Laboratory Study to Compare the Effectiveness of Chemical Dispersants When Applied Dilute versus Neat

for

Minerals Management Service

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by

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Table of Contents

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Executive Summary

The objective of the study was to determine if the application of chemical dispersants in a dilute form is likely to reduce significantly their effectiveness when compared with neat application. A series of large-scale laboratory tests were completed to evaluate the effectiveness of two dispersants, Corexit 9527 and 9500, on Alaska North Slope crude oil when applied neat and diluted with salt water.

The test results indicate that the performance of Corexit 9527, when used on Alaska North Slope (ANS) crude oil, is not affected when diluted with water at a ratio of 1:10. However, the performance of Corexit 9500 on ANS crude, was severely reduced when applied diluted with water at both 1:10 and 3:10 ratios.

It is recommended that these preliminary results be considered before using 9500 in application systems where dilution of dispersant with water is used, such as in high capacity “fire-monitor” systems. Single-nozzle application systems should be considered for the efficient delivery of Corexit 9500 in neat form to eliminate the possibility of reduced effectiveness.

Additional testing should be completed to determine if the reduced efficiency of Corexit 9500, when applied dilute, is due to factors such as the type of oil, the method of mixing or delivery of the dispersant into the water stream or the contact time between the dispersant and the water carrier.

The reason for the reduced performance of Corexit 9500 when applied in a diluted form should be investigated in consultation with the manufacturer. This would assist in the future development of dispersants and provide a better understanding of the processes involved.

1. Background

The first oil spill dispersants developed were formulated to be applied exclusively in a dilute form using vessel spray systems. Dispersants were then modified to be applied neat from aircraft to make use of their logistical advantages. These “concentrate” dispersants were also used in vessel-based, neat application systems, however, the use of vessels for application of dispersants became less common with the advent of the aerial application platforms.

There has been a renewed interest in the use of vessel-based application systems in recent years, particularly the use of single-nozzle, fire-monitor type systems (Lunel, 1995; Major, 1993; Major, 1995; Major, 1994; Marucci, 1991; SL Ross, 1995). In conventional, spray boom, vessel-based application systems, dispersants can be applied in either a neat or dilute form. For very thin slicks, in the order of a few tenths of a millimetre, dispersants must be sprayed in dilute form to achieve good coverage and proper droplet sizes. (An optimum droplet size is believed to be in the order 0.5 mm – much smaller droplets will be swept away by the wind and much larger droplets will crash through thin slicks.) For thicker slicks, in the order of millimetres, either a neat or a dilute form of dispersant application will produce the right coverage and drop sizes. Many ships carry firefighting water delivery systems including fire monitors. These usually involve very large pumps and water flows that are not easily throttled down to the flow rates needed for neat dispersant application. In these cases it is convenient to educt the dispersant into the high water flow and deliver the dispersant to the slick in dilute form (NRC, 1989).

Theoretically, it might be expected that neat application would be far more effective than dilute application. This is because dispersant formulations contain solvents that are more oil-soluble than water-soluble. Applying the dispersant in neat form means that there is optimum opportunity for the dispersant to blend and mix with the oil slick. This may not be the case for dilute application. Here the delivered spray is composed of water containing a certain amount of dispersant. The results of a field trial in Southern California in 1979 (McAuliffe, 1981) appear to support this possibility. In this study a reduced effectiveness was measured for the test where the dispersant was applied diluted with water from a spray vessel versus those where the dispersant was applied neat from an aircraft.

There is uncertainty as to how a present-day dispersant product, mixed into a water flow and then sprayed, would distribute itself with respect to the water in the final droplets. Would the dispersant be distributed evenly within each droplet, or would the dispersant be inhomogeneous, disassociated and in the form of smaller discrete globules? In any case, one might believe that the spray, composed largely of water, would not mix well with the slick, at least initially, and that some of the dispersant will be lost to the ocean before mixing with the target oil. So-called "herding" effects may also happen, seriously reducing the opportunity for dispersant-oil mixing.

Research was clearly needed in this area. If the research showed that the effectiveness of chemical dispersants was not reduced when the dispersant was applied in diluted form, then existing systems that use diluted dispersant spraying could be recommended for use. Also, new designs for dispersant eduction as part of existing ship-based firefighting systems should be encouraged.

On the other hand, if the research showed that the dispersant effectiveness was reduced when diluted dispersants were used, dilute application should be discouraged, and systems should be developed to apply dispersants from vessels in a neat form for a full range of possible slick thicknesses. Properly designed and implemented application methods should lead to greater operational success and more economical dispersant use.

