

In-Situ Burning Guidance for Safety Officers and Safety and Health Professionals

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Purpose of Report

This report is intended to support the Incident Safety Officer and other safety and health professionals involved or having responsibilities in the incident response during oil spill responses (OSR) where the strategy of controlled in-situ burning (ISB) can be used. ISB is an effective response countermeasure for oil spills on land (including wetlands), on water, and in ice and snow. This Guide presents the process of anticipating, recognizing, evaluating and controlling the hazards associated with ISB for a Safety Officer or other health professional to consider during an incident as a part of the National Incident Management System / Incident Command System (NIMS / ICS) planning cycle.

ISB has been used less frequently than other techniques such as booms and skimmers or oiled soil removal. Consequently, familiarity with the pros and cons of ISB might be limited. Extensive practical and operational experience has been gained from ISB efforts to the Deepwater Horizon OSR in 2010.

This document is available from the API Publications at www.api.org.

In-situ Burning Guidance for Safety Officers and Safety and Health Professionals

1 Introduction

1.1 Background

ISB is an effective response countermeasure for oil spills on land (including wetlands), on water, and in ice and snow. Past spill responses, such as the Deepwater Horizon oil spill response (OSR) in 2010, and academic research, have provided Safety Officers and safety and health professionals much needed data in the areas of response worker safety issues, response worker and community exposure potentials, smoke plume modeling and air monitoring as it relates to ISB. This information, as well as the lessons learned from these responses, has been incorporated into this document (i.e. “the Guide”) in an effort to capture and share this expanding knowledge base. Additionally, other API documents, including, but not limited to, *In-Situ Burning: A Decision-Maker’s Guide to In-Situ Burning* (API, 2005), *Field Operations Guide for In-Situ Burning of Inland Oil Spills* (API, 2015a), *RP 98: Personal Protective Equipment Selection for Oil Spill Responders* (API, 2015b), and *Risk Communication for In-Situ Burning: The Fate of Burned Oil* (API, 2004) should all be reviewed as they complement this Guide.

1.2 Purpose and Scope

The Guide is intended to support the incident Safety Officer (SOFR) and other safety and health professionals involved or having responsibilities in the incident response during oil spills where the strategy of controlled *in-situ* burning (ISB) can be used. Typically, oil spill response operations, including those involving ISB, are conducted using the organization structure prescribed by the National Incident Management System Incident Command Systems (NIMS/ICS) (DHS, 2009). The SOFR is position appointed as part of the Command Staff. As stated in NIMS/ICS guidance, the SOFR’s function “is to develop and recommend measures for ensuring personnel safety and to assess and/or anticipate hazardous and unsafe situations.” (DHS, 2009). This would include operations relating to ISB if this response action is selected for use during an oil spill.

The SOFR, along with the Incident Commander and other Command Staff, participate in the daily NIMS planning cycle. This a process is template for strategic, operational, and tactical planning used to develop Incident Action Plans (IAPs) designed to address many issues relating to the oil spill, including mitigation measures such as ISB. The SOFR participates in the process to help ensure that operations are conducted in the safest manner possible. Typically, during the pre-tactics and tactics meetings, the SOFR meets with the Operations Section and other members of the command to discuss the options for strategies and tactics. As the tactics are being outlined in the Form ICS-215, the SOFR works on the abbreviated JSA, Form ISC-215A. Additionally, a more formal JSA can be developed by the SOFR with the Operations Section. Formal JSAs provide greater detail and can be used to support decisions made while completing an ICS-215A. Having a solid understanding of ISB operations will allow the SOFR to follow along as the tactics are described. However, it is imperative that the Safety Officer ask questions when there is not a clear understanding of the operations being discussed.

Many SOFRs and safety and health professionals have not been involved with ISB operations and might find supporting such operations challenging without some basic understanding as to how ISB is performed and what potential hazards and risks could be associated with it. The Guide is meant to supplement the SOFR’s and safety and health professional’s training and education so that ISB site health and safety plans and control measures can be developed when and where they are needed in a

timely manner¹. The Guide uses industrial hygiene principles to aid in the identification and management of potential hazards associated with ISB and focuses on the process of anticipating, recognizing, evaluating and controlling (AREC) the hazards associated with ISB, a process the SOFR can use to effectively fulfill their role within of the NIMS / ICS planning cycle. The content of the Guide is intended to be useful to SOFRs and safety and health professionals who might not be formally educated or certified as industrial hygienists.

Due to ISB being a time sensitive operation (i.e., becomes less feasible and effective over time due to natural weathering of the spilled oil), there will be limited opportunity to learn the operations and understand the potential risks before being called upon to develop a site health and safety plan (HASP) or develop safe work practices. In the Guide are tools which a SOFR can use to assist in assessing risks associated with ISB, developing comprehensive safety messages and HASPs, and communicating safety options to the Operations and Planning Sections.

The Guide provides a list of relevant and often-cited reference materials as well as supplemental Performance Qualification Standards (PQS) that incident SOFRs can follow to document their experience and knowledge of ISB. The Guide also provides three supplemental tools intended to support safety professionals during a response:

- an example ISB Health and Safety Plan (HASP) (**Appendix A**),
- example Job Safety Analyses (JSAs) (**Appendix B**); and
- risk communication information presented as Frequently Asked Questions (**Appendix C**).

Response scenarios addressed in the Guide and Appendix material include inland (i.e. on-land and wetlands), near shore (i.e. < 4.8 kilometers from the coast) and offshore (i.e. > 4.8 kilometers from the coast) ISB of petroleum hydrocarbon oils. Because safety concerns overlap considerably for each of these scenarios, one general example of a HASP is included in **Appendix A**. Within the example HASP are sections which can be added, modified or removed based on the location and type of ISB. Performing site-specific JSAs is a key step in building an accurate and actionable HASP. The example JSAs in **Appendix B** include a variety of tasks/scenarios. These documents are not substitutes for developing safe work practices, performing a JSA, or preparing a health and safety plan that is specific to a site and oil spill response (OSR) task. The FAQs in **Appendix C** are examples of questions or concerns which may arise from the public during an ISB and which the SOFR may familiarize themselves in order effectively communicate with the ISC Public Health lead and other members of Incident Command/Unified Command (IC / UC).

1.3 Assumptions and Limitations

It is assumed that SOFRs and safety and health professionals using this Guide possess core competencies in their field and in OSR in general. It also assumes the incident response is being managed using the NIMS / ICS system and that the SOFR will have the standard ICS roles, responsibilities and authorities associated with the SOFR position.

This Guide does not provide an all-inclusive primer on OSR, ISB, or how to perform the duties of a SOFR within NIMS/ICS; rather, its purpose is to aid in anticipating, recognizing, evaluating and

¹ This guide does not include the physical hazards associated with an oil spill response as this area has already been well researched and documented. This exclusion is not to diminish the risks created by generic hazards such as thermal stress, fatigue, ergonomics, slips, trips and falls, noise, drowning, motor vehicle operations and workplace violence. These have all been found to create the highest risks for responders. Information covered by this guide is intended to improve a safety professional's understanding of ISB and assist in building ISB site specific health and safety plans to supplement a Site Safety Plan.

controlling hazards associated with ISB. It is not possible to expect all risk to be eliminated; therefore, a SOFR needs to work with the IC/UC and Operations Section Chief to determine an acceptable level of risk for ISB operations. The SOFR and/or safety and health professionals will then work with the ISB Burn Group Supervisor (Burn Boss) to assess the hazards and develop control measures that are both feasible and practicable.

The key to any spill response success, no matter the position held, is preparation. The Guide, if used to prepare for a spill, should allow SOFRs and safety and health professionals to understand safety and health issues relevant to ISB and make decisions at the pace dictated by the NIMS / ICS planning cycle.

2 Performance Standards for Safety Officers and Support Safety Personnel

The SOFR for an ISB operation is the person who works within the NIMS / ICS system to ensure that recognized safe practices are followed by all personnel throughout the burn operation. The SOFR should have the training and/or experience to: analyze the personnel safety hazards related to ISB, understand the safety consequences of specific tactical operations proposed for the location where the spilled oil is situated and with the equipment to be used, assess safe vehicle, vessel and boom usage, enforce vehicle and vessel safety and personal protective equipment (PPE) usage, evaluate PPE needs and availability, evaluate air quality impacts for workers, and effectively assist the ISB Burn Boss. The SOFR may consult with Technical Experts (including, but not limited to, Industrial Hygiene, Air Monitoring, Weather Forecasting or Fire Fighting experts) in order to establish safe work practices.

SOFRs and other safety and health professionals assigned to support ISB operations need to come prepared. Preparation could follow many paths, but a strong foundation (not necessary relating to ISB operations) includes:

- Being able to recognize, evaluate, and control the hazards associated with OSRs,
- Being able to assess and prioritize health and safety risks,
- Being able to communicate the risk to stakeholders, responders and the public,
- Understanding the hazards of spilled oil and combustion by-products produced by burning of oil,
- Being able to gather, produce, analyze and distribute safety information, as required
- Being able to gather situational information and supply it to other members of the incident command structure
- Being qualified as a NIMS/ICS Safety Officer and having at least NIMS/ICS-200 Level training (see *API Selection and Training Guidelines for In-Situ Burn Personnel*).

