Designation: ~~F1990 – 19~~ F1990 – 23

Standard Guide for In-Situ Burning of Spilled Oil: Ignition Devices[1]

This standard is issued under the fixed designation F1990; 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 relates to the use of in-situ burning of spilled oil. The focus of the guide is in-situ burning of oil on water, but the ignition techniques and devices described in the guide are generally applicable to in-situ burning of oil spilled on land as well.

1.2 The purpose of this guide is to provide information that will enable oil-spill responders to select the appropriate techniques and devices to successfully ignite oil spilled on water.

1.3 This guide is one of four related to in-situ burning of oil spills. Guide F1788 addresses environmental and operational considerations. Guide F2152 addresses fire-resistant booms, and Guide F2230 addresses burning in ice conditions.

1.4 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* In particular, the storage, transport, and use of ignition devices may be subject to regulations that will vary according to the jurisdiction. While guidance of a general nature is provided herein, users of this guide should determine regulations that apply to their situation.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D92 Test Method for Flash and Fire Points by Cleveland Open Cup Tester
D975 Specification for Diesel Fuel
F1788 Guide for In-Situ Burning of Oil Spills on Water: Environmental and Operational Considerations
F2152 Guide for In-Situ Burning of Spilled Oil: Fire-Resistant Boom
F2230 Guide for In-situ Burning of Oil Spills on Water: Ice Conditions

3. Terminology

3.1 *Definitions:*

3.1.1 *fire ~~point—~~point, n—*the lowest temperature at which a specimen will sustain burning for 5 s. **(Test Method D92)**

[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 ~~March 1, 2019~~March 1, 2023. Published ~~March 2019~~March 2023. Originally approved in 1999. Last previous edition approved in ~~2013~~2019 as ~~F1990 – 07~~F1990 – 19.~~(2013).~~ DOI: ~~10.1520/F1990-19.~~10.1520/F1990-23.

[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.

3.1.2 *flash* ~~*point—*~~*point, n—*the lowest temperature corrected to a barometric pressure of 101.3 kPa (760 mm Hg), at which application of a test flame causes the vapor of a specimen to ignite under specified conditions of test. **(Test Method D92)**

4. Significance and Use

4.1 This guide describes the requirements for igniting oil for the purpose of in-situ burning. It is intended to aid decision-makers and spill-responders in contingency planning, spill response, and training, and to aid manufacturers in developing effective ignition devices.

4.2 This guide describes criteria for the design and selection of ignition devices for in-situ burning applications.

4.3 This guide is not intended as a detailed operational manual for the ignition and burning of spilled oil.

5. Overview of the Requirements for Igniting Spilled Oil on Water

5.1 The focus of this section is on the in-situ combustion of on-water oil spills.

5.2 Successful ignition of oil on water requires two components: heating the oil such that sufficient vapors are produced to support continuous combustion, and then, providing an ignition source to start burning. The temperature at which the oil produces vapors at a sufficient rate to ignite is called the flash point. At a temperature above the flash point, known as the fire point, the oil will produce vapors at a rate sufficient to support continuous combustion.

5.3 For light refined products, such as gasoline and some unweathered crude oils, the fire point may be in the range of ambient temperatures, in which case, little if any, preheating would be required to enable ignition. For other oil products, and particularly those that have weathered or emulsified, or both, the fire point will be much greater than ambient temperatures, and substantial preheating will be required.

5.4 The energy required to raise the temperature of the surface of an oil slick to its fire point depends on the slick thickness. While the oil is being heated by an igniter, heat is being conducted and convected to the underlying water. If the slick is sufficiently thick to insulate against these heat losses and allow the surface layer of oil to heat to its fire point, the oil will start to burn in the vicinity of the igniter. The minimum ignitable thickness for most oils is about 2 to 3 mm (see Guide F1788).

5.5 Aside from oil type, other factors that can affect the ignitability of oil on water include the wind speed and the emulsification of the oil. Secondary factors include ambient temperature and waves. The effect of these factors can be summarized as follows:

5.5.1 The maximum wind speed for successful ignition for large burns has been estimated to be approximately 10 m/s (20 knots) (**1**, **2**)[3].

5.5.2 For more rapid flame spreading, slicks should be ignited at the upwind edge.

5.5.3 Weathered oils require a longer ignition time than fresher oils with a higher volatile compound content.

5.5.4 The effect of water content is similar to that of weathering, more ignition time being required to ignite a slick of emulsion. Once an emulsified slick is ignited, heat from the fire may break the emulsion and overcome this problem. Emulsion-breaking chemicals can be used to aid in initial ignition attempts.

