Testing of Oil Recovery Skimmers in Ice at Ohmsett
The National Oil Spill Response Research & Renewable Energy Test Facility

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Abstract

The mechanical recovery of oil in ice-infested water presents unique and difficult clean-up challenges. Ice can impede the movement of spilled oil making it less available for removal by the active components of oil recovery skimmers. Ice and slush that is recovered with oil can jam the skimmer, pump inlets and hoses and can provide an environment for enhanced emulsion formation. Low temperatures increase oil viscosity, further complicating processing and pumping of recovered product.

In response to these challenges, the U.S. Department of the Interior's Bureau of Safety and Environmental Enforcement (BSEE) recognized the need for comprehensive programs of testing and research in the area of oil spill response in icy waters. BSEE has supported and sponsored a number of testing and research programs at the Ohmsett facility involving oil in cold water and ice. During the winter of 2013, BSEE sponsored an oil-in-ice spill test at Ohmsett titled Skimmer Tests in Drift Ice: Ice Month 2013 at Ohmsett. The tests involved ten commercially available skimmers that represented a range of skimmer types. Testing was done in the Ohmsett test basin using a controlled test area with fabricated ice. To the best extent possible, test variables such as water temperature, oil characteristics, oil slick thickness, ice coverage and size distribution, and skimmer operations were controlled. Performance determinations were made for oil recovery rate and oil recovery efficiency as per the general principles and guidelines of ASTM F2709. Tabulated results for the same are presented.

At lower ice coverage (30% ice), there was no significant mechanical impediment for most skimmers. However, ice can interfere with the flow of oil to the skimmer periodically even in this coverage. At higher ice coverage (70% ice), there was significant impediment to skimming, with most skimmers having dramatically lower rates and efficiencies. It was also observed that with longer exposure to skimming under these conditions, operators became more proficient with regard to recovery performance. This indicates the importance of training and practice for effective skimming operations.

1 Background

Ohmsett is the largest facility for testing oil spill response equipment in North America. Built in 1974, it has facilitated the testing of a wide variety of spill countermeasures in a controlled, repeatable and safe environment (www.ohmsett.com). The U.S. Department of the Interior's Bureau of Safety and Environmental Enforcement (BSEE) manages the facility as part of its mandated requirements by the Oil Pollution Act of 1990 (OPA, 1990). In accordance with OPA '90, agencies represented on the Interagency Coordinating Committee on Oil Pollution Research (ICCOPR) are to ensure the long-term use and operation of Ohmsett for oil pollution technology testing and evaluations. More information on ICCOPR can be found at www.iccopr.uscg.gov.

2 Introduction

The mechanical recovery of oil in ice-infested water presents unique and difficult clean-up challenges. Ice can impede the movement of spilled oil making it less available for removal by the active components of oil recovery skimmers. Ice may also be damaging to response equipment. Ice floes and the resulting mixture of ice, slush, and oil can jam skimmer inlets and mechanisms. The onboard processing of this mixture may result in the inclusion of a great deal of water and an enhanced environment for the formation of emulsions. Low temperatures can increase the viscosity of oil creating additional difficulties in collection, processing, and pumping of recovered product.

In response to these challenges, BSEE recognized the need for comprehensive programs of testing and research in the area of oil spill response in icy waters. Over the past several years, BSEE has supported and sponsored testing and research programs involving spilled oil in cold water and oil-in-ice at the Ohmsett facility. A list of the research programs can be found at http://www.bsee.gov/Research-and-Training/Technology-Assessment-and-Research/tarprojectcategories/OHMSETT/. This support has also led to the use of the facility for oil-in-ice testing by other groups including various U.S. federal agencies, private organizations, industry, academia, and international groups. Included in these were the U.S. Coast Guard, National Oceanic and Atmospheric Administration (NOAA), ExxonMobil, Tesoro Corporation, Ocean Imaging, SL Ross Environmental Research, Ltd. (Canada), and NOFO (Norway).