SOFRs, in order to support operations, are preferred to have a working knowledge of ISB operations and the hazards associated with it before they arrive on-site and also be capable of demonstrating competency in a variety of operational areas. Competencies are the behaviors which encompass the desired skill, knowledge and abilities that lead to a successful ISB operation. There are no regulatory requirements for serving as a SOFR or safety support staff during an ISB. However, API's *Selection and Training Guidelines for In-Situ Burn Personnel* (i.e. *ISB Selection and Training Guide*, API, in preparation) contains PQS information for a variety of ISB positions, including the SOFR, which may be used to help identify qualified personnel to serve in the SOFR or safety support staff roles. Additional certification opportunities that may be useful for the SOFR are available from the Federal Emergency Management Administration (ISC 404) and the National Fire Protection Association (NFPA 1521 Fire Department Safety Officer; NFPA 472 Hazardous Materials Safety Officer). For convenience select PQS information listed in the ISB Selection and Training Guide which are applicable to ISB SOFRs has been

included below in a shortened form (**Figure 1** to **Figure 4**). Readers are encouraged to review the *ISB Selection and Training Guide* for greater detail on specific PQS topics.

Competency Area #1: Oil Spill Hazards Control

Requisite Knowledge	Requisite Skill
Identify Hazards to Oil Spill Responders Involved in ISB	
Understand concepts relating oil types, physical properties of oil and oil residue, flammability, behavior of oil in the environment, emission of volatiles from oil, production of combustion byproducts from burning oil and properties / use of oil dispersants.	Use reference materials to identify hazards associated with tasks associated with ISB response tactics.
Understand Exposure Limits to Oil Constituents, Combustion Byproducts and Spill Control Agents	
Understand basic toxicological principles such as exposure routes, dose-response and acute vs. chronic effects. Understand the toxicological properties of oil constituents, combustion byproducts and spill control agents. Understand terminology associated with chemical exposure limits (i.e. measures of airborne concentration (ex. ppm), types of exposure limits (ex. TLV-TWA, TLV-STEL, IDLH).	Anticipate and ensure control of chemical hazards associated with oil constituents, combustion byproducts and spill control agents.
Analyze the Behavior of Spilled Oil in Various Operational Environments	
Understand how oil behaves in each operational environment associated with an oil spill.	Be able to obtain information on local weather conditions and predict the influence of changing conditions on the spilled oil.
Identify Conditions Conducive of Successful ISB of Spilled Oil in Various Operational Environments	
Understand limiting conditions that affect ISB success in operational environments associated with an oil spill	Be capable of assessing appropriate distance from public receptors, worker safety, environmental conditions, tactics to contain the oil and maintain a minimum thickness of oil for ISB, suitability of vessels and equipment, ability to contain and limit burning to a target location, adequacy of personnel training, permissions and permits from regulatory authorities and consent of responsible party.

Figure 1—ISB SOFR PQS Competency Area #1

Competency Area #2: Planning the ISB Response

Requisite Knowledge	Requisite Skill
Identify and Evaluate Tactical Options for ISB of Spilled Oil in Various Operational Environments	
Understand fire break construction and fire boom positioning techniques and use of existing topographical or geographical features to facilitate ISB in different operational environments. Understand positioning of personnel to maintain safe positions and unimpeded exit routes.	For a given operational environment, be able to identify equipment, vehicles, vessels and personnel that will but suitable for a safe and effective ISB.
Equipment Capabilities, Quantities and Safe Operating Practices in Various Operating Environments	
Understand vehicle and vessel size, maneuverability and power supply needs. Understand vessel or personnel mobility requirements for ISB ignition, fire boom deployment and recovery (if applicable), fire suppression (if applicable), on-scene command and operational surveillance. Understand equipment and fire boom selection criteria as well as advantages and disadvantages of available equipment in regards to suitability to task. Understand safe operating procedures and safe positioning personnel in relation to equipment operation.	Be able to evaluate safety and health hazards associated with the position of equipment, vehicles or vessels to perform safe and effective ISB in the applicable operational environment.
Timeline for Daily ISB Operations	
Understand expected deployment times for personnel and equipment needed for ISB operations.	Be able to confirm transit times, deployment and recovery times and effective workday length for ISB operations. Provide incident command with timely updates of progress and anticipated deviations from the approved timeline.
Protective Actions	
Understand safe practices for addressing hazards associated with the work environment, use and movement of response vehicles, vessels and equipment as well as tasks unique to ISB (i.e. fire boom deployment, ignition, etc.)	Be capable of assessing hazards and developing a Site Safety Plan for ISB operations.

Figure 2—ISB SOFR PQS Competency Area #2

Competency Area #2: Planning the ISB Response (con.)

Requisite Knowledge	Requisite Skill
Spill Control Agent Usage	
Understand how to identify environmental conditions where use of spill control agents (demulsifiers, herders) may be successful in enhancing the effectiveness of an ISB, the legal requirements for using spill control agents and the hazards and application techniques for spill control agents.	Be capable of assessing worker safety issues related to the use of spill control agent in various operating environments and recommending safety precautions for their use. Be capable of providing information and planning details to incident command to facilitate decisions about whether to contact authorities to request use of spill control agents.
Personal Protective Equipment (PPE) during ISB	
Understand the appropriate use and limitations of general PPE, PPE for fire, oil and chemical hazards and safety equipment including personal flotation devices (PFDs) which may be used during ISB operations. Understand factors specific different ISB work tasks which guide the selection of appropriate PPE. Understand methods for preventing cross-contamination of PPE during ISB operations.	Be capable of training workers to correctly don, wear and doff PPE and safety equipment. Be capable of guiding decisions regarding selection of appropriate PPE and safety equipment for different work tasks. Be capable of ensuring that workers are trained in self- and co-worker decontamination methods and methods for removal of PPE which minimize secondary contamination.
Ignition of ISB of Spilled Oil	
Understand the construction, characteristics, anticipated effectiveness, safety and hazards of ISB ignition systems as well as optimization of ISB ignition sequencing and safe placement of ignition personnel during and after ISB ignition. This applies to on-land, on-water and aerial ignition procedures. Understand how the physical characteristics of the spilled oil and conditions in the operational environment would affect the ease of ISB ignition.	Be capable of ensuring that ISB ignition systems are deployed and used safely and that ignition specialists prepared thoroughly for ignition operations. Be capable of aiding in the development of plans for ISB ignition locations and sequencing that allow for safe placement and egress route for personnel as well as minimizing the potential to fire to spread outside of the burn area. Be capable of understanding aerial ignition safety plans, effective communications and safe use of aerial assess to conduct ISB ignition.

Figure 2 (continued)—ISB SOFR PQS Competency Area #2

Competency Area #3: Implementing an ISB Response

Requisite Knowledge	Requisite Skill
Operational Period Briefing	
Understand the components of an operational period briefing covering an Incident Command System (ICS) incident action plan.	Be capable of assisting in preparation of a concise pre-operational briefing that imparts information needed for safe and effective performance during the operational period.
Fire Suppression During ISB	
Understand how to support effective fire control and smoke management procedures, use of fire breaks, safe positioning of fire suppression equipment and crews and develop of safe egress routes for on-land ISB. Understand the performance of tactical operations which result in extinguishment of burning oil on water and how to perform fire-fighting on boom towing vessels, small boats and support vessels. Understand the capability and capacity of firefighting equipment or personnel which may be used during an ISB.	Be capable of reviewing options to ensure the availability of sufficient fire fighting resources, construction of firebreaks, egress routes and the safety of workers when fighting fires that escape the burn area for on-land ISB. Be capable of recommending options for tactical maneuvers which would extinguish on-water burns and ensuring the availability of fire-fighting equipment and safe fire-fighting procedures for fires on vessels / small boats for on-water ISB.
Medical Emergency / First Aid during ISB	
Have training or experience meeting or exceeding OSHA's Best Practices for Workplace First Aid Training Programs. Understand the location and capabilities of medical personnel stationed on-site and the nearest medical care facilities to the ISB site. Understand planning considerations for routes and means of transport to health care facilities	Be capable of identifying and designating workers available for providing first aid at a site in the event of an accident. Be capable of communicating with on-site medical personnel to discuss operational and safety objectives of an ISB. Be capable of recommending primary and secondary medical centers and the most efficient routes and means of transport to those centers.
Airborne Hazards Monitoring	
Understand the components of unburned crude oil emission and emissions of combustion by-products following ignition of an ISB. Understand how to select appropriate action levels to protect workers from overexposure to airborne constituents. Know about public health standards for the general public and how to develop air monitoring protocols for areas downwind of the ISB site. Understand how to develop a Quality Assurance Project Plan (QAPP) for air monitoring.	Be capable of recommending to incident command what airborne constituents should be monitored before, during and after an ISB, where to station air monitoring personnel to protect workers and downwind receptors. Be capable of selecting appropriate air monitoring equipment and demonstrating how read-out from the equipment relates to health-protective action levels. Familiarity with Special Monitoring of Applied Resource Technology (SMART) protocols developed by various government agencies (USCG, USEPA, NOAA, CDC, BSEE). Be capable of reviewing, critiquing and approving a QAPP for monitoring of airborne hazards.

