# Development of an ASTM Stationary Skimmer Test Protocol - Phase 3: Application

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## Abstract

The American Society of Testing and Materials (ASTM) subcommittee on skimmers recently adopted a standard methodology for measuring the nameplate capacity for a given skimmer system. Current industry practice allows manufacturers to label skimmers with a nameplate capacity that may bear little relationship to the ability of the skimmer, as a system, to recover oil. Manufacturers frequently base nameplate capacity solely on the skimmer's offload pump capability. Typically, this value is unrealistic when estimating the oil recovery rate (ORR) of a skimming system. In the absence of verifiable third party data or USCG witnessed testing, the USCG will derate manufacturer's claimed nameplate capacity by 80% or more when calculating the Effective Daily Recovery Capacity (EDRC). The USCG uses EDRC as a key component in rating and regulating the oil spill response capability of responsible parties and oil spill removal organizations (OSROs).

In March 2008, the new skimmer test protocol was used at Ohmsett to test four oleophilic skimmers and evaluate their potential use as alternatives to the skimmers currently used in the Prince William Sound (PWS) oil spill response plan. The skimmers currently used in the PWS plan are weir-type devices, which generally have low recovery efficiencies, i.e., they recover substantial volumes of water along with the oil. This can add greatly to the storage requirement, which is logistically complex and costly. It is anticipated that oleophilic devices would offer an advantage because of their generally higher recovery efficiencies.

These tests were intended to provide a comparison between four different skimmers in conditions that replicate fresh oil and the 72-hour oil spill cleanup scenarios mandated by the state of Alaska. This test initiated the first real-world application of ASTM's new skimmer test protocol.

## 1 Introduction

The skimmers currently used in Alaska's Prince William Sound (PWS) oil spill response plan are weir-type devices. Weir-type skimmers typically recover high volumes of fluid at low oil recovery efficiencies (RE), resulting in substantial volumes of water recovered along with the oil. This adds significantly to the recovered fluid's temporary storage requirement, which is complex and costly. Replacing the weir-type skimmers with oleophilic devices may offer an advantage because of the oleophilic skimmers' generally higher RE.

In March 2008, four oleophilic skimmers were tested at Ohmsett to evaluate their potential as alternatives to the skimmers currently used in the PWS plan. The four devices tested were a drum-type skimmer, a brush-type skimmer, and two disc-type skimmers.

The methodology used in these tests was based on the recently adopted American Society of Testing and Materials (ASTM) standard for quantifying skimmer nameplate capacity. It is accepted that ideal conditions will yield nameplate rates greater than those achieved under real-world spill conditions; however, implementing the nameplate capacity standard establishes verified baseline performance values for skimming systems and adds credibility to the participating manufacturers and response plans.

## 2 Statement of Theory

The ASTM subcommittee on oil skimmers (F20.12) had been developing a standard methodology for measuring the nameplate recovery rate for skimmers for a number of years. The rationale behind developing this standard was that the current industry practice for establishing nameplate capacity may not reflect the actual skimmer's performance.

Nameplate capacities, in many cases, are thought to be unrealistic and without a standard test protocol, one manufacturer's nameplate capacity is generally not comparable with another manufacturer's nameplate capacity. Federal and State regulatory agencies, along with oil spill removal organizations (OSRO), need the nameplate capacity to reflect the ability of a skimmer, as a system, to recover spilled oil. The system would include the skimmer's hydraulic power unit (HPU), the skimmer, the offload pump(s), and a modest length of cargo line to transfer the recovered oil to a storage tank.

In the absence of a standard test protocol, skimmer manufacturers frequently base nameplate capacity solely on the maximum capacity of the skimmer's offload pump. The offload pump capacity does not take into account the ability of the skimmer, as a system, to recover oil. The USCG may derate nameplate capacity by 80% or more in calculating an Effective Daily Recovery Capacity (EDRC). EDRC is the capability of an OSRO to effectively recover oil in a 24-hour period, based on the cumulative EDRCs of all the individual oil recovery systems in the OSRO's active inventory.

## 3 Description of Equipment and Processes

### 3.1 Test Area

Tests were conducted in a 7.3m x 7.3m (24 feet x 24 feet) boomed section of Ohmsett's outdoor saltwater test tank. In accordance with the ASTM Skimmer Test Standard, the boomed area was approximately three times as wide and three times as long as the largest skimmer to ensure adequate test oil volume. The skimmers, one at a time, were tethered toward the middle of the test area. Operationally, the skimmers were similar in that they employed rotational devices, either drums, brushes, or discs, which rotated down through the oil slick. As oil adhered to the rotating oleophilic surfaces, wipers scraped oil off the oleophilic surfaces and directed it into the skimmer's sump, where an onboard pump offloaded the oil to elevated calibrated oil recovery tanks. To meet the protocol's 3.5m (11 foot) static head requirement, a cargo line, that matched the size of the skimmer's discharge outlet, was connected to the skimmer and transferred oil up to elevated recovery tanks as shown in Figure 1.