During the winter of 2013, BSEE sponsored an oil-in-ice spill test at Ohmsett titled Skimmer Tests in Drift Ice: Ice Month 2013 at Ohmsett (SL Ross and MAR, 2013). This involved testing a number of skimming systems in ice during the period from February 18 to March 15, 2013. This paper will address the test methods used and the results obtained from the test.

3 Discussion

Evaluations during Ice Month were conducted in a simulated ice environment on mechanical response equipment currently used or being considered for use by the U.S. Navy (USN) and/or the U.S. Coast Guard (USCG). The tests were intended as a basis for potential improvements to mechanical response technologies as well as development of standards for the assessment of equipment recovery capabilities and efficiencies in drift-ice environments.

Ten commercially available skimmers were tested that represented a range of skimmer types. A brief description of each skimmer follows. The nameplate recovery rate for each device is as stated by the manufacturer, except where otherwise indicated.

3.1 JBF DIP 400

The JBF DIP 400 (Figure 1) is designed to be used in an advancing mode, employs the dynamic inclined plane (DIP) concept whereby encountered oil is induced under the water by an inclined, descending belt. The oil is transported under the skimmer where it then ascends to a collection well for removal.

Figure 1: JBF DIP 400

3.2 Desmi Sea Mop 3060

The Desmi Sea Mop 3060 (Figure 2) is an oleophilic rope mop skimmer that was used in this application as a crane suspended recovery device. The three rope mop loops are rotated down onto an oil slick to affect oil collection.

Figure 2: Desmi Sea Mop 3060

3.3 LORI Mini

The LORI Mini (Figure 3) is a floating brush-wheel skimmer. As the brush wheel rotates down through oil, the oil adheres to the brush and is then removed by scrapers at the top of the brush rotation.

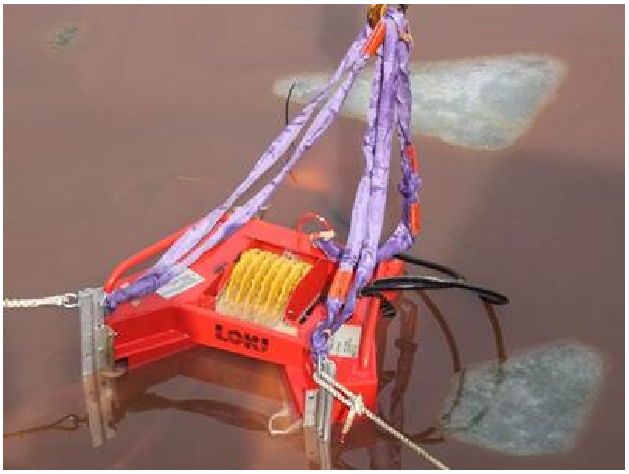

Figure 3: LORI Mini

3.4 Elastec X30

The Elastec X30 (Figure 4) is a recently-developed grooved disc skimmer based on a larger skimming system. The 760-mm (30-inch) diameter oleophilic grooved discs rotate down through an oil slick and the disc surface is coated with oil.

Figure 4: Elastec X30

3.5 Elastec TDS 118G

The Elastec TDS 118G (Figure 5) is a grooved oleophilic drum skimmer. It employs two side-by-side rotating drums.

3.6 Elastec Magnum 100G

The Magnum 100G (Figure 6) is also a grooved oleophilic drum skimmer. The Magnum 100G is larger than the TDS 118G in that it employs four drums.