Figure 3—ISB SOFR PQS Competency Area #3

Competency Area #4: Terminating the ISB Response

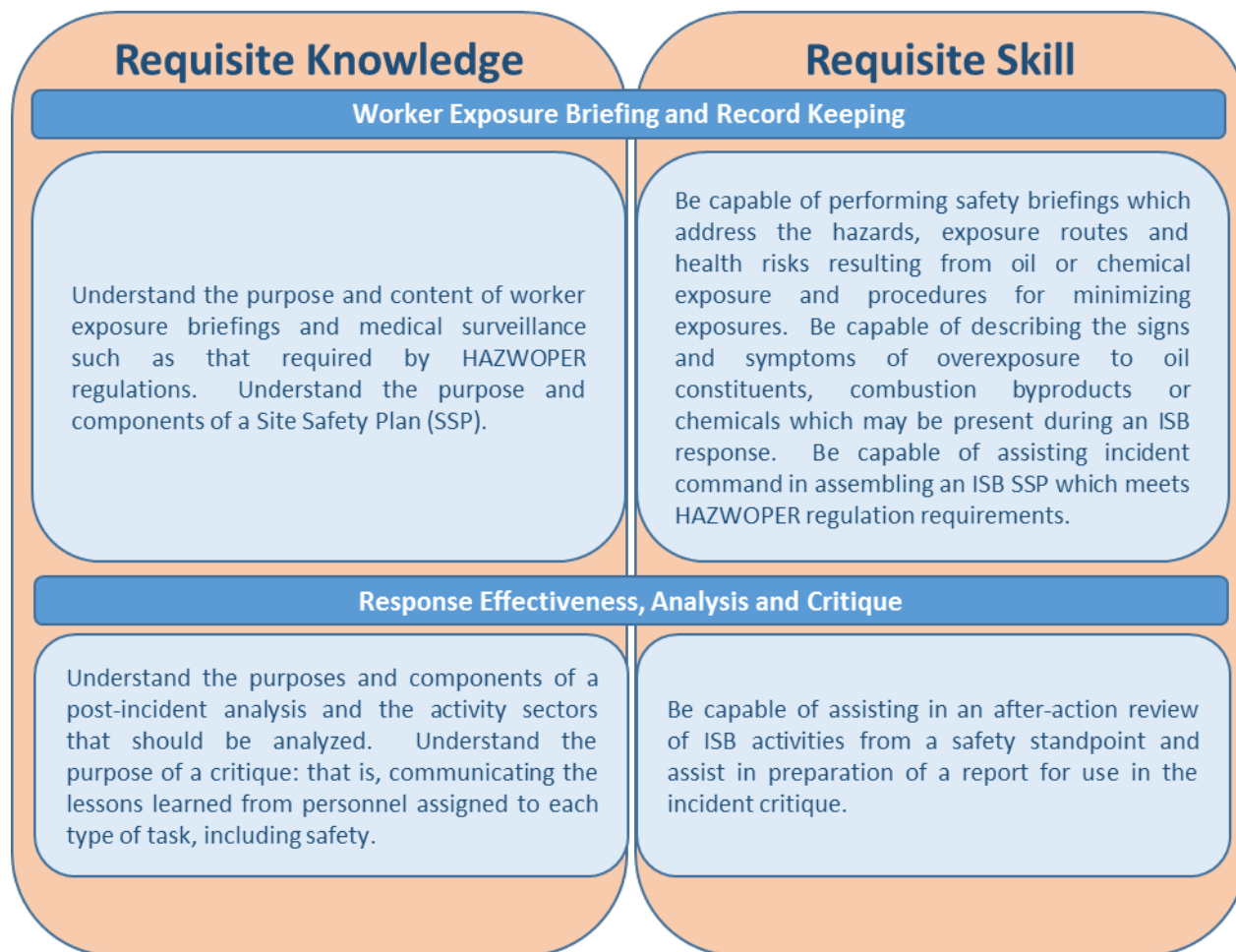


Figure 4—ISB SOFR PQS Competency Area #4

2.1 Critical Role of Communications

The key to a successful and safe ISB is good communications. The safety of response and associated, non-response personnel will depend on adherence to a HASP and the availability and proper use of reliable communications equipment prior to and throughout an ISB operation. Such communications will be needed to warn all participants and observers about the intent to burn oil and to provide information regarding potential health and safety hazards. Proper notifications can help prevent the unexpected movement of people, aircraft and vessels into pre-designated restriction zones. In addition, routine status reports to the public and stakeholders through a Liaison Officer and Public Information Officer can help reduce the kinds of over-reaction and misinterpretation which can occur during a highly visible activity such as ISB. To assist in public communications, **Appendix C** contains FAQs and answers intended to serve as draft material for explaining the process of ISB and potential hazards associated with the smoke plume or lack thereof, to responders and/or the public.

2.2 Simultaneous Operations (SIMOPS)

During a response it is expected that different operations will be performed at the same time. In order to ensure that responders working outside of the burn operations do not interfere or accidentally enter the burn area, coordination of the different operations needs to be handled. Often, this is performed in cooperation with a separate response organization branch able to track locations of response personnel and resources and ensure that safety zone boundaries and use of pre-established ingress and egress routes are enforced.

3 ISB Hazard Anticipation, Recognition, Evaluation and Control

3.1 Overview

This section covers hazard Anticipation, Recognition, Evaluation and Control (AREC) for ISB operations. In general, hazards from ISB operations will be related to:

- the spilled oil;
- response activities;
- the impacted/surrounding environment; and
- exclusion zone control.

In the sections below, each of these hazards is addressed in turn, through discussions of how each of these hazards can be evaluated and controlled. New hazards should be evaluated and controlled as they become known.

Despite the perceived hazards of ISB ignition, fire, and the resulting smoke plume, these have not been found to present the highest risks to responders. For example, lessons learned and injury logs from the Deepwater Horizon response, where ISB was used as a countermeasure, show that the highest hazards were due to vessel to vessel transfers, thermal stress (i.e., heat stress not from ISB), fatigue, slips, trips and falls (e.g., on small boats or crew vessels) and ergonomics (e.g., hand, arm, back and muscle strain). Cold stress may also be a general hazard to response workers in cold climates. As the Guide is designed to assist SOFRs and safety and health professionals in the context of an ISB, these generic hazards will not be discussed except when relevant to unique aspects of performing an ISB.

In order to anticipate ISB hazards, safety personnel can take actions in advance, such as becoming familiar with ISB operations, knowing the hazards associated with spilled oils and controlled burns, reviewing past burn plans and HASPs, and discussing operations and lessons learned with experienced

ISB responders. By anticipating hazards, a SOFR or an associated safety and health professional can better prepare for the pre-tactics and tactics meetings conducted during specific incidents.

Recognition of hazards typically initially occurs during the pre-tactics meeting when the JSA is started. Hazard recognition continues to occur as the operations are prepared and executed. Field evaluations of potential hazards is critical for proper development of HASPs and JSAs. Because new information will become available as the operations progress, the anticipation and recognition phases, as part of the continuous improvement process, need to be repeated in order to address the hazards. Once hazards are recognized, then they need to be evaluated to assess their risks and to determine what control or mitigation measures should and could be implemented. Evaluation can be performed using different risk assessment tools; no matter how it is done, results need to be clearly documented. Furthermore, as new information changes initial evaluation inputs, a new risk assessment should be performed, documented and communicated. An after action review process may also be performed to determine if controls measures were effective in promoting safe work practices and serve as tool for continued improvement of safety in the future.

The control measures selected for ISB operations, such as wearing fire resistant clothing and using skimmers to recover the residue, should reduce the overall risk, not increase it or transfer it. The hierarchy of controls should always be considered with risk elimination and risk substitution being preferred. Risk elimination or substitution is to be followed by, in order of preference, engineering controls, work practice and administrative controls, and PPE. Safety personnel can consult API Recommended Practice 98, *Personal Protective Equipment Selection for Oil Spill Responders* (API 2015b) to aid in PPE selection. Once control measures have been chosen, then responders need to be trained before they are implemented. Control measures found ineffective or that increase risks should be quickly re-evaluated.

3.2 Spilled Substance

3.2.1 Petroleum Hydrocarbon Oils

The ability to ignite and sustain an ISB is related to the volatile petroleum hydrocarbon content of the spilled petroleum hydrocarbon liquid or product (referred to as “oils”). The volatile hydrocarbon vapors are the fuel source which facilitates ISB ignition and acts to maintain the burn. There is a wide range of petroleum hydrocarbon liquids or products (referred to as “oils”), but not all are candidates for ISB. For instance, gasoline, a refined petroleum product is typically not considered for a controlled ISB as its properties (highly flammable) make burning it more difficult to control. Moreover, gasoline, which is predominately composed of lighter ends, generally evaporates too quickly to facilitate a controlled burn. Conversely, very viscous oils, such as bitumen, are typically composed of few volatile compounds and are very difficult to ignite and maintain combustion.

The principle hazards associated with oils, generally, are²:

- flammability;
- explosive vapors;
- toxicity;
- acute inhalation hazards [Hydrogen sulfide (H₂S)];
- the slippery nature of oil.

² Adapted from IPIECA, 2012, p. 6

3.2.2 Properties of Petroleum Hydrocarbon Oils

The Occupational Safety and Health Administration (OSHA) notes that an “‘average’ crude oil contains 84% carbon, 14% hydrogen, 1–3% sulfur, and approximately 1.0% nitrogen, 1.0% oxygen, and 0.1% minerals and salts” (OSHA, 1999). The properties of the spilled oil will, of course, depend on the actual material as each will possess different characteristics (**Table 1**). Oils have been classified into five groups based on their chemical and physical characteristics which influence their behavior once spilled. In general:

- **Group 1** oils (e.g. gasoline, jet fuel) are very volatile, have a low flashpoint and high vapor pressure, and are not recommended for an ISB due to the high volatility and the risk of flashback (USCG, 2003).
- **Group 2** oils (e.g. no. 2 fuel oil, diesel fuel) are moderately volatile and the lower explosive limit tends to be low. These oils are good candidates for ISB. On water, Group 2 refined oils do not emulsify and the crude oils are slow to emulsify (>24 hours) (USCG, 2003).
- **Group 3** oils consist of medium weight oils (e.g. medium crudes and no. 4 fuel oil). Although they are good candidates for ISB, on water they emulsify rapidly, typically reducing the window of opportunity to successfully initiate ISB to less than 24 hours.
- **Group 4** oils (e.g. diluted bitumen (dilbit), bunker C fuel, no. 6 fuel oil) are some of the heaviest that will burn. On water, the window of opportunity is limited for Group 4 oils as they emulsify quickly and, once emulsified, are difficult to ignite (USCG, 2003).
- **Group 5** oils have low volatile content, require intensive ignition efforts, and are not good candidates for ISB. They tend to sink in water.

