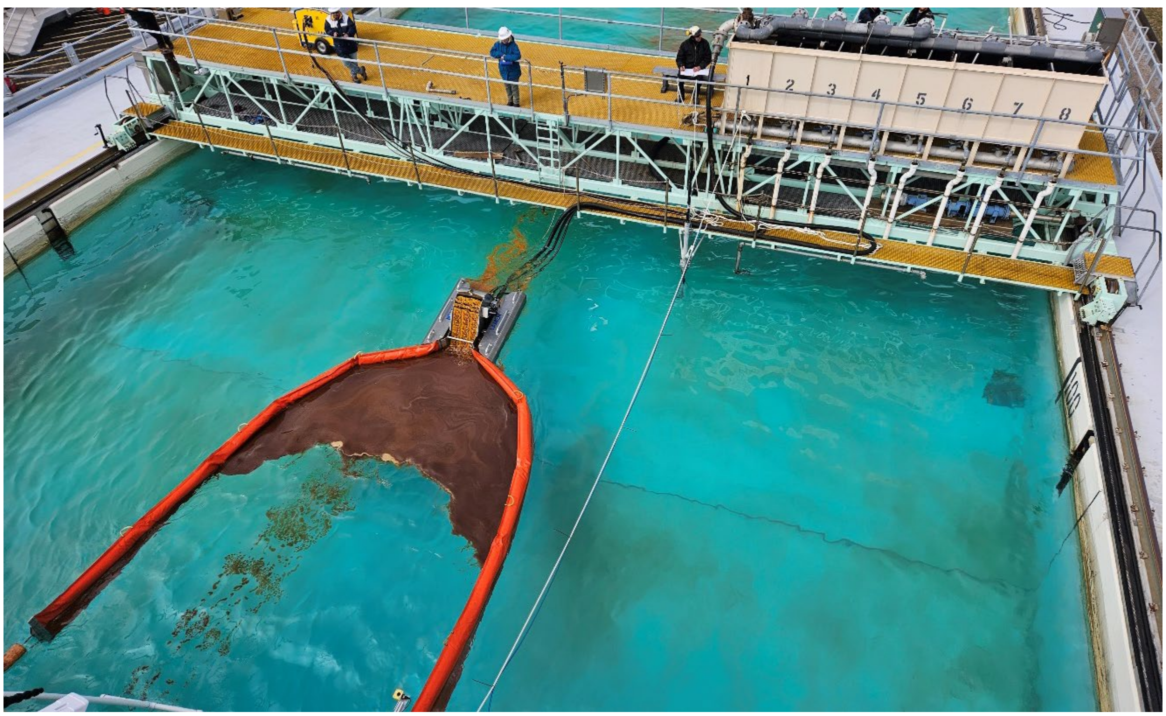
Bureau of Safety and Environmental Enforcement
Oil Spill Preparedness Division

Development of an Advancing Skimmer Test Protocol

Final Report

May 2024



(Photo Credit: Ohmsett)

Stephen Potter, David Cooper, James McCourt

US Department of the Interior
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OSRR # 1127

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Prepared under 140E0120P0013
By
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US Department of the Interior
Bureau of Safety and Environmental Enforcement
Oil Spill Preparedness Division

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U.S. Department of the Interior Library	Development of an Advancing Skimming System Test Protocol	https://library.doi.gov
National Technical Reports Library	Development of an Advancing Skimming System Test Protocol	https://ntrl.ntis.gov/NTRL/

Sources: a) BSEE (2023), b) DOI [2021], c) National Technical Information Service (2021)

CITATION

Potter Stephen, Cooper David, McCourt James. 2024. Development of an Advancing Skimmer Test Protocol. U.S. Department of the Interior, Bureau of Safety and Environmental Enforcement. Report No.: 1127. Contract No: 140E0120P0013.

ABOUT THE COVER

Advancing brush skimmer system being used during an evaluation of the new test protocol (Ohmsett)

ACKNOWLEDGEMENTS

The authors would like to acknowledge the contributions of Former Ohmsett Test Director Dave DeVitis and several members of ASTM F20.12 whose technical knowledge and detailed expertise helped in the development of the draft protocol, specifically Marc Blanchard, Todd Paxton, Mark Ploen, Paul Smith, and Donnie Wilson.

EXECUTIVE SUMMARY

Many different models of advancing skimmer systems with various oil recovery principles are commercially available. Their common operating feature is movement through the water at a minimum speed of 0.4 m/s (~0.75 knots). Unfortunately, the lack of a standard protocol to evaluate the performance of these systems has hindered comparisons of performance.

The intent of the project was to develop a test protocol for advancing skimming systems that ultimately would measure three key performance metrics of the Estimated Recovery System Potential (ERSP) Calculator. The calculator uses several variables to model the performance of a skimming system including three important measurements: 1) Maximum Total Fluid Recovery Rate, 2) Throughput Efficiency, and 3) Recovery Efficiency. The ERSP User Manual provides conservative default values for these inputs. However, there are skimmer system whose performance likely exceeds these conservative default values. Validated test data that confirms actual performance values may, in the future, be accepted by BSEE.

This project began by investigating and summarizing historical skimmer testing protocols and large-scale facilities around the world where testing could potentially take place. Protocols were found that addressed various aspects of skimmer testing, and the project team used selected portions of these to guide the development of a new test standard structure. Of the facilities examined, Ohmsett is clearly well suited to perform the envisioned advancing skimming system tests as they have hosted numerous tests of this type in the past and have experience in other aspects of oil spill response.

After the initial background tasks were completed, a working group of experts in oil spill response was convened to help flesh out and develop the actual test protocol. Multiple in-person and virtual meetings were coordinated and facilitated to assess different points of view and work through technical issues in the development of the test protocol. To encourage broad acceptance and use, the protocol was submitted to the ASTM F20.12 Removal Subcommittee for consideration as a new standard. ASTM International is an organization that relies on technical experts from more than 90 industries in over 150 countries to help draft over 13,000 standards.

Once the protocol was drafted, it underwent a review through a series of test days at Ohmsett where the protocol was evaluated using one advancing skimmer. Some minor updates to the protocol were determined to be warranted, as were some operational suggestions for Ohmsett.

The outcome of this effort was a final test protocol that meets the needs of BSEE Oil Spill Preparedness Division, has consensus among working group members, can be generically applied for use at a number of facilities around the world, and was put forward to the ASTM F20 committee for consideration as an ASTM standard.

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1 INTRODUCTION

Many different models of advancing skimmer systems are commercially available with different oil recovery principles (e.g., weir, brushes, discs, belt), method of propulsion (e.g., self-propelled, vessel-mounted, towed), and containment boom connections and configurations. However, all such systems are characterized by a forward movement through water to increase oil encounter rate and encourage oil to flow into the system. While there are a few test protocols for evaluating the performance of stationary skimmers, the protocols are typically not able to properly determine the performance of a skimming system that advances through the water in a combined sweep and collect mode. The lack of a suitable test method was identified as a research need. This project was initiated to address that need by developing a defined, repeatable test protocol for testing advancing skimming systems.

1.1 Background – ERSP Calculator

The U.S. Department of the Interior, Bureau of Safety and Environmental Enforcement (BSEE), is responsible for promoting safety, protecting the environment, and conserving offshore resources through vigorous regulatory oversight and enforcement of offshore facilities engaged in oil and gas exploration, and development and production operations on the Outer Continental Shelf (OCS). BSEE recently developed an oil spill response planning tool called the Estimated Recovery System Potential (ERSP) Calculator. This calculator computes the theoretical performance of an advancing oil recovery system for a hypothetical but realistic spill scenario (i.e., recoverable oil, low to moderate wave conditions). The calculator models the following recovery steps as the skimming system:

a) Encounters and contains oil,
b) Recovers and stores oil, and
c) Offloads it to a backup vessel, barge, or disposal facility.

The calculator is published on BSEE's website, https://www.bsee.gov/what-we-do/oil-spill-preparedness/response-system-planning-calculators) and BSEE encourages its use to prepare and submit oil spill response plans (OSRPs). Further, BSEE analysts may use this calculator as an evaluation tool when reviewing OSRPs for compliance with existing regulations.

The calculator uses several scenario-specific variables to model performance of a skimming system, including the following three important measurements:

i. Maximum Total Fluid Recovery Rate (gpm);
ii. Throughput Efficiency (%); and,
iii. Recovery Efficiency (%).

The ERSP User Manual provides default conservative values for these inputs. However, there are skimmer systems whose performance likely exceeds these conservative default values, and test data that verifies actual performance values may, in the future, be accepted by BSEE to show plan holders' compliance with regulation. The developed test protocol should provide test results that include the three performance values listed above (BSEE, 2019).

1.2 Objective

The objective of the project was to develop a test protocol for advancing skimming systems to measure the three key performance metrics used in the ERSP calculator that stakeholders (e.g., manufacturers, operators) could use in lieu of the default values. The requirements of the test protocol included the following criteria:

- It can be used to evaluate a variety of advancing skimmer designs
- It can be used at the Ohmsett facility, as well as other facilities (subject to size limitations)
- The test conditions should be realistic, reflect reasonable oil encounter rates and other spill parameters, while balancing the costs to conduct the tests, such as the amount of oil required, and the number of test runs
- The test results can be used as data inputs for the ERSP calculator.

2 METHODOLOGY

The project was divided into distinct tasks. After an initial kick-off meeting, a review of existing test protocols and reports of other advancing skimmer tests was performed. This was conducted to determine if relevant protocols could be modified to fit the needs of the project. In a related task, a review of test facilities with capabilities to conduct testing with advancing skimming systems with oil was also conducted. This initial background information was compiled and summarized into working documents to feed into the protocol development.

The next step involved the assembly of a working group of experts in oil spill response and testing to help develop the protocol. A group of experts in the field of oil spill response and testing was convened. Multiple meetings (in-person and virtual) were coordinated and facilitated to assess different points of view and work through technical issues in the development of the protocol.

To encourage broad acceptance and use, the ASTM F20 Committee on Hazardous Substances and Oil Spill Response was considered as a possible source of additional expertise. ASTM International is an organization that relies on technical experts from more than 90 industries in over 150 countries to help draft over 13,000 standards. The F20.12 Removal Subcommittee was approached to determine interest in assisting the further development of the protocol and for its ultimate consideration as a new standard. An online virtual collaboration area was created as a repository for working documents to help accelerate the protocol development process.

3 EXISTING SKIMMER TEST PROTOCOLS

A variety of protocols have been used to evaluate the performance of oil spill skimmers, including general test methods intended to be used as standards for comparing performance (e.g., ASTM International Standard Methods), and dedicated test methods developed for specific projects or facilities.

3.1 Standard Methods

Five standard methods relevant to developing an advancing skimmer test protocol were identified and reviewed. A summary of these protocols is provided in Table 1.