Figure 5: Elastec TDS 118G

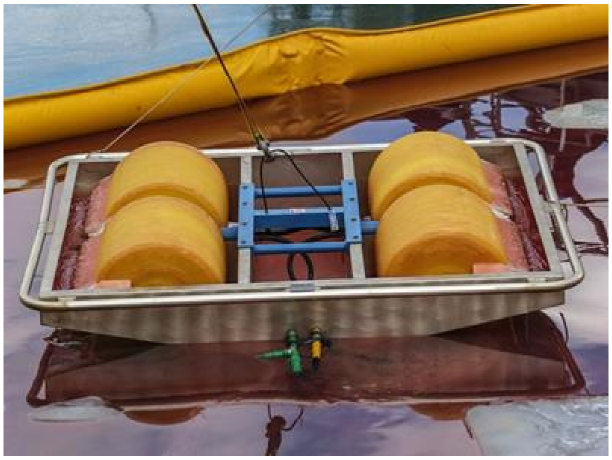

Figure 6: Elastec Magnum 100G

3.7 Lamor LRB150

The Lamor LRB 150 (Figure 7) is a brush-wheel skimmer designed to be positioned and operated from an excavator or from a crane. For this test it was operated from an excavator located on the deck next to the test area.

Figure 7: Lamor LRB 150

3.8 Lamor LAM50

The Lamor LAM 50 (Figure 8) is a brush-conveyor belt skimmer consisting of an oleophilic brush belt that can be rotated in either direction.

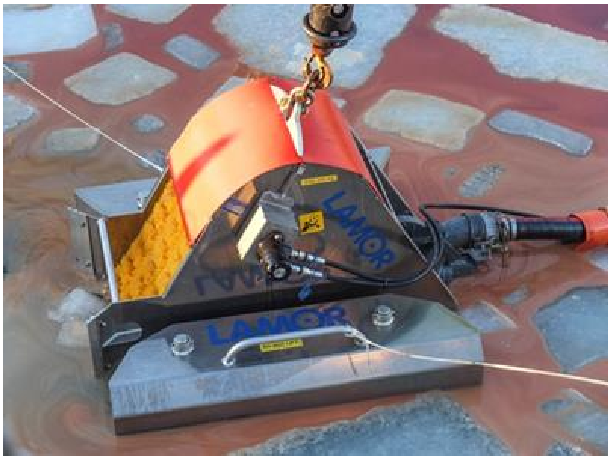

Figure 8: Lamor LAM 50

3.9 Desmi Helix

The Desmi Helix (Figure 9) is a DOP 250 self-adjusting weir skimmer with an add-on Helix brush adaptor. This brush system provides oleophilic separation in front of the weir on the skimmer.

3.10 Desmi Polar Bear

The Desmi Polar Bear (Figure 10) is a brush-wheel skimmer specifically developed and designed for use in the Arctic in cooperation with SINTEF, an independent research organization located in Norway. It contains integrated floats and six individual Polyoxymethylene (POM) brush modules, each driven by a separate hydraulic motor.

Figure 9: Desmi Helix

Figure 10: Desmi Polar Bear

4 Test Methodology

As far as practical, the protocol followed the general principles of other standardized skimmer tests, in particular ASTM F2709 Standard Test Method for Determining Nameplate Recovery Rate of Stationary Oil Skimmer Systems (ASTM, 2013a).

Initially, Alaska North Slope (ANS) crude oil was considered for use as the subject test oil. However, it has a low flash point range from -23 °C to -4 °C (-9 °F to 25 °F) for the fresh crude, and BTEX (benzene, toluene, ethyl benzene, and xylene) concentration that can be in excess of 22,000 parts per million (ppm). This raised concerns with human health, environmental impact, and fire safety. Therefore, it was decided to use Hydrocal 300, a hydrotreated naphthenic lube stock that is maintained in the Ohmsett oil inventory. As a refined petroleum product Hydrocal 300 would provide a more stable test fluid over the test period. At a nominal test temperature of 0 °C (32 °F) Hydrocal has a density of 0.90 grams/milliliter and a viscosity of 1000 cP. Its density and viscosity are comparable to those of a weathered crude oil at arctic temperatures.

