# FINAL REPORT

# Correlation of Ohmsett Dispersant Tests With At-Sea Trials: Supplemental Tests

**For:**

**United States Department of the Interior**
**Minerals Management Service**
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## Executive Summary

Dispersant effectiveness tests for the Minerals Management Service project, "Dispersant Effectiveness Tests: Relating Results From Ohmsett to At-Sea Tests," (SL Ross et al. 2005) were completed at Ohmsett in October 2003. The primary objectives of the project were met, but two secondary objectives were only partly achieved:

a) Measuring dispersant performance in the Ohmsett tank, with high dispersant-to-oil ratios (DORs) that had yielded high levels of effectiveness at sea; and
b) Conducting replicate control runs for both test oils (IFO 180 and IFO 380) at wave frequencies of 30 and 33.3 cpm.

This project addressed these two deficiencies.

The project involved a total of seven supplemental dispersion tests using IFO 180 and 380 fuel oils. Tests included: replicated controls; tests on IFO 180 and IFO 380 at high dispersant-to-oil ratios (DORs) in waves of 33.3 cpm; and tests on IFO 180 at high DORs in waves of 30 cpm. Control tests (no dispersant) with IFO 180 in 33.3-cpm waves provided a reliable estimate of oil loses by all means other than chemically augmented dispersion. These controls provided a baseline against which losses by chemically augmented dispersion could be compared. Oil recovery rates in control tests were 85% or greater, which showed that loss by "natural dispersion" and other sources in these tests were less than 15%. Tests of IFO 180 treated with Corexit 9500 (DOR of 1:25) in 33.3 cpm waves produced very high levels of effectiveness based on both visual assessment methods (visual 3 to 4) and direct measurement (6% recovered) confirming the result observed in the 2003 test. Tests with the more viscous, IFO 380 treated with Corexit 9500 (DOR of 1:25) and tested in 33.3 cpm waves also yielded a high level of effectiveness both visually (visual = 3 to 4) and by direct measurement (15% recovered). The October 2003 test with IFO 380 with Corexit 9500 yielded ambiguous results. However, result of the present test is unambiguous and is consistent with the visual observations in the 2003 Ohmsett test, confirming that a high level of dispersion was taking place. Both of these observations were more consistent with the results of the at-sea tests in winds of 14 knots, where considerable dispersion was observed. They were

not consistent with the at-sea tests at 8 to 9 knots where little or no dispersion was observed.

The present tests of IFO 180 treated with Corexit 9500 in non-breaking waves (waves at 30 cpm) yielded apparently ambiguous results in that on the one hand, there was no visual evidence of dispersion, while on the other hand, amounts of oil collected at the end of the tests (50 and 69% of the oil recovered) suggested that significant chemically augmented dispersion had actually taken place. This inconsistency between visual observations and direct measurement is similar to observations in the 2003 study. The discrepancy appears to be due to artifacts of the test method. After treatment with dispersant, the oil is highly susceptible to dispersion, but there is clearly insufficient mixing energy in the waves to cause dispersion. However, localized turbulence caused by the oil collection tools during the collection phase of the run may have caused localized dispersion, thus accounting for the lowered levels of recovered oil. Apparently, for tests at low sea states, visual observations may be more reliable in estimating dispersion than measuring the oil remaining on the tank at the end of the test until test methods are improved.

## Introduction

Dispersant effectiveness tests for the project, “Dispersant Effectiveness Tests: Relating Results From Ohmsett to At-Sea Tests,” (SL Ross et al. 2005) were in October 2003. The primary objectives of the project were met, but two secondary objectives were only partly achieved. These objectives were:

c) To measure dispersant performance at Ohmsett at high dispersant-to-oil ratios (DORs) that had yielded high levels of dispersant effectiveness at sea; and

d) To conduct replicate control runs for both test oils (IFO 180 and IFO 380) at wave frequencies of 30 and 33.3 cpm.

This study addressed these partially achieved objectives and solidified our understanding of the correlation of Ohmsett testing to at-sea testing.