A series of carefully designed dispersant effectiveness tests have been completed to help better understand the issue and to provide guidance in the selection and design of systems for the application of dispersant.

2. Objective

The objective of the study was to determine if the application of dispersants in a dilute form is likely to reduce significantly their effectiveness when compared with neat application. Dispersant effectiveness (fraction dispersed) is defined as the amount of oil that enters the water column, after the application of the dispersant, divided by the initial quantity of oil placed on the surface.

3. Test Variables

The main variables considered in the test program included the dispersant dilution factor, dispersant type and slick thickness. Oil type, dispersant-to-oil ratio, and degree of water/dispersant mixing prior to spraying were fixed in the testing to reduce experimental costs.

The values used in the testing for each of the above parameters are outlined below.

(1) Dispersant Dilution Ratio. This is the crucial parameter pertaining to the expressions "neat" and "dilute" application. Neat application means a water-to-dispersant ratio of zero. Dilute applications systems in use today generally are operated with a 5 to10% dispersant in water concentration. The majority of the dilute tests in this study were conducted using a mixture of 1 part of dispersant to 10 parts of 32 ppt salt water. A single test with Corexit 9500 was completed using a 3:10 ratio, as a follow-up to the results found with the 1:10 tests.

(2) Dispersant type. Two dispersants were tested: Corexit 9527 and 9500. These were chosen because of their dominant place in the North American market and because of their known differences in chemical formulation. These two dispersants are approved by the United States Environmental Protection Agency (EPA) and are listed on EPA's approved product schedule.

(3) Slick thickness. Two slick thicknesses were attempted based on reasonable field thicknesses for which dispersant application would be attempted. Values chosen for study were 0.75 mm and 3mm to provide a 4 times difference in thickness while not creating either too thin or too thick an oil slick. Thin slicks are difficult to achieve in a closed tank system and this proved to be the case even for the 0.75 mm slicks attempted using ANS crude. Volumes of oil were calculated that would result in the 0.75 mm and 3.0 mm oil thicknesses assuming that the oil would spread over the approximately 0.75 square metre containment area. This worked for the large oil volume and thick oil but the small oil volume did not spread over the full containment area and instead spread to an equilibrium thickness estimated to be about 1.9 mm. It was not possible to generate thinner slicks than this by mechanical spreading or through heating the oil so the tests were completed with this thicker oil. Rather than adjust the dispersant dosage to reflect this larger thickness, the dispersant dosage was set assuming that the oil covered the containment area at the design thickness. It was felt that the 1.9 mm thickness was not significantly different from the 3mm thick tests (from the standpoint of dispersant drop penetration and herding etc.) and that little additional information would be gained by increasing the dispersant quantity and essentially repeating the 3mm tests. This resulted in an application rate of less than the design dosage of 1:75 for the thinner slicks (actual dosage was estimated to be about 1:190). The results of these tests confirm the importance of applying the dispersant in the proper dosage directly on the oil and the complete waste of dispersant applied to water adjacent to the slick.

(4) Oil type. Fresh Alaska North Slope (ANS) oil was used in all tests. This oil was chosen because its properties are well known, it is known to be chemically dispersible when fresh, it will

not emulsify when fresh and it was readily available. Detailed properties of this oil are provided in Appendix A.

(5) Dispersant-to-oil ratio (DOR). Only one dose rate was used for the work. The values traditionally used in laboratory work are 1-to-20 or 1-to-25. These values were too high under the test tank application situation and "overdosed" the laboratory system, thus making the test insensitive. Preliminary tests were completed for each of the two dispersants to determine the lowest DOR that would yield near complete dispersion for the test system (see section 5 below). For both dispersants a 1:75 dispersant to oil ratio was found to be the lowest dosage able to achieve this and was the target value in all subsequent testing. It should be emphasized that the same quantity of dispersant was applied in a dilute test as was sprayed in the corresponding neat test. The total spray volumes for the dilute tests were much higher than the neat runs due to the large quantity of water delivered with the dispersant.

(6) Water/dispersant mixing prior to spraying. It is possible that this is an important variable, but it was reasonable to believe that dispersant educted into a water flow system and then sprayed through fine nozzles would be well mixed (but not necessarily homogeneous). For these tests the water and dispersant were mixed thoroughly (by vigorous shaking the dispersant supply tank contents for approximately 30 seconds) and sprayed immediately (within 5 seconds) after the mixing process. The flow lines from the dispersant supply tank to the spray nozzles were empty prior to spraying to ensure that completely mixed product reached the slick.

