Standard Guide for Estimating the Volume of Oil Consumed in an In-Situ Burn[1]

This standard is issued under the fixed designation F3195; 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 oil spills. The focus of the guide is in-situ burning of spills on water, but the techniques described in the guide are generally applicable to in-situ burning of land spills as well.

1.2 The purpose of this guide is to provide information that will enable spill responders to estimate the volume of oil consumed in an in-situ burn.

1.3 This guide is one of several related to in-situ burning. Other standards cover specifications for fire-containment booms and the environmental and operational considerations for burning.

1.4 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4.1 *Exception*—Table 1, Table 2 and Fig. 2 provide inch-pound units for information only.

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]

F818 Terminology Relating to Spill Response Booms and Barriers

F1788 Guide for In-Situ Burning of Oil Spills on Water: Environmental and Operational Considerations

3. Terminology

3.1 *burn efficiency*—the percentage of the oil removed from the water by burning. **F1788**

3.2 *gap ratio*—sweep width divided by boom length. **F818**

3.3 *residue*—the material, excluding airborne emissions, remaining after the oil stops burning. **F1788**

3.4 *sweep width* —width intercepted by a boom in collection mode, the projected distance between the ends of a boom deployed in a "U," "V," or "J" configuration. (Also known as *swath*.) **F818**

4. Significance and Use

4.1 This guide describes a methodology for estimating the effectiveness of an in-situ burn. It is intended to aid decision-makers and spill-responders in contingency planning, spill response, and training.

4.2 This guide is not intended as a detailed operational manual for the ignition and burning of oil slicks. The guide does not cover the feasibility of an in-situ burn, or the evaluation of airborne emissions from a burn.

4.3 It is generally accepted that a precise determination of the burn effectiveness will not be possible. However, the methodology presented in this guide can be used to provide a consistent and reasonable estimate.

4.4 Burn effectiveness can be reported as total volume burned or burn efficiency, or both (that is, volume burned of that available.)

5. Evaluation Approach

5.1 For most oils and under most conditions, oil slicks burn at a rate of between 2 and 4 mm/min. By accurately observing the total area of an in-situ burn and the total duration of the burn it is possible to estimate the volume of oil consumed in the burn.

5.2 If it is necessary to estimate the burn effectiveness, defined as the percentage of oil burned of that available for burning, one must also estimate either: the volume of oil spilled or available for burning; or, the volume of residue remaining after the burn.

5.3 In most cases an estimate of the spill volume or of the residue volume will be much less accurate than that of the volume of oil consumed in the burn. If all three components can be estimated independently, the calculation procedure can be refined and the overall accuracy increased.

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[1] This test method 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.

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[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.

5.4 Potential errors are described in Section 8.

6. Estimating Volume of Oil Burned

6.1 Estimating the volume of oil burned comprises three variables: burn rate of the oil, burn duration, and burn area. Note that the area actively engaged in burning must be estimated, not simply the total slick area.

6.2 The volume of oil burned is calculated as:

$$\text{Volume burned}(m^3) = \text{burn rate}(mm/min) \times \text{duration}(minutes) \times \text{burn area} \quad (m^2) \times 0.001 \quad m/mm \qquad (1)$$

6.3 Table 1 lists the burning rate for various oils. The specified burn rates represent the accepted median values for given oil types; the ranges reflect potential variability.

6.4 Discontinuities in slicks can occur due to the presence of ice or debris within the burning area. For discontinuous slicks, burn durations should be recorded for discrete portions of the slick.

6.5 For slicks of emulsions, heat from the fire may cause emulsion to break, and may lead to variations in burning rate. In this instance, estimates of the burn area should make note of the variations in slick area that is burning with time.

6.6 There are a number of methods that can be used to aid in estimating the slick area, including: the use of photographs, video, or output from remote sensing devices; the use of timed overflights; and reference to objects of known dimensions in the vicinity (for example, response vessels, containment boom). Hand-held laser range-finders can also be used to estimate lateral slick dimensions.

6.7 Fig. 1 and Table 2 (**2**)[3] provide data to estimate oil slick area in a typical catenary-shaped booming configuration based on the length of the slick within the boom.

For example, for the following conditions:

(1) a boom length of 150 metres;

(2) towed in a catenary configuration with a swath width of 50 metres (that is, a gap ratio of 0.33);

(3) with the boom approximately one-quarter full; and

(4) a slick length of 17 metres measured up-current of the apex of the boom;

(5) the burn area is estimated to be approximately 530 m^2.