The October 2003 Ohmsett tests yielded important information concerning the relationship of Ohmsett testing to at-sea dispersant tests. During that program, tests were completed for most parts of the test matrix, but data sets for control runs (no dispersant) and tests at high DORs are very limited. While results from the tests suggested certain trends, additional data points were required to fill some gaps and verify that trends are repeatable. The following questions and gaps were addressed.

1. Replicate tests with IFO 180 with Corexit 9500 at a DOR 0f 1:25 were completed at a wave frequency of 33.3 cpm to demonstrate that those conditions yielded very high levels of effectiveness as was observed at sea.
2. In the 2003 study, tests of IFO 180 treated with Corexit 9500 in non-breaking waves (30 cpm) yielded apparently ambiguous results. While tests produced little visual evidence of effective dispersion, at the end of the tests slightly less oil was recovered than in the controls, suggesting that some dispersion might indeed be taking place but at a rate too low for visual detection. In addition, the DOR used in the 2003 test was low compared with the at-sea tests. The present study repeated the tests of IFO 180 treated with Corexit 9500 in 30 cpm waves, but used a higher DOR rate of 1:25.

3. In the 2003 project, the single test of IFO 380 treated with Corexit 9500 and tested with waves at 33.3 cpm also yielded ambiguous results. While the test appeared to produce a moderate to high level of effectiveness visually, the amount of oil recovered at the end of the test suggested that indeed the dispersion rate was quite low, only slightly greater than in a control run. The present study included replicate tests of IFO 380 treated with Corexit 9500 at a DOR of 1:25 tested at waves of 33.3 cpm.
4. The 2003 study included only one control test (no dispersant added) with each of IFO 180 and 380 to provide a baseline against which tests of chemically augmented dispersion could be measured. The present project included replicate control runs with IFO 180 tested at a wave frequency of 33.3 cpm.

## Tests Conducted in 2005 Program

The following tests were completed:

1. Replicate tests (2) of IFO 180 dosed with Corexit 9500 at a nominal DOR of 1:25 and tested at wave frequency settings of 30 and 33.3 cpm.
2. A test of IFO 380 dosed with Corexit 9500 at a nominal DOR of 1:25 tested at a wave frequency setting of 33.3 cpm.
3. Replicate control tests (2) (no dispersant) with IFO 180 tested at a wave frequency setting of 33.3 cpm.

## Oil Used in 2005 Program

The stockpiles of IFO 180 and IFO 380 remaining after the 2003 tests were not sufficient for the 2005 tests. Replacement quantities of IFO 180 and 380 were prepared by blending IFO 380 (380) with marine gasoil (MGO) to produce oils of similar viscosity (at $15^{o}$ C) to the original IFO180 and IFO 380 tested in 2003. Ratios of MGO to 380 needed for blending were determined in a small-scale test, by diluting the 380 step-wise with the aid of a blending chart. Once the appropriate blend ratios were determined, eight hundred litres of replacement IFO 180 and 400 litres of IFO 380 were blended for use in this study. In each case oils were blended in 1000-litre containers. The IFO 380 was added first and was diluted by addition of the appropriate amount of MGO. The resulting mixture was mixed for several hours using air bubbling. Samples were taken and the viscosities of the blends were verified prior to testing. Properties of the blended replacement IFO 180 and 380 produced for use in the study were measured using standard methods. The stocks of IFO 380 and MGO used for blending were purchased locally through Harbor Petroleum, Manasquan, New Jersey.

## Test Procedure

A detailed description of the protocol used in testing can be found in previous publications (SL Ross et al 2000a, 2000b, 2002; SL Ross and MAR 2003, 2005; SL Ross et al., 2005). Significant improvements to the oil delivery system were implemented for the present study to facilitate the discharge of viscous oils. In earlier studies, problems had been encountered in delivering viscous oils and these modifications successfully addressed the problem. The new oil discharge system includes:

- Progressing cavity pump,
- Pump speed control system,
- Gravity fed oil hopper supply,
- Three-inch oil supply lines, and
- Stainless steel oil discharge manifold.

