DETERMINING THE VISCOSITY LIMITS FOR EFFECTIVE CHEMICAL DISPERSION: RELATING OHMSETT RESULTS TO THOSE FROM TESTS AT-SEA

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ABSTRACT

This study compared dispersant performance at the U.S. Minerals Management Service facility, Ohmsett, with dispersant performance at sea. In 2003, at-sea dispersant tests were conducted in the United Kingdom with Intermediate Fuel Oils (IFO) of differing viscosities aimed at determining the viscosity of oil that limits chemical dispersion. These tests were repeated at Ohmsett using identical combinations of oils, dispersants and DORs. The at-sea tests showed that the oil viscosity limit for dispersion at relatively low wave energies (winds = 7 to 14 knots) lay in the range between the viscosities of IFO 180 (viscosity = 2075 cP at 16°C) and IFO 380 (viscosity = 7100 cP at 16°C). Tests at Ohmsett at a wave paddle frequency of 33.3 cpm were consistent with this finding. These tests also suggested that "limiting viscosity" is not a single value, but is a variable that is influenced by wave energy and dispersant type. Results also showed that Ohmsett tests at a wave paddle frequency of 33.3 cycles per minute (cpm) produced levels of effectiveness somewhat higher than at sea while tests 30 cpm waves produced results that were lower than at sea. Tests in 33.3-cpm waves showed effects of dispersant type on dispersant performance that were consistent with those observed at sea.

INTRODUCTION

Questions have been raised concerning the potential effectiveness of dispersants on several crude oils in cold waters, specifically Alaska North Slope and Hibernia crude oils. Ideally, dispersant tests addressing these questions should be done at sea, under real-world conditions, but this is seldom feasible or economical. As an alternative, planners have conducted bench-scale laboratory studies to assess dispersibility of these oils, but these tests have yielded conflicting results. Larger scale tests in small and large wave tanks like Ohmsett might be expected to produce more consistent and realistic results because they reproduce some of the at-sea dispersion processes better than laboratory tests (SL Ross 2001, 2002a, 2002b). However, tank tests too have been criticized because their results have not been compared with at-sea tests. The present study addressed the latter concern by repeating, at the U.S. Minerals Management Service facility, Ohmsett, a series of tests performed at sea in the United Kingdom in 2003.

Details of the 2003 UK at-sea experiments are reported elsewhere (Lewis, 2004, Colcomb et al., 2005). In short, small amounts of intermediate fuel oils (IFOs) were spilled at sea, sprayed with dispersants and effectiveness was assessed. Two grades of heavy fuel oil were tested, IFO 380 (viscosity = 7100 cP at 16°C) and IFO 180 (viscosity = 2075 cP at 16°C) in the expectation that the less viscous oil might be dispersible, while the more viscous oil might not. Dispersion was assessed visually using a semi-quantitative four-point scale. The study investigated the aspects of the dispersion process visible to the trained observer, namely the shattering of the dispersant-treated slick into oil droplets by cresting waves. High levels of dispersant performance were observed in tests with the less viscous IFO 180 treated with the Corexit 9500 (9500). The 9500-treated IFO 380 produced no visible dispersion in some tests and only moderate dispersion in others, suggesting that factors such as oil viscosity were limiting the dispersion of the IFO 380. The performance of two other dispersants, Superdispersant 25 and Agma DR 379 were also studied. Lewis (2004) concluded that some dispersants will be effective on oils with a viscosity of 2000 cP [like IFO 180], but will not be effective on 7000-cP oils [like IFO 380] in waves associated with wind of 7 to 14 knots.

The Ohmsett study repeated these tests to verify that: a) effectiveness observed at Ohmsett was consistent with effectiveness observed at sea with identical combinations of oil, dispersant and DOR; and b) the limiting oil viscosity for dispersion of IFO oils predicted from Ohmsett tests is consistent with the limiting viscosity observed at sea. Ohmsett tests were one of a series of projects relating dispersant performance in laboratory and wave tank methods to performance in sea trials. Results of all tests are summarized and discussed.

Experimental Procedures

Dispersibility tests were conducted at Ohmsett using the same oils, dispersants and dispersant-to-oil ratios (DOR) used at sea. IFO 180 and 380 oils were from the same batches as those used at sea. The same dispersants, namely Corexit 9500 (9500), Superdispersant 25 (SD 25) and Agma DR 379 (Agma) were used in both tests and were applied at the same nominal DORs. Ohmsett tank water was at full marine salinity and temperature was 16°C, as in the UK tests. The test protocol used was identical to earlier studies (S.L. Ross and MAR, 2003), with the following exceptions.