5.5.5 Emulsions (especially stable emulsions) are very difficult to ignite without the use of emulsion-breaking chemicals.

6. Overview of Available Ignition Devices

6.1 *Simple Ignition Techniques:*

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

6.1.1 Propane or butane torches, or weed burners, and rags or sorbent pads soaked in fuel have been used to ignite oil on water. Propane torches tend to blow thin oil slicks away from the flames and are most applicable to thick contained slicks. Diesel is more effective than gasoline as a fuel to soak sorbents or rags because it burns slower and hotter, and hence, supplies more preheating to the oil.

6.1.2 Another effective surface-based igniter is gelled fuel. Gelling agents can be used with gasoline, diesel, or crude oil to produce a gelled mixture that is ignited and placed in an oil slick.

6.2 *Hand-Held Igniters*—A variety of igniters have been developed for use as devices to be ~~handthrown,~~hand-deployed, either from ground level or from helicopters. These igniters have used a variety of fuels, including solid propellants, gelled kerosene cubes, reactive chemical compounds, and combinations of these. Burn temperatures for these devices range from 700 to ~~2500°C,~~2500 °C, and burn times range from 30 s to 10 min. Most hand-held igniters have delay fuses that provide sufficient time to throw the igniter and allow it and the slick to stabilize prior to ignition.

6.3 *Helicopter-Slung Ignition Systems*—These systems have been adapted from devices used for burning forest slash and for setting backfires during forest-fire control operations. These devices emit a stream of ~~gelled fuel,~~ fuel, generally gasoline or a mixture of gasoline, diesel, or crude oil, or a combination thereof. As the gelled fuel leaves the device, it is lighted by an electrically-ignited propane jet. The burning gelled or not fuel falls as a stream that breaks into individual globules before hitting the slick. The burning globules produce an ~~800°C~~800 °C flame for up to 6 min. Tank capacities for the gelled fuel mixture range from 110 to 1100 L (30 to 300 gal).

7. Ignition Device Test

7.1 The following is intended as a simple test to evaluate the ability of an ignition device to ignite a thick slick of weathered oil. The ignition test does not consider operability factors, such as safe operation of the device, accuracy of deployment, and reliability of ignition components.

7.2 The test parameters are intended to reflect minimum conditions for acceptable performance. More stringent conditions, such as higher wind speed or the use of weathered or emulsified oils, may be considered for some ignition devices.

7.3 *Test Apparatus*—The ignition test is carried out in an approximately square test container. The test container must have a surface area that is the greater of ten times the area covered by the ignition device, or 1 m^2. A typical test container would be a steel pan of the required dimensions. To minimize wind-shielding by the walls of the container, the fluid level must be within 25 mm of the top of the test container.

7.4 *Test Slick*—The ignition test is carried out on a layer of oil with a maximum thickness of 10 mm and with a minimum underlying water depth of 200 mm. The oil for the ignition test is Diesel Fuel Grade No. 2, which has a minimum flash point of 60 °C (see Specification D975).

7.5 *Test Conditions*—Throughout the test, the wind speed must be 5 m/s (10 knots) or greater.

7.6 *Initial Ignition Tests*—The test is initiated by activating the ignition device and deploying it into the test slick. It is recommended that initial tests be conducted by simply placing the ignition device on the test slick. The ignition test would be considered successful when flame is observed independent of the igniter, with flame covering the majority of the area of the test container.

7.7 *Tests for Air-Deployed Ignition Devices*—For igniters intended for deployment from helicopters, additional tests should be carried out to simulate air-deployment. These tests need not include ignition of oil but should include deployment of the device from a height of 10 m (minimum, measured from the device to the ground) to confirm that the device functions as intended during deployment. Tests should include deployment and operation of the device from a helicopter to ensure that the device can function in the presence of the helicopter's downwash.

7.8 *Test Record*—The test record must include the time for successful ignition, the actual container dimensions, the initial oil layer thickness, the underlying water depth, the air and water temperature at the start of the test, the wind speed, and any general observations of igniter performance.