Oil is pumped into the hopper from drums or other supply tanks using the progressive cavity pump in reverse. The flow rate for this pump is precisely controlled using a digital control module. The pump generates 0.19 gallons per minute per revolution of the pump. The quantity of oil discharged from the hopper is measured using a sonic probe mounted above the oil supply. Photographs of the oil supply system and oil discharge header are provided in SL Ross and MAR 2005.

The dispersant spray system used in the testing was the same as that used in previous dispersant tests at Ohmsett. Corexit 9500 dispersant was used in all of the tests.

## Results and Discussion

Properties of the oils used in these tests are reported in Table 1. Test conditions and results are reported in Table 2 and are compared with results of 2003 tests in Table 3.

**Table 1: Physical properties of Oils Used in Ohmsett Testing**

| Oil | Viscosity (cP) (@ 15°C and 10 $s^{-1}$) | Density ($g/cm^3$) (@ 20° C) |
|---|---|---|
| **Oils used in 2003 At-Sea Trials and Ohmsett Tests** | | |
| IFO 180 | 2075 | 0.970 |
| IFO 380 | 7100 | 0.983 |
| **Supplemental Oils Blended in UK for 2003 Ohmsett Tests** | | |
| IFO 180 | 1645 | 0.972 |
| IFO 380 | 6515 | 0.988 |
| **Blended for 2005 Ohmsett Tests** | | |
| IFO 180 | 2410 | 0.950 |
| IFO 380 | 7025 | 0.954 |

Replicate control (no dispersant) runs were conducted, in which IFO 180 was tested at a wave frequency of 33.3 cpm. As in the 2003 control tests and controls in other recent projects (SL Ross et al. 2005, SL Ross and MAR Inc 2005), there was no visual evidence of dispersion. However, when oil remaining on the tank at the end of the tests was collected, approximately 96 and 84 percent of the original oil was recovered, leaving 4 and 16 percent of the discharged oil unaccounted for.

As discussed in SL Ross and MAR Inc. (2005), oil losses in control runs may arise from: physical dispersion, evaporation, losses over the boom and adherence to the boom. These control tests represent a baseline against which effectiveness tests are compared to determine whether significant "chemically augmented dispersion" has actually taken place.

## Table 2: Supplemental Effectiveness Tests on Heavy Fuel Oils at Ohmsett, April 2005

| Test # | Oil Type[a] | Dispersant To-Oil Ratio | Wave Freq (cpm) | Water Temp °C | Oil Temp °C | Disp. Temp °C | Oil Volume (litres) | Target $DOR_T$ | Measured $DOR_M$ | Measured Dispersant Effectiveness [b] (%) | Visual Assessments of Dispersant Effectiveness[c] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | 0 to 4 min | 4 to 10 min | 11 to 20 min. |
| S6 | IFO 380R | 1:25 | 33.3 | 56F | 65F | 55F | 72.7 | 1:25 | 1:21 | 85 | 1 | 4 | 2 |
| S1 | IFO 180R | Control | 33.3 | 54F | 68F | na | 74.6 | 0 | 0 | 4 | 1 | 1 | 1 |
| S2 | IFO 180R | Control | 33.3 | 54F | 62F | na | 82.7 | 0 | 0 | 16 | 1 | 1 | 1 |
| S5 | IFO 180R | 1:25 | 33.3 | 57F | 69F | 74F | 84.5 | 1:25 | 1:7 | 95 | 3 | 4 | 1 |
| S7 | IFO 180R | 1:25 | 33.3 | 55F | 53F | 52F | 74.3 | 1:25 | 1:23 | 86 | 4 | 3 | 3 |
| S3 | IFO 180R | 1:25 | 30 | 54F | 54F | 54F | 82.3 | 1:25 | 1:9 | 31 | 1 | 1.5 | 1 |
| S4 | IFO 180R | 1:25 | 30 | 55F | 60F | 57F | 80.2 | 1:25 | 1:9 | 50 | 1.5[d] | 1.5 | 1.5 |

a. All tests used re-blended IFO 180 or 380 (referred to as IFO 180Ror IFO 380R) as described in the text. All dispersant tests used Corexit 9500 at stated dispersant-to-oil-ratios

b. Numerical values are the percent of the oil initially discharged that was left at the end of the test, control values have not been subtracted

c. Based on Lewis four-point scale, in which 1 = no obvious dispersion; 2 = slow and/or partial dispersion; 3 = moderately rapid dispersion; and 4 = rapid and complete dispersion (see SL Ross et al. 2005)

d. At least some of the visible dispersion was due to turbulence caused by interactions with waves and boom and boom connector