1. Tests were conducted at wave paddle frequencies 30 cpm and 33.3 cpm in addition to the 35 cpm wave frequency used in earlier Ohmsett tests.
2. Effectiveness was estimated using both visual and direct measurement methods. Direct measurement involved recovering and measuring oil remaining undispersed at the end of each test and comparing this to the volume originally discharged. The visual method involved observing the treated slick and subsurface cloud of dispersed oil and quantifying dispersant performance using that same four-point scale used in the 2003 at-sea tests. Three persons working independently took visual observations at three times during each test. One of the three observers had also participated in the UK trials.
3. The actual DOR used was estimated by recording the patchiness of the oil slicks photographically at the time of spraying and correcting the dispersant application rate for the dispersant that fell onto the oil slick rather than onto open water. Slow spreading of the viscous oil resulted in under-dosing, as had occurred at sea (Lewis 2004) (Table 1).

Results and Discussion

Initial Scoping Tests.

Given the apparent influence of mixing energy on dispersant performance in the UK trials (Lewis 2004), scoping tests were performed at three wave energy settings at Ohmsett to identify the wave frequency that yielded the effectiveness most similar to the at-sea tests. Tests were performed at the 35-cpm wave frequency routinely used in earlier tests, as well as tests at 33.3 cpm and 30 cpm. These tests used a combination of oil (IFO 380), dispersant (9500) and DOR (nominal DOR of 1:50) that had produced modest dispersant performance at sea (visual=2.0) (Table 2). Effectiveness was assessed visually, as in the at-sea tests. Observers' visual assessments are reported as medians and ranges for both at-sea and Ohmsett tests.

In the test at 35 waves per minute (cpm) setting, slicks of IFO 380 were exposed to frequent cresting waves, producing a high level of dispersion (visual = 4.0), much higher than at sea (Table 2). The test at 33.3 cpm involved fewer cresting waves than at 35 cpm and produced a lower level of effectiveness (visual = 3.0), but dispersion was still greater than at sea. The test at 30 cpm involved mostly non-cresting waves, produced effectiveness that was less than at sea and only marginally greater than the control test. Clearly the 35-cpm waves used routinely in dispersant testing at Ohmsett produced levels of dispersion that were greater than at-sea in winds of 7 to 14 knots. The wave frequency producing effectiveness levels similar to at sea for IFO 380/9500/DOR=1:50 appeared to be greater than 30 and less than 33.3 cpm. All subsequent tests in the project were completed at 30 and 33.3 cpm. In addition, due to the apparently high level of effectiveness produced at the DOR of 1:50, most subsequent tests used a nominal DOR of 1:50 or less rather than the 1:25 DOR used at sea.

Overview of Results.

Dispersibility of the IFO 180 and IFO 380 with different dispersants and wave frequencies are reported in Table 3 and Figure

Table 1. Nominal Versus Measured Dispersant-to-Oil Ratios at Ohmsett and At-Sea

Nominal DOR	Measured DOR			
	At Sea[a]		Ohmsett	
	IFO 180	IFO 380	IFO 180	IFO 380
1:25	1:20 to 1:40	1:30 to 1:60	1:65	1:65
1:50	1:55 to 1:110	1:80 to 1:160	1:100 to 1:150	1:100 to 1:200
1:100	1:90 to 1:180	1:130 to 1:260	—	—

a. from (Lewis 2004)

Table 2. Results of Ohmsett Scoping Tests on IFO380 at a Nominal DOR of 1:50

Test Location	Dispersant Type	Measured DOR	Ohmsett Wave Frequency, cpm	Dispersant Performance (Visual Method)		
				Median	Min.	Max.
At Sea	Corexit 9500	1:110	Na	2.0	1.0	2.0
Ohmsett	Corexit 9500	1:180	35	4.0	4.0	4.0
Ohmsett	Corexit 9500	1:195	33.3	3.0	2.0	4.0
Ohmsett	Corexit 9500	1:150	30	1.0	1.0	1.5
Ohmsett	No dispersant	No	35	1	1	1

a. Standard conditions at Ohmsett include 75 to 100 litres of oil, laid down as a slick 5 m wide by 20 m long, sprayed immediately with dispersant at a known application rate, then agitated for up to 40 minutes.

