Designation:F1788–97 (Reapproved 2003) Designation: F 1788 – 08

# Standard Guide for In-Situ Burning of Oil Spills on Water: Environmental and Operational Considerations[1]

This standard is issued under the fixed designation F 1788; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This guide covers the use of in-situ burning to assist in the control of oil spills on water. This guide is not applicable to in-situ burning of oil on land.

1.2 The purpose of this guide is to provide information that will enable spill responders to decide if burning will be used as part of the oil spill cleanup response.

1.3This is a general guide only. It is assumed that conditions at the spill site have been assessed and that these conditions are suitable for the burning of oil. It is also assumed that permission to burn the oil has been obtained. Variations in the behavior of different oil types are not dealt with and may change some of the parameters noted in this guide.

1.4

1.3 This is a general guide only. It is assumed that conditions at the spill site have been assessed and that these conditions are suitable for the burning of oil. It is also assumed that permission to burn the oil has been obtained from appropriate regulatory authorities. Variations in the behavior of different oil types are not dealt with and may change some of the parameters noted in this guide.

1.4 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that are included for information only and are not considered standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*



## 2. Referenced Documents

2.1 *ASTM Standards:* [2]

F 1990 Guide for In-Situ Burning of Spilled Oil: Ignition Devices

F 2152 Guide for In-Situ Burning of Spilled Oil: Fire-Resistant Boom



## 3. Terminology

2.1

3.1 *Definitions:*

2.1.1

3.1.1 *burn efficiency*—burn efficiency is the percentage of the oil removed from the water by the burning.

2.1.1.1

3.1.1.1 *Discussion*—Burn efficiency is the amount (volume) of oil before burning; less the volume remaining as a residue, divided by the initial volume of the oil.

2.1.2

3.1.2 *burn rate*—the rate at which oil is burned in a given area.

2.1.2.1

3.1.2.1 *Discussion*—Typically, the area is a pool and burn rate is the regression rate of the burning liquid, or may be described as a volumetric rate.

2.1.3

[1] This guide is under the jurisdiction of ASTM Committee F20 on Hazardous Substances and Oil Spill Response and is the direct responsibility of Subcommittee F20.15 on In-Situ Burning.

Current edition approved May 10, 1997. Published July 1997.

Current edition approved Sept. 15, 2008. Published September 2008. Originally approved in 1997. Last previous edition approved in 2003 as F 1788 – 97 (2003).

[2] The boldface numbers in parentheses refer to a list of references at the end of this guide.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.1.3 *contact probability*—the probability that oil will be contacted by the flame during burning.

~~2.1.4~~

3.1.4 *controlled burning*—burning when the combustion can be started and stopped by human intervention.

~~2.1.5~~

3.1.5 *fire-resistant booms*—devices that float on water to restrict the spreading and movement of oil slicks and constructed to withstand the high temperatures and heat fluxes of in-situ burning.

~~2.1.6~~

3.1.6 *in-situ burning*—use of burning directly on the water surface.

~~2.1.6.1~~

3.1.6.1 *Discussion*—In-situ burning does not include incineration techniques, whereby oil or oiled debris are placed into an incinerator.

~~2.1.7~~

3.1.7 *residue*—the material, excluding airborne emissions, remaining after the oil stops burning.

**~~3.Significance and Use~~**

~~3.1This guide is primarily intended to aid decision-makers and spill-responders in contingency planning, spill response, and training.~~

~~3.2This guide is not specific to either site or type of oil.~~

**4. ~~Background~~**

~~4.1~~*Significance and Use*

4.1 This guide is primarily intended to aid decision-makers and spill-responders in contingency planning, spill response, and training.

4.2 This guide is not specific to either site or type of oil.

**5. Background**

5.1 *Overview of Oil Burning*:

~~4~~5.1.1 In-situ burning is one of several oil-spill countermeasures available. Other countermeasures could include mechanical recovery, use of oil-spill dispersants, and leaving the oil to natural processes.