One skimmer, the JBF DIP 400 was tested in a 7.6 m x 30.5 m (25-foot x 100-foot) boomed area within the Ohmsett tank. This allowed for testing in the advancing mode since this skimmer requires forward motion for effective operation. All other skimmers were tested within a 7.6 m x 12.8 m (25-foot x 42-foot) boomed area as shown in Figure 11. The test area dimensions were selected to provide ample room for skimmer movement through ice floes and were well in excess of the minimum dimensions specified in the ASTM nameplate test standard which mandates a minimum lateral dimension of three times the skimmer dimensions.

Tests were performed using two different ice concentrations, 30% and 70% coverage. These ice concentrations are generally regarded as thresholds for mechanical recovery in ice. Below 30% concentration, oil movement is minimally affected by the presence of ice, and above 70% concentration, oil movement is severely restricted.

Figure 11: Test Area Filled with Ice

Some 830 square meters (9,000 square feet) of salt-water ice was produced by the U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory (CRREL) and delivered to Ohmsett. The ice growth specification produced an ice density of 916.7 ± 35.7 kg/m^3. The solid ice field was cut into approximately 800 1.02 m x 1.02 m x 0.20 m (40-inch x 40-inch x 8-inch) thick slabs. Prior to testing, ice was added to the test area as required to produce the desired coverage. A target ice size distribution of 55% 1.02 m x 1.02 m (40-inches x 40-inch), 30% 0.51 m x 0.51 m (20-inch x 20-inch), and 15% small fragments was used. This mix of ice sizes was intended to provide a range that might be found in a field of broken ice, such as in the vicinity of a drilling installation. To achieve this size distribution, ice was broken using an electric jack hammer. The specified ice coverage was determined geometrically upon addition to the test field, with digital areal photographic pixel reconnoitring for confirmation.

During testing, tank water salinity was 30.5 parts per thousand. Two air-cooled trailer mounted chiller systems were used to provide 2 MW (560 tons) of cooling to help maintain near-freezing water temperatures. Maintaining a constant water temperature was a challenge due to fluctuating ambient air temperatures and solar heating. The tank temperature during the tests was between 0 °C and 3 °C (32 °F and 38 °F).

Oil spilled in ice floes tends to be thicker than oil spilled on open water. This is due to restricted oil movement, squeezing of oil between ice barriers, and viscosity effects. Therefore, a 25-mm (1-inch) slick thickness was chosen. Slick thickness maintenance was based upon the geometry of the confined test area and the specified ice coverage, and mass balance of oil removed and oil replaced.

As stated earlier, the JBF DIP 400, due to its specific design requirements, was operated in the advancing mode. To accomplish this, the skimmer was tethered to the bridge and advanced through the test area at a target speed of 0.51 m/s (1 knot). All of the other skimmers tested were designed to be operated in the stationary or slowly-advancing mode. Given the viscosity of the oil and the presence of ice, oil recovery could potentially be limited by the absence of oil in the immediate vicinity of the skimmer, so during testing the skimmers were slowly moved through the test area. For the 30% ice condition, this involved slow back-and-forth movements of the skimmer using the bridge-mounted crane (and by an excavator stationed on the deck beside the test area in the case of the Lamor LRB) with the skimmer remaining in the water throughout the test. However, in the 70% ice condition, moving the skimmer through the dense ice field moved the oil along with the ice. This made it necessary to periodically lift the skimmer out of the water and re-position it before resuming skimming. In such cases, the time spent re-positioning was recorded.

Each skimmer was tested in two ice conditions (30% and 70%), one oil thickness of 25 mm (1 inch), and with three replicate tests for a total of six tests per skimmer. Additional replicates were performed in a few cases where rate or efficiency diverged significantly from other tests in the series. In addition to testing in 25-mm (1-inch oil), it was originally proposed that testing also be performed with a thinner slick; however, time constraints prevented this. To give some indication of skimmer performance at a lesser slick thickness, during the final test run in each series, performance measurements continued as the slick diminished. This involved collecting discrete volumes in separate containers to allow separate rate and efficiency measurements.