Table 1: General test protocols for measuring skimmer performance data

Protocol Name	Summary
ASTM F631-15 (2020) Standard Guide for Collecting Skimmer Performance Data in Controlled Environments	a) Originally developed in 1980, this standard provides guidance for determining performance parameters for full-scale oil spill removal devices. b) The standard includes discussion of interferences; test facilities; test oils, test variables, procedures, and reporting. c) The standard defines a procedure for testing skimming devices in a controlled manner and establishes a common set of practices that enable comparison of skimmers under selected conditions. d) This standard has been criticized for being too loose in specifying test parameters such as oil selection, slick thickness, tow speed, and wave height. However, we note that this flexibility can be beneficial by allowing a user to select the best conditions for their device, while recommending a few select values to enable comparisons with other test results.
ASTM F2709-19 Standard Test Method for Determining a Measured Nameplate Recovery Rate of Stationary Oil Skimmer Systems	a) Evolved from testing performed at Ohmsett in 2007 and was first approved as a standard in 2008. Testing is conducted under favorable conditions (i.e., static, thick slicks, calm water) to determine a best-case performance measurement. b) The standard includes discussion of test facilities, skimmer system set-up, procedure, skimmer performance calculations, and reporting. c) The protocol was designed to be simple to use. d) This standard has been criticized for using very thick slicks, which may only be rarely achieved during actual spill responses. However, research by NOFO (NOFO 1990) observed that a slick contained at the apex of a boom could attain a thickness of several inches or more for large spills.
ASTM F3350-18 (2024) Standard Guide for Collecting Skimmer Performance Data in Ice Conditions	a) Evolved from tests at Ohmsett in 2013 of several types of skimmers in drift ice condition (SL Ross Environmental Research Limited and MAR Inc. 2013) and was first approved as an ASTM standard in 2018.

	b) Tests a skimming device operated in two different ice coverage concentrations (30 and 70% coverage). These two ice conditions are generally regarded as thresholds for mechanical recovery in ice. c) The standard includes a discussion of test facilities, skimmer system set-up, procedure, skimmer performance calculations, and reporting. d) The standard defined a new parameter, Operating Efficiency, defined as the ratio (expressed as a percentage) of the time spent actually skimming to the total test time which includes the time spent out of water repositioning the skimmer.
ISO 21072-1 Ships and marine technology – Marine environment protection: performance testing of oil skimmers	a) This protocol consists of two parts. Part 1: Moving water conditions appears to have been withdrawn; however, Part 2: Static water conditions, appears to be current. b) Historical information from a 2002 version of a working copy appears similar to ASTM F631 and a Det Norske Veritas research report (DNV 2002) with the following exceptions: 1. Addition of one oil type category (heavy emulsions) 2. More detail on establishing the required slick thickness based upon oil type 3. More guidance on minimum fluid volumes and duration of test periods c) It provides loose guidelines on topics including oil selection, slick thickness, tow speed, and wave height.
Chapman's Suggested Test Protocol for the Evaluation of Oil Spill Skimmers for the OCS	a) This is a project report of work overseen by MMS (the predecessor of BSEE) with sponsorship by the Ohmsett National Oil Spill Test Facility Interagency Technical Committee (OITC) – consisting of: 1. the US Department of Interior Minerals Management Service (MMS) 2. US Environmental Protection Agency 3. US Coast Guard 4. US Navy 5. Environment Canada b) The objective of the protocol was to use tests and model simulations to evaluate oil spill skimmer performance in the open ocean *without oil*. c) Concluded that the effectiveness of a skimmer decreases with increasing wave action and increasing current speed.

3.2 XPRIZE - The Wendy Schmidt Oil Cleanup XCHALLENGE

The Wendy Schmidt Oil Cleanup XChallenge competition was intended to inspire innovation in skimmer design and drive improvements in achievable recovery rates (Meyer et al. 2012). Ten teams (selected from more than 350 international applicants) demonstrated prototype oil recovery systems in the Ohmsett test tank. A cash prize of $1M was awarded to the team with the highest oil recovery rate (ORR) at an oil recovery efficiency (ORE) of more than 70%, while the systems advanced along the tank. The competition attempted to push the boundaries of what was achievable with mechanical recovery systems, which was reflected in the choice of test conditions and parameters. This was an advancing skimmer test, and the methodology was developed based on guidelines from ASTM's F-2709, *Standard Test Method for Determining Nameplate Recovery Rate of Stationary Oil Skimmer Systems* and ASTM F-631, *Standard Guide for Collecting Skimmer Performance Data in Controlled Environments*. The test conditions are summarized in Table 2.

Table 2: Summary of XPRIZE test parameters

Test Parameter	Description
Oil Recovery Rate	The XPRIZE committee initially determined that the competition should enable participants to attempt to recover approximately 11,360 L/min (3,000 gal/min) of oil or greater at a recovery efficiency of no less than 70%.
Speed of Advance	The advancing speed range was between one and four knots. To enable the participants to encounter that much oil, an 18.3 m (60 ft) swath width was selected with a minimum tow speed of one knot. Based on the 18.3 m (60 ft) width at one knot tow speed, the required slick thickness was 25 mm (1 in), which equated to 11,360 L/min (3,000 gpm). Contestants were also allowed to choose a narrower swath width and operate at higher towing speeds to encounter 11,360 L/min (3,000 gal/min) or greater. The XPRIZE committee later reduced the requirement of the minimum recovery rate to 9,500 L/min (2,500 gal/min).
Test Oil	Hydrocal 300
Slick Thickness	A total of 102,000 L (27,000 gal) of oil was dispensed on the surface of the tank during testing to achieve the target nominal starting slick thickness of 25 mm (1 inch). The slick thickness was verified at multiple locations in the test basin prior to each test.
Oil Recovery Measurements	Recovery tanks on the Ohmsett Auxiliary Bridge were used during the tests. Each of the eight recovery tanks had a capacity of approximately 2,300 L (600 gal). Each skimmer was allowed to reach to steady-state and then do a timed recovery period. The volume of bulk fluid recovered was measured after the test was stopped. Free water was decanted from the bottom of each recovery tank after a 30-minute settling period. After decanting, the gross oil volume was measured. The remaining fluid was stirred, and a representative sample was obtained and sent to Ohmsett's on-site lab for water content analysis per ASTM D1796 *Standard Test Method for Water and Sediment in Fuel Oils by the Centrifuge Method*. After

	deducting the free and entrained water from the total fluid recovered, the volume of (pure) oil recovered was calculated.

4 POSSIBLE SKIMMER TESTING VENUES

There are several challenges to testing marine oil spill skimmers in basins or flumes:

- Skimmers designed for offshore use or self-propelled advancing skimmers are often very large and require a correspondingly large area in which to test.
- The facility should be able to create repeatable waves of sufficient size to match intended operating conditions.
- Skimmers must be tested with suitable fluids, which typically means oil of some kind (e.g., crude oil, lubricating oil).
- The facility must have sufficient fluid storage space and handling equipment (i.e., pumps and hoses) to distribute oil on the tank and measure the amount recovered.

The test protocol should be applicable for use at any sufficiently large facility with the option to tow, use oil for testing, and generate waves. Three large-scale testing venues that could potentially allow crude oil (or similar product) to be used in their tanks were reviewed. These included the following:

- Hamburg Ship Model Basin (HSVA) in Hamburg, Germany
- National Research Council (NRC) in St. John's NFLD and Ottawa, Ontario, Canada
- Ohmsett in Leonardo, New Jersey, United States

No recent testing data was found for skimmers using oil at the HSVA facility, although historical testing in the Arctic Environmental Test Basin was conducted related to MORICE I & II projects (mechanical recovery in ice) back in the late 1990s through early 2000s. The NRC test tanks typically use simulants such as dyed vegetable oil when required to test with oil due to concerns over clean-up and decontamination requirements when testing is completed. Data on previous oil skimmer testing in advancing or stationary modes at the specified locations was scarce, except for Ohmsett where such experiments are common.

4.1 Hamburg Ship Model Basin (HSVA)

The Hamburg Ship Model Basin (HSVA) was founded in 1913 and focuses primarily on hydrodynamic research. The facility has two tanks that could potentially be used for skimmer testing: the Large Towing Tank and the Arctic Environmental Test Basin.

4.1.1 HSVA Large Towing Tank

The large towing tank measures 300 m long, 18 m wide, and 6 m deep (980 x 59 x 20 ft). The main carriage has a maximum speed of 10 m/s (20 knots). The wave maker in the tank can generate regular waves with heights of 0.5 m (1.6 ft).

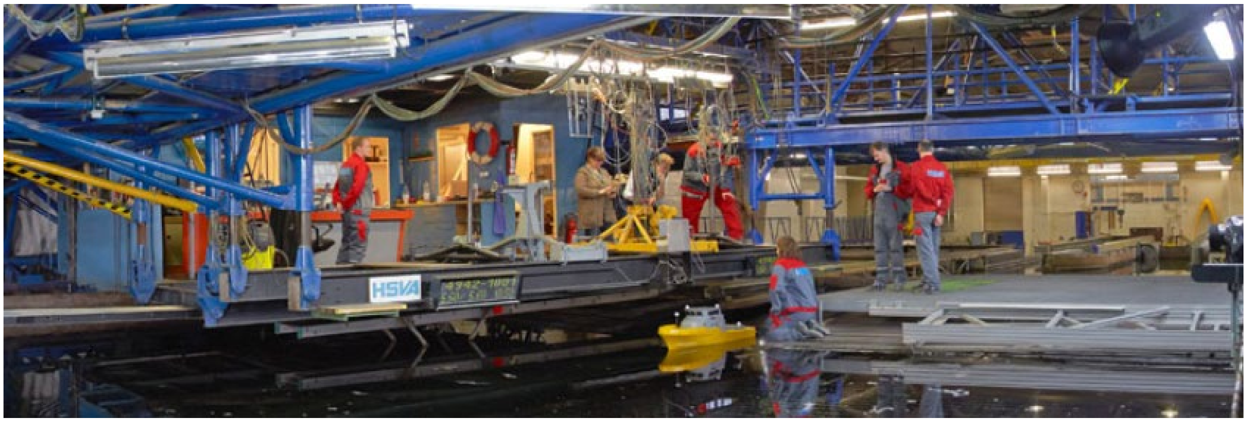

Figure 1: HSVA Large Towing Tank

4.1.2 HSVA Arctic Environmental Test Basin

The Arctic Environmental Test Basin measures 30 m long, 6 m wide, and 1.2 m deep (98 x 20 x 4 ft). Air temperatures can be controlled between -15 and 15°C (5 to 59°F), which allows the simulation of arctic ice conditions. The tank has an underwater current generator, air blowers, and a mobile wave generator. In the past, they have tested skimmers with oil (see Appendix A)

4.2 National Research Council of Canada

The Ocean, Coastal and River Engineering Research Centre of the National Research Council (NRC) Canada operates facilities in St. John's, Newfoundland, and Ottawa, Ontario, that could potentially be used for skimmer testing.

4.2.1 St. John's Institute of Marine Dynamics

The St. John's test tank measures 200 m long, 12 m wide, and 7 m deep (660 x 39 x 23 ft). The carriage has a maximum speed of 10 m/s (20 knots). The wave maker can produce regular waves up to 1 m (3.3 ft) high. Wave absorption is provided by a parabolic beach and wind generation by a bank of eight fans.

Figure 2: NRC (Canada) St. John's Test Facility.

4.2.2 Ottawa Offshore Engineering Basin

The Offshore Engineering Basin measures 75 m long, 32 m wide, and up to 12 m deep (246 x 105 x 39 ft), the basin can produce multi-directional waves up to 1 m (3.3 ft) in height. The basin can also generate current and wind to simulate real-world marine conditions. The indoor model ocean is equipped with 10 sub-floor lanes of hydraulically controlled thrusters (1000 HP total) that generate surface currents of 0.04 to 0.75 m/s (0.078 to 1.47 knots) depending on water depth.

Figure 3: NRC (Canada) Ottawa Offshore Engineering Basin

4.2.3 Ottawa Multidirectional Wave Basin

The Multidirectional Wave Basin measures 36 m long, 30 m wide, and up to 3 m deep (118 × 85 × 9.8 ft). A wide range of regular, irregular (long-crested) and multidirectional (short-crested) wave conditions with significant wave heights up to 0.5 m and regular waves up to 0.75 m can be generated using a 60-segment directional wave machine located along the basin's north wall.

Figure 4: NRC (Canada) Ottawa Multidirectional Wave Basin

4.3 Ohmsett Facility (New Jersey)

The Ohmsett test basin measures 203 m long, 20 m wide, and 2.4 m deep (670 x 65 x 8 ft). The tank's carriage has a maximum speed of 3.1 m/s (6 knots). The water is maintained at open ocean salinity (28 to 35 ppt). The flap-type wave maker can generate regular waves up to 0.59 m (1.9 ft) high and irregular waves up to a height of 0.75 m (2.5 ft). Wave absorption is provided at the end opposite the wave paddles by a wave damping beach. Testing is conducted on a regular basis using refined oil, crude oil and crude oil surrogates.