4. Experimental Setup

Test Tank

The tests were completed in the SL Ross indoor wave tank to allow the “realistic” spray application of dispersant, since the application can play a significant role in the dispersant’s final effectiveness. The test tank is 10 metres long by 1.2 metres wide by 1.2 metres deep and is fitted with a wave generating paddle at one end and a wave dissipating beach at the other. It was filled with 32 ppt salt water to a depth of 85 cm. The same water was used for all tests. The presence of small amounts of dispersant in the tank from previous tests had no effect on frsh oil slicks placed in the tank. Previous studies (SL Ross, 2000) have indicated that dispersant in the water phase in concentrations of less than 400 ppm have no effect on the dispersion rate of surface slicks. Dispersant concentrations in the water were well below this value throughout the test program.

Four litres of dispersant would have to be present in the water of the test tank to reach a concentration of 400 ppm. Less than one litre of dispersant was applied in all of the testing completed in this study. The air and water temperature was 17 °C for all tests. Two 12 volt, sealed beam, automotive headlights were mounted at the bottom of the tank and their beams directed up to the water surface to improve the visibility of the surface oil slicks. A photo of the test tank is shown in Figure 1.

Figure1 : Test Tank

Oil Containment

Oil was held in a 1.0 m by 0.75 m rectangular area in the middle of the tank using an air bubble curtain constructed from ½ inch copper pipe, as seen elevated above the water surface in Figure 2. The rising air bubbles from this submerged diffuser system entrain water as they rise which in turn creates an inflow of water at the surface above the rectangular barrier. This inflow herds the oil to the center of the area above the rectangular diffuser. The oil remains within this confinement zone even when waves are introduced.