In using the graph in Fig. 1, the *y*-axis dimension, that is, the length of the slick measured up-current of the apex of the boom should be used. This will lead to better accuracy in that the y-axis can be more precisely estimated in most instances and the estimate of burn area is less sensitive to small changes in estimating the *y*-dimension than the *x*-dimension (slick width). The data in Fig. 1 and Table 2 have been determined only for a gap ratio of 0.33, which is the commonly accepted gap ratio for effective oil containment.

6.8 Fig. 2 shows the conversion of burn rate from the units of mm/min to a more useful litres per square metres per hour (L/m^2/h) and barrels per square feet per hour (bbl/ft^2/h). For example, diesel or light crude has a burn rate of 3.5 mm/min, which equates to an areal burn rate of 210 L/m^2/h. This is calculated as (3.5 mm/min) x (1 L/m^2/mm) x (60 min/h).

7. Estimating Burn Efficiency

7.1 There are two methods of estimating burn efficiency; both methods require an estimate of the volume of oil burned (see 6.2). The first method requires an estimate of the volume of oil available for burning; the second requires an estimate of the volume of burn residue. Both methods should be used if possible to increase confidence in accuracy.

7.2 *Estimate of efficiency using volume available for burning:*

7.2.1 In many cases it will be difficult to make an accurate estimate of this due to the difficulties in accurately estimating the slick thickness and its variation over the slick.

7.2.2 If the source of the spill is known, an estimate may be possible based on such information as the tank size, pumping rate, and so on.

7.2.3 Burn efficiency when using volume available for burning is calculated as:

$$\text{Burn efficiency } (\%) = \left(\frac{\text{volume of oil burned}}{\text{volume available for burning}} \right) \times 100 \qquad (2)$$

7.3 *Estimate of efficiency using volume of burn residue*—If the residue is readily recoverable, the volume can be measured directly. Otherwise an estimate can be made of the residue volume by estimating the area and thickness of the residue, the number and size of tarballs, etc.

7.3.1 Burn efficiency when using volume of burn residue is calculated as:

$$\text{Burn efficiency}(\%) = \frac{(\text{volume of oil burned})}{(\text{volume of oil burned } + \text{ volume of residue})} \times 100 \qquad (3)$$

7.3.2 Alternatively, an estimate of the burn residue can be used in combination with an estimate of the volume of oil available for burning.

7.3.3 Burn efficiency when using burn residue and volume of oil available is calculated as:

$$\text{Burn efficiency}(\%) = 100 - \left(\frac{\text{volume of residue}}{\text{volume available for burning}} \right) \times 100 \qquad (4)$$

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

TABLE 1 Burn Rate for Various Oils

Oil Type	Burn rate, (mm/min)	Burn rate range, (mm/min)	Burn Rate[A] (L/m^2/h)	Burn Rate (gal/ft^2/h)
Gasoline	4	3.5 to 4	240	5.9
Diesel fuel	3.5	3 to 3.7	210	5.2
Light crude	3.5	3 to 3.7	210	5.2
Medium crude	3.5	3 to 3.7	210	5.2
Heavy crude	3	3 to 3.5	180	4.4
Weathered crude	2.8	2.8 to 3.5	170	4.1
Crude oil amongst dense ice	2	2 to 2.5	120	2.9
Light fuel oi1	2.5	2.5 to 3	150	3.7
Heavy fuel oil	2.5	2.5 to 2.8	150	3.2
Lube oil	2	2 to 2.5	120	2.9
Emulsified crude oil	1.5	1 to 2	90	2.2

[A] Burn rate in gal/ft^2/h provided for information only.(**1**)