Table 1 illustrates the vast differences between the groups’ behaviors which influences their amenability to ISB. Depending on the composition of an oil, these properties will vary even within the Groups.

Table 1—Oil Groups and General Behaviors³

Group	Behaviors
Group 1: Gasoline products —Not a Candidate for ISB for Safety Reasons	Specific gravity is < 0.80; API gravity >45. Very volatile and highly flammable. Evaporate and dissolve rapidly (in a matter of hours). Narrow cut fraction with no residues. Low viscosity; spreads rapidly into thin sheens. Will penetrate substrates but are not sticky. High acute toxicity to animals and plants.
Group 2: Diesel-like Products and Light Crude Oils —Candidate for ISB	Specific gravity range of 0.80-0.85; API gravity range of 35-45. Moderately volatile and soluble. Crude oils can leave residue after evaporation is complete. Low to moderate viscosity; spreads rapidly into thin slicks. Are more bioavailable than lighter oils (in part because they persist longer), so are more likely to affect animals in water and sediments.

³ Modified from API (2001): Table 1

Group	Behaviors
Group 3: Medium Crude Oils and Intermediate Products —Candidate for ISB	Specific gravity range of 0.85–0.95; API gravity range of 17.5–35. Moderately volatile. For crude oils, up to one-third will evaporate in the first 24 hours. Moderate to high viscosity; will spread into thick slicks. Are more bioavailable than lighter oils (because they persist longer), so are more likely to affect animals in water and sediments.
Group 4: Heavy Crude Oils and Residual Products —Might be a Candidate for ISB	Specific gravity range of 0.95–1.00; API gravity range of 10–17.5. Very little product loss by evaporation or dissolution. Very viscous to semi-solid; might require heating during transport. Can form stable emulsions and become even more viscous. Tend to break into tar balls quickly. Low acute toxicity to water-column biota. Penetration into substrates will be limited at first, but can increase over time. Can cause long-term effects via smothering or coating, or as residues in the water column and sediments.
Group 5: Sinking Oils —Not a Good Candidate for ISB on Water or Ice	Specific gravity >1.00; API gravity < 10. Very little product loss by evaporation or dissolution. Very viscous to semi-solid; might require heating during transport or blended with a diluent which can evaporate if spilled into the environment. Low acute toxicity to water-column biota. Penetration into substrates will be limited at first, but can increase over time. Can cause long-term effects via smothering or coating, and as residues in sediments.

3.2.3 Hazard Recognition, Evaluation, and Control for Burning Petroleum Hydrocarbon Oils

To perform an ISB, hydrocarbon vapors which evaporate from spilled oil during the early stages of a response are ignited to promote beneficial oil removal through combustion. However, the same vapor emissions which are key to igniting and sustaining an ISB can also pose a significant physical hazard to spill response workers if vapors drift away from a slick at a concentration which can unintentionally or unexpectedly ignite. Air monitoring of hydrocarbon vapors around the incident is an important step in determining where an exclusion zone and/or safety zone boundary should be established. Hydrocarbon vapor air monitoring results, as well as wind speed and direction data, can also inform those overseeing the ISB as to preferred ignition options and direction of approach. This air monitoring can be performed with combustible gas detectors which are available from a variety of commercial vendors. The SOFR should consult with members of the UC/IC to agree on action levels for flammable atmospheres (i.e., above which it is not safe to remain in the area), which in most settings is 10% of the lower explosive limit (LEL). Of note, atmospheres containing hydrocarbon vapors at levels considered hazardous to human health, but below a point of concern for flammability, are possible during oil spill responses. Therefore, both flammability hazards and chemical hazards (discussed below) should be evaluated in parallel for establishment of exclusion zones and safe working conditions.

A summary of key physical hazards relating to ISB fire hazards and control measures are presented in **Table 2** below:

Table 2—Flammability/Fire Hazards and Control Measures for ISB

Hazard/Cause	Risk/Effect	Control Measures
Intense fires ^a	Responder might not be able to move quickly enough or far away enough from heat	A, B, C, E, F, G, H, I, J, K, M, N, O
	Severe burns, thermal stress	A, B, C, D, G, H, I, J, K, M, N, O
	Damage to equipment	A, B, D
	Responder injury or equipment, vehicle, or vessel damage due to sudden site evacuation	A, B, D, E, F, G, J
Secondary fires or Unintentional fires ^b	Unexpected and uncontrolled burns	A, B, D, I, J, K, L, M, N
	Burns outside of set boundaries	A, B, D, I, J, K, L, M, N
	Injury to responders and/or public	A, B, C, D, E, G
Flashback ^c	Burns to responders and damage to equipment	A, B, C, G, H, I, J, K, M, N, O
Incidental fires ^d	Burns to responders and damage to equipment	A, B, C, G, H, I, J, K, M, N, O
	Equipment loss or failure	A, B, D, E, G, I, K, M, N
	Loss of transportation (vessel, vehicle)	A, B, D, E, G, I, K, M, N
	Damage to environment	A, B, D, K, N
Control Measures Key: A. Develop a communications plan and burn plan. B. Monitor weather, winds, and currents and designate ISB safety zones. C. Keep responders more than 4 fire diameters away from burn except for short amounts of time (then no closer than 2 fire diameters). Does not apply to firefighters in turnout gear. D. Ensure there is no vessel or vehicle movement in areas where concentrations of VOCs pose an ignition threat E. Develop a traffic/vessel control plan. F. Assign positions, outline responsibilities, and ensure personnel are trained for their position. G. Brief personnel before each shift regarding safety plans. H. Use Hazardous Waste Operations and Emergency Response (HAZWOPER) and ISB trained personnel. I. Keep all possible ignition sources at safe distances from spilled oil. J. Develop a site-specific health and safety plan (HASP), air monitoring plan, and emergency action plan. K. Prepare emergency burn termination procedures and pre-ignition checklists. L. Control oil slick movement with boom or barriers. M. Keep other sources of fuel from site. N. Onsite firefighting equipment staged in "fire-free" zone surrounding the burn. O. Level D PPE plus fire resistant clothing		
Notes: ^a Ability to burn with intense heat due to volatility. ^b Unintentional fires may occur due to migration of low flashpoint, flammable hydrocarbon vapors away from the spill location and unplanned introduction of an ignition source. ^c Vapors could allow the flames to spread at rates up to 91 meters/second creating a significant hazard to the responders working near the site. ^d Due to equipment malfunction or localized fuel spill.		

3.2.4 Chemical Hazards and Controls for Spilled Oil

The term "oils" includes a wide range of chemical mixtures that originate from crude oil. Oils are composed of hydrocarbons which are individual chemicals that are composed of carbon and hydrogen. Oils contain aliphatic and aromatic⁴ hydrocarbons. A small percentage of the overall chemical composition of oil are chemicals which contain nitrogen, oxygen or sulfur in addition to carbon and hydrogen. Some "sour" oils contains hydrogen sulfide (H₂S), a toxic and flammable gas, which can lead to severe acute toxicity at high concentrations (i.e. > 20 ppm). The chemical composition of oils are not uniform in nature, varying even within the same oilfield (OSHA, 1999).

⁴ Aliphatic refers to petroleum hydrocarbons with straight or branched chains or non-aromatic, cyclic rings of carbon and hydrogen atoms all joined with single bonds. Aromatic refers to single or conjugated planar rings with alternating single or double bonds.

Volatile petroleum hydrocarbons (e.g. benzene, toluene, ethyl benzene and xylene [BTEX] and short-chain hydrocarbons < C₁₂) are the most likely to be inhaled by response workers and also have the greatest potential to be an inhalation hazard prior to ISB ignition. **Table 3** is a summary of acute and chronic health effects associated with constituents of oil. Air monitoring of hydrocarbon vapors and comparison to occupational exposure limits (OELs) can aid in determining where an exclusion zone and/or safety zone boundary should be established. **Table 4** is a summary of control measures for chemical hazards associated with constituents of oil and chemicals used during ISB operations.

Table 3—Health Effects of Selected Volatile Components of Oil ⁵

		Benzene	Cyclohexane	Ethyl benzene	n-Hexane	Toluene	Xylenes	Naphthalene	Butane	Hydrogen Sulfide
Acute Health Effects	Eye, nose, and/or upper respiratory tract irritation	x	x	x	x	x	x	x		x
	Central nervous system effects (dizziness, headaches, narcosis)	x	x	x	x	x	x	x	x	x
	Dyspnea, shortness of breath	x						x		
	Nausea	x	x	x	x	x	x	x	x	x
	Dermatitis		x	x	x	x	x			x
	Numbness, muscle weakness				x					
	Respiratory sensitization							x		
	Dilated pupils and lacrimation									x
	Eye injury		x			x	x			
Chronic Health Effects	Known human carcinogen (IARC-1)	x								
	Possible carcinogen (IARC-2B)		x	x				x		
	Dermatitis, defatting, or drying/cracking of skin	x	x		x	x	x			
	Peripheral nervous system effects				x					
	Central nervous system (CNS) effects	x				x	x		x	x
	Weight loss									x
	Liver injury					x	x			
	Kidney injury					x	x			
	Cataracts							x		
	Anemia (aplastic/hemolytic)	x						x		

Source: OSHA, 2015; NIOSH, 2015.

⁵ It is important to note that the acute and chronic health effects listed below would not automatically be expected to occur upon exposure to crude oil vapors. The potential to experience health effects is determined by the intensity, duration, frequency and route of exposure as well as interindividual sensitivity. Different acute and chronic health effects would occur at different dose thresholds. In a controlled work environment, most people's exposure to crude oil vapors occur at levels and durations which would not be associated with an adverse health effect.

Table 4—Chemical Hazards of Spilled Oil and Control Measures.