7.9 *Optional Additional Tests*—In addition to the performance tests listed, consideration should be given to additional testing to address the following items depending on the intended application of the device:

7.9.1 The estimated accuracy of deployment of the ignition device on a target oil slick,

7.9.2 The resistance to damage of the device during deployment,

7.9.3 The performance in shallow pools (less than 100 mm deep) on solid ice,

7.9.4 The dependence on orientation of the igniter for proper performance,

7.9.5 Splash effects during impact with oil and water,

7.9.6 Effect on performance of temporary submergence of the igniter upon impact, and

7.9.7 Sensitivity to wind, rain, and sea state during ignition.

8. Operability

8.1 *Operating Instructions*—Operating instructions shall be supplied with the device and should include a description of the following items where applicable: safe operating procedures; required preparations of the igniter, or application system, or both, from storage to field use; type and amount of debris after use; training requirements; disposal requirements for spent igniters; and, retrieval and handling requirements for igniters that have misfired.

8.2 *Licensing for Transport and Use*—The ignition device should be approved for transport via cargo aircraft. Approvals, or pilot certifications, or both, may be required for devices intended for operation and deployment by helicopter. Users should note that pyrotechnic materials are not commonly transported by air and that such shipments often are rejected at the point of loading at the prerogative of the carrier despite any licensing or approvals.

8.3 *Stability During Flight*—For helicopter-slung devices, provision shall be made for stabilizing the device when carried by a swivel-hook helicopter. Any such stabilizing apparatus shall not impair the ability to jettison the device in the event of an emergency (see 9.3).

8.4 *Temperature Range*—The ignition device should function over an ambient temperature range of –10 to ~~30°C.~~30 °C.

8.5 *Wind Conditions*—The ignition device should function, including deployment and operation from a helicopter, in wind conditions up to 10 m/s (20 knots).

9. Safety

9.1 *Unintended Activation*—The device should include protection against accidental activation.

9.2 *Delay Upon Activation*—For hand-held ignition devices, upon activation of the igniter, there should be a minimum delay of ~~20 s~~ 10 s between the time the device is activated and it begins firing. It should be noted that excessive delay times may be troublesome in allowing the igniter to drift away from the target slick.

9.3 *Jettisoning of Equipment*—For helicopter-slung devices, provision shall be made for jettisoning of the device, including rapid disconnect of any power or control couplings.

9.4 *Operation*—Some ignition devices require an open flame or spark for activation, that may not be desirable or safe in certain applications, for example, for hand-held devices to be deployed from helicopters.

10. Storage

10.1 *Shipping and Storage Regulations*—The manufacturer of the device should specify shipping, handling, and storage instructions, and should note any limits on extreme temperatures, or humidity during storage, or both.

10.2 *Resistance to Degradation*—The device should function after exposure to temperature and humidity extremes and vibration that may be experienced during storage and shipping.

10.3 *Shelf-Life*—The device should have a minimum shelf-life of five years.

10.4 *Maintenance*—Operating instructions should specify any routine maintenance requirements, and should note components of the igniter that are subject to degradation, their expected shelf-life, and the procedure for refurbishment or replacement of parts following the normal shelf-life.

11. Keywords

11.1 ignition; in-situ burning; oil-spill burning; oil-spill disposal

APPENDIX

(Nonmandatory Information)

X1. BRIEF HISTORY OF IGNITER DEVELOPMENT

X1.1 This ~~Appendix~~appendix is intended to provide a brief historical review of the uses of ignition devices for the in-situ burning of spilled oil. It is not intended to be comprehensive but simply attempts to show examples of what has and has not worked in past oil spill responses and experiments.

X1.1.1 Many different ignition devices have been used over the years to ignite or attempt to ignite marine oil spills. In 1967, four attempts were made to ignite seemingly thick oil slicks on the sea near the Torrey Canyon using pyrotechnic devices containing sodium chlorate, but these attempts were unsuccessful (**3, 4**). It was concluded that the oil had emulsified to such an extent that it would not ignite.

X1.1.2 Oil on the shore from the Torrey Canyon spill proved virtually impossible to ignite and burn, although some success was reported in burning unemulsified oil in pools between rocks. In this case, flame throwers and flame-thrower fuel were used to ignite the pools, and they burned nearly to completion. Emulsified oil could be burned on the beach, as long as the flame thrower was applied, but once the flame was removed, the combustion stopped.

X1.1.3 Production of the Kontax igniter[4] ceased in the mid- to late-1970s (**5**). The device consisted of a 4-cm diameter cylindrical metal screen 30.5 cm long and capped at both ends. A metal bar coated with metallic sodium ran through the center of the cylinder. The annulus was filled with calcium carbide. The device weighed 1.2 kg. For safety reasons, the Kontax igniter was stored in a sealed plastic bag.

[4] The Kontax igniter was produced by Edward Michels GmbH of Essen, Germany.

