

# **LARGE WAVE TANK DISPERSANT EFFECTIVENESS TESTING IN COLD WATER**

Randy Belore  
S.L. Ross Environmental Research Ltd.  
717 Belfast Rd., Ottawa, Ontario  
K1G 0Z4

## **ABSTRACT**

Research experiments were completed to determine the viability of using chemical dispersants on two crude oils in very cold water conditions. Tests were completed at Ohmsett (the National Oil Spill Response Test Facility in Leonardo, New Jersey) in late February and early March of 2002. Ohmsett is a large outdoor, above-ground concrete tank (203 m long by 20 m wide by 3.4 m deep) filled with 9.84 million gallons of salt water. The tank has a wave-generating paddle, a wave-dissipating beach, and mobile bridges that transport equipment over its surface. A refrigeration unit was installed to ensure that the water was kept at near freezing temperatures during the entire test program. A total of twelve large-scale tests were completed. Corexit 9500 and Corexit 9527 were applied to fresh and weathered Hibernia and Alaska North Slope crude oils, on cold water (-0.5 to 2.4 °C), at dispersant-to-oil ratios (DORs) ranging from 1:14 to 1:81. The average wave amplitude for the tests ranged between 16.5 and 22.5 cm and the average wave period was between 1.7 and 1.9 seconds. The effectiveness of the dispersant in each test was documented through extensive video records and by measurement of the residual oil remaining within the containment boom at the end of each test. The results clearly show that both dispersants were effective in dispersing the two crude oils tested in cold-water conditions.

## **BACKGROUND**

The primary goal of this study was to determine whether two important crude oils that are produced and handled in cold waters (Hibernia and Alaska North Slope) could be chemically dispersed in near-freezing conditions. Previous small scale test results (SL Ross 1999, 2001) suggested that dispersants should be effective on these oils in cold water, but it was decided that larger scale tests - with realistic slicks, dispersant spray and mixing energies - were needed to confirm this ability.

Two recent studies have determined that realistic testing of dispersant effectiveness (DE) can be accomplished at Ohmsett (the National Oil Spill Response Test Facility in Leonardo, New Jersey: [www.ohmsett.com](http://www.ohmsett.com)). The first study (SL Ross 2000a) investigated the general feasibility of using Ohmsett for dispersant effectiveness testing. The most significant finding of this study was that hundreds of tests could be completed in the tank, using reasonable quantities of oil and dispersant, without the dispersant added to the tank having any effect on the results of subsequent dispersant effectiveness tests. In the second study (SL Ross 2000b), a protocol for DE testing at the Ohmsett facility was developed, and preliminary dispersant effectiveness tests were completed using the protocol. The Ohmsett test results were consistent with observations and measurements made at field trials. The protocol developed in the earlier study has been used in the research reported here, with a few minor modifications.

## MAJOR TEST EQUIPMENT

The main equipment components of the DE test procedure include the Ohmsett tank, the wave making system, the main equipment bridge, the oil distribution system, the oil containment boom and the dispersant spray system. Photos of these components are provided in Figures 1 through 7. Additional details of the equipment and methods used can be found in SL Ross 2000b.



Figure 1. Ohmsett Test Tank with Oil Containment Boom



Figure 2. Ohmsett Tank Wave Paddle System



Figure 3. Main Bridge with Dispersant Spray Bar in Foreground, Oil Distribution Behind