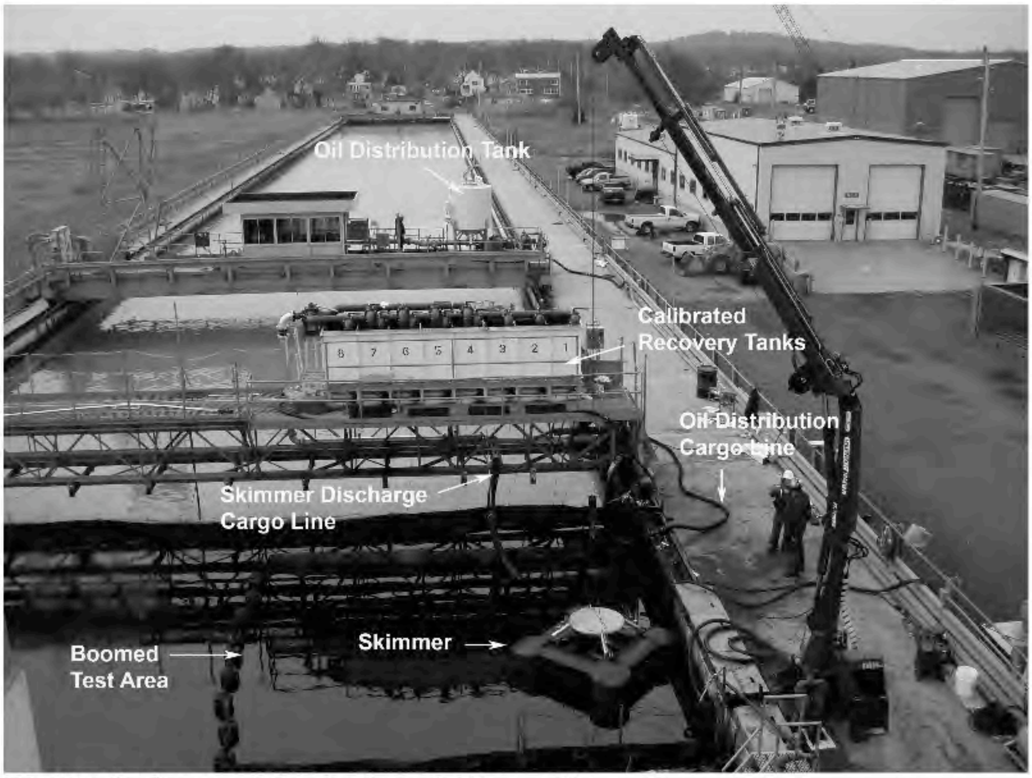

**Figure 1 Boomed test area at Ohmsett**

## 3.2 The Oleophilic Skimmers

- Skimmer #1 (Figure 2) used six 40cm (16-inch) diameter grooved drums.
- Skimmer #2 (Figure 3) used four sets of 76cm (30-inch) diameter aluminum discs.
- Skimmer #3 (Figure 4) used four sets of wheel-mounted brushes.
- Skimmer #4 (Figure 5) used four sets of 48cm (18-inch) diameter discs.


**Figure 2 Skimmer #1 (Drum-type)**

Figure 3 Skimmer #2 (Disc-type)

Figure 4 Skimmer #3 (Brush-type)

Figure 5 Skimmer #4 (Disc-type)

### 3.3 Test Oils

Tests were intended to resemble the 72-hour spill cleanup scenario mandated by the state of Alaska. Tests were performed with fresh Alaska North Slope (ANS) crude oil sourced from the Tesoro refinery in Anacortes, Washington. To gauge skimmer performance at the end of the 72-hour scenario, testing was also conducted using weathered ANS. After completion of the fresh oil tests, the used oil was placed in a tank and weathered by heating it to 60°C (140°F) and bubbling air through it, resulting in oil with approximately 20% evaporative loss by mass and somewhat higher viscosity (Table 1). Test oil temperature, during testing, averaged 7°C (45°F).