~~4~~5.1.2 In-situ burning is combustion at the spill site without removing the oil from the water. Containment techniques may be used, however, to increase the thickness of the oil (Guide F 2152). The thickness of the oil slick is an important factor in the use of in-situ burning.

~~4.1.3In-situ burning does not include incineration techniques whereby oil or oiled debris are placed into an incinerator.~~

~~4.2~~5.2 *Major Advantages and Disadvantages of In-situ Burning*:

~~4~~5.2.1 Advantages of in-situ burning include the following:

~~4~~5.2.1.1 Rapid removal of oil from the water surface,

~~4~~5.2.1.2 Requirement for less equipment and labor than many other techniques,

~~4~~5.2.1.3 Significant reduction in the amount of material requiring disposal,

~~4~~5.2.1.4 Significant removal of volatile emission components, and

~~4~~5.2.1.5 May be the only solution possible, such as in oil-in-ice situations.

~~4~~5.2.2 Disadvantages of in-situ burning include the following:

~~4~~5.2.2.1 Creation of a smoke plume,

~~4~~5.2.2.2 Residues of the burn must be dealt with,

~~4~~5.2.2.3 Time in which to ignite the oil may be limited,

~~4~~5.2.2.4 Oil must be a minimum thickness to burn, which may require containment, and

~~4~~5.2.2.5 The fire may spread to other combustible materials.

**~~5.~~6. Environmental Considerations for Deciding to Use In-Situ Burning**

~~5.1~~6.1 *Air Quality*:

~~5~~6.1.1 Several studies have been done of the air emissions resulting from in-situ burning. It has been found that the smoke plume consists largely of ~~carbon and that toxic compounds are not created.~~ carbon. The high temperatures achieved during in-situ burning result in efficient removal of most components of the oil. The thick, black smoke can be of concern to nearby human populations or ecologically sensitive areas. Since most soot precipitation occurs near the fire, this is the main area of concern. The smoke plume is, however, generally an aesthetic concern. In-situ burning should be avoided within 1 km upwind of either an ecologically sensitive or a heavily populated area, depending on meteorological conditions. No emissions greater than one fourth of the ~~1994~~2008 human health exposure limits have been detected at ground level further than 1 km from an oil fire. The values of the human health exposure limits vary with jurisdiction, and, thus, the appropriate documents should be consulted. The environmental and economic trade-offs of burning the oil, as opposed to contamination of the shoreline, must be considered.

~~5~~6.1.2 Burning can be safely conducted near populated areas if there is sufficient air turbulence for mixing, and in the absence of a low-level atmospheric inversion.

~~5.2~~6.2 *Water Quality*— Measurements show that burning does not accelerate the release of oil components or combustion by-products to the water column. Highly efficient burns of heavy oils may form a dense residue that sinks.

~~5.3~~

6.3 *Wildlife Concerns*—Although no specific biological concerns related to the use of in-situ combustion have been identified to date, benthic resources may be affected by sunken oil burn residue.

## ~~6.~~7. Operational Considerations for In-situ Burning

~~6.1~~7.1 *Safety Considerations*—The safety of the proposed operation shall be the primary consideration. Secondly, the burning operation shall not result in unintentional flashback to the source of the oil, for example, the tanker or the production platform. The third consideration is the spread of the fire to other combustible material in the area, including trees, docks, and buildings. Flashback and fire spread can often be prevented by using containment booms to tow away the oil to be burned. A fourth consideration is the safety of the ignition operation, which is often done from helicopters, and the safety of the boom tow operation must be ensured.

~~6.2~~

7.2 *Safety Monitoring and Control Requirements*—The operation must be monitored to meet safety requirements. Burning shall be monitored to ensure that fire may not spread to adjacent combustible material. Situation-specific contingency methods of extinguishing, such as boats with fire monitors, shall be available. In towed-boom operations, it has been proposed that the fire may be extinguished by increasing the tow speed so that the oil is entrained in the water. Other options for controlling the fire or the burn rate might include releasing one side of the oil containment boom or slowing down to reduce the encounter rate.

