INTRODUCTION TO
IN-SITU BURNING

Things You Should Know

The primary goal of an in-situ burn (ISB) is to minimize the oil's impact on the environment by rapidly reducing the quantity of spilled oil through burning.

Responders should evaluate operational conditions including spill location, oil type and condition (i.e., thickness, emulsification, degree of weathering), current and forecasted weather, wave height, and the presence and condition of vegetation (moisture level and time of year).

Response conditions must include sufficient oil thickness, ignitable hydrocarbon vapor concentrations, and an ignition source in order to sustain combustion of the oil through ISB.

ISB can be conducted within the following habitats: marine waters, inland waters, wetlands/marshes, land, and ice and snow.

In certain instances, ISB might provide the only means of quickly and safely eliminating large amounts of oil.

Combustion of hydrocarbon vapors yields predominantly CO2 and water vapor (~80% average combined) which are released to the atmosphere along with small quantities of particulates and other gases.

Burn residue from incompletely combusted oil is much less acutely toxic than the original oil.

Overview

In-situ burning (ISB) is a response technique that removes spilled oil from a land, snow, ice, or water surface by igniting and burning the oil. ASTM International (2014) defines controlled in-situ burning as "burning when the combustion can be started and stopped by human intervention." The combustion by-products (primarily carbon dioxide and water but also particulates, gases, and other minor components) are released to the atmosphere, with the possibility of some unburned oil or incompletely burned oil residue remaining at the conclusion of a burn.

One of the greatest benefits from ISB is that a burn can rapidly reduce the volume of spilled oil and minimize or eliminate the need to collect, store, transport, and dispose of recovered oil and oily wastes. Decision-makers from federal, state and local agencies or other stakeholders must consider the benefits and risks of conducting a burn versus using other response options, since all options have potential safety, environmental and human health risks. ISB also has the potential to significantly reduce the duration of cleanup operations. In certain instances, ISB might provide the only means of quickly and safely eliminating large amounts of oil.

ISB has been extensively researched and has been used operationally for spills since the late 1950s as a response technique for spills of oil on land. More recently it gained operational confidence and public notice for on water responses during the more than 400 individual burns conducted in response to the Deepwater Horizon oil spill. Research on the use of ISB in snow and ice has increased in the last decade as efforts to drill in more remote areas like the Arctic are being considered.

This fact sheet summarizes what ISB is, how it works, when ISB should be considered, potential human health and environmental effects, risk/benefit tradeoffs for decision making, regulatory approval process and, finally, ISB operations. For more detailed information regarding each topic, please refer to the more detailed sheets in this series **(fact sheets 2-6).**

Fact Sheet Series

Introduction

ISB is a broadly applicable oil spill response tool that can rapidly remove surface oil. ISB often compliments other oil spill cleanup techniques and has proven to be a valuable addition to the response toolbox. ISB removes spilled oil through a controlled combustion of hydrocarbons. To conduct an ISB, the response conditions must include ignitable hydrocarbon vapor concentrations emitted by the oil, sufficient oil thickness, and an ignition source. When conducted properly, ISB can minimize the spread of spilled oil, reduce or prevent exposure to spilled oil, and reduce the length of a response.

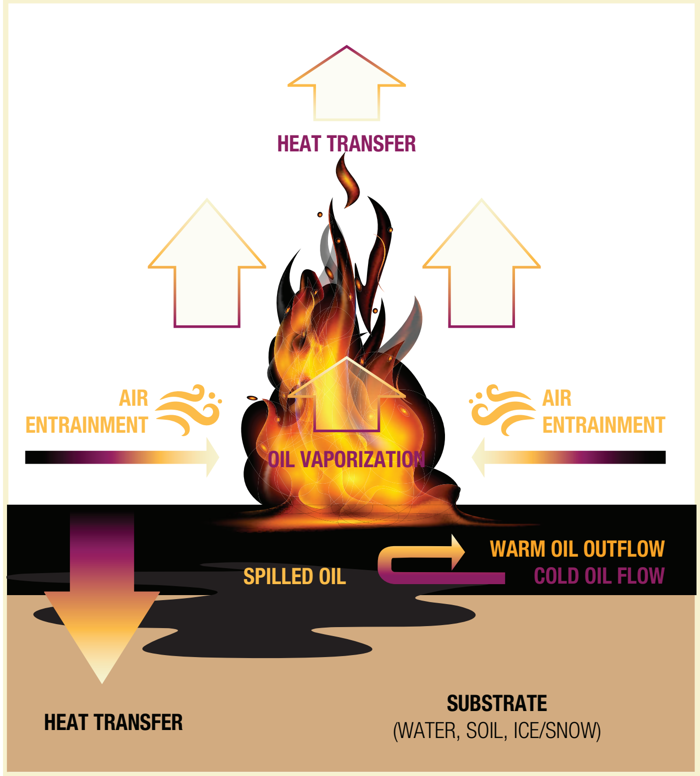
In the United States, ISB is a response option for oil spills both onshore and on water. The first documented, deliberate use of ISB occurred in 1958 for a pipeline spill in ice on the Mackenzie River near Norman Wells, Northwest Territories in Canada. Since then, ISB has been used on inland spills many times. Extensive research on ISB began in the late 1970s, initially for its use in arctic, ice-covered waters. Additional research over the next 30 years investigated use on open water spills and on environmental effects from inland and wetland burns. ISB was rarely used for on water spills until the Deepwater Horizon incident, during which over 400 burns were successfully conducted.