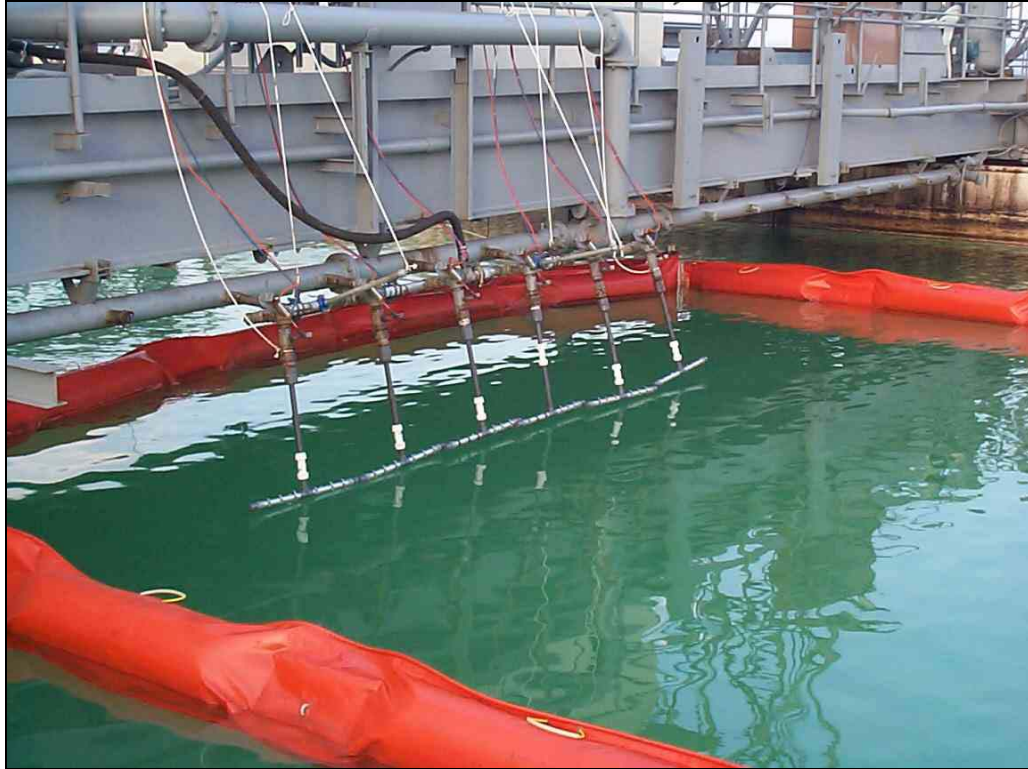


Figure 4. Oil Distribution System

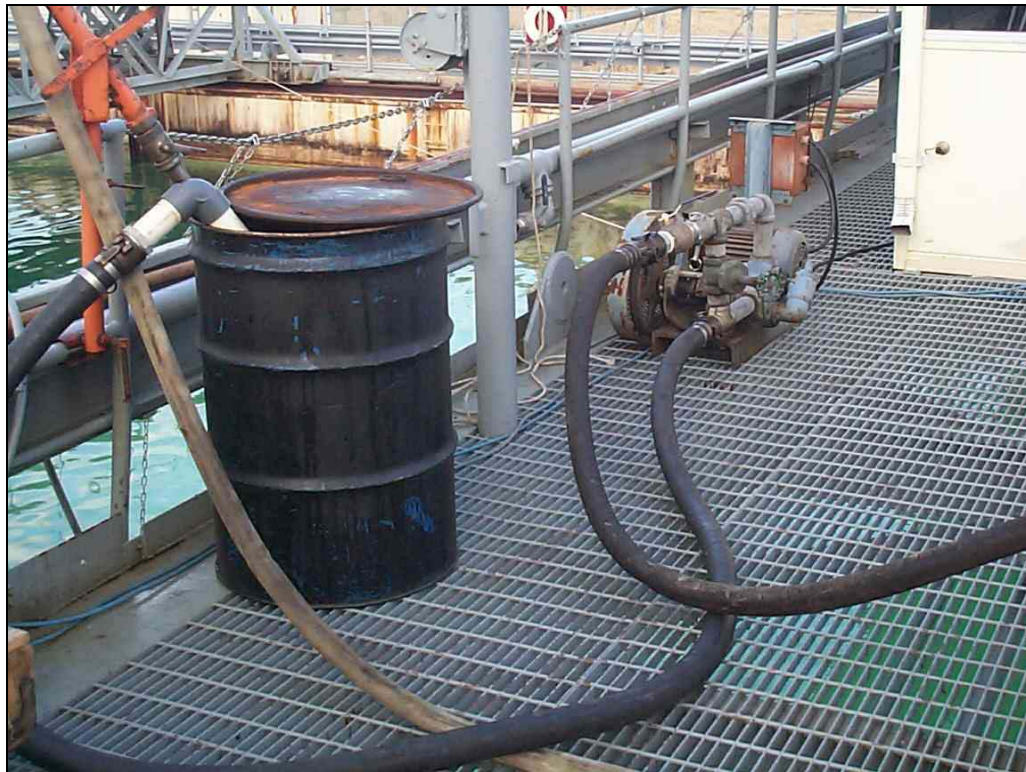


Figure 5. Oil Delivery Pump and Supply Drum



Figure 6. Dispersant Supply Tank and Pump



Figure 7. Dispersant Spray Bar in Operation

## TEST PROCEDURE

The following steps, specified in the 2000 test protocol, were completed for each test.

