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Standard Guide for Collecting Skimmer Performance Data in Controlled Environments[1]

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1. Scope

1.1 This standard provides a guide for determining performance parameters of full-scale oil spill removal devices in recovering floating oil when tested in controlled environments.

1.2 This guide involves the use of specific test oils that may be considered hazardous materials after testing is completed. It is the responsibility of the user of this guide to procure and abide by the necessary permits for disposal of the used test oil.

1.3 *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:*

D 97 Test Method for Pour Point of Petroleum Products[2]

D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (the Calculation of Dynamic Viscosity)[3]

D 971 Test Method for Interfacial Tension of Oil Against Water by the Ring Method[3]

D 1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method[2]

D 2983 Test Method for Low-Temperature Viscosity of Automotive Fluid Lubricants Measured by Brookfield Viscometer[4]

D 4007 Test Method for Water and Sediment in Crude Oil by the Centrifuge Method (Laboratory Procedure)[4]

F 625 Practice for Classifying Water Bodies for Spill Control Systems[5]

F 808 Guide for Collecting Skimmer Performance Data in Uncontrolled Environments[6]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *data collection period*, *n*—the period of time during a test run when the performance data are recorded.

3.1.2 *emulsification factor*, *n*—the increase in total fluids in storage as a result of emulsification by the skimming mechanism, the skimmer pump, or other component of the skimmer.

$$EF = (WC_F - WC_0)/(100 - WC_F) + 1 \quad (1)$$

where:

WC_F = the final water content %, and

WC_0 = the initial water content %.

3.1.3 *nameplate recovery rate*, *n*—the maximum skimming capacity of a device as stated by the manufacturer.

3.1.4 *oil encounter rate*, *n*—the volume of oil per unit time actively directed to the removal mechanism (m^3/h).

3.1.5 *oil recovery efficiency*, *n*—the ratio, expressed as a percentage, of the volume of oil recovered to the volume of total fluids recovered.

3.1.6 *oil recovery rate*, *n*—the volume of oil recovered by the device per unit of time (m^3/h).

3.1.7 *oil slick*, *n*—the oily fluid encountered by the skimmer.

3.1.7.1 *Discussion*—Most real oil slicks actually are composed of various proportions of pure oil, water-in-oil (W/O) emulsions, and oil-in-water (O/W) emulsions; therefore, efficiencies and other performance criteria must be differentiated between those based on the oil slick itself, and those based on only the water-free oil contained within the oil slick.

3.1.8 *oil slick encounter rate*, *n*—the volume of oil slick per unit time actively encountered by the skimmer, and therefore, available for recovery (m^3/h).

3.1.9 *oil slick recovery efficiency*, *n*—the ratio, expressed as a percentage, of the volume of oil slick recovered to the volume of total fluids recovered.

3.1.10 *oil slick recovery rate*, *n*—the volume of oil slick removed from the water surface by the skimmer per unit of time.

3.1.11 *oil slick thickness*, *n*—the average thickness of the oil slick encountered by the test device (mm).

3.1.12 *test fluid*, *n*—the oil or oil/water mixture distributed on the water of the test facility and presented to the spill removal device for recovery.

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[2] *Annual Book of ASTM Standards*, Vol 05.01.

[3] *Annual Book of ASTM Standards*, Vol 10.03.

[4] *Annual Book of ASTM Standards*, Vol 05.02.

[5] *Annual Book of ASTM Standards*, Vol 11.04.

[6] Discontinued; see 1998 *Annual Book of ASTM Standards*, Vol 11.04.

3.1.13 *throughput efficiency*, *n*—the ratio, expressed as a percentage, of the volume of oil recovered to the volume of oil encountered.

4. Significance and Use

4.1 This guide provides quantitative data in the form of oil recovery rates, throughput efficiencies, and oil recovery efficiencies under controlled test conditions. The data can be used for evaluating design characteristics of a particular spill removal device or as a means of comparing two or more devices. Caution must be exercised whenever test data are used to predict performance in actual spill situations as the uncontrolled environmental conditions that affect performance in the field are rarely identical to conditions in the test tank. Other variables such as mechanical reliability, presence of debris, ease of repair, ease of deployment, required operator training, operator fatigue, seaworthiness, and transportability also affect performance in an actual spill but are not measured by this guide. These variables should be considered along with the test data when making comparisons or evaluations of spill removal devices.