How ISB Works

ISB works the same as the burning of any hydrocarbon liquid wherein the hydrocarbon vapors that volatilize or evaporate from an oil slick and not the oil itself is what actually burns. Combustion, and thus oil removal, continues as long as the oil continues to emit sufficient vapors to sustain a burn. The main by-products of combustion are CO_2, water vapor and particulates (soot). Spilled oil begins to burn when an ignition source heats oil to a temperature that produces hydrocarbon vapors above the slick in sufficient quantities to support combustion. Once a fire is ignited, hot air rising above the fire draws air in from the sides that help to concentrate vapors. For burns on water, this airflow also draws surrounding oil toward a fire. Most heat from a fire rises, but a small portion goes into the oil to produce more vapors for combustion (**Figure 1**). This self-sustaining process continues until the remaining liquid oil can no longer produce sufficient vapors to sustain combustion.

When applying ISB to floating oil slicks, the oil generally must first be collected and concentrated using containment booms and vessels to increase the oil thickness. The underlying water serves to cool the oil such that thin slicks may be too cold to emit enough vapors to initiate and sustain combustion. Thicker oil slicks minimize the cooling effects of the underlying water enabling enough vapors to be emitted to initiate combustion.

FIGURE 1. Key oil and heat transfer processes during ISB. (Source: adapted from Fritt-Rasmussen, 2010)



Once ignited, the heat from the burning will often maintain sufficient vapor emissions for even thinner slicks to sustain combustion. For more information on how ISB works and what happens to burned oil, please refer to **ISB Fact Sheet 2 – Fate of Burned Oil**.

ISB Decision-making

When an oil spill occurs, decision makers must be prepared to quickly determine the best response countermeasures for the incident specific conditions. Response options are evaluated using a Spill Impact Mitigation Assessment (SIMA)[1] consensus-based planning tool to determine which option or set of options, given the incident-specific conditions, result in the best outcome for the resources at risk.

[1] The term Net Environmental Benefit Analysis and its acronym NEBA have been used extensively over the years to describe a process used by the oil spill response community for guiding selection of the most appropriate response option(s) to minimize the net impacts of spills on people, the environment and other shared values. Industry has consulted directly with non-industry stakeholders who have expressed support for transitioning to a more appropriate term. Industry is thus introducing the term Spill Impact Mitigation Assessment (SIMA) as a replacement for NEBA. For purposes of this document, all references to SIMA should be understood to mean NEBA in its broader context.

The SIMA process brings together key stakeholders, including regulators and natural resource trustees, to address resource-management decision-making needs for an oil spill response. The stakeholders and response decision makers compare and rank the pros and cons (or "trade-offs") of the applicable response options relative to the spilled oil's potential impact on the ecological, socio-economic and cultural resources at risk and choose those that will best mitigate the potential impacts. ISB is one of the response options that is typically considered in the SIMA process.

The primary goal of ISB is to rapidly reduce the quantity of spilled oil in order to minimize the oil's impact on the environment. However, burning oil may generate large amounts of black smoke, which raises concerns about the effects of the smoke plume on humans, wildlife and the environment. ISB may also not fully remove all of the oil from the spill surface; a small percentage of unburned oil and residual by-products may remain. Decision makers must assess the tradeoffs between the spilled oil's potential impacts and the potential impacts from the use of ISB and decide which results in the best outcome for the environment.