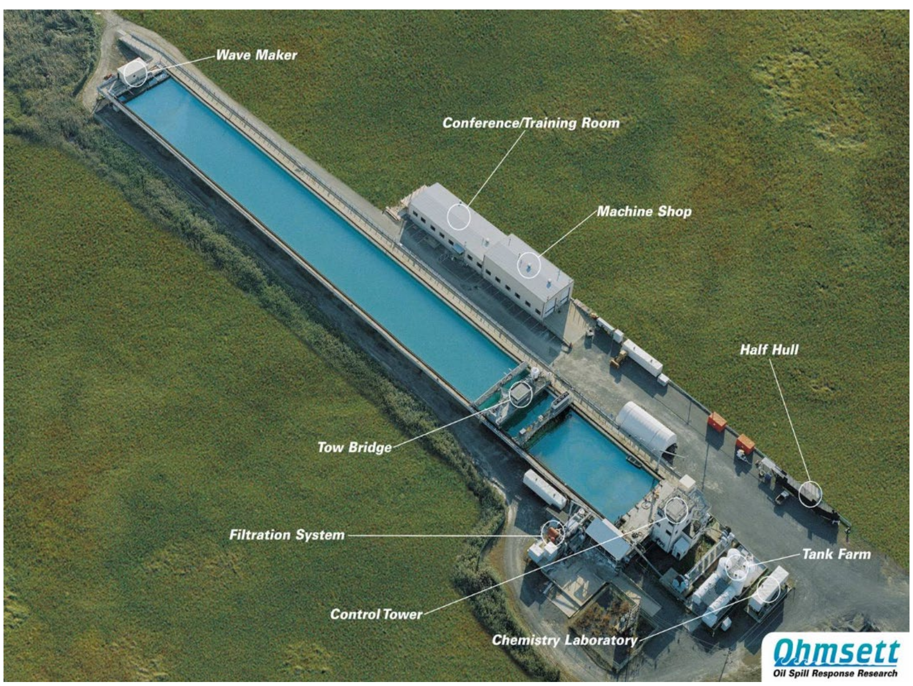

Figure 5: BSEE Ohmsett

4.4 Summary of Features

A summary of features of the reviewed test tanks is presented below in Table 3.

Table 3: Comparison of tanks, main specifications

Specification	HSVA Hamburg, Germany		NRC St. John's, Canada	NRC Ottawa, Canada		Ohmsett Leonardo, N.J.
	Large tow tank	Arctic environmental test basin	IMD	Offshore Engineering Basin	Multidirectional wave basin	Large tow tank with wave capabilities
Length, m	300	30	200	75	36	203
Width, m	18	6	12	32	30	20
Depth, m	6	1.2	7	12	3	2.4
Max tow speed, m/s (knots)	10 (20)	Portable current generators	10 (20)	installed current generators	installed current generators	3.1 (6)
Max wave height, m	0.5		1	1	0.75	0.75

5 TECHNICAL WORKING GROUP

It was important to build a consensus protocol from a broad range of stakeholders, including manufacturers, regulators, researchers, and end-users. A technical working group was established to gather input on aspects of the test protocol from various groups. An initial roster of prospective members was identified by the Project Team and was sent to BSEE for review and consideration before their inclusion as members of the targeted working group. The group of stakeholders is listed in Table 4 below.

Table 4: Initial Working Group Members

Name	Organization/Related Experience
Kristi McKinney	BSEE Project Manager
John Caplis	BSEE, manager of ERSP calculator project
Joe Mullin	BSEE, former manager of oil spill research program
Grant Coolbaugh	Test Engineer, Ohmsett
Marc Blanchard	MSRC, Oil Spill Removal Organization (OSRO) in the U.S.
Dave Devitis	Former Ohmsett Test Director
Mike Crickard	USCG, National Strike Team
Vince Mitchell	LAMOR, equipment manufacturer
Frank Marcinkowski	PCCI/US Navy Supsalv

Steve Potter	SL Ross, Oil Spill Research, Principal Investigator
James McCourt	SL Ross, Oil Spill Research, Moderator
David Cooper	SL Ross, Oil Spill Research, Senior Test Director

The first Working Group meeting was held in person at Ohmsett in early June, 2022. Nine additional meetings of task groups and the full working group were conducted virtually through 2023 to improve the draft protocol and try to reach a consensus before approaching ASTM for its possible adoption as an ASTM standard.

An online collaboration area was established within the ASTM F20 main committee to share draft files and solicit input from a broader audience as the protocol was being developed. Additional members of ASTM were able to provide their comments and help accelerate the development process.

6 DEVELOPING THE PROTOCOL

The protocol was developed in an iterative manner, starting with group discussions, identifying a robust outline of topic areas, followed by review and editing. This cycle was then repeated several times as different sections of the protocol became the topic of focus. The format of the protocol followed ASTM guidelines and was modeled after existing skimmer test standards. A summary of the development of each protocol section, including considerations and deliberations by the Technical Working Group members is presented below.

6.1 Scope

This section describes the nature of the test protocol, including what it is intended to test and how the test results are intended to be used. There was broad agreement by the Working Group Members that the test protocol would focus on advancing skimmer *systems*, that the results should be compatible with the ERSP calculator, and that testing in waves was encouraged for at least some tests if a system was intended for offshore use. The group defined an advancing skimming system as a skimmer that is moved through the water at 0.4 m/s (~0.75 knots) or faster, and that may include containment boom used to collect oil and direct it to the skimmer. Onboard storage, discharge pumps, secondary storage, and support vessels would not be evaluated as part of the system testing.

6.2 Referenced Documents

The protocol references several other ASTM standard skimmer tests (F631, F2709) and methods for measuring test fluid properties (e.g., interfacial tension, density, viscosity, and water content), and published reports on similar tests.

6.3 Terminology

The protocol defines technical language and industry terms to ensure clarity for end users. The defined terms included the main performance metrics of the skimmer system: Oil Recovery Rate, Recovery Efficiency, and Throughput Efficiency.

6.4 Significance and Use

This section explains the context of the protocol in relation to the oil spill response industry and regulations, and the intended application of the results. The protocol is intended to measure the performance of advancing skimmer systems in a more realistic manner than other industry practices, and for the results to be compatible with the ERSP calculator.

6.5 Oil Type and Properties

This section deals with the specifics of the test oil. Obtaining actual crude oil can be a very lengthy and cumbersome process in North America as the quantities required for testing are non-trivial, and obtaining such samples is not part of the typical extraction and refining process. If crude oil is being used, it should be weathered (at least slightly) to reduce the concentration of volatile organic compounds and minimize subsequent changes to the oil properties as the oil inevitably continues weathering during testing. Processed or manufactured oils offer some advantages, as they will typically be more consistent over time and can be more resistant to emulsification. Irrespective of the source of the test oils, they should be selected by the discrete ranges of viscosity as found in the Appendix of ASTM F631 (see Table 5 below) to allow for comparisons to be made with historical, and future testing.

Table 5 Candidate Test Oil Properties

(ASTM F631 - 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.

6.6 Oil Slick Thickness and Distribution

This section describes the target thickness of the oil on water that should be presented to the advancing skimming system. The Working Group considered several factors during discussions including:

1. Realism – expected or historically attained during actual spill response operations.
2. Compatibility with ERSP Calculator – so that actual measured recovery performance can be used instead of the default estimated values within the Calculator.
3. Cost – testing costs are linked to the size of the facility, the complexity of the testing and analyses, and the volume of oil used during a test.
4. Feasibility – a low viscosity oil will naturally spread to a thinner slick layer than a more viscous oil.

Ultimately, the Working Group decided to prescribe slick thicknesses based on the hypothetical spill scenarios used to develop the ERSP Calculator, which uses slick thickness of 0.1 in (2.5 mm), 0.05 in (1.3 mm), and 0.025 in (0.63 mm) in the calculations for the first three Operating Periods of a Batch Spill response. It was agreed that a target slick thickness of 2.5 mm be used for "Level 1" testing.

Properties of the oil (viscosity, pour point) will greatly influence how a slick will spread and the ultimate slick thickness (in a real-world scenario) which will have to be considered in the planning stage of setting up the test runs. Oil thickness gets converted to a volumetric rate based upon the speed and stated swath width of the advancing system to ensure the system encounters the correct "volumetric flow rate" of oil (calculated average slick thickness * swath width * speed of advance). There will be a practical limit as to the length of the guide/deflecting boom that can be used in any test tank facility.

One compromise that was reached was that the application of the slick in advance of a skimming system does not have to be completely continuous as long as slick is reasonably uniform and the volume meets the calculated capacity of the system (average slick thickness * swath width * speed of advance). The capacity will be constrained by two primary factors, specifically collection/encounter rate and skimming and pumping efficiency (not starve, nor overwhelm).

6.7 Speed of Advance

This section describes the speed that the advancing skimming system should be moved relative to the water, whether by towing, self-propulsion, or with current generators. A minimum cut-off speed of 0.4 m/s (~0.75 knots) was specified, as many conventional skimmers are towed at lower speeds.

The relative movement of the system through the water must be consistent and monitored (steady state) during the timed measurement phase of a test run. Achieving high speeds can impact a variety of factors such as test duration, power requirements, and even safety. One challenge is to determine the upper limit of speed that maintains effective containment and collection of the oil. Considerations were given to either test up to containment failure or up to the speed recommended by the manufacturer.

Moving a skimming system through the water was contrasted with moving water (and oil) past a skimming system. Comparisons were made with how skimmers may be evaluated at facilities around the world, or even testing in a near-shore or offshore environment if permission to use oil can be obtained.

6.8 Test Runs and Data Collection

This section described how long a test would take and what would determine the end of a test run. Some considerations of the Working Group included:

- The duration of a test run must be long enough to generate credible and reproducible results.
- Once steady-state conditions are observed during a run then collection of fluid from the discharge hose can be quantified (redirected to a calibrated collection vessel).
- The collection of fluid must provide an adequate volume to generate data (representative bulk water content, emulsification, overall volume determination within an acceptable margin of error) that satisfy the goals of the test.

As an example calculation, limitations for the Ohmsett facility provide a run distance of approximately 150 m after acceleration of the skimming system up to operational test speed has been accomplished. As shown in the graph below (see Figure 6), towing at up to 5 knots takes approximately 1 minute to cover the distance. Slower towing will obviously provide larger time buffers to perform a test. As long as steady-state conditions are observed, the fluid collection "run time" can be relatively short – with 30 seconds being proposed as adequate for the minimum collection time period.

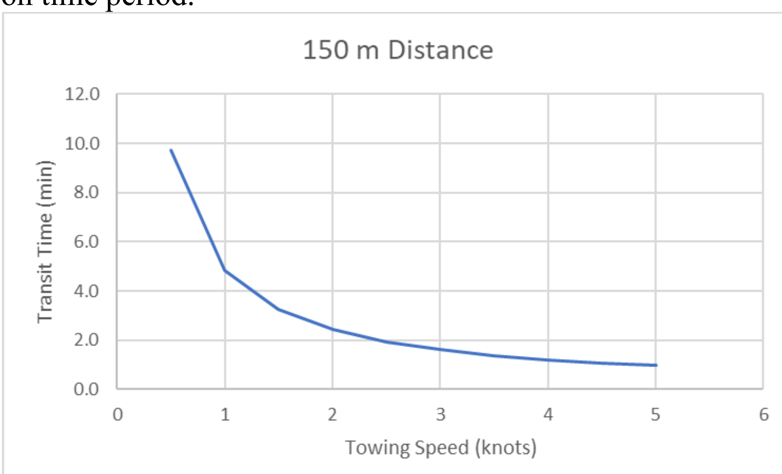

Figure 6 Tow Speed vs. Transit Time

6.9 Measurement of Recovered Fluids

There are three critical measurements that must be made on the recovered fluid to quantify the amount of oil recovered during a test.

1. The first measurement is the total volume of fluid recovered over the test period duration.

2. The second is the total volume of free water collected after a defined settling period or "decant time" in the collection vessel.
3. The third measurement is a determination of the residual water in the bulk oil (entrained or emulsified) requiring an oil/water analysis. It is obviously important to have recovery tank volumes sufficient to accommodate the volumes of oil expected to be processed during a test run.