5. Summary of Guide

5.1 The spill removal device may be tested in a wave/tow tank or other facility that is suitable for controlling the appropriate test parameters. Significant testing results can be obtained using simple test tanks or ponds, particularly when calm water and low velocity advancing tests are desired as an economical means to screen and compare devices. Controlled test variables include relative velocity, oil properties and slick thickness, wave conditions, and pertinent device variables. It is essential that the device be operated in a steady-state condition during the sampling period when oil encounter rate, recovery rate, recovery efficiency, and device parameters are monitored, measured, and recorded.

6. Interferences

6.1 The table of results (see 13.1) shall address the possibility of test facility effects. For example, wall effects may interfere hydrodynamically with the device's performance.

6.2 Care should be taken that any containment means that is not inherent in the skimming device does not affect the oil distribution to the device.

7. Test Facilities

7.1 Several types of test facilities can be used to conduct the test outlined in this guide.

7.1.1 *Wave/Tow Tank*— A wave/tow tank has a movable bridge or other mechanism for towing the test device through water for the length of the facility. A wave generator may be installed on one end, or on the side of the facility, or both.

7.1.2 *Current Tank*— A current tank is a water-filled tank equipped with a pump or other propulsion system for moving the water through a test section where the test device is mounted. A wave generator may be installed on this type of test facility.

7.1.3 Other facilities, such as private ponds or flumes, may also be used, provided the test parameters can be suitably controlled.

7.2 Ancillary systems for facilities include, but are not limited to, a distribution system for accurately delivering oils to the water surface, skimming systems to assist in cleaning the facility between tests, and adequate tankage for storing the test oils.

8. Test Oils

8.1 Test oils for use with this guide should be selected to fall within the parameters specified in Appendix X1. These oils may be crude, refined, or simulated.

8.2 If test oils vary significantly from the recommended ranges, the test report shall discuss the implications of such deviations on the performance of the device.

8.3 The viscosity of oil varies greatly with temperature. Frequently test oils must be distributed in the test facility at temperatures different from the water temperature. When this occurs, the oil generally will approach the surface water temperature.

8.4 If oils that originally meet the conditions stated in Appendix X1 are reused, their properties may change and should be evaluated prior to reuse.

9. Safety Precautions

9.1 Test operations shall conform to established safety (and regulatory) requirements for both test facility operations and oil handling. Particular caution must be exercised when handling flammable or toxic test oils.

10. Test Device

10.1 The test device shall be deployed in accordance with facility operating characteristics. The device must be operated in accordance with the manufacturer's specified operating instructions with respect to mechanical operations and established maintenance routines. Modifications to the device, in any modification from commercial design, shall be recorded with the test results.

10.2 The make and model of the device, its nameplate recovery rate, and any other identifying specifications shall be recorded with the test results.

11. Test Variables

11.1 At the outset of the test, the independent or control test parameters are selected. The test evaluator should include a discussion of the procedures that were used to establish calibration and standardization. Data should be expressed with an indication of variability. Typical test variables include:

Test oils	as stated in Appendix X1
Test speed	upper and lower limits and speed increments selected as appropriate within ± 0.1 m/s
Oil slick thickness	1, 5, and 25 mm and other thicknesses as appropriate

Wave conditions	wave characteristics of significant height, average length, and average significant period and pattern may be varied as appropriate to the design of the skimmer
Wave height	0 mm, 150 mm, and 450 mm
Debris	Use various materials to simulate various forms of natural debris that may hinder skimmer operation. Recommended materials include: polypropylene rope, ½ in. diameter, cut into lengths ranging from 4 in. to 2 ft; softwood lumber, nominal dimensions 2 by 2 in., lengths ranging from 4 in. to 2 ft; foam sponges, nominal size 4 to 12 in; broken ice, nominal size 1 to 4 in. diameter; seaweed, lengths up to 5 ft; plastic or aluminum disposable containers (such as soda cans); sorbent pads, booms, or sheets; or other suitable materials. Use adequate number of pieces to produce concentrations at the skimmer inlet area corresponding to 50 % surface coverage.

