High Capacity Advancing Oil Recovery System Performance Testing at Ohmsett for the Wendy Schmidt Oil Cleanup X CHALLENGE
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ABSTRACT

Ohmsett - The National Oil Spill Response Research & Renewable Energy Test Facility was selected as the test venue for the $1.4 Million Wendy Schmidt Oil Cleanup X CHALLENGE. The competition was designed to inspire a new generation of innovative solutions for recovering spilled oil from the seawater's surface.

Ten finalists, selected from more than 350 entries from around the world, demonstrated oil cleanup systems during rigorous testing where they each had 10 days to demonstrate their individual technology in the Ohmsett test tank. In this head-to-head competition, a $1 Million Grand Prize was awarded to the team that demonstrated the ability to recover oil from the water's surface at the highest oil recovery rate (ORR) at an oil recovery efficiency (ORE) of more than 70%.

This was the largest oil recovery test ever conducted at Ohmsett. This paper discusses the test setup and methodology used during high capacity advancing oil recovery system performance testing at Ohmsett.

1 INTRODUCTION

The X PRIZE Foundation, a non-profit organization, selected Ohmsett as the test venue for the $1.4 Million Wendy Schmidt Oil Cleanup X CHALLENGE. This challenge, the Foundation's sixth major competition, was designed to inspire a new generation of

innovative solutions for recovering spilled oil from the seawater's surface.

The $1 Million Grand Prize would go to the team with the highest oil recovery rate (ORR) provided the ORR was greater than 9,464 liters per minute (L/min) (2500 gallons per minute (gpm)) and the system's recovery efficiency (RE) was greater than 70%. To put this in perspective, prior to the competition, the largest capacity skimmer ever tested at Ohmsett achieved an ORR of approximately 3400 L/min (900 gpm).

Testing was conducted by Ohmsett staff with competition oversight by impartial judges provided by X PRIZE. The judges included personnel from industry and government agencies with oil spill response experience, and to guarantee fairness, a judge was present whenever a team was on-site.

Testing was conducted from July through September of 2011. To ensure that the last team that tested did not have the advantage of additional development time, all team equipment had to be en route to Ohmsett by the same date. Tools and spare parts were required to be in the main shipment and additional parts or tools were not allowed to be brought to the facility at a later date.

2 TEST METHOD

This was an advancing skimmer test and the methodology was developed based on guidelines from ASTM's F-2709 (ASTM 2008a) and ASTM F-631 (ASTM, 2008b).

3 TEST APPARATUS

3.1 Test Area

Ohmsett's test basin is 203 m long x 20 m wide (667 ft x 65 ft) with three moveable bridges that span the width of the tank. The bridges, mounted on rails that run the length of the tank, can travel at speeds up to 3.1 m/s (6 knots). For this

competition, each team's oil recovery system was arranged between the Main Bridge and the Auxiliary Bridge. The team's ancillary equipment, such as hydraulic power units and control stands, were mounted on the Main and/or Auxiliary Bridge.

At the south end of the basin is a wave generator and at the north end is a wave attenuating beach system. After an allowance for the wave-generating equipment, beaches, and acceleration and deceleration zones, the teams had approximately a 122-m (400-ft) long test area to operate their system under steady state conditions. The test tank is shown in Figure 1.

Figure 1: Ohmsett Test Tank with a 25 mm (1 inch) oil layer.

3.2 Test Oil

Hydrocal 300, a medium viscosity lube stock (viscosity approximately 200 cP), was used as the test oil because its properties would remain consistent over the course of testing. The Hydrocal was dyed red for better visibility.

3.3 Slick Thickness

To ensure the oil recovery systems would encounter test oil at a sufficient rate, 102,000 L (27,000 gal) of oil was dispensed on the surface of the tank, which spread

out to create an oil slick 25-mm (1-inch) thick.

3.4 Oil Distribution and sampling

303,000 L (80,000 gal) of test oil were held in 76,000 L (20,000 gal) calibrated frac tanks. As test oil was transferred from the frac tanks to the test basin, the oil levels in the frac tanks were carefully measured to ensure the proper amount of oil was transferred to create the 25-mm thick (1-inch) slick. The oil was sampled as it was dispensed into the test tank and surface oil was sampled prior to each official test.

3.5 Oil Recovery

Two banks of four-cell calibrated recovery tanks, located on Ohmsett's Auxiliary Bridge, were used during the test (Figure 2). Each of the eight recovery tanks had a capacity of approximately 2300 L (600 gal) and fills at 44.7 L/mm (11.8 gal/in). Fluid depth was measured with a 1.2 m (4 ft) aluminum ruler, and readings are accurate to within 3 mm (1/8 inch).