As skimming was initiated for a test, the recovered fluid (oil + water) was directed to a slop tank. This continued for sufficient time to purge fluids remaining in the cargo hoses from the previous test and to achieve a visually noted steady state in recovery. After this period, the discharge was directed to a calibrated measurement tank as the representative test aliquot. Once a predetermined volume had been collected, the discharge was directed back to the slop tank. The time for collection was recorded and the test ended.

At the conclusion of the test run, the depth of collected fluid was measured immediately. The collected fluid was allowed to settle for 30 minutes to allow any free water to descend to the bottom of the collection tank. Using a valve on the bottom of each collection tank, the free water was decanted. Another measurement was taken to determine the amount of fluid remaining in the collection tank. The contents in the tank were then vigorously stirred to homogenize the fluid and a representative fluid sample was obtained. This sample was sent to Ohmsett's on-site oil/water laboratory to determine the amount of water entrained in the oil. The oil that was dispensed into the test area was also sampled and sent to determine the amount of water that may have been initially present. All of these measurements were used to calculate the total fluid, oil, and water recovered in the elapsed time, allowing the calculation of the following two performance measurements, as per ASTM F631 Standard Guide for Collecting Skimmer Performance Data in Controlled Environments (ASTM, 2013b) and F2709 Standard Test Method for Determining Nameplate Recovery Rate of Stationary Oil Skimmer Systems (ASTM, 2013a):

Oil Recovery Rate (ORR): the volume of oil recovered by the device per unit of time. *Note that the measurement is of oil only, after netting out free and emulsified water.*

$$\mathrm{ORR} = \frac{V_{\mathrm{oil}}}{t} \tag{1}$$

Where: ORR = Oil Recovery Rate, liters/min (lpm) (gallons/min (gpm))
V_{oil} = Volume of oil recovered, liters (decanted and lab corrected)
t = Elapsed time of recovery, minutes

Oil Recovery Efficiency (ORE): the ratio, expressed as a percentage, of the volume of oil recovered to the volume of total fluids recovered.

$$ORE = \frac{V_{oil}}{V_{total\ fluid}} \times 100 \qquad (2)$$

Where: ORE = Oil Recovery Efficiency, %
$V_{total\ fluid}$ = Volume of total fluid (water and oil) recovered

An additional non-ASTM definition was also used to reflect the fact that, particularly in 70 % ice coverage, a significant portion of the test period was spent re-positioning the skimmer to find thick patches of oil. This was termed Operational Efficiency (OppEff%) , and is defined as the ratio, expressed as a percentage, of the time spent actually skimming, to the total test time.

5 Results

For clarity, a brief summary of the data is presented for each skimmer. Caution should be exercised in assessing the reported performance results given the limitations imposed by the test schedule. While each skimmer was given three or more test runs to ensure consistency of results, there was not adequate time in the test program for a comprehensive quantitative evaluation of optimum operating parameters such as disc/brush/drum speed, pump speed, and skimmer orientation relative to the ice.

5.1 JBF DIP-400

The DIP 400 was tested in the advancing mode for five separate runs (denoted test numbers 3 through 7; tests 1 and 2 were dry runs used to confirm rigging) in 30% ice coverage. Speed of advance was varied in the five runs between 0.18 m/s and 0.51 m/s (0.35 and 1.0 knots). The results are summarized in Table 1.

Table 1: Performance Values JBF DIP 400

Test #	Ice Coverage, %	Speed m/s (knots)	ORR, lpm (gpm)	ORE, %
3	30	0.51 (1.00)	14.0 (3.7)	14
4	30	0.26 (0.50)	35 (9.2)	28
5	30	0.18 (0.35)	4.9 (1.3)	12
6	30	0.26 (0.50)	16.7 (4.4)	12
7	30	0.26 (0.50)	21 (5.5)	28

5.2 Desmi SeaMop 3060

The SeaMop 3060 was tested in six separate runs; three each in 30% and 70% ice coverage. Performance values in 25-mm (1-inch) thick oil and the diminishing oil slick tests are shown in Table's 2 and 3, respectively, below.