12. Procedure

12.1 Prior to the test, select the operating parameters, such as tow speed (as applicable), wave conditions, test fluid, and oil distribution rate. Then prepare the facility and spill removal device for the test run. Occasionally, it may be necessary to preload the device with test fluid to achieve steady-state operation within a reasonable period of time. Any preload must be carefully measured and discharged into the device. Measure or note immediately prior to each test the following parameters describing ambient conditions:

12.1.1 Air temperature (°C),

12.1.2 Water temperature near the surface (°C),

12.1.3 Wind speed (m/s),

12.1.4 Wind direction relative to the test device, and

12.1.5 General weather conditions, for example, rain, overcast, sunny, etc.

12.2 Start the wave generator (if necessary), test fluid distribution system, tow mechanism or water flow (if necessary), and the spill removal device to begin a test run. Direct the discharge flow of recovered fluid from the device into a holding tank or back into the test tank out of the device's sweep path during the transient start-up period. After steady-state operation is achieved, monitor the discharge flow to obtain performance data. The discharge may be pumped through a flowmeter to obtain a flow rate and sampled periodically to obtain the oil-to-fluid ratio. Alternatively, the discharge may be diverted into calibrated sample tanks from which the flow rate and oil-to-fluid ratio may be determined. In either case, the data collection period begins when sampling starts and ends when sampling stops. During the data collection period or immediately thereafter, measure and record the following parameters:

12.2.1 Test fluid distribution rate (m^3/h),

12.2.2 Fluid recovery rate (oil and water) (m^3/h),

12.2.3 Tow speed or current speed (m/s),

12.2.4 Wave characteristics (see Practice F 625 for environmental descriptors and classifications),

12.2.5 Length of data collection period,

12.2.6 Oil encounter rate (m^3/h),

12.2.7 Oil slick encounter rate (m^3/h), and

12.2.8 Operating parameters of the spill recovery device such as belt speed (m/s), weir setting (mm below fluid level), pump speed (r/min), etc.

12.3 At the completion of the data collection period, divert the discharge of the spill removal device back into the holding tank or test tank. Stop the wave generator, tow mechanism or water flow, oil distribution, and spill removal device. Depending on the degree and variability of changes in the oil properties, the test evaluator will determine the required schedule of analysis to provide representative samples. Analyze representative samples of the discharge to determine oil-to-fluid ratio. Analyze representative samples of the recovered test oil to determine the following:

12.3.1 Density (g/mL),

12.3.2 Viscosity (mm^2/s),

12.3.3 Surface tension (mN/m),

12.3.4 Interfacial tension with respect to test tank water (mN/m), and

12.3.5 Water content (percent of total mixture).

12.4 Perform the analyses in 12.3 at the surface water temperature or in such a way that the values of these parameters at the surface water temperature can be determined from the analytical data.

13. Report

13.1 Prepare a schematic diagram of the layout for the test series.

13.2 Prepare a table of results for the test run containing the following entries:

13.2.1 Test identification number.

13.2.2 Date and time of day.

13.2.3 Average speed (tow speed or current speed, m/s) during data collection period.

NOTE 1—This rate is averaged over the data collection period.

13.2.4 Test oil type.

13.2.5 *Oil slick thickness*—Calculation of slick thickness should include a brief discussion of the method used for measuring variation in the thickness, especially for heavy oils.

13.2.6 For regular waves, include height, average period (or length), and whether head or following. For irregular waves, include significant height, significant frequency, spectral characteristics, and whether head or following. Primary and secondary (reflected) wave basin characteristics shall be described.

13.2.7 Oil properties at test temperatures, including density, viscosity, surface tension, interfacial tension with tank water, and initial water content of oil.

13.2.8 Recovered oil properties as performed in 12.3.

13.2.9 Total volume of oil distributed during data collection period.

13.2.10 Total volume of oil encountered during data collection period.

13.2.11 Total volume of fluid (oil/water) recovered during data collection period.

13.2.12 Average oil distribution rate (see Note 1).

13.2.13 Average oil encounter rate (see Note 1).

13.2.14 Average fluid (oil/water) recovery rate (see Note 1).

13.2.15 Average oil recovery efficiency (see Note 1).

13.2.16 Average oil recovery rate (see Note 1).

13.2.17 Average oil slick distribution rate (see Note 1).

13.2.18 Average oil slick encounter rate (see Note 1).

13.2.19 Average oil slick recovery rate (see Note 1).

13.2.20 Average oil slick recovery efficiency (see Note 1).

13.2.21 Average emulsification factor (see Note 1).

13.2.22 Average throughput efficiency (see Note 1).

13.2.23 Ambient conditions, including air temperature, surface water temperature, wind speed, wind direction, and brief statement of weather conditions during test run.