**Table 1 Test oil properties**

| Oil | Density, (g/mL @ 20°C) | Viscosity, (cP @ 20°C) | Viscosity, (cP @ 7°C) |
|---|---|---|---|
| Fresh ANS crude oil | 0.868 | 18 | 83 |
| Weathered ANS | 0.926 | -- | 201 |

### 3.4 Oil Distribution

Pre-load and replenishment oil was distributed from a 5700L (1500 gallon) calibrated storage tank located on Ohmsett's Main Bridge. Pre-charging these oil lines eliminated mass balance accounting for residual oil in the lines during transfers.

### 3.5 Slick Thickness

To simulate ideal conditions for recovery, the slick thickness should be substantial. Testing performed at Ohmsett in the summer of 2007, showed there was no significant change in performance, as measured by Oil Recovery Rate (ORR), when the slick thickness was varied from 5cm (2 inches) to infinity. For simplicity, the test may be performed with a diminishing oil thickness.

The general approach was to preload the test area with 4100L (1080 gallons) of oil to achieve an initial slick thickness of 7.5cm (3 inches). The tests, done in triplicate, measured the skimmer's performance as the slick diminished from 7.5cm to 5cm (3 inches to 2 inches).

### 3.6 Oil Recovery

A series of eight calibrated recovery tanks, located on Ohmsett's Auxiliary Bridge, were used during the test. Each of the eight recovery tanks has a capacity of approximately 950L (250 gallons) and fills at 0.9L/mm (5.8 gallon/inch). Fluid depth was measured using a 1.2m (4-foot) aluminum ruler; readings are accurate to within 3mm (1/8 inch).

During a test, oil discharged from the skimmer traveled 4.5m (15 feet) vertically, through a 15cm (6-inch) discharge cargo line, to a manifold located just above the recovery tanks. Valves attached to the manifold allowed the fluid flow to be directed to individual recovery tanks for measurement and decanting of free water.

## 4 Application of Equipment and Processes

### 4.1 Test Method

The test method employed was based on a final draft version of ASTM's F-2709, *Standard Test Method for Determining Nameplate Recovery Rate of*

*Stationary Oil Skimmer Systems* (ASTM 2008a). This protocol, which has recently been balloted and adopted, was developed in conjunction with the USCG National Strike Force (NSF), and complies with the test criteria found in ASTM F-631, *Standard Guide for Collecting Skimmer Performance Data in Controlled Environments* (ASTM, 2008b).

## 4.2 Preliminary Tests

The protocol requires that tests be conducted for a minimum of either three minutes or until 910L (240 gallons) of oil are recovered, whichever occurs first. If the volume criterion is met first, the minimum measurement period is 30 seconds for a valid test.

It was anticipated that each test would last approximately one minute to remove 2.5cm (one inch) of oil from the slick. This brief measurement period did not allow much time to adjust and optimize the skimmer and pump settings. Therefore, prior to testing, each manufacturer was allowed up to four hours of practice runs to determine the optimum settings with fresh ANS.

## 4.3 Performance Tests

The measurement period for each test began when:

- The skimmer operation had been adjusted to its optimum settings,
- The discharge hose was full,
- The oil recovery and discharge flow appeared to be at steady state.

At the beginning of each test, recovered fluid was diverted to a tank designated as slop. When the above conditions were met, the flow of recovered fluid was diverted from the slop tank to a recovery tank. Collection continued until approximately 1400L (360 gallons) of oil was recovered, which corresponded to 2.5cm (one inch) of slick thickness. The recovery tank's fluid level was noted and after a one hour settling period, free water was decanted from the bottom of each tank. After the collected fluid was decanted, it was stirred, a representative sample was taken, and the sample was sent to Ohmsett's on-site lab to determine the amount of entrained and emulsified water. After deducting the free and entrained/emulsified water from the total fluid recovered, the volume of (pure) oil recovered was divided by the recovery time to determine the ORR. The volume of free and entrained water was also used to calculate the RE of the skimmer.

## 4.4 Oil Recovery Rate and Oil Recovery Efficiency

The two performance measurements of interest are ORR, which is the total volume of oil recovered by the device per unit of time (water that is recovered along with the oil is not included in this calculation), and RE, which is the ratio of the volume of oil recovered to the volume of total fluid recovered.

These are resolved using the following formulae:

$$ORR = \frac{V_{oil}}{t}$$

(1)

Where: ORR = Oil Recovery Rate, liter/min (lpm) (gallon/min (gpm))
$V_{oil}$ = Volume of oil recovered, L (gal) (decanted and lab corrected)

t = Elapsed time of recovery, minutes

And:

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

Where: RE = Recovery Efficiency, %

$V_{total\ fluid}$ = Volume of total fluid (water and oil) recovered

## 5 Presentation of Data and Results

### 5.1 Skimmer #1 (Drum-type skimmer)

Using the best of three runs (Table 2), skimmer #1 had an average ORR of 439 lpm (116 gpm) and an average RE of 93% in fresh oil. In weathered oil, the skimmer had an average ORR of 748 lpm (198 gpm) and an average RE of 85%.