One of the challenges is to account for hold-ups in the system. Fortunately, hold-up in hoses gets zeroed out if the system has reached steady state and the run time ends while the system is still operating in steady-state conditions. This may be more complicated if the skimming system has internal recovery tanks but that can be addressed on a case-by-case basis as part of the testing plan. It remains important to clear the system of oil at the end of each run so that recovery efficiency can be calculated – which relies on the difference between oil that was deposited as a slick in front of the advancing skimming system and was available to be collected and the total oil that was ultimately recovered off the water surface.

6.10 Accounting for Emulsification During the Test

Depending on the choice of test oil and the nature of the skimmer, emulsification of the oil may occur when there is turbulence or mixing energy while oil and water are being collected and recovered, such as in the skimmer, pump, and transfer hoses. This water in the recovered fluid must be accounted for in the performance calculations by sampling and testing fluid collected after each run. Initial oil samples used in each run should also be measured for water – to confirm either the absence of water in the starting oil, or to quantify initial water content if the starting oil has been reused from previous testing. This will allow accurate calculations for water uptake, and collection efficiency during a test run. One of the challenges would be to obtain a *representative* sample of the oil. If measuring from a holding tank following a decant time after free water has been released, some sort of stirring/mixing should be introduced to obtain a relatively homogenous oil sample. Water content down to single digit percentages should be adequate for this measurement.

6.11 Observations During the Test

Parameters that will have an impact on test results, such as oil distribution rate and speed of advance, should be measured. Weather conditions (general conditions, temperature, wind speed and direction) should be logged and noted for each run. Additionally, observations should be made with respect to possible containment failure and mode, the behavior of oil in the boomed/diversion area, sea keeping of the advancing skimmer system, change of draft (hydrodynamics), and wave conformance (if applicable). Video of the runs should be taken from multiple angles including "birds-eye view" and underwater camera (if possible) to determine and record any containment failure modes. As an option, load cells on the tow lines could also be logged.

6.12 Use of a Portion of the Tank

The skimming system should be evaluated as it would conceivably be used during an actual spill response. It may require the entire width and length of a test tank to conduct a test run. If the skimming system is moving at a speed that would allow a test run to be completed in a relatively short span, then the full test tank may be segmented to limit the amount of oil being used to attain the target slick thickness for that run. In a similar manner, the entire width of a facility test tank may not be required for use during test runs to evaluate smaller systems. This option is highly dependent upon the test tank configuration, the speed of the test run, and the size of the equipment.

6.13 Waves

Testing in waves would provide an added level of realism for evaluating skimmer systems, but it also adds complexity to any testing along with increased costs. Calm conditions (no waves) was selected as the default standard testing environment, with an option to add runs featuring waves. Some participants at the initial workshop felt strongly that testing in waves should be a requirement for systems whose intended use would be in an offshore environment (beyond protected harbor). Wave conditions are defined in ASTM F631 which can be used as the basis for selecting wave criteria for the advancing skimmer protocol (regular wave height, wave period). Simple wave patterns are preferred which increases the likelihood that conditions can be somewhat reproduceable between facilities. One concern is that regular waves propagated in a system with *some* reflections off walls (imperfect absorption of wave energy) will ultimately degrade to an irregular harbor chop; however, relatively short run times help ensure tests can be completed before test tank conditions degrade to the point of concern.

6.14 Equipment Failure

Data verification must be performed as part of any test including QA/QC and calibration of any measuring equipment. Actual testing protocol should contain a checklist to ensure that all verifications are performed and documented. There are many challenges that will occur during large-scale testing that may invalidate data or slow the testing process. Some issues include:

1) containment failure – some minor leakage of a few blobs of oil may be acceptable, but the exact speed at which failure occurs may be impacted by the amount of oil loading in the boom. Defining the point at which oil losses become unacceptable may require an experienced test director. This issue can readily be addressed by slowing the speed of the skimming system through the water in a subsequent run.

2) equipment component failure – may invalidate a run depending on the exact failure. Whenever possible, include spares for all equipment being evaluated.

3) datalogger and/or sensor failure – have spares available or run multiple sensors with overlap when practical.

4) battery failure – ensure batteries are charged/fresh before each run, and that equipment has been turned on (cameras, other sensors).

5) variability due to operator “non-optimized” operation – practice operations in advance of testing or preferably have manufacturer/proponent provide an experienced operator along with any ancillary equipment.

6) weather events that force a halt to tests.

There should also be documentation generated for equipment failure recovery that details exactly what failed and how long to repair/replace and resume testing (if possible). It is acknowledged that some failures may not be serviceable given the typical tight time constraints during testing.

6.15 Report

This section provides detailed guidance on describing equipment, documenting conditions and collecting and reporting the results of the tests.

6.16 Other Considerations

Outdoor testing facilities must face challenges such as the implications of wind, weather, and waves (sea state). Oil properties will be impacted by changes in temperature – even oil being exposed to a cool, cloudy morning will have evolving physical properties if the afternoon becomes bright, sunny and warm. Fluctuations in viscosity and pour point of test oil due to temperature shifts in the tank water can affect the distribution or spread of oil on the water surface. These fluctuations should be minor, but this reinforces the need to monitor and record oil, tank water, and atmospheric temperatures during a test period.

The early draft protocol for Advancing Skimming Systems was reviewed to identify additional factors that may impact how to maintain a steady encounter rate. It highlighted the need for an oil distribution system capable of creating a slick with symmetrical coverage across the recovery zone and be able to handle a range of oil viscosities.

7 DISCUSSION

The testing protocol was developed with assistance from a range of stakeholders who provided input and discussion on all portions of the testing protocol. A series of meetings were conducted with a core working group starting in June 2022 through December 2023. Additional stakeholders from ASTM also provided input along the way. Ultimately a protocol was generated and submitted to the ASTM F20.11 subcommittee for ballot action. The protocol passed the first round of ballot action with no negatives, and one comment that was editorial in nature.

The draft protocol has been included in Appendix C (main protocol) and Appendix D (test data sheets).

8 CONCLUSIONS AND RECOMMENDATIONS

Workable test standards that are accepted by both industry and regulators are ideally achieved through a consensus process. ASTM was an excellent venue for this because they had a ready-made system to gather and subsequently notify interested participants. They also provide a forum to schedule interim meetings to discuss the process and provide a platform on which the draft protocol could reside and attract comments.

A workable test protocol was developed as a result, as evidenced by the fact that it went through a preliminary balloting process with zero negative votes cast.

The outcome of this effort was a final test protocol that meets the needs of BSEE Oil Spill Preparedness Division, has consensus among working group members, and was put forward to the ASTM F20 committee for consideration as an ASTM standard.

As a result of a full-scale test of the protocol at Ohmsett (a recommendation emanating from the initial workshop), the protocol was improved in several minor ways in order to assist those planning on evaluating advancing skimming systems.

Additional testing using full-scale equipment at Ohmsett is recommended. Testing has been performed with one type of skimmer and it revealed some minor deficiencies in the draft protocol which were addressed. Testing of other equipment may reveal additional deficiencies and should lead to a more robust protocol.

9 REFERENCES

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ASTM D971-20 Standard Test Method for Interfacial Tension of Insulating Liquids Against Water by the Ring Method, ASTM International, West Conshohocken, PA, 2020, DOI: 10.1520/D971-20

ASTM D1298-12b(2017) Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method, ASTM International, West Conshohocken, PA, 2017, DOI: 10.1520/D1298-12b-17

ASTM D1796-22 Standard Test Method for Water and Sediment in Fuel Oils by the Centrifuge Method (Laboratory Procedure), ASTM International, West Conshohocken, PA, 2022, DOI: 10.1520/D1796-22

ASTM F2709-19 Standard Test Method for Determining a Measured Nameplate Recovery Rate of Stationary Oil Skimmer Systems, ASTM International, West Conshohocken, PA, 2019, DOI: 10.1520/F2709-19

ASTM D2983-22 Standard Test Method for Low-Temperature Viscosity of Automatic Transmission Fluids, Hydraulic Fluids, and Lubricants using a Rotational Viscometer, ASTM International, West Conshohocken, PA, 2022, DOI: 10.1520/D2983-22

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NOFO 1990. Technical Report on NOFO Exercise 24/90, 12 to 14 June, 1990, Norwegian Clean Seas Association for Operating Companies. Stavanger, Norway.

SL Ross Environmental Research Limited and MAR Inc. 2013. Skimmer Tests in Drift Ice: Ice Month 2013 at Ohmsett. Sterling, VA: Bureau of Safety and Environmental Enforcement.

Appendix A: Test Facilities – Additional Details

Hamburg Ship Model Basin (HSVA) in Hamburg, Germany

The Hamburg Ship Model Basin
HSVA Hamburgische Schiffbau-Versuchsanstalt GmbH
Bramfelder Straße 164 | D-22305 Hamburg, Germany
Phone: +49 (0)40 69 203-0 | Fax: +49 (0)40 69 203-345
info @ hsva.de

HSVA has led developments of influenced methods, and testing technology standardization. It has evolved and expanded to include service and consulting for maritime industry customers around the world. Today there are seven testing facilities:

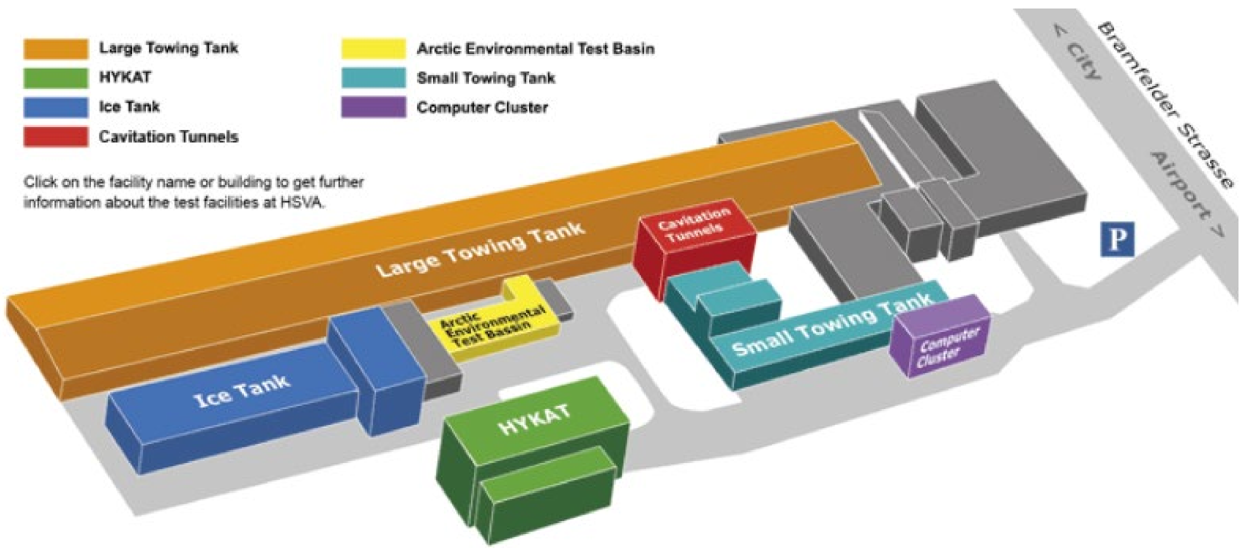

Figure A-1: Hamburg Ship Model Basin

HSVA Large Towing Tank

The main wavemaker is a duplex flap type (18 m wide) that is hydraulically driven. The facility is capable of producing not only standard waves but also computer-simulated wave patterns with selected spectra, wave groups, and the replication of recorded wave sequences.