Hazard/Cause	Risk/Effect	Control Measures
VOC inhalation ^{a,e}	Acute effects (general)-irritant to skin, eyes and respiratory tract, CNS depressant, drowsiness, fatigue	A, B, C, D, E, F, G, H, I
	Acute and chronic health effects due to specific constituents (see Table 3)	
Hydrogen Sulfide inhalation ^{b,e}	Sudden loss of sense of smell	A, B, C, D, E, F, H
	Acute effects (see Table 3)	
Dermal contact with oil constituents ^{c,e}	VOCs-Absorption into blood stream and systemic toxic effects	A, B, D, E, I, J, K, L, M
	VOCs-Irritation of skin	
	VOCs-Dermatitis	
	Heavier Compounds-Irritation d	
	Heavier Compounds-Dermatitis	
	Heavier Compounds-Sensitization of skin	
Control Measures Key: A. Develop site specific safety plan & air monitoring plan. B. Develop with Operations Section safe work practices focused on keeping personnel free of contamination and away from fresh oil. C. Keep personnel, vessels, vehicles upwind of spilled oil. D. Use HAZWOPER trained personnel. E. Train personnel on hazards of contact and inhalation of oil and to report symptoms of overexposure. F. Continuously perform real-time area monitoring with multi-gas meter for VOCs and hydrogen sulfide. G. Monitor personnel for VOCs (full shift samples) to characterize exposures. H. Select, provide and train responders on use of PPE as determined by Job Safety Analysis (JSA). I. Keep public away from fresh oil. J. Substitute, if possible, solvent based degreasers with safer products. K. Prevent secondary contamination and accidental ingestion of oil - provide hygiene facilities or materials for hand, arm and face washing. L. Establish decontamination station. M. Train personnel on proper use of PPE and ensure appropriate PPE is available for use.		
^a Inhalation of VOCs which have high vapor pressure (i.e. likely to evaporate).		
^b Inhalation of hydrogen sulfide from sour crude oil or the decomposition of biological materials in oil.		
^c Handling oil coated equipment, ropes and boom, operations where there is the potential for oil contaminated water to splash (e.g., boat operations, boom retrieval), and performing post-burn maintenance on the boom.		
^d Polycyclic Aromatic Hydrocarbons (PAHs), creosote, coal tar.		
^e The SOFR may consult with technical specialists, such as Industrial Hygienists or Toxicologist, regarding acceptable exposure limits and potential toxicities which may result from inhalation exposures or dermal contact with petroleum products.		

Continuous or frequent monitoring with real-time instrumentation should be employed to measure concentrations of different constituents in the air during the response. Common examples of real-time instruments which can be used to monitor hydrocarbon vapors and gases include multi-gas meters equipped with photo-ionization detectors (PIDs) and chemical-specific colorimetric detection tubes. PID equipped multi-gas meters are not chemical-specific and provide a readout for total volatile organic compounds (VOCs) which is appropriate for monitoring the complex mixtures of hydrocarbon vapors which are emitted from crude oil. Colorimetric detector tubes are chemical-specific and can be used to detect individual hydrocarbon constituents of crude oil which may be present as vapors. There are also some chemical-specific real-time monitoring instruments, such as benzene and H₂S monitors, which are commercially available. In addition, in order to characterize personal exposures, consideration should be given to full shift, personal sampling (analytical) for constituents of concern associated with the spilled oil using passive diffuser badge (preferred) or industrial hygiene sampling pumps. The SOFR may consult

with Technical Experts with expertise in air monitoring or industrial hygiene in order to select appropriate air monitoring equipment and methodology, to understand the strengths and limitations of air monitoring equipment which may be available during an oil spill response, to establish air monitoring protocols and to interpret the resulting data.

In order to evaluate potential inhalation hazards for responders, airborne concentrations of volatile chemicals and gases need to be compared to occupational exposure standards selected for use as action levels during a response. Many organizations, such as the US Coast Guard (USCG), default to using the American Conference of Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs) as an occupational exposure standard for response activities. TLVs are typically based on the most current science and more conservative than Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs). Occupational exposure standards for select volatile petroleum hydrocarbons and H₂S which can be found in oil are listed in **Table 5**. There is no occupational exposure standard for crude oil hydrocarbon vapor mixtures. However, total VOC readouts may be compared to occupational exposure standards for hydrocarbon vapor mixtures which have a similar constituency as what would be expected from crude oil (i.e. gasoline vapors). The SOFR should consult with Technical Specialists, the public health lead, other members of the UC/IC and other available resources (i.e. toxicologists, public health professionals) in order determine the scope and breadth of an air monitoring protocol for volatile hydrocarbon vapors and which occupational exposure standards may be appropriate for use in evaluating potential exposures to response workers. For additional reference, the reader is referred to the *Emergency Response to Oil Spill Initial Sampling Strategy* developed by OSHA for air monitoring crude oil spills (OSHA, 2010).

Table 5—Occupational Exposure Standards and Guidelines

Analyte	CAS Number	ACGIH		OSHA		NIOSH		Units
		TLV-TWA ^a	TLV-STEL ^b	PEL-TWA ^c	PEL-Ceiling ^d	REL-TWA ^e	REL-STEL ^f	
Benzene	71-43-2	0.5	2.5	1	5	0.1	1	ppm
Cyclohexane	110-82-7	100	NE	300	NE	300	NE	ppm
Ethyl benzene	100-41-4	20	NE	100	NE	100	125	ppm
n-Hexane	110-54-3	50	NE	500	NE	50	NE	ppm
Toluene	108-88-3	20	NE	200	300, 500**	100	150	ppm
Xylenes	varies	100	150	100	NE	100	150	ppm
Naphthalene	91-20-3	10	NE	10	NE	10	15	ppm
Hydrogen Sulfide	7783-06-4	1	5	NE	20, 50**	NE	Ceiling 10**	ppm
Gasoline Vapors	8006-61-19	300	500	500	NE	NE	NE	ppm

NE = Not Established. **10-min peak per 8-hour shift.

^a ACGIH The Threshold Limit Value-Time Weighted Average (TLV-TWA) is the concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers could be repeatedly exposed, day after day, without adverse effect (ACGIH, 2015).

^b ACGIH Threshold Limit Value-Short-Term Exposure Limit (TLV-STEL) is the concentration that shall at no time be exceeded (ACGIH, 2015).

^c OSHA Permissible Exposure Limit-Time Weighted Average (PEL-TWA) is the permissible concentration in air of a substance that shall not be exceeded in an 8-hour work shift or a 40-hour work week (OSHA 29 CFR 1910.1000).

^d OSHA Permissible Exposure Limit-Ceiling (PEL-Ceiling) is the concentration to which workers cannot be exposed to for any period of time. If instantaneous monitoring is not feasible, then the ceiling shall be assessed as a 15-minute time-weighted average (TWA) exposure, which shall not be exceeded at any time during the working day. (OSHA 29 CFR 1910.1000).

^e NIOSH Recommended Exposure Limit-Time Weighted Average (REL-TWA) is a concentration believed to be protective of worker safety and health over a working lifetime (NIOSH, 2015).

^f NIOSH Recommended Exposure Limit-Short-Term Exposure Limit (REL-STEL) is a 15-minute TWA exposure that should not be exceeded at any time during a workday (NIOSH, 2015).

3.3 Response Activities

3.3.1 Burn Operations Plan

In order to maintain organization within the response effort, a site-specific burn operations plan and an ISB application will be drafted prior to ignition. Approval of the burn operations plans and the ISB application must be obtained from UC/IC prior to ignition. The ISB Worker Health and Safety Plan, a supplement to the overarching HASP, will also need to be developed prior to approval. The ISB Worker Health and Safety Plan should specifically address operational details included in the Burn Operations Plan (Burn Plan) as the risks associated with any particular burn will need to be addressed on a case-by-case basis. The Burn Plan includes:

- **Resources:** Details the equipment and personnel needed to execute an ISB.
- **Burn feasibility:** Verification that topographic circumstances, current weather conditions, proximity to population centers and access for ignition are suitable for initiation of an ISB.
- **Operational checklists:** A chronological checklist of all operations critical for completion before, during, and after ignition.
- **Action plan:** To supplement the operational checklists, a plan that details vehicle and vessel deployment, method of ignition, weather forecasts, types and amount of vegetation (for on-land ISB) and water conditions (for near-shore and off-shore ISB) for the specific geographic area.
- **Communications:** Means of communication between operations and various stakeholders.
- **Burn termination criteria:** Pre-established criteria that indicates the environment, community or worker health or safety is threatened and ISB operations must be terminated.

3.3.2 Response Vehicles and Use of Fire Breaks (on-land ISB).

For land-based ISB, a variety of different response vehicles and equipment can be used to help facilitate burn operations and potentially provide means for containment of an ISB to a defined geographic area. Types of vehicles and equipment potentially used during a land-based ISB include passenger vehicles or work trucks, fire engines, portable fire foam tanks, emergency medical service (EMS) vehicles and mobile trailers. Each of these vehicle types represents a hazard to workers in the area of an ISB. Construction equipment, such as bulldozers and backhoes can also be used to construct fire breaks prior to initiating a land-based ISB. The ISB Worker Health and Safety Plan should include information on the location of fire breaks and safe-distances from fire breaks during ISB activities. The ISB Worker Health and Safety Plan should also include general information of vehicle and traffic safety in addition to information regarding hazards associated with specialized vehicles or construction equipment.

3.3.3 Boom Handling

Fire boom is larger and heavier than conventional boom which can create additional stressors to the responders handling it (USCG, 2003). Boom retrieval is particularly difficult as the fabric might become waterlogged and damaged due to the fire which increases the ergonomic and crushing/pinch point hazards. Likewise, fire boom can become slippery and could be a dermal contact hazard when it is contaminated with oil or burn residue (USCG, 2003). Workers handling boom should be equipped with proper PPE that limits dermal contact with spilled oil or burn residue.