**Table 2 Summary of results for Skimmer #1 (Drum-type skimmer)**

| Test | Drum Speed (rpm) | Test oil | ORR (lpm) | ORR (gpm) | RE (%) |
|---|---|---|---|---|---|
| 1 | 53 | Fresh | 446 | 118 | 92 |
| 2 | 51 | Fresh | 420 | 111 | 93 |
| 3 | 51 | Fresh | 450 | 119 | 94 |
| 23 | 65 | Weathered | 768 | 203 | 85 |
| 24 | 55 | Weathered | 719 | 190 | 84 |
| 26 | 47 | Weathered | 757 | 200 | 88 |

### 5.2 Skimmer #2 (Disc-type skimmer)

In fresh oil, the skimmer had an average ORR of 483 lpm (128 gpm) and an average RE of 67% as shown in Table 3 and Table 4.

In supplementary tests, the aluminum discs were exchanged for fibrous coated discs. As these supplementary tests took place after the initial round of tests, all of the fresh oil had been expended. However, there was a sufficient quantity of weathered oil remaining. When the skimmer was tested with the fibrous-coated discs recovering weathered oil, the average ORR was 848 lpm (224 gpm), even though there were 20% fewer discs due to space limitations. The corresponding RE was 82%. Residual oil could be seen on the fibrous coating and had a more aggressive wiper been used, ORR and RE could have improved.

**Table 3: Summary of results for Skimmer #2 (Disc-type skimmer-Aluminum Discs)**

| Test | Disc Speed (rpm) | Test oil | ORR (lpm) | ORR (gpm) | RE (%) |
|---|---|---|---|---|---|
| 4 | 53 | Fresh | 484 | 128 | 69 |
| 5 | 55 | Fresh | 469 | 124 | 67 |
| 6 | 56 | Fresh | 495 | 131 | 66 |
| 27 | 30 | Weathered | 374 | 99 | 86 |
| 30 | 42 | Weathered | 488 | 129 | 75 |
| 31 | 39 | Weathered | 492 | 130 | 86 |

**Table 4: Summary of results for Skimmer #2 (Disc-type skimmer-Fabric Discs)**

| Test | Disc Speed (rpm) | Test oil | ORR (lpm) | ORR (gpm) | RE (%) |
|---|---|---|---|---|---|
| 33 | 24 | Fabric Disc Weathered | 779 | 206 | 99 |
| 35 | 26 | Fabric Disc Weathered | 889 | 235 | 75 |
| 36 | 36 | Fabric Disc Weathered | 878 | 232 | 72 |

### 5.3 Skimmer #3 (Brush-type skimmer)

In fresh oil, the skimmer had an average ORR of 310 lpm (82 gpm), and an average RE of 43%. In the second and third weathered oil tests, the amount of water estimated in the oil slick lead to initial readings of greater than 100% efficiency. At the start of test #21 and #22, a preload of weathered oil was added to the test area to create the initial 7.5cm (3-inch) test slick. A sample was taken of the oil while it was being discharged into the test area and was analyzed in the lab to estimate the initial water content of the slick as a whole. This sample overstated the amount of water that was contained in the oil prior to skimming. It is likely that while the oil sat in the test area prior to the test, water entrained in the oil was released. Had half of the water dropped out, the corresponding values for test #21 would be an ORR of 910 lpm (240 gpm) and an RE of 91%. For test #22, the ORR would be 830 lpm (220 gpm) and an RE of 84%. These two tests, averaged with test #20, yields an average ORR of 720 lpm (190 gpm) and an average RE of 90%. Table 5 summarizes the results for Skimmer #3.