Figure 2: Recovery Tanks on the Auxiliary Bridge

The skimmer's discharge line connected to Ohmsett's manifold system via a 254-mm (10-inch) flange. A wye downstream of the flange splits the flow into two 254-mm

(10-inch) pipes, and recovered fluid traveled 4.5 m (15 ft) vertically up to a 203-mm (8-inch) 3-way valve located on each bank of recovery tanks. The 3-way valve allowed flow to be diverted to bypass mode as the skimmer was brought up to steady state conditions, and collect mode for the timed collection period. When in bypass mode, the recovered fluid traveled up to the recovery tanks, through the 3-way valve and back down to the test basin. When in collect mode, recovered fluid flowed through the 3-way valve and into the recovery tanks. Valves on the bottom of the recovery tanks allowed for decanting free water from the recovered fluid.

4 TEST PROCEDURE

4.1 Preliminary Tests

The ASTM standard suggests a minimum measurement period of 30 seconds (ASTM, 2008a). The minimum 30 second test period would be waived only if the system filled all eight recovery tanks (18,000 L (4800 gallons)) within 30 seconds.

Prior to official testing, each manufacturer was allowed one day of practice runs to optimize their system and determine the best tow speeds for calm conditions and the best tow speed for wave conditions.

4.2 Performance Tests

The measurement period for each test began when:

- The skimmer system was at its proper tow speed;
- The skimming system was adjusted to its optimum setting;
- The oil recovery and discharge flow appeared to be at steady state;
- The team signaled they were ready to begin the measurement period.

When the above conditions were met, the 3-way valve on each bank of recovery

tanks was turned to divert the flow from bypass mode to collect mode and timing started. At the end of the run, the depth of fluid in each tank was measured, followed by a 30-minute settling period, after which free water was decanted from the bottom of each recovery tank and a second depth measurement was taken. After decanting, the remaining fluid was stirred and a representative sample was taken to the Ohmsett on-site lab for water content analysis per ASTM D-1796 (ASTM, 2011). After deducting the free and entrained 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.

4.3 Oil Recovery Rate and Oil Recovery Efficiency

The two performance measurements are:

Oil Recovery Rate (ORR): Total volume of oil recovered per unit time.

$$ORR = \frac{V_{oil}}{t} \qquad (1)$$

Where: ORR = Oil Recovery Rate, liter/min (L/min) (gallon/min (gpm))

V_{oil} = Volume of oil recovered, L (gal) (decanted and lab corrected)

t = Elapsed time of recovery, minutes

and: Recovery Efficiency (RE): The ratio of the volume of oil recovered to the volume of total fluid recovered.

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

Where: RE = Recovery Efficiency, %

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

5 THE TEAMS

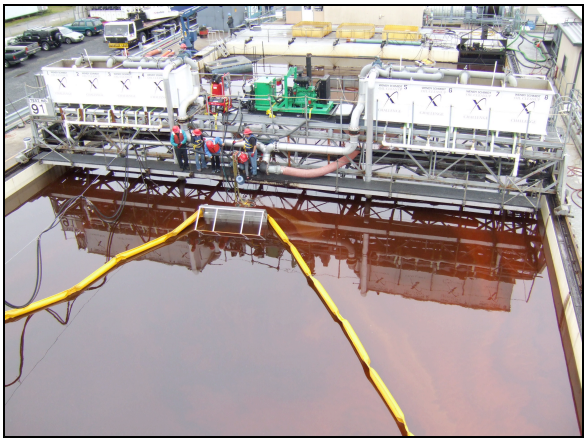

Figure 3: Voraxial – Florida, USA.

Figure 4: OilWhale – Finland.

Figure 5: PPR – Alaska, USA.

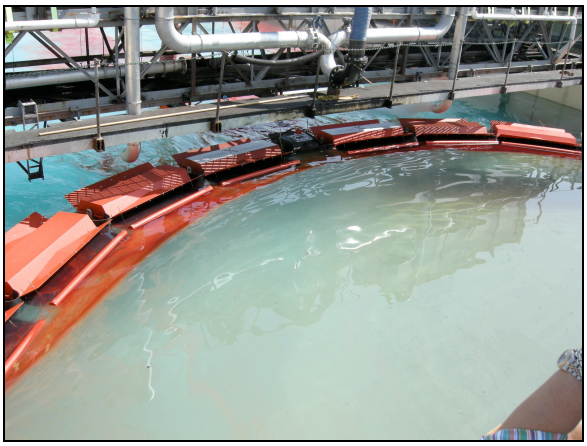

Figure 6: Vor-Tek – California, USA.

Figure 7: Lamor – Finland.

Figure 8: Crucial – Louisiana, USA.

Figure 9: OilShaver – Norway.