1. Position a rectangle of containment boom in the tank.
2. Load desired test oil into Main Bridge oil distribution system. Start re-circulating.  
Measure oil temperature periodically. When oil warm enough, set position of oil pump re-circulating valve by calibrating flow from discharge hose with bucket and stopwatch. Connect discharge hose to oil distribution system.
3. Start dispersant pump re-circulating.
4. Position Main Bridge towards north end of rectangle of boom.
5. Spray dispersant over north boom until good spray pattern established. Shut solenoid valve.
6. Turn on videos, data acquisition.
7. Accelerate bridge to specified speed.
8. When Main Bridge oil distribution system is 5 m south of north end of rectangle of boom, begin laying down test slick by opening air-actuators. When oil appears from nozzles start stopwatch.
9. Lay oil for 20 m travel distance. Close air actuators when specified oil discharge time reached.
10. When dispersant spray bar is 1 m from beginning of test slick, activate solenoid valve to begin spray – hold open until spray bar is 1 m past end of test slick.
11. Turn on waves at desired setting.
12. Turn off and secure oil and dispersant pumps.
13. Visually observe dispersion.

14. One hour after first waves hit slick, stop waves and allow surface to calm.
15. Herd remaining surface oil to downwind end of rectangle of boom for recovery and volumetric/water content measurements.

At the end of each one-hour test, the oil remaining in the containment boom area was herded to a central collection area. The oil was recovered using a long-handled ladle for tests where only a small amount of oil remained, or a P-trap skimmer for those tests where large oil volumes remained. The oil and water collected were placed in a decant vessel where free water was removed from the sample.

## **TEST MATRIX**

A total of twelve large-scale tests were completed. Corexit 9500 and Corexit 9527 were applied to fresh and weathered Hibernia and Alaska North Slope crude oils, in dispersant-to-oil ratios (DORs) ranging from 1:14 to 1:81. The water temperature was maintained between  $-0.5$  to  $2.4$  °C throughout all of the testing. Morning air temperatures ranged from  $-5$  to  $6$  °C. Afternoon air temperatures ranged between  $3$  to  $17$  °C. Between 60 to 80 liters of oil were used in each test and the oil was spread on the water surface to form slicks between 1.1 and 1.8 mm thick. Waves were generated using a wave paddle stroke of 7.6 cm and frequency of 35 cycles per minute. The average wave amplitude for the tests ranged between 16.5 and 22.5 cm and the average wave period was between 1.7 and 1.9 seconds. The characteristics of the oil used in the tests are shown in Table 1. The evaporated oils were generated by bubbling air through heated drums of the oil. The percentage values shown in Table 1 are expressed as volume percent evaporated. The weight of the oil was monitored during the air sparging using a weigh scale and a drum lift.



Table 1. Physical Properties of Fresh and Evaporated Crude Oils

<b>OIL</b>	<b>Density (kg/m<sup>3</sup>)</b>	<b>Viscosity Pa.s (cP) @1.3 °C &amp; 10 s<sup>-1</sup></b>
<b>Hibernia Crude</b>		
Fresh	854	0.43 (430)
7.9% Evaporated	867	0.66 (660)
10.3% Evaporated	876	1.87 (1870)
<b>ANS Crude</b>		
Fresh	873	0.025 (25)
10% Evaporated	903	0.16 (160)
20% Evaporated	923	1.94 (1940)

## TEST RESULTS

It was clear from visual observations which tests resulted in significant dispersion and which did not. However, to maintain compliance with the test protocol, estimates of maximum possible DE were made for all tests. The DE values are based on a comparison of the amount of oil applied at the beginning of the test to the amount recovered at the end. The DE values reported in Table 2 for tests 1 and 11 are known to be too high due to the observed loss of non-dispersing oil over the end containment barrier. This oil loss is discussed more fully in the following paragraph. Table 2 summarizes the test results, arranged by oil and dispersant type rather than by order of test completion. With the exception of the control tests (tests 1 and 6) and test 11, all of the tests resulted in high percentages of oil dispersing into the water column. The dispersion, observed by those who attended the tests, is extensively documented in the video clips provided for each of the tests.