**Table 5 Summary of results for Skimmer #3 (Brush-type skimmer)**

| Test | Brush Speed (rpm) | Test oil | ORR (lpm) | ORR (gpm) | RE (%) |
|---|---|---|---|---|---|
| 7 | Est. 24* | Fresh | 310 | 82 | 38 |
| 8 | Est. 20* | Fresh | 378 | 100 | 42 |
| 9 | -- | Fresh | 242 | 64 | 49 |
| 20 | 12 | Weathered | 423 | 112 | 95 |
| 21 | 16 | Weathered | 910** | 240** | 91** |
| 22 | 16 | Weathered | 830** | 220** | 84** |
| * Speed not measured directly: estimated based on hydraulic input readings.<br>** Initial water content in slick on tank overestimated. Reported values are based on estimated initial water content. | | | | | |

## 5.4 Skimmer #4 (Disc-type skimmer)

As with the other skimmers, it was observed that while spinning the discs faster generally picked a greater quantity of oil, resulting in a higher ORR, the greater disc speed picked up an even greater quantity of water. At high rpm, ORR averaged 355 lpm (94 gpm) with an average RE of 65%, which is lower than the preferred threshold of 70%. Slowing the rpm by 25% reduced ORR to an average of 284 lpm (76 gpm), but RE improved to an average of 86%.

Tests in weathered oil were conducted at the slower rpm. In weathered oil, the skimmer had an average ORR of 558 lpm (148 gpm) and an average RE of 75% (Table 6).

**Table 6 Summary of results for Skimmer #4 (Disc-type skimmer)**

| Test | Disc Speed (rpm) | Test oil | ORR (lpm) | ORR (gpm) | RE (%) |
|---|---|---|---|---|---|
| 10 | 77 | Fresh | 249 | 66 | 55 |
| 11 | 79 | Fresh | 340 | 90 | 67 |
| 12 | 79 | Fresh | 476 | 126 | 74 |
| 13 | 58 | Fresh | 283 | 75 | 88 |
| 14 | 60 | Fresh | 289 | 76 | 85 |
| 15 | 60 | Fresh | 281 | 76 | 84 |
| 17 | 62 | Weathered | 435 | 115 | 65 |
| 18 | 59 | Weathered | 647 | 171 | 81 |
| 19 | 60 | Weathered | 594 | 157 | 79 |

# 6 Summary of Results

The results of the four skimmers in fresh and weathered oil are summarized in Tables 7 and 8. In fresh oil, the first disc skimmer had the best ORR of 483 lpm (128 gpm) with a corresponding RE of 67%. The drum skimmer had a lower ORR, 439 lpm (116 gpm), but a higher RE of 93%.

In weathered oil, the disc skimmer with the fibrous coated discs had the best ORR of 848 lpm (224 gpm) with an RE of 82%. Had a more effective scraping system been used with the prototype fibrous discs, the ORR, and probably RE, would likely have been higher.

**Table 7 Summary of fresh-oil results**

| Skimmer | ORR (lpm) | ORR (gpm) | RE (%) |
|---|---|---|---|
| Skimmer #1 - Drum | 439 | 116 | 93 |
| Skimmer #2 - Disc | 483 | 128 | 67 |
| Skimmer #3 - Brush | 310 | 82 | 43 |
| Skimmer #4 - Disc | 355 | 94 | 65 |

**Table 8: Summary of weathered-oil results**

| Skimmer | ORR (lpm) | ORR (gpm) | RE (%) |
|---|---|---|---|
| Skimmer #1 - Drum | 748 | 198 | 85 |
| Skimmer #2 - Disc | 848 | 224 | 82 |
| Skimmer #3 - Brush | Est. 720 | Est. 190 | Est. 90 |
| Skimmer #4 - Disc | 558 | 148 | 75 |

## 7 Conclusions

In March 2008, four oleophilic skimmers were tested at Ohmsett following the recently adopted ASTM standard methodology for quantifying skimmer nameplate capacity. The standard is intended to provide ideal recovery conditions and allow the skimmer system to operate and collect oil at its maximum possible recovery rate.

The four devices selected for testing were a drum-type skimmer, a brush-type skimmer, and two disc-type skimmers. All of these skimmers used rotating oleophilic devices, either brushes, discs, or drums, to collect spilled oil. Oil recovery rates and recovery efficiencies were sensitive to the rotational speed of the oleophilic device. As rpm increased, the device usually picked up greater quantities of fluid, along with an increasing percentage of water.

The most promising of the skimmers appears to be Skimmer #2, a disc-type skimmer, which in supplementary tests exchanged the aluminum discs with fiber-coated discs. The fibrous coating picked up far more oil than the original aluminum discs, however, the original scrapers were not aggressive enough in removing all the oil that collected on the fiber-coated disc. With a more aggressive scraping system, ORR and RE should improve.

As these tests show, large oleophilic skimmers are able to collect light viscosity oil at high recovery rates and high recovery efficiencies, and with further development may be viable replacements for weir-type skimmers.

The ASTM standard proved to be simple and effective. Four skimmers were tested with two oils in less than ten days and yielded repeatable results.

## 8 Acknowledgements

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## 9 References

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