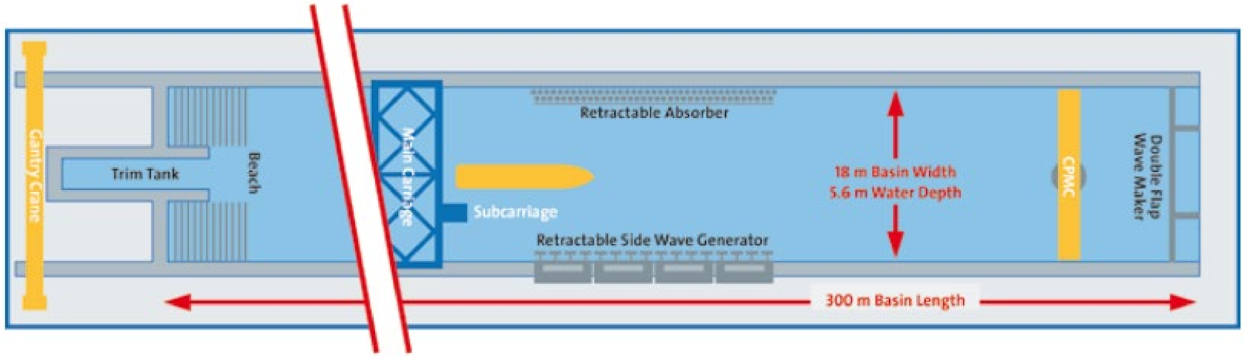

Figure A-2: Large towing tank schematic

Large Towing Tank Equipment

- Tests performed: Resistance, propulsion and tracking tests, horizontal planar motion testing (Towing and tracking, CPMC), flow observation (paint and underwater TV), wake measurements, propeller open water tests, seakeeping tests (in regular or irregular waves), measurement of forces and pressures acting on hulls or offshore structures, rolling tests, mooring tests, static submarine tests, non-steady submarine tests
- Side Wave Generator: A Snake-type wavemaker consisting of 80 flaps each of 0.5 m in width, for beam and oblique waves in the range from 20° to 160° wave direction. Regular waves, irregular long- and short-crested seas, wave packets, user-defined wave trains and spectra can be generated.

HSVA Arctic Environmental Test Basin

The facility boasts special features that enable the simulation of authentic Arctic conditions. It can generate propagating waves, currents, and wind to mimic the natural environment. Additionally, it has controlled lighting systems designed to promote optimal algae growth, creating a comprehensive setting for various types of marine research.

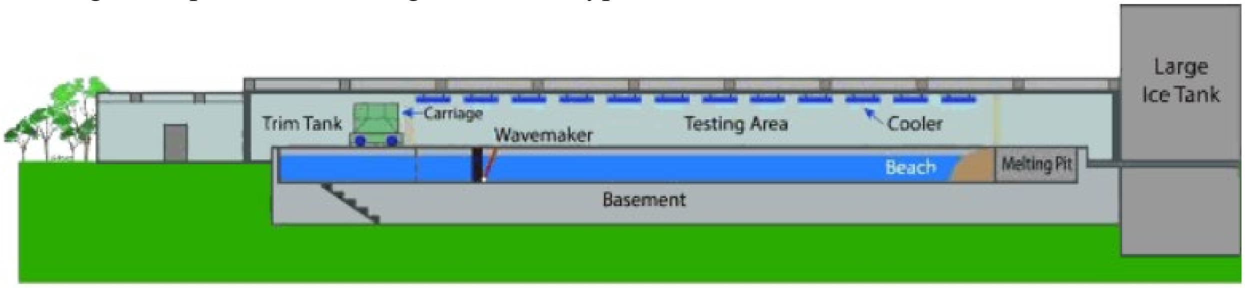

Figure A-3: Arctic environmental test basin - Side View

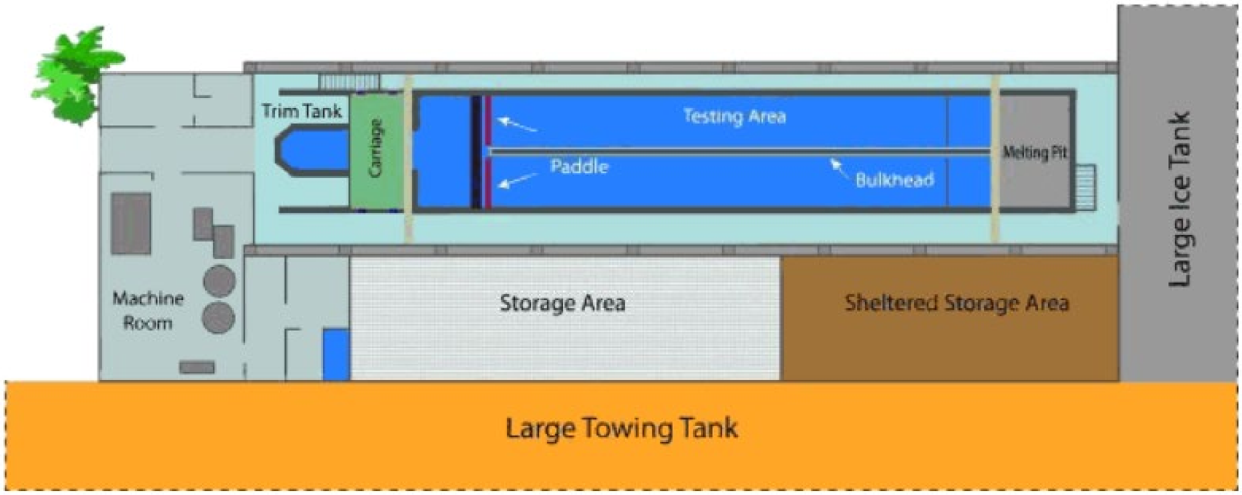

Figure A-4: Arctic environmental test basin - overhead view

The basin is equipped to facilitate a diverse array of research activities. These include examining the physical formation of ice, analyzing ice's microstructure, and investigating sedimentological processes. It's also used for studying how oil penetrates and disperses within ice, the biodegradation of oil-contaminated ice, and the natural weathering of oil. Additionally, the basin allows for the exploration of marine biological processes occurring in ice, sea ice ecology, the modeling of oil spill trajectories, and the development of strategies and methods to combat oil spills.

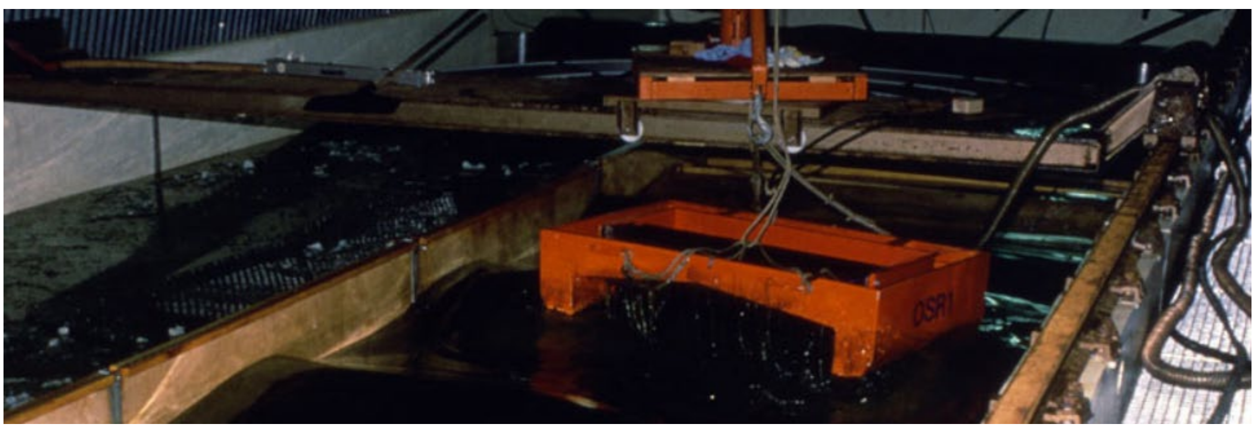

Figure A-5: Testing in arctic environmental test basin

The test basin was involved with the MORICE I & II projects involving mechanical oil recovery in ice (testing of lifting grated belt and various oil skimmers).

MORICE (Mechanical Oil Recovery in Ice Infested Waters) is a skimmer designed to recover oil spills in ice-infested waters. It encompassed a series of projects that were initiated in 1995 as a multinational effort between Norwegian, Canadian, American and German researchers. MORICE researchers initially developed ten concepts with the potential to recover oil in ice, and evaluated these concepts at laboratories in Trondheim, Norway and Hamburg, Germany in 1996. Between 1997 and 2001, researchers tested various configurations and prototype recovery systems in

Norway, Germany, and Alaska. Testing of the full-scale prototype and two internal recovery systems (the MORICE unit and the LORI brush skimmer) at Ohmsett in January 2002 was the culmination of five years of international research.

NRC in Canada

St. John's Facilities: Institute of Marine Dynamics

National Research Council Institute of Marine Dynamics 1 Arctic Avenue St. John's, Newfoundland and Labrador A1B 3T5

The testing facility is outfitted with an array of specialized equipment. This includes capacitance and sonic wave probes for detailed measurements, Qualisys optical tracking for precise movement analysis, and precision gimballed towing dynamometers for force measurements. Additionally, the facility utilizes inertial measurement systems and propulsion control systems tailored for free-running models. All these are complemented by high-definition video recording, which is synchronized with the digitally-recorded sensor data to ensure comprehensive monitoring and analysis.

Ottawa Facilities

National Research Council 1200 Montreal Road, Building M-58 Ottawa, Ontario K1A 0R6

Offshore Engineering Basin

Regular seas and long- and short-crested irregular seas up to 1 m in height are generated by 168 individually controlled and vertically adjustable wavemaker segments. Having wavemakers in an "L" configuration on two walls enables us to generate complex sea conditions that mimic real ocean environments, like multi-directional sea states. Wind generation is provided by an adjustable horizontal array of 12 analog controller fans.

Multidirectional Wave Basin

The wave generator can be raised or lowered to accommodate a wide range of water depths and the wave boards can be operated in piston, flapper, or combination mode to suit various water depths and wave conditions. The wave generator control system includes active wave absorption so that incident wave energy reflected from a model structure can be absorbed without being re-reflected. Efficient passive wave absorbers are installed around the perimeter of the basin to control unwanted wave reflections, enhancing the quality and realism of the simulated sea states. Optional solid walls can be installed along the east and west sides of the basin to improve the quality of the long-crested wave fields. Local wind fields can be simulated using a bank of computer-controlled fans. Local currents can be generated in two directions by forcing water flow through a set of four tunnels located below the central part of the basin floor. The currents and winds can be generated independently or in combination with waves.

Ohmsett Facility (New Jersey)

Ohmsett Facility NWS Earle Waterfront 801 State Route 36, Building R-24 Leonardo, NJ 07737

Ohmsett is well-equipped to perform advancing skimmer tests, offering ample deck space for hardware setup. It has sufficient tank capacity for storing recovered fluids and provides flexible towing connections that are readily adjustable. The facility allows for test durations of 300 seconds at 1 knot, and 46 seconds at 6.5 knots. The fluid handling system can accommodate various types of crude and refined oils, with the ability to simulate weathering and emulsification processes. It also has the capability to perform on-site analytical testing.