Table 2: Performance Values Desmi SeaMop 3060

Test #	Ice Coverage, %	Speed, rpm	ORR, lpm (gpm)	ORE, %	OpEff, %
8	30	3	36 (9.5)	84	100
9	30	3	31 (8.1)	82	100
10a	30	4	33 (8.7)	70	100
11	70	5	25 (6.6)	68	100
12	70	5	24 (6.2)	61	100
13a	70	5	30 (8.0)	72	100

Table 3: Performance Values, Diminishing Slick Tests, Desmi SeaMop 3060

Test #	Ice Coverage, %	Speed, rpm	ORR, lpm (gpm)	ORE, %	OpEff, %
10b	30	4	35 (9.2)	73	100
10c	30	4	24 (6.2)	60	100
13b	70	5	24 (6.4)	68	100
13c	70	5	24 (6.2)	60	100

5.3 LORI Mini

The LORI Mini was tested in six separate runs; three each in 30% and 70% ice coverage with performance data in 25-mm (1-inch) thick oil and a diminishing slick test as follows in Tables 4 and 5:

Table 4: Performance Values LORI Mini

Test #	Ice Coverage, %	Speed, rpm	ORR lpm (gpm)	ORE, %	OpEff, %
14*	30	51	20 (5.4)	38	100
15*	30	52	30 (8.0)	45	97
16a	30	52	42 (11)	55	100
17	70	49	7.2 (1.9)	20	100
18	70	51	8.3 (2.2)	25	95
19a	70	28	4.9 (1.3)	64	100
* Ice concentration measured in the range of 37 to 42%.					

Table 5: Performance Values, Diminishing Slick Tests, LORI Mini

Test #	Ice Coverage, %	Speed, rpm	ORR, lpm (gpm)	ORE, %	OpEff, %
16b	30	54	42 (11)	50	100
16c	30	54	32 (8.4)	45	100
16d	30	54	33 (8.7)	41	100
19b	70	28	9.5 (2.5)	82	100

5.4 Elastec X30

The Elastec X30 was tested with four test runs in the 30% ice cover and one run in 70% ice. Results for tests in 25-mm (1-inch) thick oil and a diminishing slick are as follows in Tables 6 and 7:

Table 6: Performance Values Elastec X30

Test #	Ice Coverage, %	Speed, rpm	ORR, lpm (gpm)	ORE, %	OpEff, %
20	30	35	61 (16)	60	100
21	30	26	49 (13)	79	100
22	30	26	53 (14)	80	100
23a	30	26	45 (12)	77	100
34	70	18	7.6 (2.0)	79	72

Table 7: Performance Values, Diminishing Slick Tests, Elastec X30

Test #	Ice Coverage, %	Speed, rpm	ORR, lpm (gpm)	ORE, %	OpEff, %
23b	30	26	45 (12)	76	100
23c	30	26	27 (7.2)	69	100

5.5 Elastec TDS 118G

The TDS 118G was tested in six separate runs; three each in 30% and 70% ice coverage in Tables 8 and 9.

Table 8: Performance Values Elastec TDS 118G

Test #	Ice Coverage, %	Speed, rpm	ORR, lpm (gpm)	ORE, %	OpEff, %
24	30	47	87 (23)	71	100
26a	30	47	95 (25)	74	100
27	30	46	80 (21)	65	100
36	70	22	10.6 (2.8)	91	74
37	70	22	9.8 (2.6)	84	72
38a	70	22	11.4 (3.0)	82	77

Table 9: Performance Values, Diminishing Slick Tests, Elastec TDS 118G

Test #	Ice Coverage, %	Speed, rpm	ORR, lpm (gpm)	ORE, %	OpEff, %
26b	30	47	80 (21)	68	100
26c	30	47	68 (18)	66	100
38b	70	22	8.7 (2.3)	78	75
38c	70	22	5.3 (1.4)	75	81

5.6 Elastec Magnum 100G

The Magnum 100G was tested in seven separate runs; three in 30% ice coverage, and four in 70% ice coverage in tables 10 and 11.