Table 3. Summary of Ohmsett Test Results

Test #	Oil Type	Dispersant Type	Wave Frequency: Nominal, min^{-1}	Wave Frequency: Measured, Min^{-1}	Volume of Oil Spilled, liters	Target DOR	Measured DOR	Dispersant Performance, Visual Method (a)			Dispersant Performance, Direct Measurement (b)
								median	min	max	
1	IFO 380	no disp.	35	34.6	70.8	no disp.	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
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	no disp.	0	1	1	1	26
16	IFO 180	9500	33.3	33.4	78.8	1:50	1:100	4	4	4	84
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. Visual dispersant effectiveness assessment method described in Table 1.
b. Oil remaining on the water surface at the end of the tests is measured

1. The control test (no dispersant) with IFO 180 at wave energy 33 cpm produced no dispersion visually, as at sea. At the end of the test 74% of the original oil volume remained undispersed. The 26% of the original oil not accounted for may have been lost through a combination of natural dispersion, adherence to the boom and to a lesser extent inefficiencies in collection. Losses in control tests with IFOs were slightly higher than in earlier Ohmsett dispersant tests with crude oil (SL Ross and MAR, 2003).

The difference between the amount spilled and collected was termed dispersant effectiveness (DE), as in earlier studies, though it is recognized that this difference is actually made up of both chemically dispersed oil and oil lost by natural dispersion and clingage on the boom. Corexit 9500 applied at a nominal DOR of 1:50 and tested in 33.3 cpm waves produced apparent complete and rapid dispersion of IFO 180 (visual=4.0) (Fig. 1A) and a DE of 84% (Fig. 1B), showing that IFO 180 was highly dispersible under these conditions, as was observed at sea. Effectiveness declined to near control levels at a wave frequency of 30 cpm (visual = 1.2, DE = 21%). Visually, SD-25 too appeared to produce almost complete and rapid dispersion of IFO180 at 33.3 cpm (visual=3.8) (Fig. 1A), but direct measurements showed that the actual effectiveness was far less than suggested by the visual assessment (DE= 45%) (Fig.1B). Effectiveness of SD-25 could not be distinguished visually from 9500, but direct measurement showed it to be markedly less effective as had been observed with IFO 180 at sea. At 30 cpm SD-25 yielded no dispersion either visually (visual= 1.0) or by measurement (DE=21%). Agma appeared to produce some effectiveness visually at 33 cpm (visual = 2.2), as had been observed at sea, but direct measurements showed no increase in dispersion over the control (DE = 17).

Results with IFO 380 contrasted somewhat with IFO 180. The control test (no dispersant) with IFO 380 in 35 cpm waves showed no dispersion (visual = 1.0, DE = 30%)(Table 4). This loss in the control test was also higher than in earlier Ohmsett tests with crude oil (SL Ross and MAR, 2003). Corexit 9500 applied at a nominal DOR of 1:50 appeared to produce "very rapid and complete dispersion" (visual = 4.0) when tested at 35 cpm, but dispersion was not complete (DE = 60%). At 33.3 cpm 9500 appeared to produced "moderately rapid dispersion" visually (visual =3) Fig. 1C), but direct measurement showed that effectiveness was actually low, approaching the level of controls (DE= 34%)(Fig. 1D). The lower effectiveness of 9500 on IFO 380 than on IFO 180 is consistent with at-sea results. The combination of a high level of effectiveness of 9500 on IFO 180 and very low effectiveness on IFO 380 is consistent with Lewis' conclusion that the viscosity limit for dispersion appears to lie between the viscosities of IFO 180 and 380. It must be remembered that in the Ohmsett tests the actual DOR values were lower than at sea. Effectiveness of 9500 on IFO 380 declined to control level (visual=1.2, DE=26%) at 30 cpm. Dispersant performance varied somewhat with dispersant product. SD 25 produced moderately rapid dispersion at 33.3 cpm (visual = 3.5 and 2.8, DE= 53% and 29%). Performance of SD 25 could not be distinguished from 9500 either visually or by direct measurement. Variation in effectiveness between with SD 25 tests at 33.3 cpm appeared to due to differences in DOR. SD 25 was ineffective at 30 cpm (visual= 1.0, DE=18%). Agma appeared to produce some dispersion visually with IFO 380 at 33.3 cpm (visual = 2.0), but direct measurements showed little dispersion (DE=16%). This was less than with Corexit or SD-25. Agma was not tested at 30 cpm.