Figure A-6: Deck area as working platform at Ohmsett, and the Auxiliary Bridge

Appendix B: ERSP related data

Table B-1 ERSP US measurement test duration

Starting speed (kt)	Travel distance (ft)	Test distance (ft)	
0.25	100.0	450.0	
TEST DURATION			
Advancing Speed (kts)	**Time to travel 100 ft (seconds)**	**Total Test Time (assume 450 ft) (seconds)**	**Total Test Time (assume 450 ft) (minutes)**
0.25	237.0	1066.5	17.8
0.50	118.5	533.2	8.9
0.75	79.0	355.5	5.9
1.00	59.2	266.6	4.4
1.25	47.4	213.3	3.6
1.50	39.5	177.7	3.0
1.75	33.9	152.4	2.5
2.00	29.6	133.3	2.2
2.25	26.3	118.5	2.0
2.50	23.7	106.6	1.8
2.75	21.5	97.0	1.6
3.00	19.7	88.9	1.5
3.25	18.2	82.0	1.4
3.50	16.9	76.2	1.3
3.75	15.8	71.1	1.2
4.00	14.8	66.7	1.1

Table B-2 ERSP US measurement encounter rates

Input Slick Thickness (inch)											
0.10											
ENCOUNTER RATES/ Distribution Rates GPM											
Advancing Speed (kts)	**Swath (feet)**										
	10	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**
0.25	16	24	32	40	47	55	63	71	79	87	95
0.50	32	47	63	79	95	111	126	142	158	174	190
0.75	47	71	95	119	142	166	190	213	237	261	284
1.00	63	95	126	158	190	221	253	284	316	348	379
1.25	79	119	158	198	237	277	316	356	395	435	474
1.50	95	142	190	237	284	332	379	427	474	521	569
1.75	111	166	221	277	332	387	442	498	553	608	664
2.00	126	190	253	316	379	442	506	569	632	695	758
2.25	142	213	284	356	427	498	569	640	711	782	853
2.50	158	237	316	395	474	553	632	711	790	869	948
2.75	174	261	348	435	521	608	695	782	869	956	1043
3.00	190	284	379	474	569	664	758	853	948	1043	1138
3.25	205	308	411	514	616	719	822	924	1027	1130	1233
3.50	221	332	442	553	664	774	885	995	1106	1217	1327
3.75	237	356	474	593	711	830	948	1067	1185	1304	1422
4.00	253	379	506	632	758	885	1011	1138	1264	1391	1517

Table B-3 ERSP metric measurement test duration

Starting speed (m/s)	Travel distance (m)	Test distance (m)	
0.1	30.0	100.0	
TEST DURATION			
Advancing Speed (m/s)	Time to travel 30 m (seconds)	Total Test Time (assume 100 m) (seconds)	Total Test Time (assume 100 m) (minutes)
0.1	300.0	1000.0	16.7
0.2	150.0	500.0	8.3
0.3	100.0	333.3	5.6
0.4	75.0	250.0	4.2
0.5	60.0	200.0	3.3
0.6	50.0	166.7	2.8
0.7	42.9	142.9	2.4
0.8	37.5	125.0	2.1
0.9	33.3	111.1	1.9
1	30.0	100.0	1.7
1.1	27.3	90.9	1.5
1.2	25.0	83.3	1.4
1.3	23.1	76.9	1.3
1.4	21.4	71.4	1.2
1.5	20.0	66.7	1.1
1.6	18.8	62.5	1.0
1.7	17.6	58.8	1.0
1.8	16.7	55.6	0.9
1.9	15.8	52.6	0.9
2.0	15.0	50.0	0.8

Table B-4 ERSP metric measurement distribution rates

Input Slick Thickness (mm)											
2.5											
ENCOUNTER RATES/ Distribution Rates m³/hr											
Advancing Speed (m/s)	Swath (metres)										
	1	3	6	9	12	15	18	21	24	27	30
0.1	1	3	5	8	11	14	16	19	22	25	27
0.2	2	5	11	16	22	27	33	38	44	49	55
0.3	3	8	16	25	33	41	49	58	66	74	82
0.4	4	11	22	33	44	55	66	77	88	99	110
0.5	5	14	27	41	55	69	82	96	110	123	137
0.6	5	16	33	49	66	82	99	115	132	148	165
0.7	6	19	38	58	77	96	115	134	154	173	192
0.8	7	22	44	66	88	110	132	154	176	198	219
0.9	8	25	49	74	99	123	148	173	198	222	247
1	9	27	55	82	110	137	165	192	219	247	274
1.1	10	30	60	91	121	151	181	211	241	272	302
1.2	11	33	66	99	132	165	198	230	263	296	329
1.3	12	36	71	107	143	178	214	250	285	321	357
1.4	13	38	77	115	154	192	230	269	307	346	384
1.5	14	41	82	123	165	206	247	288	329	370	411
1.6	15	44	88	132	176	219	263	307	351	395	439
1.7	16	47	93	140	187	233	280	326	373	420	466
1.8	16	49	99	148	198	247	296	346	395	444	494
1.9	17	52	104	156	208	261	313	365	417	469	521
2.0	18	55	110	165	219	274	329	384	439	494	549

Appendix C: Advancing Skimming System Test Protocol

1. Scope

1.1 This test method defines a procedure and the measurement criteria to quantify the performance of an advancing skimming system for use in oil spill response.

1.2 This test method is designed to provide data that can be used as inputs to the Estimated Recovery System Potential (ERSP) calculator, a planning tool that estimates the performance of an advancing skimming system for each of the first three days following the instantaneous discharge of a batch oil spill, or daily for an ongoing continuous discharge of oil.

1.3 This test method includes the option of testing in waves if the device is intended for nearshore or offshore conditions, and the user wants to use values for throughput efficiency that are greater than the default values in the ERSP calculator.

1.4 It is accepted that the measured fluid recovery rate, throughput efficiency, and recovery efficiency, as determined by this test method may be higher than what is typically achievable under actual conditions of a spill. However, the results are intended to provide a reasonable estimate of skimmer performance in the conditions simulated in the ERSP calculator.

1.5 This test method involves the use of test oils that may be considered hazardous materials. It is the responsibility of the user of this test method to procure and abide by necessary permits, regulations, safety and health considerations for the use and disposal of test oil.

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

1.7 This standard does not purport to address all 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:

INTERFACIAL TENSION	
D971-20	Standard Test Method for Interfacial Tension of Insulating Liquids Against Water by the Ring Method
DENSITY	
D1298-12b(2017)	Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
D5002-22	Standard Test Method for Density, Relative Density, and API Gravity of Crude Oils by Digital Density Analyzer
D4052-22	Standard Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter
D7777-13 (2018)	Standard Test Method for Density, Relative Density, or API Gravity of Liquid Petroleum by Portable Digital Density Meter
VISCOSITY	
D7042-21a	Standard Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)
D2983-22	Standard Test Method for Low-Temperature Viscosity of Automatic Transmission Fluids, Hydraulic Fluids, and Lubricants using a Rotational Viscometer
WATER AND SEDIMENT	
D4007-22	Standard Test Method for Water and Sediment in Crude Oil by the Centrifuge Method (Laboratory Procedure)
D1796-22	Standard Test Method for Water and Sediment in Fuel Oils by the Centrifuge Method (Laboratory Procedure)
SKIMMER PERFORMANCE	
F631-15(2020)	Standard Guide for Collecting Skimmer Performance Data in Controlled Environments
F2709-19	Standard Test Method for Determining a Measured Nameplate Recovery Rate of Stationary Oil Skimmer Systems

2.2 Other Documents

Effective Daily Recovery Capacity (EDRC) planning tool (aka ERSP calculator). BSEE. ERSP User Manual (The “Estimated Recovery System Potential (ERSP) Calculator” can be found at: https://www.bsee.gov/what-we-do/oil-spill-preparedness/response-system-planning-calculators

Buist, I, J.McCourt, S.Potter, W.Schmidt, D.Devitis, R. Smith 1999. Ohmsett tests to determine optimum times to decant temporary storage devices. In Proc. Arctic Marine Oilspill Technical Seminar. Environment Canada. Ottawa.

3. Terminology

3.1 advancing skimming system – a system operating in advancing mode (at a speed of advance of 0.4 m/s or greater) to recover oil spilled on the water surface. The system may include containment boom used to collect oil and direct it to the skimmer. Note: other Ancillary equipment, such as onboard storage, discharge pumps used for decanting or to transfer recovered product, secondary storage, and support vessels, are not tested as part of this protocol.

3.2 speed of advance (SOA) - the forward speed of the system (m/s)

3.3 sweep width (aka swath)—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. (F818)

3.4 oil slick encounter rate - the volume of oil slick per unit time actively encountered by the skimmer, and therefore available for recovery (m^3/h) (F631)

3.5 throughput efficiency (TE) – the ratio, expressed as a percentage, of the volume of oil recovered to the volume of oil encountered. (F631)

3.6 recovery efficiency (RE) - the ratio, expressed as a percentage, of the volume of oil recovered to the volume of total fluids recovered. (F2709)

3.7 oil recovery rate - the volume of oil recovered by the device per unit of time (m^3/h). (F631)

3.8 fluid recovery rate – the volume of fluid recovered by the device per unit of time (m^3/h). (F631)

3.9 wave height (significant wave height) - the average height, measured crest to trough, of the one-third highest waves, considering only short-period waves (that is, period less than 10 s), (m). (F625)

3.10 Level 1 – test parameters based on the ERSP calculator spill scenario, which specifies an encounter rate based on a 2.5 mm (0.1 inch) slick thickness.

3.11 Level 2 – alternative test parameters to Level 1, which could include thinner or thicker slicks.

3.12 Steady state collection period – timed period of test for measuring recovery rates (ORR and FRR), with skimmer operating at steady collection rate and speed of advancement (s).

3.13 Test duration – length of time from beginning of a test (including getting system up to target speed of advancement and initial operation of collection and recovery equipment to purge any residual fluid from previous tests in the system and recovery hoses), running at steady state conditions, final recovery, and repositioning of equipment back to the starting position (if necessary).

3.14 Untimed portion of test – final portion of a test following the steady-state collection period where oil that was deposited in front of the skimming system is collected for throughput efficiency calculations.

4 Significance and Use

4.1 Current industry practice has been to claim the capacity of a skimmer based on the throughput of the discharge pump (which is typically measured using water as a test fluid) and then applying a de-rating factor to account for various inefficiencies.

4.2 Existing test protocols (e.g., F631, F2709) measure stationary or possibly slowly advancing skimmers. This test method will assist spill response equipment manufacturers and users to verify and accurately report skimming system performance for advancing skimmer systems operating at 0.4 m/s (~0.75 kt) or greater.

4.3 The Bureau of Safety and Environmental Enforcement (BSEE) recently developed a new planning tool - known as the Estimated Recovery System Potential (ERSP) calculator - to better estimate the performance of an advancing skimming system as it encounters, contains, recovers, stores, and offloads its recovered fluids to secondary storage. A test method was required to provide data for this calculator for users that wish to use values that are different from the default settings.

4.4 The ERSP calculator requires inputs specific to the skimming system including its speed of advance, its sweep width (which is used to calculate the oil encounter rate), maximum total fluid recovery rate, throughput efficiency, and recovery efficiency. This test method is designed to simulate the system’s speed of advance and oil encounter rate to provide data on the skimmer’s maximum total fluid recovery rate, throughput efficiency, and recovery efficiency.

4.5 This test method encourages performance testing using one or more oil types for comparison purposes.

4.6 Tests shall be conducted under well-documented conditions and generate repeatable results. Alternative test methods for collection of skimmer performance are covered under existing standards (for example, F631).

4.7 For skimming systems that include more than one option for the discharge pump, the test described in this test method may be used to measure the performance of the skimming component of the system. Performance of the pumping component can be measured independently using the same viscosity of oil and the discharge head conditions noted in this test method. The measured recovery rate of any specified skimming component and pump combination would be the lesser of the skimming component and the pump capacity.

5 Oil type and properties

5.1 Test oils for use with this guide should be selected to fall within the parameters specified in Table X.1.1 (from F631), specifically: viscosity, interfacial and surface tension, and specific gravity (these oils may be crude, refined, or simulated).

	Viscosity mm2/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
m[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	

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

[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.

5.2 If crude oil is used, it should be weathered to reduce hazardous vapors, more accurately simulate the conditions likely to be found in an actual spill response, and minimize subsequent property changes, specifically density and viscosity. The intent is to use an oil that is moderately weathered, which resembles conditions in the first few days after a large spill.

5.3 The ERSP calculator estimates the potential for system performance for the first three days of a spill. However, it does not consider how emulsification of the oil may affect a skimming system's performance, and testing of recovery of emulsions is not required. Emulsification of oil that occurs as the skimming system recovers oil during these tests is measured.

5.4 The ERSP calculator does not differentiate outputs based on the type of oil or product being recovered. Its design assumptions most closely approximate the spreading and emulsion characteristics of categories II, III, and IV oils. It is a less accurate predictor of non-persistent category I oils such as gasoline or diesel fuel. Therefore, it is recommended that testing be done with category II oil from Table X.1.1 as it most closely mimics a moderately weathered crude oil and is readily available in appropriate quantities. Exceptions to this recommendation are for those skimmers specifically designed for a particular oil type. Equipment manufacturer's guidance should be followed in this instance.