Figure 10: Koseq – Netherlands.

5.9 $300,000 Second Place Winner: NOFI – Norway

The NOFI system was designed with inflatable boom arms extended forward and outward to channel oil through a narrow throat in the system (Figure 11). The fluid entered a more open, semi-quiescent area which allowed the fluid to self-decant before pumps offloaded the fluid to the recovery tanks on the Auxiliary Bridge.

Figure 11: The NOFI skimmer system.

5.10 $1 Million First Place Winner: Elastec/American Marine – Illinois, USA

Four banks of oleophilic discs, with concentric grooves, were mounted between

two pontoons (Figure 12). Oil that adhered to the discs was scraped into a sump, and then pumped to recovery tanks on the Auxiliary Bridge.

Figure 12: The Elastec/American Marine skimmer system.

6 RESULTS

After each team's system was rigged in the tank, they were given one day to optimize their settings and determine their optimum tow speed between 0.5m/s – 2.0m/s (1 and 4 knots). Following the optimization day, teams were given two additional days to complete up to four runs in calm conditions and four runs in wave conditions. Test results were valid if they were within 20% of the calm or wave run mean. The final combined mean was calculated by averaging the three best calm water runs and the three best wave runs.

Table 1: Summary of Results.

Team	ORR combined	RE combined (%)	ORR calm	RE calm (%)	ORR waves	RE waves (%)
Elastec Fig. 12	17,678 L/min 4670 gpm	89.5	17,814 L/min 4,706 gpm	88.9	17,538 L/min 4,633 gpm	90.1
NOFI Fig. 11	10,266 L/min 2,712 gpm	83.0	11,197 L/min 2,958 gpm	91.9	9,335 L/min 2,466 gpm	74.0
Koseq Fig. 10	7,817 L/min 2,065 gpm	87.9	8,748 L/min 2,311 gpm	98.2	6,882 L/min 1,818 gpm	77.6
OilShaver Fig. 9	7,597 L/min 2,007 gpm	90.7	7,601 L/min 2,008 gpm	92.6	7,594 L/min 2,006 gpm	88.8
Crucial Fig. 8	7,147 L/min 1,888 gpm	71.3	8,135 L/min 2,149 gpm	79.7	6,155 L/min 1,626 gpm	62.8
Lamor Fig. 7	5,349 L/min 1,413 gpm	92.5	5,156 L/min 1,362 gpm	91.4	5,546 L/min 1,465 gpm	93.6
Vor-Tec Fig. 6	8,589 L/min 2,269 gpm	57.3	11,409 L/min 3,014 gpm	72.1	5,773 L/min 1,525 gpm	42.5
OilWhale Fig. 4	3,865 L/min 1,021 gpm	42.8	5,894 L/min 1,557 gpm	44.6	1,836 L/min 485 gpm	41.0
PPR Fig. 5	3,642 L/min 962 gpm	92.1	3,956 L/min 1,045 gpm	96.9	3,324 L/min 878 gpm	87.3
Voraxial Fig. 3	2,623 L/min 693 gpm	49.2	3,562 L/min 941 gpm	63.9	1,685 L/min 445 gpm	34.5

7 SUMMARY

Ten skimming systems were tested at Ohmsett in the $1.4 Million Wendy Schmidt Oil Cleanup X CHALLENGE. Prior to the competition, the highest ORR measured at Ohmsett was approximately 3400 L/min (900 gpm) with a RE over 70%. To qualify for a prize, a system's ORR had to exceed 9,464L/min (2500 gpm) with at least a 70% RE. Two teams surpassed these goals: the $300,000 second place winner, NOFI achieved a combined ORR of 10,266 L/min (2712 gpm) with a RE of 83.0%; the $1 Million first place winner, Elastec/American Marine had a combined ORR of 17,678 L/min (4670 gpm) with a RE of 89.5%. Elastec/American Marine's ORR was five times greater than the highest capacity skimmer previously tested at Ohmsett.

8 ACKNOWLEDGEMENTS

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9 REFERENCES

ASTM, *Annual Book of ASTM Standards: F 2709 - Standard Test Method for Determining Nameplate Recovery Rate of Stationary Oil Skimmer Systems*, American Society for Testing and Materials, West Conshohocken, PA, 2008a.

ASTM, *Annual Book of ASTM Standards: F 631 - Standard Guide for Collecting Skimmer Performance Data in Controlled Environments,* American Society for Testing and Materials, West Conshohocken, PA, 2008b.

ASTM, *Annual Book of ASTM Standards: D 1796 – Standard Test Method for Water and Sediment in Fuel Oils by the Centrifuge Method (Laboratory Procedure),* American Society for Testing and Materials, West Conshohocken, PA, 2011.