Table 4: Comparison of Effectiveness Results of Laboratory, Wave Tank, and At-Sea Tests

		Laboratory Tests								Wave Tank Tests								At Sea (c)	
Test name		SFT (a,b)		Exdet (a,b)		BFT (a,b)		WSL (a,c)		SLR (a,d)		Ohmsett (e)							
Oil Type		180	380	180	380	180	380	180	380	180	380	180			380			180	380
Mixing Energy												30 cpm	33 cpm	35 cpm	30 cpm	33 cpm	35 cpm		
Control		0.06	0.05			3	4			0 (1)	0(1)		26(1)				30(1.0)	1	1
C9500	1:25	7	5	44	32	77	65	95	51	97 (4)	53 (3)	36(1.0)			13(1.3)			3,3.4	1,1,1.3
	1:50			31	21	72	41	86	48	50(3)	32 (3)	21(1.2)	84(4)		26(1.2)	34(3.0)	58(4)	3.2	1.7
	1:100							66	45	39 (3)								2.3	
	1:150																		
SD 25	1:25			14	6	79	57	-	63	82(3)	15(1)				20(1.1)	53(3.5)		1.7,2.0	2,2,2.5,2.7
	1:50			4	4				52		1(1)	21(1)	45(3.8)		18(1.8)	29(2.3)		1	1.4
	1:100								50		1(1)							-	
	1:150																		
Agma	1:25			18	6				26	23 (2)	1(1)	24(1)	17(2.2)			16(2)		1.5,2.0	1.6, 1.7
	1:50			5	4				12									-	1
	1:100								9									-	
	1:150																		

a. Test names are SFT = swirling flask test, BFT = Baffled flask test, WSL = Warren Spring test, SLR = SL Ross wave tank
b. From Clark et al. 2005 (these proceedings)
c. From Lewis 2005
d. From Belore et al. 2005 (these proceedings)
e. Values in parentheses are visual observations on four-point scale

In short, Ohmsett results reflect the at-sea results well in qualitative terms. The less viscous oil, IFO 180, was readily dispersed with 9500 at 33.3. cpm at Ohmsett, while than IFO 380 showed limited dispersion as seen at sea. Corexit 9500 produced the most effective dispersion with IFO 180 at Ohmsett as at sea, while differences between products were less evident in IFO 380 tests. At-sea 9500 was the only product to produce highly effective dispersion, but at Ohmsett SD 25 was also highly effective at the higher wave energy of 33 cpm. As at sea, both Corexit and SD 25 were more effective than the Agma product on these viscous oils.

At sea dispersants were effective on the 2075 cP-viscosity IFO 180, but not the 7100 cP-viscosity IFO 380 at winds of 7 to 14 knots, though the precise limiting viscosity between 2000 and 7000 cP could not be determined. Tests at Ohmsett in 33 cpm waves appear to be consistent with this finding, with the IFO 180 being highly dispersible with Corexit and while the IFO 380 produced dispersibility levels just above control levels ((DE = 34%). The latter finding must be confirmed, however, because the IFO 380 received a significantly lower dispersant treatment than the IFO 180 due to the slower spreading of the IFO 380 than the IFO 180.

Comparison of Visual and Direct Measurement Methods.

The accuracy of visual methods in assessing dispersant performance was compared to direct measurements in all tests (Figure 2). At Ohmsett, the designation "no obvious dispersion" or visual = 1 was applied to tests in which there was no visible evidence whatsoever of slick shattering into droplets by cresting waves. In all visual = 1 to 1.4 tests measured DE values ranged from 18 to 26%, similar to the control run for IFO 180 at 33 cpm. In these runs, visual assessment appeared to predict direct measurements accurately. There was one apparent false negative visual observation. IFO 180 treated with 9500 at a nominal DOR of 1:25 and tested at 30 cpm produced no visible evidence of dispersion (visual = 1.1), though some effectiveness was detected by direct measurement (DE = 36%).