5.5 Regular measurements of the test oil physical properties may be needed throughout the tests to ensure they fall within specifications. If the properties of the test oils vary significantly from the recommended ranges, the test report shall discuss the implications of such deviations on the performance of the device.

5.6 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. In these situations, the oil will usually quickly reach the surface water temperature of the tank.

5.7 If oils that originally meet the conditions stated in Table X.1.1 are reused in subsequent tests, their properties may change and should be evaluated prior to reuse.

6 Oil slick thickness and distribution

6.1 Level 1 (minimum required slick thickness)

6.1.1 The default slick thickness assigned for Day 1 of a spill response in the ERSP Calculator (Level 1) is 2.5 mm (0.0025 m).

6.1.2 The test shall be designed to place the skimmer or collection well of the system in a similar operating condition to what is expected when deployed in the field.

6.1.3 The volumetric rate of oil that is distributed in front of the advancing skimmer system is calculated by applying a formula of:

$$V_R = W * SOA * t * 3600 \text{ s/h}$$

Where V_R is the volumetric rate of oil in m^3/h
W is the sweep width (m)
SOA is the Speed of Advance in (m/s)
t is the slick thickness in (m) (0.0025 m is specified)

6.1.4 The oil should be distributed in front of the advancing skimming system across as much of the sweep width as possible.

6.1.5 It is possible that the skimmer may not be capable of recovering the calculated volumetric rate of oil. In this case the oil encounter rate should be reduced to match the recovery rate of the skimmer being tested. This may be accomplished by reducing the Speed of Advance (but not below 0.4 m/s) or by reducing the sweep width. The slick thickness shall be kept to 2.5 mm for Level 1 testing.

6.1.6 The volumetric rate may be adjusted to reflect expected oil entrainment (losses) if data is available. For example, if the guide boom is predicted to capture 80% of the oil encountered at the entry to the skimming swath, then V_R should be reduced by 20%.

6.1.7 If the fielded (operational) sweep width exceeds the width of the testing facility, guide boom should be deployed at the angle normally found in full-scale deployment and V_R should be calculated using the fielded (operational) swath.

6.2 Level 2 (optional alternative slick thickness testing)

6.2.1 Additional testing may be performed at slick thicknesses other than Level 1 conditions. These tests are optional and may be performed at the manufacturer's discretion. For example, the manufacturer may wish to test the skimmer at a volumetric rate greater than the Level 1 slick thickness, for example to investigate higher or maximum ORR. Similarly, slick thicknesses less than 2.5 mm may be conducted to investigate skimmer performance later in a spill response or at smaller spills. In no case shall tests be performed at a speed of advance of less than 0.4 m/s (0.75 knots).

6.2.2 It will be up to the test operators to design the booming and towing system to provide the desired slick thickness at the intended towing speeds. If feasible, additional testing may be conducted to determine the maximum effective speed/slick thickness condition that the skimmer may achieve.

6.3 The oil should be dispensed such that it creates a quiescent slick in front of the skimmer. Discharging in a downward biased stream should be avoided to minimize plunging that may lead to premature entrainment under the collection system

6.4 The way in which the oil is dispensed shall mimic how the skimmer will encounter the oil. For example, if the guide booms and skimmer are tested as a system, the oil should be dispensed at the mouth of the boom spanning the entire opening.

6.5 The "Estimated Recovery System Potential (ERSP) Calculator" can be found at: https://www.bsee.gov/what-we-do/oil-spill-preparedness/response-system-planning-calculators

7 Speed of advance

7.1 The system should be tested at its designed or manufacturer-recommended operational speed for field recovery operations.

7.2 The system can be tested at additional speeds for comparative purposes, at the discretion of the test operator.

7.3 If recommended operational speeds are unknown, the test matrix should employ incremental speeds starting at a nominal rate 0.4 m/s (~0.75 knots) and continue until detrimental effects are observed or quantitatively confirmed.

7.4 A minimum speed of 0.4 m/s (~0.75 knots) should be respected, to differentiate between stationary skimmers operated in a slowly advancing mode.

8 Test runs and data collectdion

8.1 A test run consists of three stages: i) preliminary stage where the advancing skimmer system is brought up to target speed of advance and fluid recovery rate, ii) steady-state collection stage where performance data is collected, and iii) reset stage where advancing skimmer system is returned to initial conditions.

8.2 Steady-state conditions are necessary to generate accurate and repeatable results.

8.3 Sufficient time at the beginning of a test must pass to allow for the system hold-up (volume of hoses and internal wetted components of skimming system) to be purged prior to steady-state measurements of recovered fluid flow and its composition (free/entrained water, emulsified oil/oil, emulsion water content).

8.3.1 This could be accomplished experimentally, for example by measuring the elapsed time between when the empty system first encounters oil until it begins discharging to the recovery tank, or by flushing the advancing skimmer system and recovery hoses with water at the end of a run.

8.4 Test duration should encompass the collection of data once steady-state conditions are achieved and maintained. While a suggested (minimum) period of 30 seconds should provide ample time for the collection of fluid for this purpose, alternative timeframes may be used as long as steady-state conditions are maintained and alternative duration tests do not bias the results.

8.5 Multiple performance measurements (i.e., fluid recovery rate, oil recovery rate, recovery efficiency) may be incorporated into a single transit, where discharge is redirected into separate containers. These may be analyzed for flow rate and composition independently as individual runs to help generate run statistics. However, only one measurement of throughput efficiency is likely possible for a given test run.

9 Measurement of recovered fluids

9.1 Selected properties of the test oil (that may vary throughout the day due to environmental effects) should be measured at the beginning of each run. Initial oil used in a run should be sampled and its water content, viscosity at an identified shear rate ($10s^{-1}$, $100s^{-1}$, or other), and density determined at both at a standard temperature (15°C) and the actual run temperature. This allows for a better profile of properties versus temperature so that comparisons can be made with other runs that may happen at different temperatures, and it allows for direct monitoring of the test oil to determining if excessive weathering (increase in density) is taking place.

9.2 Measure volumetric fluid recovery rate by diverting recovered fluid from a slop tank to a calibrated vessel for a timed period. Depending on the available storage space and the recovery rate of the skimmer, more than one vessel may be needed.

9.3 The measurement of throughput efficiency requires that the skimmer be given the opportunity to recover all oil that it encounters. For systems that have internal processing (for example an internal recovery well or settling tank) the measurement of the throughput efficiency may extend beyond the timed portion of the test. The method for measuring throughput efficiency should account for skimmer variations and should be fully detailed in the test report for clarity.

9.4 It will be up to the test director to estimate the throughput efficiency considering such factors as oil remaining on the surface, hold up volumes within the device, and hold up volumes within the transfer hose versus at the start of the test. Clearly this will not be a precise amount but should be within the acceptable error bounds.

9.5 It is suggested that any residual oil in the skimmer and recovery hoses be purged with water between each test to allow for easy visual determination that fluid hold-up is expelled in a subsequent test run. This will reduce the errors in Throughput Efficiency measurement.

9.6 Cubic metres (alternatively litres if volumes are small) should be used for oil quantity recovered, and m^3/h (alternatively L/h) should be used for oil slick recovery rate.

9.7 Once fluid is recovered and a specified wait period has occurred (see below: Account for emulsification), free/entrained water should be determined.

9.8 The effects of uncontrolled parameters that could affect oil movement on the tank (e.g., winds, solar heating, wave reflections, currents) should be minimized where possible, and documented during the tests.

10 Accounting for emulsification during the test

10.1 Oil used in a test is sampled and any initial water content must be determined. This is especially important if oil is recycled during testing. Emulsions in samples can be broken using heat or chemical means (addition of emulsion breaker). Care must be taken if using emulsion-breaking chemicals in terms of affecting important oil properties if the oil is being re-used.

10.2 Once fluid from a test is recovered in a calibrated vessel, a wait period of 30 minutes should occur to allow for initial separation of free/entrained water. (If the recovered fluid has emulsified, or if the parent oil is sufficiently viscous, free/entrained water may not readily separate). Decanting free water should be conducted from the bottom of the vessel. Remaining fluid should be sampled to determine its overall oil and water composition.

10.3 A minimum wait period referenced above should be 30 minutes for type I and II oils, increasing to 60 minutes for Type III and beyond, (ref: Buist et al. 1999)

11 Observations During the Test

11.1 High-quality video should be recorded showing the entire test area from an elevated perspective. This can allow for a review of conditions and events that lead up to a possible failure mode, such as entrainment or splash-over.

11.2 Multiple perspectives including underwater cameras is suggested. Observations can include sea-keeping, changes in draft (hydrodynamics), wave conformance, and the behavior of oil immediately in front of the skimmer at test speed and as the speed varies.

11.3 Additional criteria include the monitoring and documentation of environmental conditions during the test.

12 Use of a Portion of the Tank

12.1 Generally, testing should be done with systems at full-scale, or as close to it as possible; however, if systems do not need the entire area of a tank it would be acceptable to use only a portion. This may mean not using the entire length of the tank (i.e., shorter runs) or not using the entire width.

12.2 Any barriers used to restrict oil movement in the tank should not interfere with the operation of the skimmer.

12.3 Due to the difficulty in obtaining representative hydrodynamic conditions, testing with currents to produce water motion relative to the skimmer should be discouraged, as opposed to actually moving the skimmer through the water.

13 Waves

13.1 Users who wish to claim a throughput efficiency value in the ERSP calculator greater than the default value of 75% for a nearshore or offshore system should provide supporting data obtained through testing in wave conditions.

13.2 The ERSP assumes that ambient conditions for the recovery scenario are generally conducive to skimming operations and specifies default values for Throughput and Recovery Efficiencies. Higher values are allowed if they are based on results from tests using ASTM F631; however, ASTM F631 is designed for stationary skimmer operation and is not applicable to advancing skimmers. The results from testing in waves may be useful to vendors, developers, operators.

13.3 It is desirable to test in calm conditions, and with waves for any skimmer intended to be used in anything but harbor or nearshore conditions. The wave characteristics should be appropriate for the design and size of the skimmer and the intended operating environment, and may include more than one set of conditions.

13.4 Wave-making capabilities are likely to be significantly different between facilities and may limit the achievable test conditions. This standard does not prescribe wave conditions to be modeled, but rather requires that wave conditions during the test be recorded, analysed, and reported. At a minimum, measurements that should be reported are wave height and period for regular waves; significant wave height, peak period, and spectral coefficients for random waves.

Furthermore, it is suggested that when testing in waves, the motions of the recovery system be measured and recorded, especially surge, pitch, and heave of the vessel, and vertical accelerations at the mouth of the skimming device.

13.5 Recommended wave heights are consistent with F631 and include wave heights of 0, 0.15 m, and 0.45 m. F631 does not specify a period for these waves. A period between 2.5 and 3 s is recommended.

Note: It is acknowledged that the preferred orientation for skimmer operation in the field is in the same direction as the waves (and wind). However, to our knowledge, no test facilities are currently available to test in this manner at speeds above 0.4 m/s. We recommend this as a research topic for facility improvement.

14 Equipment Failure

14.1 Equipment failure during testing may invalidate the results of the run.

14.2 If the equipment can be repaired in an expeditious manner, the test can be repeated. The nature of the failure should be documented.

14.3 The test operator should consult with the manufacturer to develop a critical spare parts list.

15 Report

15.1 Prepare a schematic diagram of the layout for the test series including travel distance for the runs.

15.2 Provide a detailed description of the skimmer system as tested.

15.3 Prepare a data table for the test run containing the following:

a. Test identification number
b. Date and run start time
c. Test oil type, initial water content (emulsified), initial density at standard temperature (15°C) and test temperature, initial viscosity at standard temperature (15°C) and test temperature, surface tension and interfacial tension with tank water (15°C) and test temperature.
d. Ambient conditions
    i. Air temperature (°C)
    ii. Water temperature near surface (°C)
    iii. Wind speed (m/s)
    iv. Wind direction (relative to test device) (NSEW, °)
    v. General weather conditions (sunny, cloudy, overcast, foggy, misting, drizzling, raining)
e. Average tow speed and direction in m/s (or knots) (averaged over data collection period)
f. Target oil slick thickness: target thickness across sweep width.
g. Oil distribution rate: derived from the targete oil slick thickness, sweep width, and target tow speed.
h. Wave profile (if active): for regular waves – identify significant height (average crest to trough of the 1/3 highest waves), average period, and whether head or following. For irregular waves, include significant height, significant frequency, and spectral characteristics, and whether head or following. Primary and secondary (reflected) wave basin characteristics shall be described.