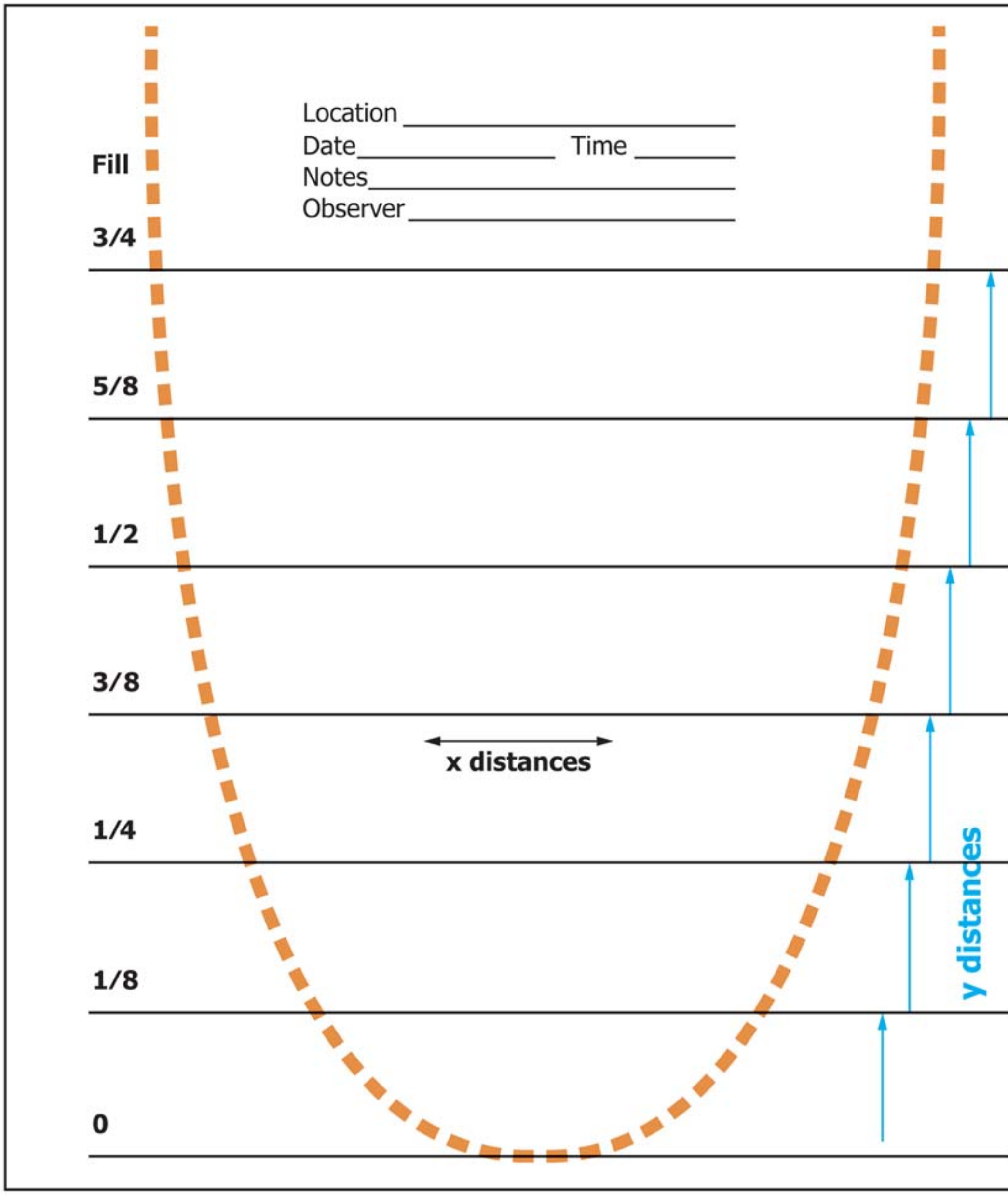

FIG. 1 Estimation of Slick Area within a Boom

8. Discussion of Potential Errors

8.1 It is accepted that under field conditions, precise estimates of burn volumes and efficiency may not be possible. Any assumptions made in the estimation process should be noted for subsequent verification and investigation of potential errors. The following is a general discussion of the main areas for potential errors in the estimation of burn efficiency.

8.2 *Burn Rate*—Table 1 provides average burn rates for various petroleum products. These rates are typical averages: where appropriate, ranges of observed burn rates are also listed in Table 1. Note that for most oils the variability within a given range is ± 20 % or less. For emulsified crude oil the variability may be much larger.

8.3 *Burn Duration*—Estimates of burn duration should be very accurate relative to other elements of the efficiency estimate. For example, measured burn durations should be accurate to within plus-or-minus a few seconds out of tens of minutes, representing an accuracy of within a few percent or less.

8.4 Note that the burn may not be continuous over the entire elapsed time. In such cases, an estimate should be made of the multiple time periods and burn areas to increase the overall accuracy.