A re-examination of four recent studies (Table 3) show that controls in the earliest tests were somewhat variable, but improved methods in recent tests have reduced that variability somewhat. In the earliest study involving the Alaskan oils, the estimates of oil recovered at the end of the test varied from 80 to 120 percent of the amount discharged. In the 2003 IFO tests this value declined to 70 to 102 percent. In the present tests the value was 84 to 96 percent and in the most recent tests on viscous OCS crude oils the range was from 70 to 89 percent. These improvements have derived from upgrading of methods for sampling and analysing the water content of the spilled and collected oil, decanting the free water from the collected oil, and accounting for evaporation of light ends during tests. The combined results of control tests with IFO 180 from the present and earlier tests suggest that losses in controls are in the range of 0 to 16 percent of the volume spilled. Measured values for losses during control tests in waves of 30 cpm would be expected to be similar to or lower than these and were not tested.

**Table 3: Oil Recovery Rates in No-Dispersant Control Runs at Ohmsett**

| Name of Oil | Oil viscosity (at 15° C and $10^{s-1}$) | Volume of oil spilled (litres) | % Recovered in Control | | Reference |
|---|---|---|---|---|---|
| | | | 33.3 cpm | 35cpm | |
| ANS | 98 | 108 | | 102 | a |
| Endicott | 1630 | 103 | | 88 | a |
| North Star Fr | 101 | 103 | | 120 | a |
| Pt. Mac Fr | 740 | 104 | | 78 | a |
| IFO 380 (O) | 7100 | 70.8 | | 70 | b |
| IFO 180 (O) | 2075 | 76.8 | 102 | | b |
| **IFO 180 R** | **2410** | **74.6** | **96** | | c |
| **IFO 180 R** | **2410** | **82.7** | **84** | | c |
| Harmony | 1825 | 68 | 87 | | d |
| Elly | 3600 | 78 | 70 | | d |
| Gina | 4000 | 63 | 87 | | d |
| Gilda | 4800 | 51 | 89 | | d |
| Irene | 19920 | 54 | 83 | | d |
| Heritage | 36000 | 36 | 74 | | d |
| Heritage | 36000 | 87 | 83 | | d |

a. SL Ross and MAR 2003
b. SL Ross et al. 2005
c. This project
d. SL Ross and MAR 2005

The new tests with IFO 180 treated with Corexit 9500 at a DOR of 1:25 tested at a wave frequency of 33.3 cpm produced high levels of effectiveness based on both visual assessment methods (visual 3 to 4) and direct measurement (only 5 and 14% of the spilled oil were left on the surface at the end of the test.) The high effectiveness in these tests confirmed the result from the October 2003 tests (Test #16 in Table 4).

IFO 380 treated with Corexit 9500 (DOR of 1:25) and tested with 33.3 cpm waves yielded a high level of effectiveness both visually (visual = 3 to 4) and in terms of oil recovered (15% oil recovered). Both the at-sea trials and earlier Ohmsett tests yielded ambiguous results for tests with IFO 380 and Corexit 9500. The at-sea tests consistently produced little effectiveness (visual = 1 to 1.2) at the lower wind speeds of 8 to 9 knots, but yielded somewhat higher effectiveness (visual= 2 to 3) at the higher wind speed of 14 knots (Lewis 2004). The 2003 test at Ohmsett (Table 4, Test #3) appeared to produce considerable visual evidence of dispersion, but the amount of oil that was recovered was only slightly less than in control tests. The results of the present test are consistent with the visual observations observed in the earlier Ohmsett test, that indeed a high level of dispersion was taking place. Both of these observations are consistent with the results of the 14-knot winds test during the at-sea trials that at least some dispersion was taking place.