15.4 Prepare a table of observations collected during the test run including:

a. sea keeping,
b. changes in draft (hydrodynamics)
c. containment failure mode
d. Wave conformance
e. Behavior of oil in the (containment pocket/immediately in front of the skimmer) at test speed, and as speed varies.

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

a. Total volume of oil distributed during data collection period.
    i. Average oil distribution rate (m^3/h) during data collection period.
b. Total volume of oil encountered during data collection period.
    i. Average oil encounter rate (m^3/h) during data collection period.
c. Average encountered slick thickness. The average oil distribution rate into the collection area divided by the sweep width of the run, or by direct sensors in or above the water column.
d. Total volume of fluid (oil/water) recovered during data collection period.
    i. Average fluid recovery rate (m^3/h) (consisting of oil and water)
    ii. Average water content of recovered fluid (free water)
    iii. Average oil slick recovery efficiency
    iv. Average oil slick recovery rate (m^3/h) (fluid less recovered free water, and emulsified water concentration in excess of the starting water-in-oil emulsion concentration that was initially distributed in the test area)
    v. Properties of recovered oil
        1. water content (emulsified),
        2. emulsion stability – measure sample water content at beginning/ (being deposited in front of system during test / and end of test. (after 1 hour separation time allocation).
    vi. Average emulsification factor
    vii. Average throughput efficiency
e. Length of data collection period
f. Volume of oil in skimming device at beginning of data collection period.
g. Volume of oil in skimming device at end of data collection period.
h. Recovery tank volume at beginning of collection period.
i. Recovery tank volume at end of collection period.
j. Operating parameters for the device such as belt or disc speed, weir setting, pump speed, power pack capacity, discharge hose size and length, etc.
k. Brief discussion of interferences or limiting factors such as wall effects of the tank.
l. Any additional qualitative observations related to equipment performance.

Appendix D: Advancing Skimming System Datasheets

I. Test ID

Test ID:	Date:	Test Director:
Run start time:	Run end time:	Operator:

II. Test Oil Properties

Test oil:	Initial water content (%):
Initial density (15°C, g/mL):	Test density (test temperature, g/mL):
Initial viscosity (15°C, $10s^{-1}/100s^{-1}$, cP):	Test viscosity (test temperature, $10s^{-1}/100s^{-1}$, cP):

III. Environment (Temperature/Precipitation/Wind)

Air temperature (°C):	Condition (Sunny/Partial Cloud/Cloudy/Overcast/Foggy)	
Precipitation: n/a or (Mist/Drizzle/Rain/Sleet/Snow)	Average wind speed:	Wind direction (NSEW, °):

IV. Test Set-up

Average tow speed target (m/s or knots):	Tow direction (NSEW, °):	Water temperature near surface (°C):

V. Oil Distribution

Target slick thickness (mm):	Swath width (m):	Target oil distribution rate (m^3/h): (Tow Speed*Slick Thickness*Swath width)

VI. Wave Profile (optional)

Regular waves		
Significant height (cm): Average crest to trough for 1/3 highest	Average period (s):	Wave direction (NSEW)
Irregular waves		
Significant height (cm):	Significant period (s):	Spectral characteristics:

VII. Observations

a) sea keeping:	b) changes in draft (hydrodynamics):
c) behavior of oil in pocket at test speed:	d) wave conformance:
e) containment failure mode:	f) other:

VIII. Test Layout Sketch

Major equipment pieces – locations (birds eye-view)

IX. Results

Oil applied	
Total volume oil distributed during data collection (m^3):	Average oil distribution rate during data collection (m^3/h):
Total volume oil encountered during data collection (m^3):	Average oil encounter rate during data collection (m^3/h):
Average encountered slick thickness (mm):	
Fluid recovered	
Recovered fluid test temperature (°C):	Duration of data collection (mm:ss)
Total volume fluid recovered during data collection (m^3):	Average fluid recovery rate (m^3/h):
Average water content of recovered fluid (free water) (as % of recovered fluid):	Average oil slick recovery efficiency

IX. Results continued

Fluid recovered (after decant break)	
Average oil slick recovery rate (m^3/h):	Water content of recovered oil (emulsion) (%):
Emulsion stability (water content of oil at start test versus recovered oil water content after 1 h settling). $Initial_{H2O}$ (%): $Final_{H2O}$ (%):	Average emulsification factor (calculation) AEF = $(final_{H20} – initial_{H2O})/initial_{H20} + 1$
Average throughput efficiency (%):	

Emulsification factor - 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.

$EF = (WC_f – WC_0) / (WC_0) + 1$ where: EF is the emulsification factor WC_f = the final water content (%) WC_0 = the initial water content (%)	Example: WC_f = 15% WC_0 = 10% EF = (15-10)/(10) + 1 = 5/10 + 1= EF = 1.5 In this instance, water increased by a factor of 1.5

Volume of oil in skimming device at beginning of data collection period (m^3 or L):	Volume of oil in skimming device at end of data collection period (m^3 or L):
Recovery tank volume at beginning of data collection period (m^3 or L):	Recovery tank volume at end of data collection period (m^3 or L):

X. Operating Parameters

Skimming system	
Belt/Disc speed or weir setting:	Pump speed:
Power pack capacity:	Power pack capacity (or same):
Discharge hose size (diameter):	Discharge hose length:

XI. Additional Factors

Interferences:
Additional observations:

Appendix E: Protocol Evaluation at Ohmsett

A number of items were identified that would help in the use of the Advancing Skimming Systems Testing Protocol at Ohmsett. The compiled comments have been forwarded to the ASTM F20.12 subcommittee for consideration in updating the protocol.

Analysis Comments

1. Suggested improvement of analysis turn-around time: Method of water in oil measurement (entrained water/weak emulsion) – attempt to use chemical emulsion breaker (alcopol/DriMax) plus heat (50°C water bath) for samples in a standard 40mL cylindrical clear glass sample vial. Fill vial to a level just below the "shoulder" near the top. Measure the height of the water (typically at the bottom) vs the total height of the liquid(s). *This method can allow a tech to measure multiple samples quickly. This can be accomplished with a digital caliper, to the nearest 1/10 of a mm. Typical working height ~70-75mm. This will provide a rough estimate in a sub 1% range (0.13%-0.14% for each 0.1mm). Water content to nearest 0.5% should suffice at this scale. We are dealing with accuracy vs. precision. How accurate (representative) is the oil sample being pulled from the holding tank?*

General Testing Comments

2. Perform an initial run with the boom moderately loaded with oil (50-60 gallons used) with staggered speeds: 0.6, 0.8, 1.0, 1.2, 1.4… for 10 seconds (interval) with skimming system in place but not recovering oil. This will provide a useful view of the hydrodynamics of the skimming system with oil and, possibly identify the likely initial mode of failure at the critical towing speed, and help narrow the number of subsequent runs to test near the point of failure. *Possible suggested add-on: does not affect the function of the actual protocol but would trigger a non-editorial protocol change.*
3. Method of oil application – pipe with holes vs. pipe with slots (particularly for more viscous oils). Use of a spill plate or diffuser to reduce/eliminate the projection of oil in a lateral or plunging mode which can trigger early entrainment failure. Oil should be deployed in a wide enough swath to test the entire encounter width of the skimming system (delivery system as tested delivered oil pretty much to the front of the skimmer, bypassing the side containment booms). *This level of detail is beyond the protocol, but can help Ohmsett/others in setting up testing.*
4. Oil being used should be sampled for water content for **each test run** (feed oil and collected oil). If oil is being recycled, water content may drift over time as water droplets coalesce and drop out any weak emulsion or entrainment. Section 9.1 states "Initial oil used in a run should be sampled and its **water content**, viscosity at an identified shear rate (10s-1, 100s-1, or other), and density determined at both at a standard temperature (15°C) and the actual run temperature." Section 9.6 deals with recovered fluid property measurements. Perhaps rewording to: "Initial oil should be sampled for each test run and analysed for water content, viscosity at an identified shear rate (10s-1, 100s-1, or other),

and density determined at both at a standard temperature (15°C) and the actual run temperature."

5. Measuring the oil temperature at the surface of the water once the slick is deposited may be suggested to determine if the oil temperature changes over time. *Initial oil temperature, water temperature, and possibly collected fluid temperature are identified in the protocol. Initial oil temperature can be measured in the holding tank, the test tank water temperature can be measured with a probe, and the collected fluid temperature can be measured during sampling negating the need to directly measure the slick in-situ. NOTE: slick temperature is only an issue if oil is deposited for a length of time that allows solar radiation to appreciably increase the slick temperature. Testing at a facility that can deposit a slick in front of the collection boom as the skimming system collects the slick should minimize the time the slick is on the water surface and subsequently reduces the possibility of the oil changing properties due to temperature increase from solar radiation impacts.*
6. Recommended wave conditions (i.e., 0.15 m, 0.45 m heights and 2.5 to 3 s period) were appropriate for the system tested. *These settings provided appropriate movement of the skimming system and enabled observations of system response to waves.*
7. Recommend flushing the skimmer sump and recovery hoses with water after each test. *This was helpful to provide a clear indication of when recovered oil reached the recovery tanks for the subsequent run. This should at least be a recommended practice.*
8. It is desirable to have an experienced operator running the skimmer, and having the same operator for all tests. *This can help speed up problem solving if equipment issues arise. Having the same operator potentially eliminates an extra variable when comparisons are being made between runs.*
9. It may be helpful to see inside the skimmer during operation, to observe how full the sump is, how coated the brushes are, etc. *This can help optimize the settings for recovery operations as well as during troubleshooting when problems arise. This, of course, will be highly dependent upon the equipment design.*
10. Dry runs/practice runs were necessary for all participants to understand roles. *There are many tasks that occur during a test run and many participants work at more than one task. Practice run(s) help train operators to perform their roles and reduces the risk of operational errors.*

Department of the Interior (DOI)
The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

Bureau of Safety and Environmental Enforcement (BSEE)
The mission of the Bureau of Safety and Environmental Enforcement works to promote safety, protect the environment, and conserve resources offshore through vigorous regulatory oversight and enforcement.

BSEE Oil Spill Preparedness Program
BSEE administers a robust Oil Spill Preparedness Program through its Oil Spill Preparedness Division (OSPD) to ensure owners and operators of offshore facilities are ready to mitigate and respond to substantial threats of actual oil spills that may result from their activities. The Program draws its mandate and purpose from the Federal Water Pollution Control Act of October 18, 1972, as amended, and the Oil Pollution Act of 1990 (October 18, 1991). It is framed by the regulations in 30 CFR Part 254 – *Oil Spill Response Requirements for Facilities Located Seaward of the Coastline*, and 40 CFR Part 300 – *National Oil and Hazardous Substances Pollution Contingency Plan*. Acknowledging these authorities and their associated responsibilities, BSEE established the program with three primary and interdependent roles:

- Preparedness Verification,
- Oil Spill Response Research, and
- Management of Ohmsett - the National Oil Spill Response Research and Renewable Energy Test Facility.

The research conducted for this Program aims to improve oil spill response and preparedness by advancing the state of the science and the technologies needed for these emergencies. The research supports the Bureau's needs while ensuring the highest level of scientific integrity by adhering to BSEE's peer review protocols. The proposal, selection, research, review, collaboration, production, and dissemination of OSPD's technical reports and studies follows the appropriate requirements and guidance such as the Federal Acquisition Regulation and the Department of Interior's policies on scientific and scholarly conduct.