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Standard Guide for Visually Estimating Oil Spill Thickness on Water[1]

This standard is issued under the fixed designation F2534; 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 provides information and criteria for estimating the thickness of oil on water using only visual clues.

1.2 This guide applies to oil-on-water and does not pertain to oil on land or other surfaces.

1.3 This guide is generally applicable for all types of crude oils and most petroleum products, under a variety of marine or fresh water conditions.

1.4 The thickness values obtained using this guide are at best estimates because the appearance of oil on water may be affected by a number of factors including oil type, sea state, visibility conditions, view angle, and weather.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *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.*

1.7 *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]

F1779 Practice for Reporting Visual Observations of Oil on Water

3. Significance and Use

3.1 Estimations of oil slick thickness are useful for:

3.1.1 Estimating amount (volume) of oil in an area,

3.1.2 Positioning oil spill countermeasures in optimal locations,

3.1.3 Evaluating a spill situation,

3.1.4 Estimating volume for legal or prosecution purposes, such as for an illegal discharge, and

3.1.5 Developing spill control strategies.

3.2 This guide is only applicable to thin sheens (sheen and rainbow sheen up to about 3 µm). Thick oil and water-in-oil emulsions do not show visual differences with respect to thickness (**1, 2**).[3]

4. Summary of Thickness Estimation Results

4.1 Table 1 has been summarized from a variety of literature sources (see Appendix X1).

4.2 It should be noted that the only physical change in appearance that is reliable is the onset of rainbow colors, at 0.5 to 3 µm thickness. All other appearances vary with weather, visibility conditions, viewing angle, oil type, water conditions and color, presence of waves, and the presence of other material on the water surface. Therefore it is important to treat these as estimates and where possible give ranges of thicknesses. If volume is to be calculated, it should also be given as a range of values.

5. Summary

5.1 The change in visual appearance of an oil slick on water provides a means to estimate oil slick thickness. Only the appearance of rainbow colors at 0.5 to 3 µm is a strong indication of slick thickness and only in the range noted. Other appearances change with the variables noted and thus should be used with caution.

6. Keywords

6.1 oil observations; oil thickness; oil thickness estimation; oil visibility; slick thickness

[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 F20.16 on Surveillance and Tracking.

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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.

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

TABLE 1 Visibility Characteristics (Appearance)

	Minimum Observable Thickness	Minimum Onset Thickness (µm)			
		Silvery	Rainbow	Dark Rainbow	Dark[A]
Average	0.08	0.1	0.5	3	> 3
Typical Range	0.05 to 0.2	0.1 to 0.3	0.2 to 3		> 3

[A] This color is sometimes called 'oil-like,' 'dark colored,' 'brown,' 'black,' or 'metallic.'

APPENDIX

(Nonmandatory Information)

X1. SUMMARY AND BACKGROUND OF SLICK THICKNESS DATA

X1.1 Introduction

X1.1.1 An important tool for working with oil spills has been the relationship between appearance and thickness. Little research work has been done on the topic in recent times because thickness charts were available for many years (Practice F1779) (Fingas et al., 1999) (**3**). In fact, present thickness charts actually date from 1930 (Congress, 1930) (**4**). It was recognized before 1930 that slicks on water had somewhat consistent appearances. A series of experiments were conducted in the 1930s and resulted in charts that are still used. Only a few experiments have been done in recent years. This Appendix will summarize this development of slick appearance charts.

X1.1.2 The early work may not have accounted for several factors:

X1.1.2.1 *Effect of Slick Heterogeneity*—Oils, especially heavier ones, do not form slicks of consistent thickness on the water surface. Even visual examination shows a type of 'fried egg' vertical profile. This effect is, however, not as relevant on larger slicks and with less viscous products. Many slicks do not cover the entire area. The effect of surface tension is to pull some oils together so that slicklets are formed rather than one uniform slick.

X1.1.2.2 *Effect of Evaporation*—The early experiments ignored the effect of evaporation on mass balance.

X1.1.2.3 *Effect of View Angle*—View angle is critical to observing slicks on water, especially with respect to the sun. How this affects appearance thresholds is not fully explored.

X1.1.2.4 *Effect of Waves on the Surface*—The appearance of oil slicks on calm water versus that with different wave conditions may be different.

X1.1.2.5 *Effect of Atmospheric and Viewing Conditions*—Factor that may be important are haze and cloud cover. Haze strongly reduces visibility. Slicks are often less visible in the absence of a cloud cover. Glitter or reflection from the sea is known to cause viewing problems.

X1.1.2.6 *Effect of Oil Type*—Dark oils are more visible on the surface than gasoline or diesel fuel.

X1.2 Slick Visibility

X1.2.1 *Theoretical Approaches:*

X1.2.1.1 Horstein (1972) (**5**) reviewed theoretical approaches and used interference phenomenon to correlate the threshold of rainbow colors to slick thickness. The appearance of rainbow colors is the result of constructive and destructive interference of light waves reflected from the air-oil interface with those reflected from the oil-water interface (Fingas et al., 1999) (**3**). The difference in optical path lengths for these two waves depends on the refractive index of the oil. The refractive indices of given wavelengths results in different optical path lengths. This difference can be given as:

$$\Delta L = 2t(\mu^2 - \sin^2 I)^{1/2} \qquad (X1.1)$$

where:

ΔL = the difference in optical path length,
t = the film thickness,
μ = the refractive index of the film, and
I = the angle of light incidence.