13.2.24 Length of data collection period.

13.2.25 Volume of oil in device at beginning of data collection period.

13.2.26 Volume of oil in device at end of data collection period.

13.2.27 Operating parameters of the device such as belt speed, weir setting, pump speed, etc.

13.2.28 For tests conducted in the presence of debris, report the following:

13.2.28.1 Size and type of debris forms used;

13.2.28.2 Approximate concentration, expressed as surface coverage (percent);

13.2.28.3 Mode of debris handling, or processing, or both;

13.2.28.4 Effectiveness of debris handling, or processing, or both; and

13.2.28.5 When comparing results, specify reasons for performance degradation (if any), differentiating between oil encounter degradation and that of the skimming mechanism.

13.2.29 Brief discussion of interferences or limiting factors (see 6.1).

13.3 If any of the data required by 13.2 are not applicable to the device being tested, a statement must be included in the table of results describing the reasons for omitting the data.

13.4 Report qualitative comments on device operating parameters such as mechanical reliability, ease of repair, ease of deployment, required operator training, operator fatigue, seaworthiness, and transportability.

14. Keywords

14.1 oil; oil recovery; skimmer

APPENDIX

(Nonmandatory Information)

X1. STANDARD TEST OILS

X1.1 Values in Table X1.1 refer to test fluid properties at test temperatures. Test methods for fluid properties are specified as follows: viscosity, Test Methods D 445 and D 2983 (report shear rate for viscosity measurement, should be in the range of 1 to 10 s^{-1}); density, Test Method D 1298; interfacial tension, Test Method D 971; pour point, Test Method D 97. For all test oils (with the exception of emulsions), maximum sediment and water (BSW) of 0.1 % (see Test Method D 4007).

X1.2 Of the five viscosity ranges, numbers I, II, and IV are especially recommended as being indicative, respectively, of lightly weathered, moderately weathered, and significantly weathered crude oils.

X1.3 The following lists examples of hydrocarbon oils that could be used to fall within the specified ranges. This list is intended for guidance only; it should be noted that viscosities of all oils will vary greatly with both temperature and the specific product. Selected oils may be crude, refined, or simulated. In the case of crudes and light refined products, it is acceptable and may be desirable to pre-weather the oil in order to produce a desired viscosity, increase the oil's flash point to a safe level, and produce a more stable test fluid.

TABLE X1.1 Candidate Test Oils

NOTE 1—Test oils should be selected to fall within these five categories.

	Viscosity, mm^2/s	Density, g/mL	Oil-Air Interfacial Tension, mN/m	Oil-Water Interfacial Tension, mN/m	Pour Point,°C
I[A]	150 to 250	0.90 to 0.93	28 to 34	20 to 30	< −3
II[B]	1500 to 2500	0.92 to 0.95	30 to 40	20 to 30	< −3
III[C]	17 000 to 23 000	0.95 to 0.98	20 to 40	20 to 40	< 10
IV[D]	50 000 to 70 000	0.96 to 0.99	20 to 40	20 to 40	...
V[E]	130 000 to 170 000	0.96 to 0.99	20 to 40	20 to 40	...

[A] 1) Alaska North Slope crude oil, 10 to 15 % weathered by volume.
2) Fuel oil No. 4 (heavy); can be prepared by blending 40 % fuel oil No. 2 and 60 % fuel oil No. 6.

[B] Fuel oil No. 5; can be prepared by blending 20 to 25 % fuel oil No. 2 with 75 to 80 % fuel oil No. 6.

[C] Residual fuel oil (that is, fuel oil No. 6 prepared to above criteria).

[D] Residual fuel oil (that is, heavy cut of fuel oil No. 6).

[E] Emulsified crude oil, 50 to 80 % water content. The oil may be emulsified by blowing compressed air through water on which the oil is floating.