The designation "slow and/or partial dispersion" or visual = 2 was applied to tests in which there was little apparent change in the behaviour or the amount of oil in the treated slick, but dispersed oil droplets were occasionally observed caused by cresting waves. Tests ranked as visual = 1.5 to 2.4 by observers produced measured DE values of 18 to 26%, values that were indistinguishable from runs ranked as visual = 1 to 1.4. Apparently, the limited dispersion observed in these tests was very minor indeed and/or temporary, suggesting that the visual = 2 category, as applied at Ohmsett, is prone to false positive errors. Tests ranked "moderately rapid dispersion" or visual = 3, were characterized by having both extensive shattering of treated slicks by cresting waves producing extensive brown-black clouds of dispersed oil droplets in the water column and large patches of thick oil clearly visible throughout the test. Tests ranked as visual = 2.5 to 3.4 produced measured DE values in the 30 to 40% range, slightly higher than in the controls and the former two dispersant performance categories. "Rapid and complete dispersion" or visual = 4 was used to describe tests in which slicks were apparently quickly and completely shattered into brown-black clouds of fine dispersed oil droplets by the first few cresting waves passing through the slicks leaving little or no oil on the surface. Visual =3.5 to 4 tests produced DE values ranging from 45% to 86% and therefore clearly reflected high levels of dispersion performance. The descriptor for this category is not accurate because, although dispersion appears visually to be rapid and complete early in the test, as the test progressed small amounts of undispersed oil accumulated on the boom, showing that dispersion was not complete. The ranking 3.5 to 4.0 was applied to a broad range of measured levels of effectiveness, DE = 45% to 86% and it was not possible to visually distinguish different levels of dispersion within this range.

Comparison of Ohmsett and At-Sea Results.

Ohmsett tests were related to at-sea tests by comparing dispersant performance in pairs of tests involving identical oils and dispersants and similar DORs. Direct comparison of the full set of at-sea test results with Ohmsett results was not possible because the actual DORs measured for the Ohmsett tests were substantially lower than nominal DORs. In both Ohmsett and at-sea studies dispersant spray systems were calibrated to deliver known DORs to continuous slicks. However, the viscous IFO oils did not spread evenly forming patchy slicks, resulting in some dispersant being sprayed into open water and the slicks being under-dosed. Slick patchiness was recorded photographically in both studies so that "measured" dispersant dosages could be estimated and a limited number of tests receiving similar treatments could be identified. However, the number of test pairs available for comparison is smaller than planned and many of the Ohmsett tests were conducted at DORs that were lower than intended allowing comparisons to tests that yielded lower levels of effectiveness in at-sea tests.

At Ohmsett all tests conducted in 30-cpm waves produced very little visible dispersion, even though some oil/dispersant/DOR (O/D/DOR) combinations tested had produced high levels of dispersion at sea. It was concluded that the 30 cpm wave setting at Ohmsett were not energetic enough to disperse these viscous oils given the dispersants and DORs used. One 30-cpm test of IFO 180 treated with 9500 at a nominal DOR of 1:25, the highest tested, did yield an elevated DE value of 34%, suggesting that some dispersion may be possible with viscous oils in non-breaking waves when higher DORs are used.

Most tests conducted at 33.3 cpm produced some effectiveness at Ohmsett. Most of the O/D/DORs tested at Ohmsett involved low DOR levels that had produced only limited levels of dispersion in the at sea tests. These tests invariably yielded somewhat higher visual dispersion scores at Ohmsett than at sea. This was consistent with the earlier conclusion that wave energies at the 33.3 cpm wave setting at Ohmsett may be somewhat higher than those at sea in winds of 7 to 14 knots. This conclusion assumes that the visual method used to determine effectiveness yields comparable results in both environments. It could be argued however, that better visibility at the Ohmsett than at sea makes visual detection of dispersed oil easier resulting in consistently higher visual rankings at Ohmsett than at-sea. Sufficient data are not available to test this argument.

The usefulness of direct measurements (DE values) made at Ohmsett for predicting dispersion under similar conditions at sea in winds of 7 to 14 knots was studied by comparing DE measurements to visual at-sea results in paired tests (Figure 3). Evidently oil/dispersant/DOR (O/D/DOR) combinations that yielded low levels of effectiveness at sea (visual = 1-2) produced DE values at Ohmsett ranging from less than 20% to almost 55%. The single Ohmsett test at 33.3 cpm of conditions that produced a high level of effectiveness at sea (IFO 180 / 9500/ DOR = 1:100) produced a DE at Ohmsett of 84% suggesting that DE values at Ohmsett of 84% or higher in 33.3 cpm waves will correspond to effective dispersion at sea.

Combined Results of Laboratory and Wave Tank Tests.