X1.2.1.2 Horstein points out that if ΔL contains an even number of wavelengths, then maximum destructive interference will occur. Destructive interference occurs when light waves are in a phase alignment that they annul each other and thus the resulting amplitude of light is less. Constructive interference is the opposite. If ΔL contains an odd number of wavelengths, then maximum constructive interference will occur.

X1.2.1.3 Then the maximum destructive interferences occur at:

$$\lambda = \Delta L / x \qquad (X1.2)$$

where:

λ = the wavelength under consideration, and
x = an even integer such as 2, 4 etc.

X1.2.1.4 The maximum constructive interferences occur at:

$$\lambda = 2\Delta L / x \qquad (X1.3)$$

where:

x = an odd integer such as 1, 3, 5, 7 etc.

X1.2.1.5 Tables of constructive and destructive wavelengths resulted in a color chart for visible oil as: thickness less that 0.15 µm—no color apparent, thickness of 0.15 µm—warm tone apparent, thickness of 0.2 to 0.9 µm—variety of colors (for

TABLE X1.1 Relationships Between Appearance and Slick Thickness

Author	Year	Oil	Type	Number	Height (m)	Viewing Angle	Visibility Thresholds (μm)					
							Minimum	Silvery	Rainbow	Darkening Colors	Dull Colors	Dark[A]
Congress (**4**)	1930	various incl. Bunker, fuel oil	e	>15	ship board	oblique	0.1					
Allen et al. (**6**)	1969	Crude-Santa Barbara	e	multiple	ns	ns		0.05 to 0.18	0.23 to 0.75	1 to 2.5	2.5 to 5.5	
API (**7**)	1969	general	l		ns	ns	0.04	0.08	0.15 to 0.3	1	2	
Horstein (**5**)	1972	Arabian and Louisiana crudes	e	>20	1 to 2	various	<0.15	up to 0.15	0.15 to 0.9	0.9 to 1.5	1.5 to 3	
Horstein (**8**)	1973	various	e & l		ship & aerial	various	0.038	0.076	0.15 to 0.31	1	2	
Parker et al. (**9**)	1979	North Sea and Arabian crudes	e	2	ship & aerial	various	0.1					
ITOPF (**10**)	1981	general	l		aerial	ns	0.1	0.1	0.3	0.1		
Schriel (**11**)	1987	general	e & l		aerial	various	0.05	0.1	0.15	0.3	1	2
Schriel (**11**)	1987	general	e & l		aerial	various		0.1	0.3	1	5	15
Duckworth (**12**)	1993	various crudes	e	several	ns	ns	0.1	0.1	0.1 to 1			
Brown et al. (**13**)	1995	Crude-Norman Wells	e	32	30 m	nadir	0.094					
		Diesel	e	25	30 m	nadir	0.165					
		Lubricating oil	e	16	30 m	nadir	0.077					
		Hydraulic oil	e	13	30 m	nadir	0.159					
Coast Guard (**14**)	1996	general - tar codes	l				0.04	0.075	0.15	0.3	1	3
Bonn Agreement (**15**)	2003		l				0.04	0.04 to 0.3	0.3		5	>5 to 50[B]
						Average	0.09	0.1	0.6	0.9	2.7	8.5

[A] Dark is sometimes stated as 'true oil color,' 'black,' 'brown' or 'darker colors' or 'metallic.'

[B] The Bonn agreement document has two thicknesses in addition, based on oil distribution: 50 to 200 for patchy, discontinuous distribution and > 200 μm for continuous slicks.

Legend: e = experiment; l = literature; ns = not specified.

example, rainbow), and for thickness greater than 0.9 μm—colors of less purity, heading toward grey. The color generation by constructive and destructive interference provides the only physical measure that provides a positive indication of thickness. Thus if the rainbow colors are seen, then the thickness for that area ranges from 0.2 to 0.9 μm.

X1.2.1.6 Horstein also calculated the differential reflectivity of oil and water. He calculated that the reflectivity of oil is 0.041 and that of water is 0.021 at an incidence angle of 30°. At 60° oil shows a reflectivity of 0.09 and water of 0.06; and at 75°, oil has a reflectivity of 0.25 and water that of 0.21. These angles are calculated as the angle of light incidence from the vertical, and thus show that reflectivity increases as the angle of viewing becomes less vertical. The reflectivity may explain the visibility of very thin films of oil (less than shown by coloration) on the water surface. This calculation demonstrates that viewing angle is important and that the greatest contrast is seen from near vertical angles.

X1.2.2 *Literature Review:*

X1.2.2.1 Literature results are summarized in Table X1.1 (Fingas et al., 1999) (**3**).

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