X1.1.4 The Kontax igniter had a unique feature, that is, it did not require activation or a starter. When the device was exposed to water, the sodium metal reacted to produce heat and hydrogen, which instantly ignited. At the same time, the calcium carbide reacted with water to produce acetylene, which was subsequently ignited by the burning hydrogen. The flame from the burning acetylene preheated and ignited oil vapors. Tests to evaluate Kontax were performed in 1969 by the Dutch government (**6**). The tests were carried out 25 miles offshore and on beaches and the oils used were heavy and light Arabian crude. The igniter material Kontax was used in 25-kg bagged form. One test involved a 9-tonne slick covering about 2000 m^2 (0.5-cm thick) in a free-floating lumber boom. The bags containing the Kontax were punctured and thrown into the slick. The igniters were successful. Flames of 15 to 20 m high were reported, and a 98 to 99 % oil-removal efficiency was estimated. A Kontax-to-oil ratio of 1:100 by weight was estimated to be appropriate. The potential of Kontax also was demonstrated at the Arrow spill in 1970 where some of the spilled oil was primed with two drums of fresh oil and ignited with a Kontax igniter.

X1.1.5 The Kontax igniter produced a large flame area (3000 cm^2) with a relatively low flame temperature ~~(770°C).~~(770 °C). This combination produced a relatively high flame emissivity of 2.25 kW/m^2. Although Kontax proved effective in both field and tank trials as a surface-deployed igniter (**5, 7**), the device proved less effective when dropped from a height of 11.5 m, simulating deployment from a helicopter. The ignition success rate declined from 100 % in the surface tests to 60 % in the aerial tests. The main reason for the latter result was that the large splash caused by the Kontax igniter entering the water drove the oil away. By the time the oil had returned, the igniter had generated a ring of calcium hydroxide foam that kept the oil away.

X1.1.6 Energetex Engineering (**5**) tested a modification to the Kontax igniter, which involved combining a small amount of gasoline with the device. This inclusion of gasoline was intended as a fuel to bridge the calcium hydroxide foam barrier. This modification resulted in a slightly higher flame temperature ~~(790°C)~~(790 °C) and better aerial deployment ignition success (80 %).

X1.1.7 It is not clear why Kontax was taken out of production. It may have been due to a general lack of interest in in-situ burning at the time, or due to the dangers and stringent requirements for storing, transporting, and using the igniters. Another igniter, Oilex Fire[5] consists of a sorbent (Oilex) plus a hydro-igniting agent. The company reported on the use of the chemical on small spills in Swiss lakes and in the Adriatic Sea (**7**).

X1.1.8 On December 27, 1976, the Argo Merchant went aground near Nantucket Island and spilled most of its cargo of 28 000 tons of No. 6 fuel oil. Part of the response by the U.S. Coast Guard involved attempts to burn the oil. One 30-m × 40-m × 15-cm thick slick was treated with Tullanox 500 (a wicking and insulating agent), primed with 200 L of JP-4 and ignited with JP-4-soaked cotton sheets set afire with a flare. About 95 % of the Tullanox was blown off the treated slick by wind and the flames would not spread from the sheet to the primed slick. In another experiment, boxes of Tullanox 500 charged with JP-4 fuel were dropped onto a slick from a helicopter and ignited with timed thermite grenades. The isolated boxes burned but the flames did not spread (**6, 8**).

X1.1.9 On January 28, 1977, some 300 000 L of No. 2 fuel oil was spilled onto the ice-covered waters of Buzzards Bay, Massachusetts by the barge Bouchard No. 65. Boxes of Tullanox soaked with jet fuel were dropped from helicopters onto pools of oil in the broken ice with delay-fuses. Thermite grenades were used to ignite the boxes. The ensuing fires burned for 1½ to 2 h and consumed 4000 to 8000 L of oil. The 38 to 46-km/h (20 to 25 knot) winds drove the flames from pool to pool in areas where adjacent pools were nearby. In other areas, the fires did not spread. At a later date, another series of burns were initiated by knotted rags soaked in diesel (**9, 10**).