Table 10: Performance Values Elastec Magnum 100G

Test #	Ice Coverage, %	Speed, rpm	ORR, lpm (gpm)	ORE, %	OpEff, %
28	30	38	144 (38)	76	100
29*	30	39	163 (43)	79	100
30a*	30	39	129 (34)	76	100
31	70	23	13.2 (3.5)	69	82
32	70	23	13.6 (3.6)	67	80
33a	70	23	14.4 (3.8)	72	82
35	70	24	12.5 (3.3)	75	76
* Ice concentration measured in the range of 20 to 23%.					

Table 11: Performance Values, Diminishing Slick Tests, Elastec Magnum 100G

Test #	Ice Coverage, %	Speed, rpm	ORR, lpm (gpm)	ORE, %	OpEff, %
30b*	30	39	110 (29)	72	100
30c*	30	39	68 (18)	62	100
33b	70	23	8.7 (2.3)	62	74
33c	70	23	7.9 (2.1)	62	81
* Ice concentration measured in the range of 20 to 23%.					

5.7 Lamor LRB 150

The Lamor LRB 150 was unique in the test program in that it remained fixed to the front end of an excavator in deployment and operation. The technique used was to essentially sweep across the length of the test area in successive passes in Tables 12 and 13.

Table 12: Performance Values Lamor LRB 150

Test #	Ice Coverage, %	Speed, rpm	ORR, lpm (gpm)	ORE, %	OpEff, %
45	30	12	72 (19)	86	77
46	30	14	87 (23)	74	81
47a	30	14	163 (43)	85	46
48	30	13	231 (61)	90	62
39	70	9	14.0 (3.7)	72	72
40	70	10	23 (6.0)	65	80
41a*	70	10	21 (5.6)	65	65
* Ice concentration measured to be 62%.					

Table 13: Performance Values, Diminishing Slick Tests, Lamor LRB 150

Test #	Ice Coverage, %	Speed, rpm	ORR, lpm (gpm)	ORE, %	OpEff, %
47b	30	14	121 (32)	85	75
47c	30	14	220 (58)	85	90
41b*	70	10	18.9 (5.0)	57	80
41c*	70	10	16.7 (4.4)	64	79
* Ice concentration measured to be 62%.					

5.8 Lamor LAM 50

The Lamor LAM 50 was tested in six separate runs; three each in 30% and 70% ice coverage. Data for the six performance runs and the four diminishing slick tests are as follows in Tables 14 and 15:

Table 14: Performance Values Lamor LAM 50

Test #	Ice Coverage, %	Speed, rpm	ORR, lpm (gpm)	ORE, %	OpEff, %
49	30	7	16.3 (4.3)	64	96
50	30	7	24.2 (6.4)	69	100
51a	30	7	14.0 (3.7)	62	100
42	70	5	6.1 (1.6)	68	76
43	70	7	5.3 (1.4)	53	73
44a	70	7	9.8 (2.6)	63	78

Table 15: Performance Values, Diminishing Slick Tests, Lamor LAM 50

Test #	Ice Coverage, %	Speed, rpm	ORR, lpm (gpm)	ORE, %	OpEff, %
51b	30	7	15.5 (4.1)	60	100
51c	30	7	10.2 (2.7)	55	91
44b	70	7	8.3 (2.2)	62	80
44c	70	7	6.1 (1.6)	61	72

5.9 Desmi Helix

The Helix was tested in six separate runs; three each in 30% and 70% ice coverage. Data for these six runs and the four diminishing slick determinations are as follows in Tables 16 and 17:

Table 16: Performance Values Desmi Helix

Test #	Ice Coverage, %	Speed, rpm	ORR, lpm (gpm)	ORE, %	OpEff, %
61	30	20	121 (32)	72	100
62	30	19	170 (45)	78	100
63a	30	19	102 (27)	71	100
58	70	21	13.2 (3.5)	24	76
59	70	21	19.3 (5.1)	45	72
60a	70	13	12.9 (3.4)	61	88
Tests 52 through 55 are not reported: at their conclusion it was found that a missing gasket allowed excessive water infiltration. The gasket was replaced and the tests repeated as 61 through 63.					