~~6.3~~

7.3 *Oil Thickness*— Most oils can be ignited on a water surface if they are a minimum of 2 to 3 mm thick (Guide F 1990). Once ignited, the oils will burn down to a thickness of about 1 mm. Physical containment, such as with oil-spill containment booms, is usually necessary to achieve the minimum thicknesses required. Specific information on this is provided in the appendix.

~~6.4~~7.4 *Oil Type and Condition*—Highly weathered oils will burn, but will require sustained heat during ignition. Oil that is emulsified with water may not burn. Not enough data are available to determine water-content levels that limit ignition. Indications are, however, that stable emulsions which typically contain about 70 % water cannot be ignited and that oils containing less than about 25 % water will burn. Treatment with chemicals to remove water (de-emulsifiers) before burning can permit ignition.



~~6.5~~7.5 *Wind and Sea Conditions*—Strong winds may extinguish the fire. In-situ burning can be done on the sea with winds less than about 40 km/h (about 20 knots). High sea states are not conducive to containment by booms. Wave heights of 1 m or more may result in splash-over of the oil.

~~6.6~~

7.6 *Burn Efficiency*— Burn efficiency, which is the percentage of oil removed by burning, has been measured as high as 99 % for contained oil. Presence of debris, water, or ice can lower this to as much as half. Burn efficiency is largely a function of oil thickness and flame-contact probability. Contact probability is the probability that oil will be contacted by the flame during burning. Inhomogeneous oil distribution on the surface can result in an incomplete burn. This can result as the flame may be extinguished over a patch that is not thick enough to burn, while adjacent patches that are thick enough will subsequently not be burned. Contact is usually random and is influenced by wind speed and direction and can be controlled by human intervention in some cases.

~~6.7~~7.7 *Burn Rate*—Oil burns at the rate of about 3.7 mm/min, which means that the surface of the oil slick regresses downwards at the rate of 3.7 mm/min. This translates to a rate of about 5000 L/m$^2$/day (or 100 gal/ft$^2$~~/day). Burn rate is relatively independent of physical conditions and oil type. Using these values, it is possible to calculate the rate of burning in booms and in other burn operations.~~

~~6.8~~*/day). Heavy oils can burn at lesser rates such as about 2 mm/min. Other than this factor, burn rate is relatively independent of physical conditions and oil type. Using these values, it is possible to calculate the rate of burning in booms and in other burn operations.*

7.8 *Containment*— Oil slicks must be a minimum ~~of 2~~ thickness to ~~3 mm thick to~~ be ignited. As oil naturally spreads quickly to much thinner slicks than this under normal circumstances, physical containment is generally necessary for burning. Fire-resistant booms are commercially available for this purpose. While these booms can be used in a variety of configurations, they are best used in a catenary mode and towed at speeds less than 0.35 m/s (0.7 knots). At speeds greater than this, oil is lost under the boom by entrainment. Slicks can sometimes be naturally contained by ice or against shorelines.

~~6.9~~7.9 *Ignition*—Slicks can be ignited with a variety of devices (Guide F 1990). Enough heat must be supplied for a sufficient length of time. Weathered oils generally require a longer heating time to ignite.

~~6.10~~7.10 *Residue Cleanup*:

~~6~~7.10.1 Residue is the material remaining after the oil stops burning. Residue is similar to a highly weathered oil, depending on the burn conditions. It is viscous and often highly adhesive. Highly efficient burns result in heavier and denser residue. These residues may actually be ~~more dense~~ denser than sea water.

~~6~~7.10.2 Floating residue can be removed manually with sorbents, nets, or similar equipment.

~~**7.Summary**~~

~~7.1In-situ burning is a viable countermeasure that has the potential to quickly remove large amounts of oil. The air emissions of in-situ burning are below health and environmental concern levels at nominal distances from the combustion source.~~

**8. Summary**

8.1 In-situ burning is a viable countermeasure that has the potential to quickly remove large amounts of oil. The air emissions of in-situ burning are below health and environmental concern levels at certain distances from the combustion source.