IFO 180 treated with Corexit 9500 and tested in non-breaking waves (waves at 30 cpm) yielded little or no visual evidence of dispersion in the central parts of the slick at any time during the test. The amounts of oil collected at the end of the tests (50 and 69% of the oil recovered) appear to be less than in the controls, suggesting that a small but significant amount of chemically augmented dispersion had taken place during the test. This apparent inconsistency between visual observations and direct measurement is consistent with the observations in the 2003 study, where little dispersion was apparent visually, but where amounts of oil recovered were less than in controls.

## Table 4: Summary of Ohmsett Results from Tests in 2003 and 2005

| Test # | Oil Type | Dispersant Type | Wave Frequency: Nominal, $Min^{-1}$ | Wave Frequency: Measured, $Min^{-1}$ | Volume of Oil Spilled, Litres | Target DOR | Measured DOR | Dispersant Performance, Visual Method [b] | | | Dispersant Performance, Direct Measurement [c] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Median | Min | Max | |
| 1 | IFO 380 | no disp. | 35 | 34.6 | 70.8 | 0 | 0 | 1 | 1 | 1 | 30 |
| 2 | IFO 380 | 9500 | 35 | 34.4 | 98.1 | 1:50 | 1:180 | 4 | 4 | 4 | 58 |
| 3 | IFO 380 | 9500 | 33.3 | 32.4 | 17.7 | 1:50 | 1:200 | 3 | 2 | 4 | 34 |
| **2005-6** | **IFO 380** | **9500** | **33.3** | **34** | **72.7** | **1:25** | **1:21** | **3** | **3** | **4** | **84** |
| 4 | IFO 380 | 9500 | 30 | 29.1 | 99.7 | 1:50 | 1:150 | 1 | 1 | 1.5 | 26 |
| 7 | IFO 380 | 9500 | 30 | 29.2 | 32.2 | 1:25 | 1:65 | 1 | 1 | 2 | 13 |
| 20 | IFO 380 | SD25 | 33.3 | 33.5 | 52.3 | 1:50 | 1:100 | 3.5 | 3 | 4 | 53 |
| 9C | IFO 380 | SD25 | 33.3 | 33.1 | 82.9 | 1:50 | 1:170 | 2.75 | 2 | 3.5 | 29 |
| 5 | IFO 380 | SD25 | 30 | 28.7 | 71.6 | 1:50 | 1:140 | 1 | 1 | 1 | 18 |
| 6 | IFO 380 | SD25 | 30 | 28.9 | 61.9 | 1:25 | 1:65 | 1 | 1 | 1.2 | 20 |
| 8 | IFO 380 | Agma | 33 | 32.9 | 78.8 | 1:50 | 1:100 | 2 | 2 | 2 | 16 |
| 10 | IFO 180 | no disp. | 33.3 | 32.6 | 76.8 | 0 | 0 | 1 | 1 | 1 | 26 |
| **2005-1** | **IFO 180** | **no disp** | **33.3** | **34** | **74.6** | 0 | 0 | **1** | **1** | **1** | **4** |
| **2005-2** | **IFO 180** | **no disp** | **33.3** | **34** | **82.7** | 0 | 0 | **1** | **1** | **1** | **16** |
| 16 | IFO 180 | 9500 | 33.3 | 33.4 | 78.8 | 1:50 | 1:100 | 4 | 4 | 4 | 84 |
| **2005-5** | **IFO 180** | **9500** | **33.3** | **34** | **84.5** | **1:25** | **1:7** | **4** | **4** | **4** | **94** |
| **205-7** | **IFO 180** | **9500** | **33.3** | **34** | **74.34** | **1:25** | **1:23** | **4** | **4** | **4** | **86** |
| **2005-3** | **IFO 180** | **9500** | **30** | **30** | **82.3** | **1:25** | **1:9** | **1** | **1** | **1.5** | **31** |
| **2005-4** | **IFO 180** | **9500** | **30** | **30** | **80.2** | **1:25** | **1:9** | **1.5** | **1** | **1.5** | **50** |
| 14 | IFO 180 | 9500 | 30 | 28.8 | 77.6 | 1:50 | 1:100 | 1.2 | 1.2 | 1.2 | 21 |
| 19 | IFO 180 | 9500 | 30 | 29.1 | 80.8 | 1:25 | 1:60 | 1 | 1 | 1.25 | 36 |
| 15 | IFO 180 | SD25 | 33.3 | 33.3 | 75.6 | 1:50 | 1:100 | 3.5 | 3.5 | 4 | 45 |
| 13 | IFO 180 | SD25 | 30 | 29.2 | 83.7 | 1:50 | 1:130 | 1 | 1 | 1 | 21 |
| 12 | IFO 180 | Agma | 33.3 | 33.0 | 86.1 | 1:50 | 1:150 | 2 | 2 | 2.5 | 17 |
| 11 | IFO 180 | Agma | 30 | 28.7 | 85.3 | 1:50 | 1:100 | 1 | 1 | 1 | 24 |