X1.1.10 Starting in 1977, considerable effort was devoted to developing an aerial ignition capability for potential spills from offshore exploration activities in the Beaufort Sea. Energetex Engineering evaluated and tested five devices (Kontax, Kontax with gasoline, solid propellant, solid fuel, and gasoline with sodium). Solid fuel and solid propellant igniters with a fuse wire were ranked highest (**5**). Subsequently, two igniters were developed in Canada: the Dome igniter (**11-13**) and the EPS igniter (**14, 15**). Solid propellants, also known as solid rocket fuels, are composed of a solid mixture of various portions of ammonium perchlorate oxidizer, metal fuel (magnesium or aluminum), and an organic binder. They have been used in a variety of igniters. Solid propellant

[5] Oilex Fire was produced by Keltron Inc. of Switzerland.

igniters, in various shapes and utilizing various starters (electrical, chemical or fuses) have been extensively tested (**15**). Such igniters exhibit very high flame temperatures (about ~~1230°C)~~1230 °C) and high flame emissivities (1.75 kW/m^2) but are consumed rapidly. They require mounting in a housing to suspend them no more than 5 cm above the oil/air interface. In water surface tests, solid propellant gave an 89 % ignition success rate, and an 80 % success rate in aerial-deployment tests with a fuse-wire starter (all other starter mechanisms resulted in lower success rates).

X1.1.11 The EPS igniter, also known as the Pyroid igniter (**15**)[6] is approximately 25 cm^2 and 13 cm high and weighs nearly 2 kg. The unit consists of a pyrotechnic device sandwiched between two layers of foam flotation and is activated by a self-contained firing mechanism. It is intended to be a hand-thrown device. The device is simple in design and operation, being activated by pulling on a firing clip which in turn strikes a primer cap. A 25-s delay column then provides sufficient time to throw the igniter and let it settle within the target oil slick. A specially formulated ring of fast-burning ignition material is then ignited, and this in turn ignites the primary incendiary material. The incendiary material is a solid propellant consisting of typically 40 to 70 % ammonium perchlorate, 10 to 30 % metal fuel (magnesium or aluminum), 14 to 22 % binder, and small amounts of other ingredients to aid in the casting and curing processes. The firing mechanism and the incendiary materials are sandwiched between two polystyrene foam slabs to provide both buoyancy and protection for the device on impact. All components except the firing mechanism are combustible, so that very little debris is left in the environment after a burn.

X1.1.12 These components have been designed so that the igniter experiences a minimum of roll if dropped onto a hard surface (like ice) or shallow water. The igniter can float in as little as 5 cm of water/oil. The flame released will be oriented properly regardless of which side of the igniter is up. The EPS igniter has been designed to produce a ring of fire with temperatures approaching ~~2000°C (4170°F)~~2000 °C (4170 °F) immediately adjacent to the perimeter of the igniter. This intense flame has a typical duration of about 2 min.

X1.1.13 The EPS igniter was designed to provide a 75 % probability of functioning properly when dropped at an airspeed of about 30 km/h from an altitude of approximately 15 m. Field tests indicate a high probability of successful ignition.

X1.1.14 Some solid-fuel igniters employ gelled kerosene cubes, for example, solid barbecue starter, suspended above the oil/air interface. Because of the lower flame temperatures ~~(770°C)~~(770 °C) and flame emissivities 0.5 kW/m^2) generated, it is necessary to suspend the cubes within 3 cm of the oil surface in order to successfully ignite oil. Surface ignition tests have given an 84 % success rate while aerial tests have resulted in an 80 % success rate using a fuse wire starter (**5**). Solid fuel is used in one commercially available igniter discussed in X1.1.15.

X1.1.15 Laser-based ignition systems received considerable attention in the 1970s and 1980s (**16-19**). In static tests on land the concept proved to be capable of igniting fresh and weathered, unemulsified oil in 1–m^2 pools on ice (**18**). The use of lasers mounted in helicopters to ignite spilled oil has been investigated, and the various components of a helicopter-borne system have been researched under contract to Environment Canada and the Minerals Management Service; however, further development to the prototype stage and subsequent commercialization await private sector involvement.

X1.1.16 In Alaska, a forest-fire fighting tool known as the Heli-torch was found in the mid-1980s to be an effective aerial ignition system for spilled oil (**20**). The Heli-torch emits a burning stream of gelled gasoline that remains burning on an oil slick for a period of a few minutes. Testing with alternative fuels has indicated increased heat flux with gelled diesel and gelled crude oil. Considerable testing and refinement of the device has resulted in the Heli-torch being stockpiled around the world as the igniter of choice for in-situ burning.

X1.1.17 The in-situ test burn during the Exxon Valdez spill in 1989 was ignited by gasoline, gelled with a commercial gelling

[6] The Pyroid igniter is an air-deployable pyrotechnic device developed by the Canadian Environmental Protection Service of Environment Canada in cooperation with the Canadian Department of National Defense Research Establishment, Valcartier (DREV) (**15**).