**9. Keywords**

~~8~~9.1 fire-resistant booms; in-situ burning; oil-spill burning; oil-spill containment; oil-spill disposal

## APPENDIX

**(Nonmandatory Information)**

### X1. INTRODUCTION TO THE IN-SITU BURNING OF OIL SPILLS

**INTRODUCTION**

In-situ burning has been used as an oil-spill countermeasure around the world (**1, 2**) ~~.[2]~~.[3] Recently, extensive research has been conducted on the many facets of burning oil (**3, 4, 5**). The emissions from and basic principles of oil-spill burning are now relatively well-understood.



**X1.1 Basic Principles of Burning Oil**

X1.1.1 Oil slicks can be ignited if they are at least 2 to 3 mm thick and will continue to burn down to slicks of about 1 to 2 mm thick (**6**). These thicknesses are required because of heat transfer. Sufficient heat is required to vaporize material for continued combustion. In a thin slick, most of the heat is lost to the water, vaporization is not sustained, and combustion ceases.

X1.1.2 Containment is usually required to concentrate oil slicks so that they are thick enough to ignite and burn (**7**). Fire-resistant containment booms can be used to keep fire from spreading back to the spill source, such as an oil tanker (**8**). Burning in situ without the benefit of containment booms can be undertaken only if the oil is thick enough (2 to 3 mm) to ignite. For most crude oil spills, this only occurs for a few hours after the spill event unless the oil is confined behind a barrier. Oil on the open sea spreads rapidly to equilibrium thicknesses. For light crude oils, this is about 0.01 to 0.1 mm, for heavy crudes and heavy oils, this is about 0.05 to about 0.5 mm.

X1.1.3 Oil can be contained by natural barriers. For example, ice has been shown to serve as a natural boom. Several successful experiments and burns of ~~real~~actual spills have shown that burning is a proven countermeasure for spills in ice (**4, 9**). Spills have occasionally been contained by shorelines. Burning could be applied in these instances, if the shoreline is remote and no combustible materials such as trees and docks are nearby.

X1.1.4 It is uncertain whether oil that is completely emulsified with water can be ignited. Oil containing some emulsion can be ignited and burned (**10**). During the successful test burn of the Exxon Valdez oil, some patches of emulsion were present (probably less than 20 %) and this did not affect either the ignitability or the efficiency (**11**) . It is suspected that fire breaks down the water-in-oil emulsion, and thus water content may not be a problem if the fire can be started. There is inconclusive evidence at this time on the water content at which emulsions can still be ignited. One test suggested that a heavier crude would not burn with about 10 % water ~~(**10**~~(**6**), another oil burned with as much as 50 % (**12**) , and still another burned with about 70 % water (**13**). One study indicated that emulsions may burn if a sufficient area is ignited (**13**). Further studies indicate that stable emulsions will not burn but oil containing less than 25 % water can be ignited. Emulsions may not be a problem because chemical de-emulsifiers could be used to break enough of the emulsion to allow the fire to start.

X1.1.5 Most, if not all, oils will burn on water if slicks are thick enough. Except for light-refined products, different types of oils have not shown significant differences in burning behavior. Weathered oil requires a longer ignition time and somewhat higher ignition temperature (**12**).

X1.1.6 Burning efficiency is the amount of oil before burning, less the volume left as residue, divided by the initial volume of the oil. The amount of soot produced is usually ignored in calculating burn efficiency. Efficiency is largely a function of oil thickness. Oil thicker than about 2 to 3 mm can be ignited and burns down to about 1 to 2 mm (**6, 14**). For example, a slick of 2 mm burning down to 1 mm yields a maximum efficiency of 50 %. A pool of oil 20 mm thick burns to approximately 1 mm, yielding an efficiency of about 95 %. Current research has shown that other factors such as oil type and low water contents only marginally affect efficiency ~~(**4**~~(**8**).

[3] The boldface numbers in parentheses refer to a list of references at the end of this guide.