Table 17: Performance Values, Diminishing Slick Tests, Desmi Helix

Test #	Ice Coverage, %	Speed, rpm	ORR, lpm (gpm)	ORE, %	OpEff, %
63b	30	19	98 (26)	66	100
63c	30	19	45 (12)	54	100
60b	70	13	8.7 (2.3)	49	57
60c	70	13	7.6 (2.0)	46	74

5.10 Desmi Polar Bear

The Polar Bear was tested in four separate runs; two each in 30% and 70% ice coverage. Hydraulic problems with the unit prevented more extensive testing and the diminishing slick tests were not completed. Performance data was as follows in Table 18:

Table 18: Performance Values Desmi Polar Bear

Test #	Ice Coverage, %	Speed, rpm	ORR, lpm (gpm)	ORE, %	OpEff, %
56	30	ND	61 (16)	11	100
57	30	ND	155 (41)	29	100
65	70	19	17.4 (4.6)	42	100
66	70	16	37 (9.7)	52	100

6 Conclusions

Ten commercially-available skimmers, some specifically built for Arctic use and some adapted from conventional designs, were tested at Ohmsett in drift ice concentrations of 30% and 70%. The skimmers represented a range of skimming principles including rope mop, disc, drum, brush, and submersion plane designs.

In 30% concentration, ice is not a significant impediment for most skimmers, although ice can interfere with the flow of oil periodically even in this coverage. The exception was the JBF DIP skimmer which requires significant forward motion for effective operation. The skimmer quickly jammed with ice and had poor performance in terms of oil recovery rate and oil recovery efficiency. For other skimmers, careful attention by the skimmer operator and the ability to direct the skimmer to thicker patches of oil was important for optimizing skimmer performance.

In 70% concentration, ice is a significant impediment to skimming with most skimmers having dramatically lower rates and efficiencies in the denser ice compared with the 30% ice. The exception was the Desmi SeaMop. Its skimming principle is somewhat unique in that the skimmer remains suspended above the ice and water during operation so the device is less affected by ice than other skimmers. Additionally, it does not disturb the ice which is helpful in dense ice concentrations when oil would be moved along with the ice.

In most cases, operating efficiency, and to some extent recovery rate and efficiency, improved somewhat through the tests with a specific skimmer, indicating the importance of training and practice for effective skimming operations. The limited amount of test time combined with the number of skimmers that were tested did not allow a thorough investigation of this issue. Future testing should address this potential effect and attempt to remove it as a variable.

The bulk of the testing was done with a nominal 25-mm (1-inch) oil layer. Although there was inadequate time in the test program to do a thorough test with thinner layers, some tests were done with a diminishing layer of oil to determine the effect on rate and efficiency. In all but a few cases, performance in terms of rate and efficiency were adversely affected by a decrease in slick thickness.

As noted, some of the skimmers tested were not developed specifically for use in arctic conditions. Simple improvements such as a debris guard ahead of the active skimming component should be considered to enhance the flow of oil to the skimmer. Some form of debris guard at the skimmer sump would also be useful to prevent small ice pieces from jamming the discharge hose.

The number of skimmers included in the limited time of the test program did not allow for a comprehensive evaluation of each skimmer’s capabilities and determination of optimal settings. Skimmer operators were allowed some practice time in the tank prior to the recorded performance tests, but otherwise relied on their experience and judgment in establishing settings such drum or brush speed.

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