Table 2. Cold Water Dispersant Effectiveness Test Results Summary

Oil Type	% Evap. By Volume	Air Temp °C am pm	Water Temp °C am pm	Oil Volume (liters)	Oil Thickness (mm)	Dispersant Type	DOR	Max DE (%)	Test #
Hibernia	0.0	5.6 6.1	1.6 2.4	86	1.17	none	0	84*	1
	0.0	5.6 6.1	1.6 2.4	82	1.21	Corexit 9500	1:33	>90	2
	7.9	0.6 6.7	0.3 0.8	88	1.47	Corexit 9500	1:38	82	3
	10.3	0.6 10.0	-0.5 0.4	68	1.76	Corexit 9500	1:14	95	5
Hot Hibernia	0.0	0.6 10.0	-0.5 0.4	69	1.80	Corexit 9500	1:14	98	7
ANS Crude	0.0	0.6 10.0	-0.5 0.4	20	n/a	none	0	n/a	6
	0.0	-5.0 2.8	-0.4 0.0	71	1.15	Corexit 9527	1:32	98	9
	10	1.7 3.9	0.2 2.0	79	1.28	Corexit 9527	1:48	99	8
	20	-5.0 2.8	-0.4 0.0	77	1.25	Corexit 9527	1:44	99	10
	0.0	0.6 6.7	0.3 0.8	71	1.14	Corexit 9500	1:34	97	4
	0.0	3.3 16.7	-0.3 0.9	74	1.20	Corexit 9500	1:81	93*	11
	20	3.3 16.7	-0.3 0.9	76	1.23	Corexit 9500	1:38	96	12

\* considerable quantity of black, non-dispersing oil escaped the containment area in these tests

In the control case (test #1: no dispersant applied), all of the oil remained on the surface and was herded by wind and wave to the north containment boom where occasional cresting waves would splash small amounts of oil over the end boom. A significant amount of oil was seen to exit the containment area by this process. The oil from this control test was observed to remain on the surface after the splash over. End boom “splash over” was not as prominent in the tests where dispersant was applied because most of the oil dispersed into the upper water layer prior to being herded to the downwind end containment barrier. In some of the tests where dispersant was applied, oil-and-water mixtures (coffee colored mixtures) were observed splashing over the end containment boom. However, this oil quickly dispersed into the water column after the splash over. This is seen in the video records of the tests. The one exception to

this behavior occurred in test #11, where low dispersant dosage was used. In this test, “black” oil observed splashing over the end boom remained on the surface, in the form of sheen, and did not appear to disperse.

Figure 8 shows a typical test (test #3) shortly after the onset of wave cresting. The photo provides an indication of the wave energies used in the tests and the absence of surface oil and the presence of dispersed oil following a successful test. This is more clearly seen in the color version of the photo in the conference CDROM version of the paper. A video clip of a portion of the same test can also be viewed from the CDROM version by clicking on the following link ([video clip](#)).

Wave amplitude and period measurements were made during 5 to 10 minutes of each test. These records were analyzed for average wave amplitude and period. The average wave amplitude for the tests ranged between 16.5 and 22.6 cm and the average period was between 1.7 and 1.9 seconds.



Figure 8. Successful Dispersion, Start of Cresting Wave at Right of Photo

For those tests where quantities allowed, the oil remaining in the containment boom at the end of the tests was collected for determination of volume, water content, density and viscosity. As would be expected, the densities and viscosities of the oils increased over the duration of the tests. The Hibernia oil density increased from a fresh oil value of  $854 \text{ kg/m}^3$  to densities ranging between  $916$  to  $950 \text{ kg/m}^3$ . The Hibernia crude oil viscosities increased from a fresh oil value of  $430 \text{ cP}$  to values between  $2890$  and  $4700 \text{ cP}$ . These viscosities are for the parent oil after breaking any emulsion that may have formed during the test. The water contents of the collected emulsions ranged from  $17$  to  $30\%$ .

The ANS crude oil densities increased from a fresh oil value of  $873 \text{ kg/m}^3$  to densities ranging from  $932$  to  $1005 \text{ kg/m}^3$  for the residues. The viscosities of the oil residues for the ANS tests were not measured due to equipment failure. The water contents of the collected emulsions ranged from  $27$  to  $43\%$  in the tests with ANS crude oil.

The total quantity of dispersant added to the test tank during the program was about  $70$  liters. The concentration of dispersant in the water by the end of the testing was less than  $10 \text{ ppm}$  based on the  $10$  million liter volume of the tank and the  $70$  liters of dispersant.