The Ohmsett study was one of five in which oils, dispersants and DORs tested at sea in the UK in 2003 were retested in standard laboratory effectiveness tests and wave tank tests. The objective was to compare dispersant effectiveness results from a range of dispersant testing methods with dispersant performance at sea and to consider the ability of each method to predict dispersibility-limiting conditions at sea. Apparatus used and results are summarized in Table 5. Study details are reported elsewhere (Clark et al., 2005; Colcomb et al. 2005, Lewis, 2004; Belore et al., 2005).

Limitations of laboratory tests in predicting dispersant performance are known from earlier work (e.g., Daling and Lichtenthaler, 1986). The potential advantages of wave tank tests for predicting dispersant performance have been assumed based on the understanding that wave tank testing can reproduce many of the at-sea operational and dispersion processes that cannot be reproduced in lab tests. One of the objectives of this work was to attempt to verify this assumption. The following is a very brief overview of the results.

Most laboratory and wave tank tests produced high levels of effectiveness in tests with combinations of oil, dispersant and DOR (O/D/DOR) that yielded high levels of effectiveness at sea. The exception was the Swirling Flask Test (SFT), which produced very low estimates of effectiveness under conditions that produced the highest levels of dispersant performance at sea. There are possible explanations for this, but none were tested in this study. No further testing was conducted on the SFT.

IFO 180 proved to be more dispersible than IFO 380 by all methods. Both wave tanks and most laboratory methods ranked the performance of the dispersant products in the same order as at sea, but some did not. Conflicts in results between test methods in terms of performance ranking of dispersant products are well known (e.g., Daling and Lichtenthaler 1986).

All laboratory test methods, except the SFT, produced high levels of dispersant performance for some O/D/DOR conditions that produced little or no effectiveness at sea. This suggests that processes that limit dispersant performance at sea may be prevented from operating in laboratory tests. These limiting processes may include dispersant failing to mix with the oil and simply running off into the water because the oil is too viscous to permit mixing. This problem appears to be overcome, in part, in tests in both the SL Ross wave tank and at Ohmsett wave tank. In these tests some O/D/DOR conditions that produced little or no effectiveness at sea produced no effectiveness in tests in the tanks.

Based on the data sets developed in these projects, most methods can be calibrated to identify O/D/DOR conditions that will produce high levels of dispersion at sea and to distinguish them from others that produce low levels of effectiveness at sea. Lewis 2004 used the empirical relationship between WSL data and at-sea data to demonstrate that moderate and high levels of dispersion performance at sea were achieved under O/D/DOR combinations that produced over 60% and 80% effectiveness, respectively, in tests in the WSL apparatus.

CONCLUSIONS

Dispersant performance at Ohmsett was strongly influenced by wave energy. The scoping test showed that Corexit 9500 dispersed IFO 380 effectively in 35 cpm waves and that effectiveness declined with wave frequency to near control levels in 30 cpm waves. A similar trend was seen with the other oil and the other dispersants. The 35-cpm wave frequency used routinely in earlier Ohmsett dispersant testing produced levels of dispersion that were greater than at-sea in winds of 7 to 14 knots. Tests at 33.3 cpm also produced dispersant performance slightly higher than at sea, while those at 30 cpm produced effectiveness levels lower than at sea.

Ohmsett results qualitatively reflected the at-sea results reasonably well. At Ohmsett IFO 180, the less viscous oil was more readily dispersed with Corexit 9500 than IFO 380 as had been observed at sea. At-sea with winds of 7 to 14 knots the limiting oil viscosity for dispersion appeared to lie between 2075 and 7100 cP, though the precise limiting viscosity was not known. Tests at Ohmsett at 33.3 cpm appear to be consistent with this finding, showing a high level of dispersibility of the IFO 180 (DE = 84) with Corexit and a near-control level of dispersibility of IFO 380 (DE = 34%). The latter finding must be confirmed, however, because the IFO 380 oil received a significantly lower dispersant treatment than the IFO 180 due to the slower spreading of the IFO 380 compared to the IFO 180.

Of the three dispersants tested, Corexit 9500 produced the most effective dispersion with IFO 180 Ohmsett, as at sea, but its performance could not be distinguished from SD 25 on IFO 380. Also as at sea, both Corexit and SD 25 were more effective than the Agma product on these viscous oils.

A comparison of Ohmsett results with those of the at-sea trials suggest that combinations of oil, dispersant and DOR producing a DE of 84% or higher in 33.3 cpm waves at Ohmsett will produce highly effective dispersions at sea.

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