Figure 5—Fire Boom Being Deployed from Vessel During Training
(USCG, 2010a)

For on-water ISB, booms are often retrieved using cranes and winches on a vessel's deck. When booms are being moved using equipment, responders should keep clear of cables and lines under tension and out of their bight (a loop where, if tightened, could entrap a person and cause serious injury). Crane operations on vessels can be particularly hazardous as the roll of a vessel can swing a load uncontrollably or cause it to fall. Cranes safety precautions, such as using a lead line to control the load, should be developed.



Figure 6—Deck Operations for Boom Deployment
(USCG, 2010b)

3.3.4 Vessel-to-Vessel Transfers (On-water ISB)

Although not entirely unique to ISB operations, vessel to vessel transfers were determined to be one of the most hazardous tasks during Deepwater Horizon ISB operations (Mabile 2013). Vessel to vessel transfer hazards include man overboard, pinch points, crushing (between the two vessels), and crane line failure which may result in severe injury/death and drowning. Controls to prevent injury include developing JSAs for the task, ensuring personnel are trained on performing transfers, and maintaining and testing crane function prior to use (Mabile, 2013). Additional controls include:

- ensuring the sea state is below 3 on the Beaufort scale⁶;
- requiring personnel to wear a Type 1 Personal Flotation Device (PFD);
- requiring two people to assist the person being transferred;
- clear communications between the vessels performing transfer;
- explicit approval from receiving vessel for transfer to commence;
- having a life ring with a retrieving line at the rail;
- readying a portable rescue ladder;
- performing a safety brief prior to transfer that includes man overboard procedures.

3.3.5 Use of Additives

In some situations, additives are used to promote ignition of the spilled oil. Prior to selection for use, the additive Safety Data Sheet (SDS) should be reviewed to ensure that the hazards can be controlled to reduce risk to an acceptable level. Ignition promotion additives usually have the desired characteristic of being very flammable. For example, fresh light crude oil, gasoline, diesel and kerosene have been used as ignition promoters. Emulsion breaker additives, such as aluminum chloride, may also be used to reduce the oil's water content to facilitate ignition and sustained burning. These chemicals are highly acidic skin and eye irritants. Risks, therefore, include fire, skin and/or eye irritation, and dermatitis in addition to the risks discussed earlier associated with oils. Other additives to oil slicks (e.g. oil herders) can be used to alter surface tension, constrict a slick's surface area, and thicken to oil to make it more amenable to ISB.

3.3.6 Igniter Operations

Ignition devices each have their own set of hazards and should only be assembled and used by trained personnel following manufacturer's or developer's directions. Key hazards of ignition devices are generally associated with the materials used such as gelled fuel, gasoline, crude oil, diesel, or a mixture thereof, which can result in fire or explosion if not properly handled. Another, although lesser, hazard is dermal exposure to the chemicals used which can result in skin irritation or chemical absorption. Studies have not found that commercial ignition devices are susceptible to accidental activation, temperature extremes, or vibration (Buist et al., 2013).

When soaking rags or sorbent materials for use as an ignition device, it is recommended that diesel be used as it has a more powerful flame and is slower burning (Buist et al., 2013). Flares, used alone with a float or attached to gelled fuel in a plastic bottle, can be used to ignite floating oil. Inland and in marshes, propane and butane torches and weed burners (see Figure 7) have been used to ignite oil (Buist et al., 2013). Additional information on ignition systems can be found in the *Interagency Aerial Ignition Guide* (NWCG, 2015) and *Interagency Ground Ignition Guide* (NWCG, 2011) from the National Wildfire Coordinating Group.

Controls to mitigate igniter hazards include working with the manufacturer to develop the best ignition system, training personnel involved in ignition procedures, measuring for VOCs prior to deploying igniter, and ensuring, for aerial deployment, that aircraft fly perpendicular to the position of vehicles, vessels or boom to reduce possibility of flying over personnel (NOAA, 1996).

⁶ The Beaufort Sea scale is a measure that relates wind speed to the observed conditions at sea or on land. For more information see <http://www.rmets.org/weather-and-climate/observing/beaufort-scale>



Figure 7—Igniting Oil with a Propane Burner
(Photo source: API, 2002)

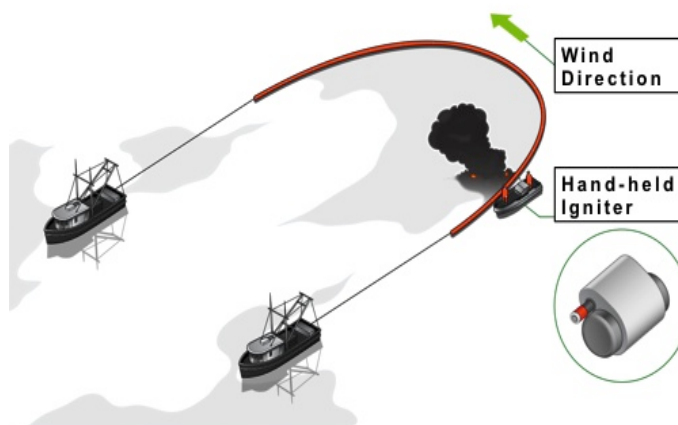


Figure 8—Fire Boom Deployed Using Two Vessels with Hand-held Ignition
(Drawing courtesy of BP)

3.3.7 Fire Control

Similar to ignition control, fire control has the added issues of distance and size (Mabile, 2013). Burning should not be used when there is the potential for the fire to spread uncontrollably or back to the source (well, tank, truck, pipeline, railcar, vessel, etc.) (ARPEL, 2006). Regional Response Team (RRT) IV (1995) directs that a risk assessment, at a minimum, needs to include:

- the expected size and duration of burn based on estimated oil volumes, burn rates and burn-area control measures, etc.;
- the location of the burn and any possible change in location due to spreading of oil on land or water, equipment failure, construction of fire break or use of containment boom, etc. (this should include the possible movements of personnel, response vehicles and vessels and animals to areas where potential exposures to excessive heat and/or combustion products is reduced or eliminated);

- the movement and duration of burn for any oil that might be released (accidentally or in response to an emergency) from within an area of controlled burning;
- the location and type of fixed equipment/facilities that could conceivably be exposed to burning oil or heavy concentrations or combustion products.

On land, the fuel loading of vegetation⁷ which could be accidentally ignited should be considered (API, 2015a). Responders may consider the removal or reduction of excess vegetative fuel or construction of a fire break which separates the spilled oil from vegetative fuel sources as a fire control measure.

Red flag conditions indicate that a burn should be postponed, and include:

- wind gusts greater than 40 mph (35 knots);
- relative humidity less than 20 %;
- air temperature greater than 80 °F; or
- a cold front is expected to pass within the next 12 hours (air inversion) (API, 2015a).

The best way to control a burn is to manage containment or barriers effectively. On land, different types of fire breaks apply depending on terrain and circumstance. These include a wetted perimeter, a line of mowed vegetation, felled trees or tilled ground, ditches, roads or even snow and ice. On water, fire boom is commonly used as an oil collection and containment method. Fire booms also provide containment barriers for some inland burns, such as those performed in a wetland or to supplement burns performed on ice or snow. For oil spilled amongst ice on water, breaks in the ice can naturally contain the slick if ice is thick enough. However, low concentrations of ice will not function well as containment and fire boom could be needed.

There are techniques to help prevent secondary fires. Personnel should be aware that during inland burns, even well-planned firebreaks and berms might not provide a sufficient barrier to prevent secondary fires. Responders and safety personnel should be vigilant during the burn, constantly monitoring the potential of the fire to escape containment. Having on-the-ready firefighting resources present during a burn is a control measure to address secondary fires that may start outside the main containment barrier. Even though extinguishing a burn can be difficult after ignition, on-the-ready firefighting resources can help terminate a burn if circumstances warrant. On water, if boom is used in a tow, in order to prevent the fire from reaching the towing vessels, the direction of movement should be into the wind and at a speed matching the flame's propagation rate (approximately 0.4 knots) (ARPEL, 2006).

3.3.8 Terminating the Burn

As a burn is terminated, either naturally or intentionally, risks from burn operations are greatly reduced. On land or on water burns, fire monitors or water cannons can be stationed nearby in strategic locations to help control a burn (USCG, 2003). Aircraft with water-bombing capabilities can also be used for on-land burns if available (ARPEL, 2006). API (2015a) notes that, for pool fires, firefighting foam could help suffocate a fire but there needs to be enough foam supply or this control measure might not succeed. Should foam be selected as a control, calculations will need to be performed and vetted with the firefighters prior to the burn.

⁷ Vegetative fuel loading refers to the weight per unit area of fuel, typically expressed in terms of tons per acre or tonnes per hectare.

During Deepwater Horizon, several methods were tested and found to work to terminate on-water burns. Fires can be extinguished over water by having the towing vessels speed up, entraining oil into the water as it escapes under the fire boom, allowing the fire to self-extinguish when the fuel loading becomes minimal. An alternative method is to have one vessel release its boom and allow the oil/fire slick to dissipate, thereby reducing slick thickness to a point below that needed to sustain a burn. Caution should be used with this option as it will allow the fire to expand initially in size as it increases the spread of the oil slick thereby increasing the radiant heat and smoke production (USCG, 2003).

3.3.9 Residue Clean Up

After termination of an ISB, the burn area may contain burn residue with higher viscosity and differing chemical composition (i.e., relatively higher content of high molecular weight hydrocarbons) as compared to the parent oil. The burn area could also contain some amount of unburned oil that can potentially be reignited if it has sufficient volatile components and is of sufficient thickness for ignition. Unlike unburned oil, burn residue is depleted of volatiles and would be difficult to ignite. On land unburned oil or burn residue can be recovered using a variety of manual or mechanical methods. On water, unburned oil or burn residues often continue to float, which would facilitate recovery efforts. However, residues may also sink, hindering recovery.