8.5 *Burn Area*—Estimates of the burn area should be accurate to within ± 10 % depending on the proximity to the burn and the size of the burn area. Curves approximating the area contained within a partially filled boom, as shown in Fig. 1, can be used to assist in this regard. Note that Fig. 1 is an idealized representation of oil contained within a boom and does not account for real-world issues such as discontinuous slicks

TABLE 2 Estimation of Slick Area Within a Boom

Dimensions for an Oil-filled Catenary Boom						
Metric Units						
Boom size	150 m – 50 m opening			200 m – 66 m opening		
Fill	Length (m)	width (m)	area (m^2)	Length (m)	width (m)	area (m^2)
¾ three quarters	51	48	2020	68	64	3590
⅝ five eighths	43	46	1610	57	61	2860
½ one half	34	44	1220	45	59	2170
⅜ three eighths	26	41	860	35	55	1530
¼ one quarter	17	38	530	23	51	940
⅛ one eighth	9	32	220	12	43	390
U.S. Customary Units						
Boom size	500 ft – 166 ft opening			700 ft – 233 ft opening		
Fill	Length (ft)	width (ft)	area (square ft)	Length (ft)	width (ft)	area (square ft)
¾ three quarters	165	156	21000	231	218	41200
⅝ five eighths	137.5	149	16800	193	209	32900
½ one half	110	142	12700	154	199	24900
⅜ three eighths	82.5	132	9000	116	185	17600
¼ one quarter	55	122	5500	77	171	10800
⅛ one eighth	27.5	102	2300	39	143	4500

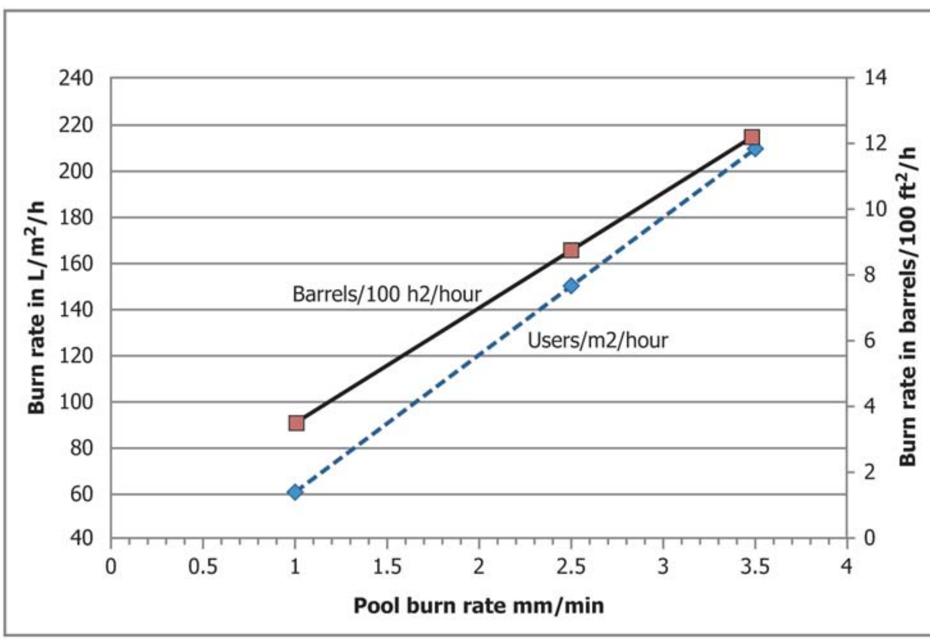

FIG. 2 Conversion of Burn Rate

within the boom, and lateral variations in the shape of deployed boom due to varying wind and current forces. Accuracy of the estimate will be increased if care is taken to document the duration that various areas are engaged in the burn, which may change due to variations in tow speed and crosswind, and may decrease over time as the oil within the boom is consumed. Finally, note that the key to an accurate estimate is to document the area of oil that is actually burning rather than the total slick area.

8.6 *Volume of Oil Available for Burning*—If the source of the spill is known an accurate estimate of oil available for burning may be possible. If the volume must be estimated based on slick area and thickness, an accurate estimate may not be possible due to the difficulties in accurately estimating the slick thickness.

8.7 *Residue Volume*—If the residue can be collected subsequent to the burn, an accurate estimate may be possible. If not, a visual estimate can be made but may have an error range of greater than ± 10 %.

9. Keywords

9.1 burning effectiveness; in-situ burning; oil spill control systems; oil spill response

REFERENCES

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