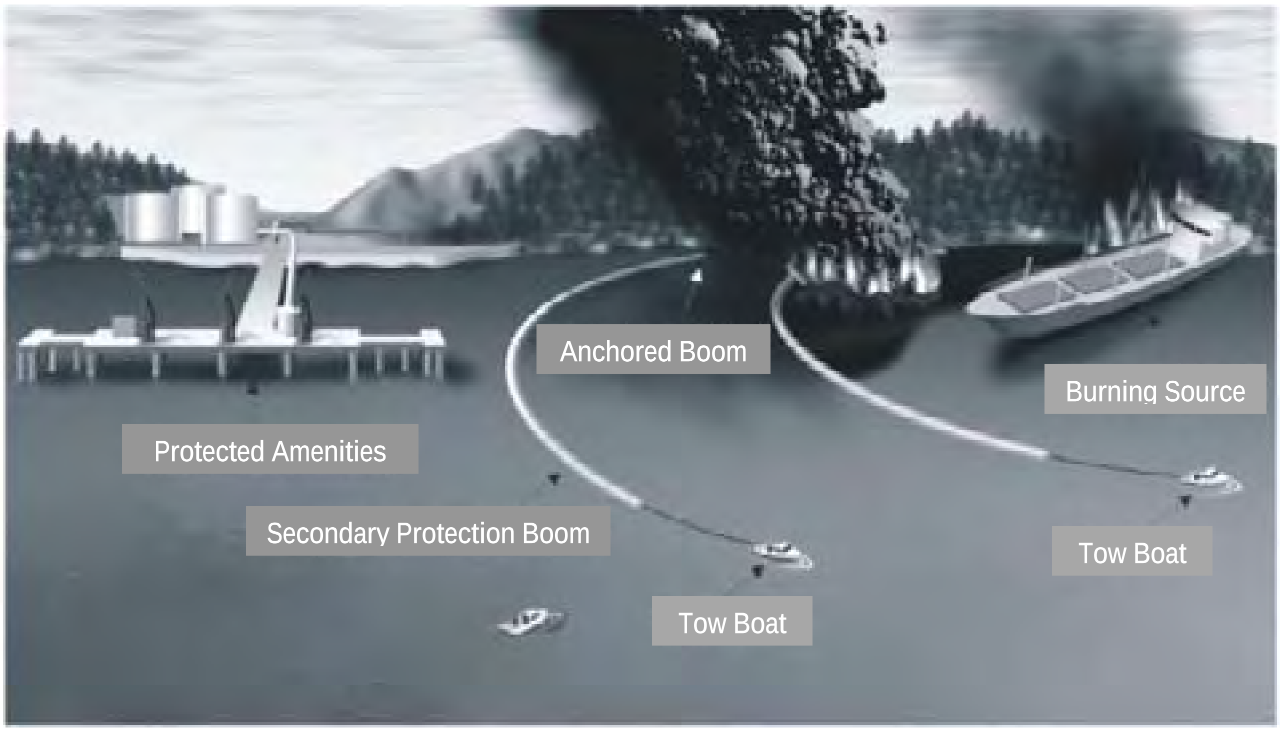


Figure C5: Anchored Boom

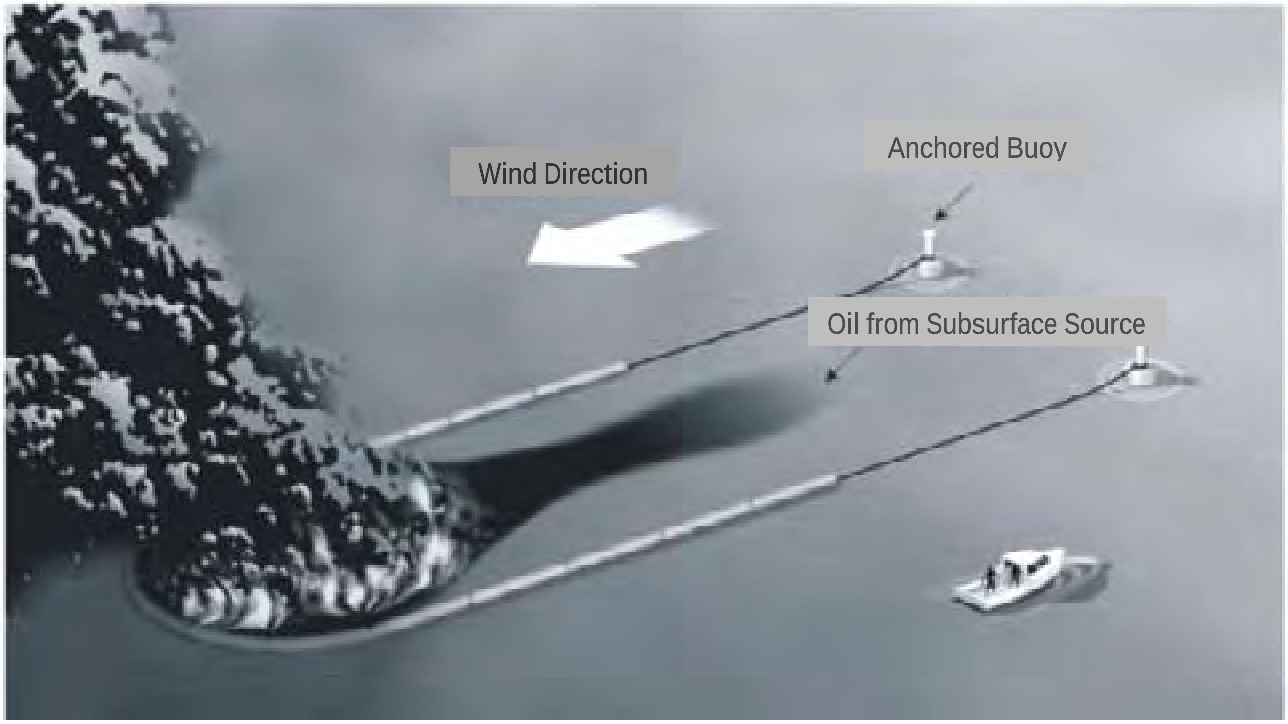


Figure C6: Deflection Boom

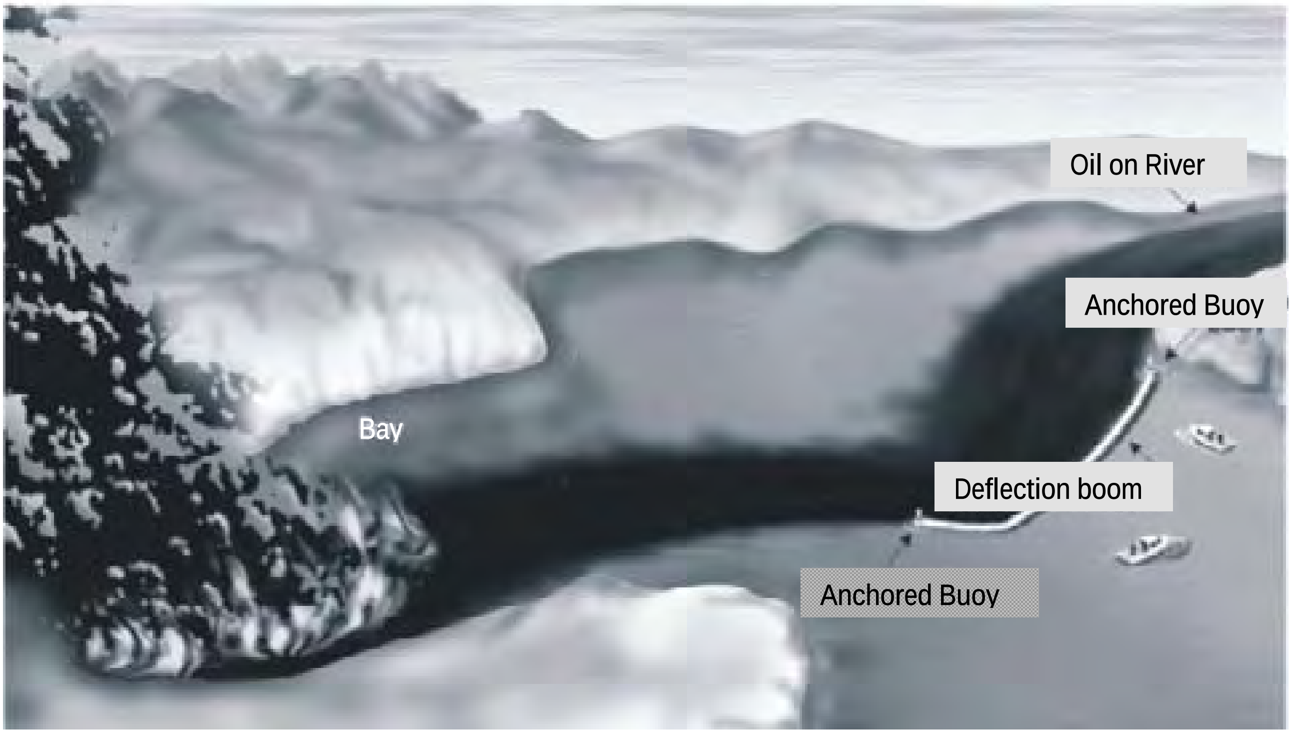


Figure C7: Burning against Shoreline

Figure C8: Use of Temporary Steel Boom

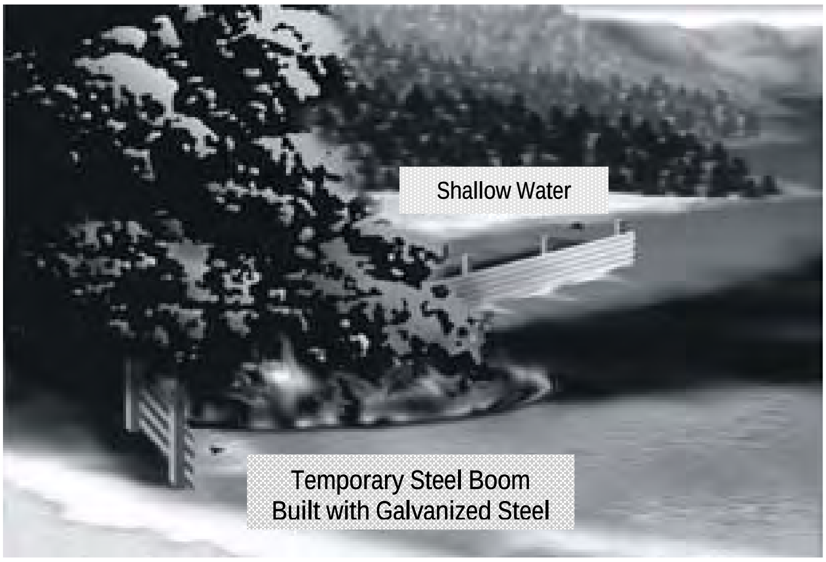
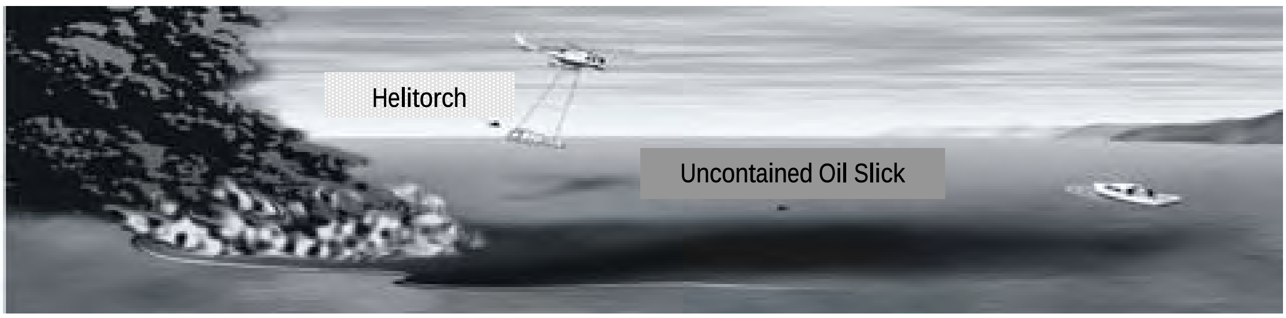


Figure C9: Unconfined Burning



ARPEL

Regional Association of Oil and Natural Gas Companies in Latin America and the Caribbean

Established in 1965, ARPEL is an association of 30 state owned and private oil and gas companies and institutions with operations in Latin America and the Caribbean, which represent more than 90 percent of the Region's upstream and downstream operations. Since 1976, ARPEL holds formal UN-ECOSOC special consultative status.

ARPEL works together with its members –through its various Committees and Working Groups- on issues that contribute to sustainable development in the Region:

- *Economic issues*: regional energy integration, pipelines and terminals, downstream and fuels
- *Environmental issues*: climate change, atmospheric emissions, oil spill contingency plans and best practices in environment and occupational health and safety management.
- *Social issues*: corporate social responsibility and relations with indigenous peoples

ARPEL develops a proactive attitude on issues of interest to the industry and produces documents representing the views of its members. It also promotes interaction among its members and with governments building alliances and establishing agreements with international organizations with the aim of presenting and developing a regional perspective. To accomplish its objectives, ARPEL organizes regional workshops and symposia to share information and best practices and develops technical documentation for capacity building and information exchange on the issues of interest to its members. To support its management ARPEL has an interactive Portal in which all documents developed by ARPEL Technical Committees and Working Groups are available for its Members. This tool also facilitates the virtual interaction within the ARPEL community and with those stakeholders that interrelate with it.

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