Figure 2: Air Bubble Curtain Piping

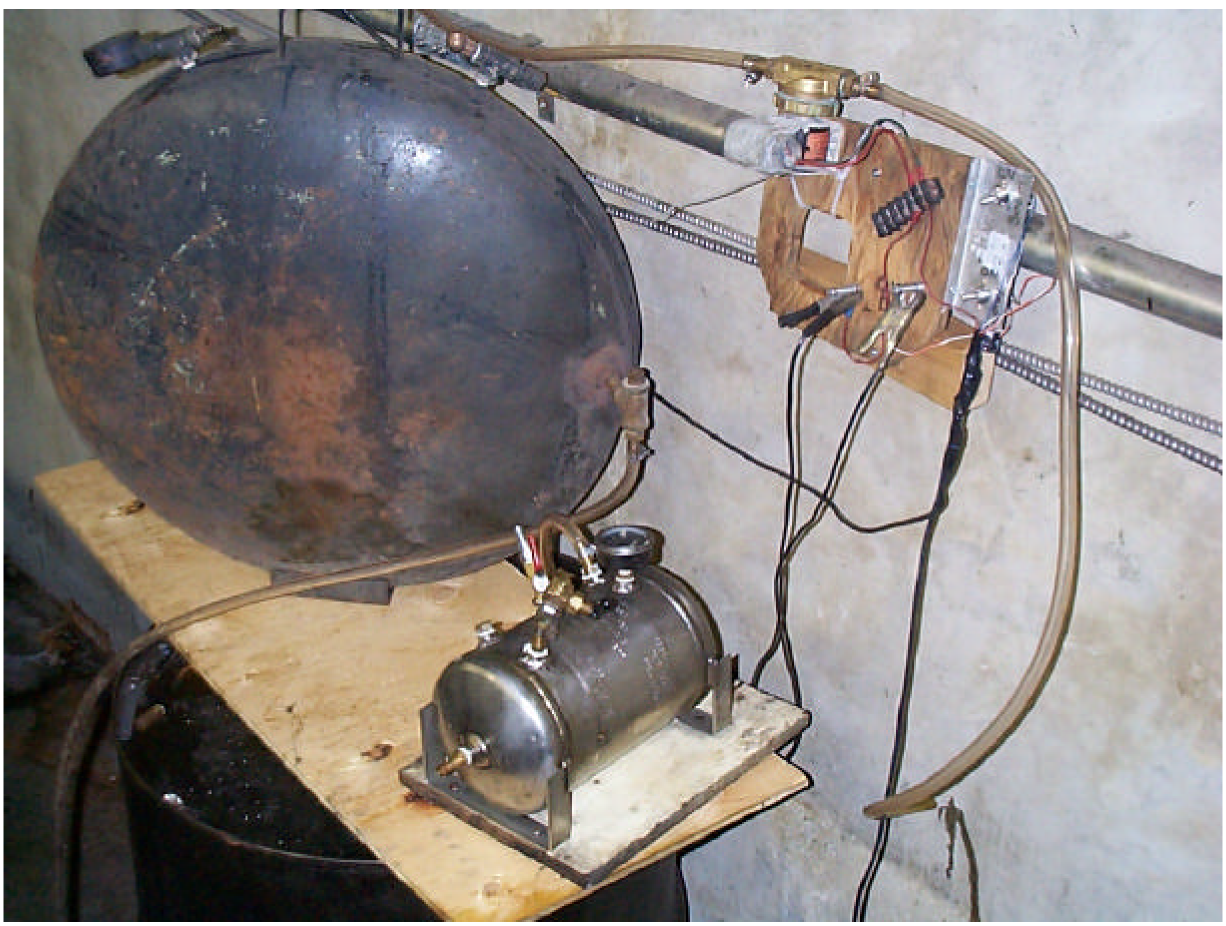
Dispersant Application System

Dispersant was applied using an overhead spray boom mounted to the ceiling above the center of the test tank. Over-spray from the boom was collected by plastic sheeting that extended from the ceiling to short lengths of eaves trough that were suspended just below the arc of the spray nozzles. The boom was counter-weighted and powered using a rope and pulley system. On the end of one rope was a weight that held the boom in its start position. The other rope was attached to a “take-up” spool driven by a variable speed electric motor and clutch mechanism. The motor speed was set to achieve the required boom speed, allowed to run up to speed and the clutch then engaged to pull the boom through its arc over the center of the tank to apply the dispersant. The overhead boom, plastic sheeting and rope-pulley system are shown in Figure 3.

Figure 3 : Dispersant Spray Boom

The dispersant was applied through Spraying System Company, 15 degree, flat-fan nozzles. These are the same nozzles used in full-scale, vessel-based dispersant application systems. The dispersant was held in a small stainless steel pressure vessel connected to another tank that was charged with air to the pressure required for the spray application (40 to 80 psi). For the "diluted" dispersant tests, the dispersant supply tank was vigorously shaken for approximately 30 seconds immediately prior to application to ensure that the dispersant and water were fully mixed. An electrically controlled valve was mounted at the outlet of the dispersant supply tank to start and stop the dispersant supply to the spray nozzles. For the dilute tests, the spray line to the nozzles was drained and cleaned prior to the test to ensure that the product reaching the slick was fully mixed. A photo of the dispersant delivery system is shown in Figure 4. The spray was turned on and allowed to stabilize for a few seconds and then the boom take-up spool was started to cause the boom, and spray nozzles, to pass over the test slick. The spray nozzles released the dispersant from a height of about 1.8 metres above the oil slick. The plastic sheeting and eaves trough captured the excess spray at either end of the boom travel to minimize dispersant over-spray. An estimate of the spray boom speed needed to achieve proper slick dosing for a given oil thickness, design dosage, nozzle type and flow pressure was made prior to each test using the tables shown in Appendix B. These speed estimates were approximate and were adjusted, based on the results of the cookie tray measurements, to achieve the proper final spray quantity.

Figure 4: Dispersant Spray Pressure Tanks & Valve



The amount of dispersant applied per unit area of surface was measured for each test by collecting the spray in a “cookie” tray suspended just above the water surface at one edge of the oil containment zone as seen in Figure 5. The tray was weighed before and immediately after the application to determine the quantity of dispersant applied.

Figure 5: Dispersant Measuring Tray

Water Sampling Ports

Four water sampling tubes were mounted under the center of the oil containment zone. Three lines were positioned at a depth of 15 centimetres below the surface; one in the center of the zone and the other two along the center of the tank’s long axis, 25 centimetres on either side of the middle port. The fourth line was positioned at a depth of 30 centimetres below the center of the containment zone. In preliminary tests all four sampling tubes were used. For subsequent testing only the two central ports were used to allow more frequent sampling of in-water concentrations while still maintaining a reasonable number of samples for analysis.