## **RECOMMENDATIONS**

The test setup and procedures could be improved in the following ways:

1. The containment area should be extended to include as long a section in the tank as possible. The oil should be discharged as close as possible to the south end of the containment area and the wave paddle. This will provide a longer time for dispersion to occur prior to wind and wave herding of the surface oil to the north boom segment. The north end containment boom's freeboard should also be increased to minimize the splash-over of any oil that does drift to the boom.

2. There is a delay in the onset of waves once the wave paddle is started. To counter this delay the wave paddle motion should be initiated just as the oil is starting to be discharged. By starting the waves sooner the oil will not have as much opportunity to drift to the side boom, on windy days, prior to the onset of the cresting waves which are clearly responsible for the initiation of rapid oil dispersion.

3. The tests should be shortened to 20 to 30 minutes. The results show that the main dispersion process occurs within about 10 minutes of the onset of cresting waves.

4. Ideally, the entire tank surface, tank sidewalls and containment boom should be flushed of surface oil prior to each test. This will ensure that any surface oil seen outside of the containment area can be confidently attributed the test being completed.

5. Tests should be completed only when the tank is clear enough and the lighting is bright enough to permit visual confirmation of the formation of a dispersed oil cloud and the loss of the surface slick. This “visual clarity” check might best be established by pre-mixing a few liters of oil with dispersant and pouring the mixture into the tank. If the resulting dispersed oil cloud is visible from the crow’s nest of the main bridge then the testing could continue. If not, the tank would have to be cleaned or the test would have to be delayed until a brighter day.

6. In-water oil concentrations could be measured in the center of the tank over the duration of the test to determine if the concentration of oil in the water increases after the dispersant

application. It is not recommended that a quantification of the total oil dispersed into the water column be attempted, as this would require a very substantial effort.

7. The drop size distribution of suspended solids in the tank could be measured at the same time and location as the in-water oil concentration measurements. The drop size data could be used to confirm whether or not the dispersed oil is in small enough drops to be considered permanently dispersed.

8. The surface slick should be photographed just prior to the dispersant application so a better quantification of oil thickness and coverage could be made for use in determining the dispersant-to-oil ratio.

9. A continuous video of the test should be made from the crow's nest of the main bridge, rather than the main bridge deck, to provide a better overview of the test.

## **SUMMARY**

Corexit 9500 and Corexit 9527 were applied to fresh and weathered Hibernia and Alaska North Slope crude oils, on cold water (-0.5 to 2.4 °C), in dispersant-to-oil ratios (DORs) ranging from 1:14 to 1:81. The effectiveness of the dispersant in each test was determined through visual and video observations and by measurement of the residual oil remaining within the containment boom at the end of each test. The results clearly show that these dispersants were effective in dispersing both oils in cold-water conditions. Maximum dispersion estimates ranged from 82 to 99%. In some tests water containing dispersed oil was seen splashing over the north containment boom, due to breaking wave action. The oil, in the form of fine drops mixed with water, quickly

diffused into the water column outside of the containment boom and did not resurface to form a surface slick while the waves were present. Only in the control tests and the low dispersant dosage test was “black” oil seen to escape the north containment boom and remain on the surface. Changes in the test setup have been recommended to remedy this splash over problem.

A total of 70 liters of dispersant was sprayed into the 10 million liter tank during these tests. Based on this volume of dispersant, the maximum possible concentration of dispersant in the water at the end of the testing was about 7 ppm. The dispersant added to the tank during the test program therefore would not have affected the results of subsequent tests.

## **ACKNOWLEDGEMENTS**

This project was co-funded by the Minerals Management Service (MMS) and ExxonMobil Research and Engineering and the author thanks Mr. Joseph Mullin (MMS) and Dr. Richard Lessard (ExxonMobil) for their generous support and technical assistance. The experimental work at the Ohmsett facility was expertly managed and completed by MAR Incorporated staff and their considerable involvement in the project is also acknowledged.

## **BIOGRAPHY**

Randy Belore is a vice president at SL Ross and has been working in oil spill countermeasures research and development with the company since 1981. His specialties include oil spill fate and behavior modeling, oil spill chemical dispersant effectiveness testing, and the research and development of spill countermeasures techniques. Mr. Belore has B.A.Sc. and M.A.Sc. Degrees in Engineering from the University of Waterloo.

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