Recovery methods on land and water include using containment boom, sorbent boom and pads, manual recovery (e.g. shovels), or mechanical equipment once the residue or unburned oil has cooled. On water, for residue or unburned oil that has sunken, options include using fishing trawlers and divers. Manual recovery in open water is usually performed from a low-freeboard vessel. Mechanical recovery can be accomplished with larger vessels. Recovered residue will need to be stored for transportation. On land, residue is typically loaded directly into a tank truck. On a vessel, a tank or floating bladder can be used.

Chemical hazards of unburned oil may be similar to those listed in **Table 4** for freshly spilled oil. Chemical hazards of burn residue are predominantly dermal as the volatile components have been removed. Control measures for dermal contact with spilled oil listed in **Table 4** may also be appropriate when addressing burn residue. Steps for reducing risk associated with recovery of unburned oil or burn residue include development of a task-specific JSA, reigniting unburned oil to reduce amount, allowing unburned oil or residue to remain in environment, using mechanical equipment for recovery whenever feasible, and training responders on how to recover these materials safely with emphasis on ergonomics and back safety.

3.3.10 Decontamination

Decontamination of personnel and equipment prevents cross contamination to other areas. On shore, the OSR decontamination plan can be used for ISB operations. On vessels, decontamination can be a difficult task due to limitations in the space, the amount of support personnel and equipment available, including storage for contaminated rinse water, and the ability to safely remove PPE on a moving platform. Each vessel that handles contaminated equipment and boom should establish a decontamination zone on the deck of the vessel when feasible in order to remove gross contamination prior to reaching shore where a more thorough decontamination can be performed. Likewise, personnel should be decontaminated to prevent exposure and cross contamination to the interior of the vessel.

Hazards of decontamination include exposure to aerosolized petroleum hydrocarbons and dermal contact, thermal stress, slips, trips and falls, and ergonomic issues. The risks include injury, illness and muscle-skeletal strain. Controls include developing a JSA for the decontamination station prior to operations and ensuring an appropriate amount of supplies and personnel are on-site.

3.4 The Working Environment During an ISB

The hazards encountered in the working environment during response could include severe weather, insects and wildlife, poisonous plants, slips, trips and falls, thermal stress, ultra-violet radiation, fatigue,

stress, noise, work over-water, ice or land, and night operations. These hazards are not unique to ISB operations and, as such, are not addressed in this Guide. References to learn more about how to assess the risk and control hazards associated with the working environment include: *NIEHS Oil Spill Cleanup Training Tool* (NIEHS 2010) and *IPIECA Oil Spill Responder Health and Safety* (IPIECA, 2012) both of which are in the bibliography⁸.

3.4.1 Most Common ISB Hazards

The hazards most commonly identified during ISB as having the potential to impact the working environment is heat from the fire as well as the thick, black smoke plumes produced by burning the oil. The sections below discuss heat as a hazard of the working environment near an ISB as well as various components of an ISB smoke plume and controls to help limit potential exposures to these components.

3.4.2 Heat

Burning of oil produces intense heat. Reported flame temperatures for burning crude oil have been reported in excess of 2100 °C. The heat from an ISB will move away from the source, through the atmosphere either as conductive (i.e. transferred through the air) or radiative (i.e. transferred through the heating of nearby objects), and decrease in intensity with distance from the source. Production of heat by an ISB creates a potential hazard for response workers. The heat from ISB can contribute to heat exhaustion in response workers and could burn unprotected skin given a sufficient exposure period and heat intensity.

3.4.3 Combustion By-Products

Once ignited, the oil removal rate is a function of the type of oil, its thickness, and environmental conditions with most burns lasting less than an hour (Buist et al., 1999). The volume of oil during a burn is rapidly reduced. Oil will burn at a rate of approximately 1.0 - 4.5 millimeters (mm) of thickness per minute depending on the type of oil, percent water content (emulsification), and its initial thickness. Thicker oil slicks typically burn faster and then slow down as oil is removed. For example, Group 2 oils greater than 10 mm thick can burn at a rate of 4.0 mm/min initially and will slow down to approximately 2.0 mm/min as the thickness decreases to 5 mm. Once a burn is complete, the production of combustion by-products stops.

The combustion by-products produced during a burn are illustrated in **Figure 9**. On a percentage mass basis, carbon dioxide (CO₂) and water are the predominant combustion by-products produced by burning of oil. However, burning of oil also produces smoke, which is a visible suspension of particulate matter in air. This particulate matter (PM) is primarily composed of carbon and commonly referred to as soot. Burning of oil can produce smaller amount of combustion gases (carbon monoxide (CO), nitrogen oxides (NO_x), sulfur oxides (SO_x)). In an outdoor environment, the concentrations of these combustion gases will rapidly dissipate in the atmosphere. Burning of oil can also result in emission of volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs). PAHs will be predominantly adhered to carbon particulates in smoke.

⁸ During the Deepwater Horizon event, the National Institute of Occupational Health and Safety (NIOSH) developed guidance for oil spill responder health monitoring and surveillance which may also be of use to ISB Safety Officers (King and Gibbins, 2011).

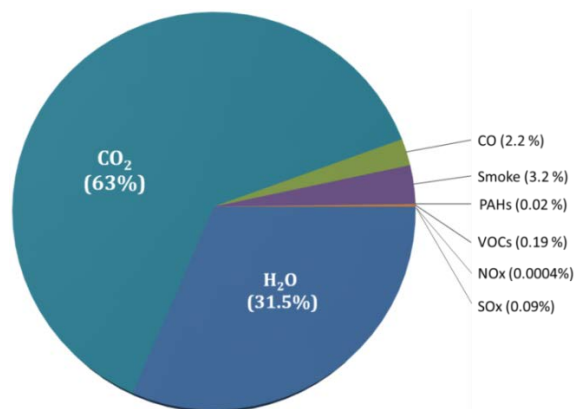


Figure 9—Graphical Depiction of Emissions from ISB
(adapted from Booher and Janke, 1997)

The thick, black smoke in the burn plume can be of concern to nearby human populations or ecologically sensitive areas and resources but is often not a human health concern more than a few kilometers downwind if there is good atmospheric mixing. Since most PM precipitation occurs near the fire, this is the main area of concern.

3.4.3.1 Smoke Particulates

The visible black particulate matter which emanates from burning of oil is 80% to 90% inert elemental carbon with only trace amounts of organic compounds (Booher and Janke, 1997). It is important to note that the quantity of PM produced by a burning pool of oil will be influenced by the type of petroleum that is burning. This PM yield ranges from 1 to 15% of the original oil volume (Fingas, 2011; Ferek et al., 1997). For example, approximately 5-8% of the volume of burning diesel fuel is emitted as PM, compared to 1 to 2% for burning crude oil (Fingas, 2010).

The individual particles in particulate matter are not uniform in size. Some components of particulate matter are large enough to be seen as smoke. Others are so small that they can only be detected with electron microscopy. All particulate matter produced by ISB is transported into the air by turbulence and updrafts. Larger particles usually remain in the air for a few minutes to hours and settle to the ground near the source; while smaller particles (aerodynamic diameter of ten micrometers and smaller, PM₁₀) can remain in the air from several days to weeks and be spread by winds over wide areas or long distances from the original source (Middlebrook et al., 2011). These particles are generally removed from the atmosphere by wet precipitation or when they come in contact with other surfaces. Only the smallest particles (aerodynamic diameter of 2.5 micrometers and smaller, PM_{2.5}) tend to remain in the air for long periods; however, as distance from the burn increases, the dilution of particulate matter in the atmosphere increases.

3.4.3.2 Combustion Gases

The combustion gases emitted during an ISB generally do not provide a serious threat to human-health and safety except in the direct vicinity of a burn. The concentrations of gases in a smoke plume can exceed concentration levels of concern at a burn origin point, yet are quickly diluted below such thresholds within very short distances from the fire. There are many oxygenated gaseous combustion by-products generated during an ISB, including carbon dioxide, water vapor, carbon monoxide, sulfur oxides, sulfuric acid, nitrogen oxides, and VOCs. Research has shown that these by-products are common components of any petroleum oil combustion and are found to have little concern to downwind populations under most weather conditions.

3.4.4 Less Common Hazards: Atmospheric Temperature Inversion

A temperature inversion occurs when the air temperature close to the earth cools down creating a pocket overlaying thin layer of warmer air that acts like a lid that prevents normal convective overturning of the atmosphere from penetrating through the inversion (**Figure 10**). This typically occurs at night as the sun sets and the air temperature cools. This phenomenon could prevent airborne PM (such as smoke from an ISB) from rising vertically and dispersing but does not prevent lateral transport and dispersion of PM horizontally. The height of where the inversion occurs negatively influences the height of the mixing layer.

Because of the potential for atmospheric inversions, ISB operations are not typically performed during early morning hours or at night as this can increase the risk of the smoke plume remaining close to the ground thereby potentially decreasing visibility and increasing the potential for exposure of responders. However, in some cases, especially in remote areas on land or ice, night operations can be performed due to the time sensitivity of ISB. API (2015a) states that atmospheric stability classes A, B, and C⁹ (unstable) are best for ISB operations when there is strong solar radiation and low wind speed creating increased atmospheric turbulence. A stable atmosphere, on the other hand, could possibly keep the smoke close to the ground. The timing of initiating an ISB can be adjusted to occur before or after atmospheric temperature inversions or during stable conditions to help facilitate vertical transport and dispersion of PM and other combustion by-products.