Careful consideration is given before seeking approval to conduct an ISB and many factors are analyzed prior to approval, including human health effects, environmental effects, geographic area, anticipated weather conditions, safety, and socio-economic concerns. **ISB Fact Sheet 3 – ISB Human Health and Environmental Effects** provides greater analysis of human health and environmental health effects. The advantages and disadvantages of using ISB are highlighted in **Figure 2**.

For more information on SIMA and ISB trade-offs, refer to **ISB Fact Sheet 4 – Assessing ISB Benefits and Risks**.

These considerations are best made in the pre-spill planning process when ample time is available to make decisions. During a responsetime is often of the essence, particularly for ISB due to weathering and spreading concerns. Therefore, a pre-determined decision-making process can help ensure that these decisions are made in a timely manner. Some US regional response teams have developed guidelines to help responders evaluate possible response options.

In addition to assessing tradeoffs, other considerations for ISB decision-making during a spill are:

- Is ISB an applicable response option for a given spill incident?
- Are incident conditions suitable for safe and effective conduct of a burn?
- What are predicted levels of air emissions from combustion?
- Are any specialty consultations needed?
- Can the decision to execute be made within the time window of opportunity for ISB?
- Is a Burn Execution Plan ready and are trained responders and equipment available?

Source: American Petroleum Institute 2015.

FIGURE 2. ISB Benefits and Risks (modified from Fingas and Punt, 2000)

ISB Benefits	ISB Risks
• Has high efficiency oil removal rates from water, land, and ice surfaces • Requires less equipment and less labor-intensive than other response options • Can be conducted at night • Can be applied in remote areas where other methods cannot be used because of distances and lack of infrastructure • Prevents or minimizes spill impacts to the environment and other resources at risk • Combusts the more toxic components of oil and prevents them from entering the water column. • Can significantly reduce oil and oily waste that require storage, treatment, and/or disposal	• Requires a minimum oil thickness to ignite and burn • May need to recover residue or unburned oil • Sunken residue could be thick enough to smother/coat benthic organisms and habitats • May have a public health concern about burn emissions into the air and water - sensitive individuals can be vulnerable to combustion by-products • Visible smoke plume can alarm the public • Has limitations when conducted in close proximity to populated areas • Has risk of fire spreading to other combustible materials

ISB Approval in the U.S.

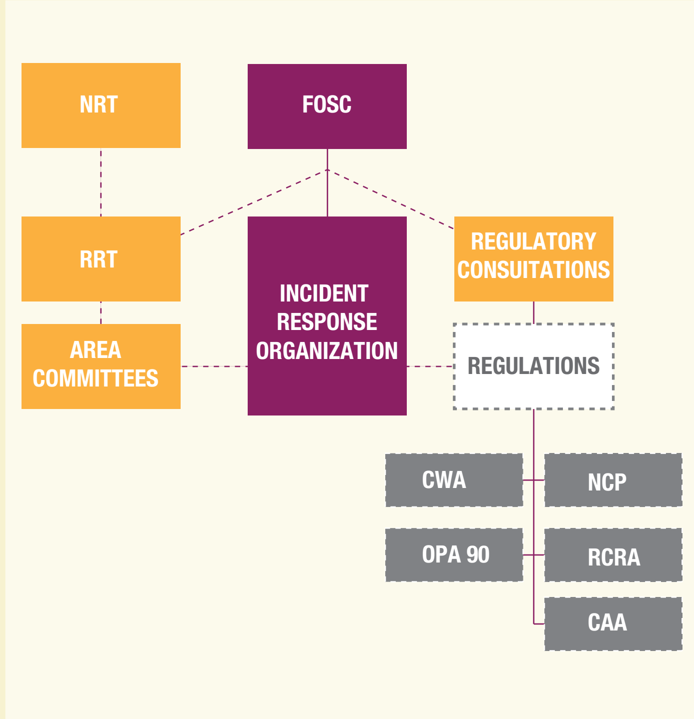
In the United States, the use of ISB as an oil spill response tool is regulated by both federal and state laws. Regional Response Teams (RRT), made up of federal and state agencies, have developed guidelines that provide a common decision-making process to evaluate the appropriateness of using ISB during a spill response. The basic framework for this response management structure is a unified command system that brings together the functions of the federal and the state government and the responsible party (i.e., the spiller) to achieve an effective and efficient response, where the Federal On-Scene Coordinator (FOSC) retains authority (40 C.F.R. § 300). The Unified Command (UC) FOSC examines if ISB is a practical option for the incident-specific conditions taking into account all the applicable laws special consultation with other agencies, preauthorizations and oil spill response guidelines (**Figure 3**). If ISB is considered to be a practical option, the FOSC will notify the incident-specific RRT and seek their concurrence for the intended use of ISB (40 CFR 300.115(b)(2)). **ISB Fact Sheet 5 – ISB Approvals** provides more information on applicable regulatory laws and approval processes.