a. Supplemental tests (2005) are labeled and printed in bold.
b. Visual dispersant effectiveness assessment method described in SL Ross et al. (2005).
c. Oil remaining on the water surface at the end of the tests. Control values have not been subtracted.

In the present study, although there is no visual evidence of dispersion caused by interaction of the non-breaking waves and the slick, some small amounts of dispersion were indeed observed in small, localized areas of turbulence caused by waves interacting with the end boom and connectors on the side boom. In addition, slicks show a strong tendency to disperse during the oil collection process after the end of the test. As a consequence, despite the best efforts of the cleanup workers, some dispersion is clearly caused by the tools used to collect the oil off the tank. Dispersion losses caused by these two sources may account for the lower-than-expected oil recoveries at the end of the tests in non-breaking waves.

## Summary

A total of seven supplemental dispersion tests were completed using IFO 180 and 380 fuel oils. These tests included controls and tests at high dispersant-to-oil ratios on IFO 180 and IFO 380 in waves of 33.3 and on IFO 180 in waves of 30 cpm.

The control tests showed that oil recovery rates in these tests may have improved with experience and improved methods, as oil recovery rates were 85% or greater. Tests of IFO 180 treated with Corexit 9500/DOR of 1:25 in 33.3 cpm waves produced very high levels of effectiveness based on both visual assessment methods (visual 3 to 4) and direct measurement confirming the result from the 2003 tests. Tests with the more viscous, IFO 380 treated with Corexit 9500/DOR of 1:25 and tested in 33.3 cpm waves also yielded a high level of effectiveness both visually (visual = 3 to 4) and in terms of oil recovered (15% recovered). The IFO 380/Corexit 9500 test in October 2003 yielded ambiguous results; the results of the present test is unambiguous and is consistent with the visual observations in the 2003 Ohmsett test, confirming that a high level of dispersion was taking place. Both of these observations were more consistent with the results of the at-sea tests in winds of 14 knots, where considerable dispersion was observed. They were not consistent with the at-sea tests at 8 to 9 knots where little or no dispersion was observed.

IFO 180 treated with Corexit 9500 and tested in non-breaking waves (waves at 30 cpm) yielded apparently ambiguous results in that there was no visual evidence of dispersion due to wave-slick interactions during the test, but amounts of oil collected at the end of the tests (50 and 69% of the oil recovered) were less than in the controls, suggesting that significant chemically augmented dispersion had taken place. This inconsistency between visual observations and direct measurement is consistent with the observations in the 2003 study. The discrepancy appears to be due to artifacts of the test method. After treatment with dispersant the oil is highly susceptible to dispersion, but there is clearly not sufficient mixing energy in the waves to cause dispersion. However, localized turbulence caused by interactions of the waves with the boom, and mixing caused by collection tools, may have caused localized dispersion, thus accounting for the lowered levels of recovered oil. Apparently, for tests at low sea states, visual observations may be more reliable in estimating dispersion than measuring the oil remaining on the tank at the end of the test until test methods are improved.

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