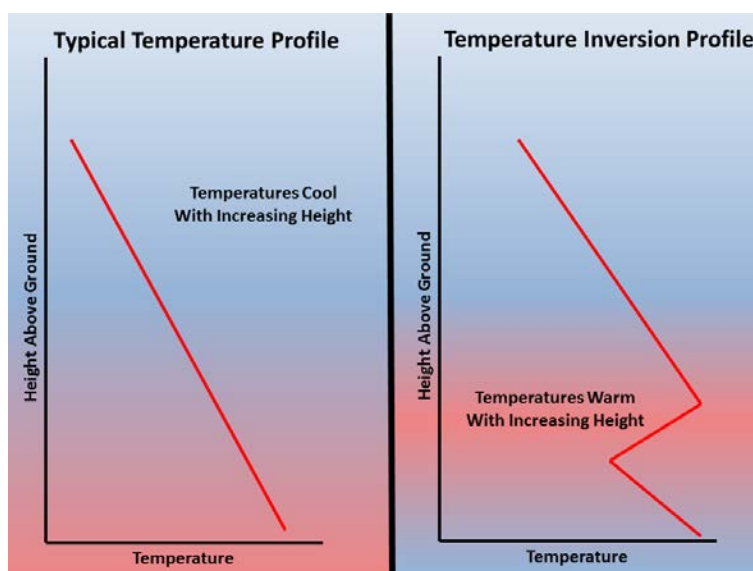


Figure 10—Temperature and Inversion Profiles

3.4.5 Hazards and Controls for Smoke Plumes

Because of its visibility and size, the smoke plume associated with the controlled burning of oil is often the factor of largest concern for the public and responders. The public may perceive visible smoke plumes as harmful even though actual health impacts may be minimal or absent. In order to ensure that the smoke plume does not become an actual concern for the responders or public, an understanding of where and in what concentration the plume will likely travel should be achieved prior to burn operations. Projecting the movement and dilution of a smoke plume and monitoring the concentration of particulates (based on size)

⁹ See API (2015a) Appendix C for information regarding atmospheric stability classes.

are the primary means to evaluate the risks associated with the plume. Monitoring for selected sizes of particulate matter (e.g., $PM_{2.5}$ and PM_{10}) will better characterize the plume's true hazards.

Fine carbon particulate matter ($PM_{2.5}$) represents the greatest hazard to the general public and responders. The $PM_{2.5}$ (fine) particulates are small enough in size that they can be inhaled deeply into the lungs; PM_{10} (coarse) particulates can also be inhaled, but are typically caught in the thoracic region of the respiratory system and, therefore, do not penetrate deep into the lungs. Fine PM can be transported from the combustion source, due to wind and environmental stability, resulting in potential inhalation exposures for a wider area of the public. Of note, airborne particulate matter is often present as a component of background in many locations. The SOFR may coordinate with technical experts (such as Environmental Scientists or Incident Meteorologist) to determine site-specific background concentrations of ambient particulate matter. For near shore or on-land burns, ISB air monitoring should be coordinated with an overall incident air monitoring plan which may include monitoring of both responders and the community surrounding a spill.

Volatile organic compounds, PAHs, and combustion gases are additional combustion by-products of burning oils that, while also having the potential to impact human health, will pose less of a concern for the public given their relatively lower emissions and rapid dilution into ambient air which will act to minimize exposures.

When evaluating the risk of exposure to particulate matter in the smoke plume for responders, the National Response Team (NRT) recommends using the United States Environmental Protection Agency's (USEPA) National Ambient Air Quality Standards (NAAQS) for $PM_{2.5}$ and PM_{10} and averaging the concentration levels over one hour (not 24 hours) to ensure that overall PM NAAQS are not exceeded at any time. In addition, the USEPA has established an air quality index (AQI) based on $PM_{2.5}$. The AQI is a nationally uniform index used for reporting and forecasting daily air quality. The AQI informs the public how clean or polluted the air is using a standardized vocabulary (i.e. Good, Moderate, Unhealthy, etc.) and an easy-to-understand normalized numerical scale of 0 to 500 which corresponds to a range of airborne $PM_{2.5}$ concentrations (USEPA, 2012). The SOFR, in cooperation with local public health officials, regulators and Incident Command, should determine which health standards are applicable for ensuring that response personnel and the public are not overexposed to respirable particulates and other combustion by-products and determine appropriate response actions relating to transient decreases in air quality associated with ISB.

Table 6 summarizes estimates of airborne emissions from burning crude oil at the burn site and one kilometer downwind and compares them health standards available in the literature¹⁰. As shown in **Table 6**, particulate concentrations are highest at the burn site but decrease quickly with distance as particulates become diluted with the ambient air, disperse, and fall out (Buist et al., 2013). Although the levels of $PM_{2.5}$ and PM_{10} are expected to exceed their NAAQS at the site of the burn, the levels will rapidly dissipate as distance increases from the smoke source. For example, following controlled burns of oil released in the Deepwater Horizon spill, fine particulate matter concentrations were reduced to 0.007-0.02 mg/m^3 at a distance of ~39 kilometers downwind of the spill (Middlebrook et al., 2012). In other monitored oil burns, total suspended particulate concentrations within the smoke plume were between 100-180 mg/m^3 and dropped to <0.20 mg/m^3 when measured approximately 30 meters downwind of the plume (Booher and Janke, 1997). Particulate concentration would need to be monitored at ground level during a burn in order to understand the potential hazard for response personnel and the public.

¹⁰ OELs, such as ACGIH TLVs and OSHA PELs, can be applied to responder exposures; however, for community or public health exposures, preferential consideration should be given to use of the EPA National Ambient Air Quality Standards (NAAQS) and any applicable state standards.

Table 6—Estimated Airborne Emissions from Burning of Oil and Comparison to Occupational and Public Health Standards

Component of Concern		Occupational Standards ^a	Public Health Standards ^a	Range at the Burn Site	Range One Kilometer Downwind
Smoke Particulates	PM _{2.5}	Not Established	35 µg/m ³ (24 hr EPA NAAQS) 0–12 µg/m ³ (AQI: 0–50, Good) 12.1–35.4 µg/m ³ (AQI: 50–100, Moderate) 35.5–55.4 µg/m ³ (AQI: 101–150, Unhealthy for Sensitive Subgroups) 55.5–150.4 µg/m ³ (AQI: 151–200, Unhealthy) 150.5–250.4 µg/m ³ (AQI: 201–300, Very Unhealthy) > 250.5 (AQI: 301–400, Hazardous)	0.0–2.4 mg/m ³ ^b (from diesel)	No data identified for ISB
	PM ₁₀	Not Established	150 µg/m ³ (24 hr EPA NAAQS)	850 µg/m ³ ^c	86 µg/m ³ ^d
PAHs		200 µg/m ³ (OSHA PEL) ^e	Not Established	0.0–13.1 µg/m ³ ^b	No data identified for ISB
Gases and Vapors	CO ₂	5,000 ppm (OSHA PEL)	Not Established	26 - 543 ppm ^f	<32 ppm ^g
	SO ₂	0.25 ppm (ACGIH STEL) 5 ppm (OSHA PEL)	0.075 ppm (1 hr EPA NAAQS) 0.5 ppm (3 hr EPA NAAQS)	2 ppm ^{h,i}	< 0.0012 ppm ⁱ
	NO ₂	5 ppm (OSHA Ceiling)	0.1 ppm (1 hr EPA NAAQS)	0.0001–0.0006 average ppm ^j	0.0001 ppm ^j
	CO	50 ppm (OSHA PEL)	35 ppm (1 hr EPA NAAQS) 9 ppm (8 hr EPA NAAQS)	0.14–0.15 average ppb ^j	0.14 ppb ^j
	Total VOCs ^k	300 ppm (ACGIH TLV) 500 ppm (OSHA PEL)	Not Established	0.0026–0.0083 average ppm ^j	0.0013–0.0016 ppb ^j

Notes: Units of ppm are most appropriate for gases and vapors, and µg/m³ is more appropriate for particulates and fumes. ^a USEPA (2015) ^b Fingas & Punt (2000). ^c Buist et al. (1999). ^d Fingas et al. (1994). ^e While the Occupational Safety and Health Administration (OSHA) has not established an occupational exposure standard for PAHs, there is an exposure limit for volatiles from coal tar pitch that covers the PAHs anthracene, benzo(a)pyrene, phenanthrene, acridine, chrysene, and pyrene. The current air standard for coal tar pitch volatiles in the workplace is 0.2 milligram/cubic meter (mg/m³) based on an 8-hour time-weighted average (TWA) permissible exposure limit (PEL) for the benzene-soluble fraction of coal tar pitch volatiles. ^f Fingas (2010) ^g Fingas et al. (1995) ^h Booher & Janke (1997) ⁱ Note that the level of SO₂ is dependent on the amount of sulfur in the oil. SO₂ levels are typically very low. Detection tubes can be used to perform real time sampling. Buist et al. (1999). ^j Middlebrook et al. (2012). ^k The ACGIH Threshold Limit Value (TLV) provided is for gasoline vapors. There are no established limits in U.S. for VOCs, crude oil or total hydrocarbons. Fingas et al. (1994) notes that the VOCs emitted from crude oil exceed those emitted from burned oil

Airborne particulate concentrations can be evaluated using real-time instrumentation such as aerosol monitors. These types of instruments can be equipped with size-selective impactors which measure particulate matter concentrations within a particular size distribution. Collection of real-time readings will allow safety personnel to monitor air quality related to the ISB and advise response workers or members of UC/IC of actions which may be taken to minimize potential exposures. The SOFR may consult with technical experts in the fields of air monitoring and/or industrial hygiene to ensure proper selection, use and calibration of aerosol monitors based on site-specific conditions.