Operational Requirements

Although ISB is a viable response measure for many habitats, the location of a spill combined with certain spill conditions greatly influences the effectiveness of ISB. For example, ISB may be the best option for inland spills when oil is spreading over large areas faster than other recovery methods can collect and recover oil. Another example is when oil spills occur in ice or in wetlands; responders may not be able to safely access the oil with other response options and may prefer to use ISB. However, there are conditions when ISB may not be an appropriate response option, such as an open water spill with wind and wave conditions that cause rapid emulsification of oil. These conditions rapidly deplete the oil of the more ignitable volatiles compounds and incorporate water to form a thicker oil emulsion that is harder to ignite. As a result, the window of opportunity for ISB in marine habitats could be short unless there is a continuous source, such as a well blowout.

Spilled oil must also have a minimum thickness in order to provide ignitable hydrocarbon vapor concentrations. The necessary thickness varies depending upon oil type. For fresh crude oil, a minimum thickness of 2-3 mm is generally required. For diesel and weathered crude oil, a minimum thickness of 3-5 mm is needed, and for emulsified and heavy fuel oils, a minimum thickness of 5-10 mm is required (American Petroleum Institute 2015a).

FIGURE 3. Generic U.S. spill response structure showing major regulatory components (API 2016).



Figures 4, 5 and **6** show examples of ISB being used in an inland marsh, offshore and on ice.

FIGURE 4. An oiled marsh being burned after Hurricane Katrina. (Source: NOAA 2005).

Weather conditions are also a critical factor when using ISB as a response measure. Responders should ensure that there are no fronts or storms forecasted that might increase fire control hazards. An atmospheric inversion by a storm or front coming in can trap an ISB smoke plume near the ground or water and limit dilution of smoke particulates. This also increases the likelihood of human or animal exposures downwind. For on-water responses, wind speeds need to be less than 18 knots with wind-driven wave heights less than 1 meter in order for ignition of the oil vapors to occur. For on-land burns, wind speed should be less than 12 knots. High plant and soil moisture levels are desired to aid fire control. Soil moisture saturation also limits any heat effects on roots.

Oil removal rate is generally estimated at 3.75 mm/min (0.15 inch/min) or 5000 L/m2/day (100 gal/ft2/day). Oil removal rates will decrease to 1 mm/min as a slick thins and the concentration of ignitable vapors declines. For spills on water, burning will cease at slick thicknesses of 1-2 mm as the heat needed to release more vapors for combustion is increasingly transferred to the underlying water and the slick cools.

Responders should also evaluate other important operation conditions including spill location relative to population centers, oil type and condition (i.e., slick thickness, degree of emulsification, etc.), wave height (if on water), and the presence and condition of vegetation (moisture level, time of year, etc. (if on land)). The seasonal time of year is also a factor for on-land responses. It is better to apply ISB when plants are dormant and not actively growing. **ISB Fact Sheet 6 – ISB Operations** provides more information on operational planning and oil spill response readiness.

FIGURE 5. In-situ burning during the Deepwater Horizon response. (U.S. Navy 2010).

FIGURE 6. Field testing at SINTEFs arctic station on Svalbard. (SINTEF 2007).

Figure Sources

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Figure 2 – Fingas, M., and M. Punt. 2000. In-situ burning: a cleanup technique for oil spills on water. Ottawa, ON: Environment Canada.

Figure 3 – American Petroleum Institute (2016). In-Situ Burning: A Decision Maker's Guide, API Technical Report 1256. Washington, DC

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Figure 5 – U.S. Navy (2010). In-situ Burning during the Deepwater Horizon response – photo. Retrieved from: http://archive.defense.gov/WeekInPhotos/WeekInPhotosSlideShow.aspx?Date=05/02/2010

Figure 6 – SINTEF 2007. Field testing at SINTEFs arctic station on Svalbard (78°N), April 2007.

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