5. Preliminary Test System "Calibration"

An appropriate dispersant dosage and mixing energy level combination for the two dispersants was determined prior to starting the tests. Too little dispersant or mixing could result in poor dispersion and the possibility that the test would be insensitive to the effects of dispersant dilution. Conversely too much dispersant or too much mixing could overwhelm the system and again mask the effects of dilution. To identify suitable dosages and mixing energies, small volumes of the ANS crude were pre-mixed with various quantities of the two dispersants. These samples were then placed in the test tank under various wave conditions and the resulting dispersion efficiencies observed. From past experience it was known that the amount of dispersant required to achieve full dispersion when pre-mixed with oil is much less than the recommended field dosage. For this reason dosages of 1:50, 1:75 and 1:100 were used in this assessment. The wave paddle setting was also adjusted during this stage to increase or decrease the mixing energy being applied. Visual observations were used to identify the best dispersant dosage and mixing energy level. The 1:50 pre-mixed dispersant to oil tests resulted in essentially 100% dispersion of the oil within about 5 minutes. It was evident from these results that the 1:50 dosage was more than required to achieve full dispersion. The 1:100 ratio was not as successful with only about 70% dispersion even under the highest wave energy possible without having oil escape the bubble barrier. The 1:75 dosage resulted in essentially 100% dispersion for both dispersants and was selected for use in the main test program. The energy level chosen for the work was set by adjusting the paddle's variable speed dial at 45. This resulted in waves with a crest to trough amplitude of about 20 cm, a wavelength of 1.3 m and a period of about 1.4 seconds.

The system powering the spray boom's movement was also calibrated prior to starting the final test matrix. The variable speed motor was run at different speeds and the boom's speed calculated for each setting. This then allowed an estimate of the motor's speed setting to be made for each test, given the oil thickness being treated, the dispersant amount required, and the flow rate of the nozzles being used in the testing. Tables B1 through B5 show the approximate spray boom speeds required for various slick thicknesses, nozzle types, spray pressures and dispersant dosage conditions. Figure B1 shows the calibration data for the spray boom motor setting versus boom speed estimate. Figure B1 was used to identify the required motor setting once an approximate boom speed was identified from Tables B1 to B5.

The final estimate of dispersant effectiveness for each test was made by sorbing the oil left in the containment area at the end of the test and comparing the amount sorbed with the amount used in the test. Unfortunately sorbents pick up a considerable amount of water along with the oil and so their initial weight after sorbing is not an accurate measure of the amount of oil picked up. To solve this problem the sorbents were left to drip-dry overnight and weighed the next day. This posed another problem because there is also some oil evaporation over this period. To correct for this evaporation loss, both during the time the oil was on the water surface and while drying overnight, a quantity of oil (about 1.5 litres) was placed on the tank in the containment area and allowed to “weather” for 30 minutes (duration of all tests). This oil was then sorbed from the surface and allowed to drip-dry. The weight of the sorbents and oil was measured after 24 hours to determine the approximate amount of oil loss through evaporation when this test protocol was followed. The results showed that about 15% total loss occurred after 24 hours. This loss also includes the evaporation of oil while on the water surface. To estimate the evaporation loss during the test period a quantity of oil was also sorbed from a cookie tray and hung over night to see what the evaporation loss would be if the oil was not placed on the water surface for the 30 minute test period. About 10% of the oil was lost through evaporation in this test. It appears that about 5% of the oil evaporated while on the water surface (if rapid dispersion did not occur) and an additional 10% was lost from the sorbents as they “dried” overnight. For the tests where the dispersant was not 100% effective, the dispersant effectiveness estimates were adjusted to reflect the likely loss of 10% of the oil during the overnight drying stage. The competing processes of evaporation and dispersion make it difficult to determine the actual evaporation loss during the test period so an adjustment was not made for this in the dispersion calculation. This resulted in a slightly higher (up to 5%) estimate of effectiveness than was likely achieved, for those tests where only a small amount of oil actually dispersed.

6. Test Method

The key elements of the test method or procedures can be summarized as follows.

The dispersant spray apparatus was prepared by fitting the appropriate nozzles to the spray boom, putting the appropriate dispersant or dispersant and water mixture in the application pressure vessel, adjusting the air pressure used to drive the dispersant boom and setting the boom drive motor to the appropriate speed.

The underwater lights, water sampling lines, dispersant measurement tray, video camera and air bubble barrier were all started or put in place.

The oil was placed within the containment zone, the dispersant was applied, the dispersant measurement tray was removed and weighed and the wave paddle started.

Water samples were taken every 5 minutes and the behavior of the slick observed.

After 30 minutes the wave paddle was stopped and the oil remaining in the containment zone was sorbed to estimate the dispersion efficiency. The water samples were analyzed for oil concentrations using the procedures specified for the Horiba OCMA-350 NDIR Oil Content Analyzer.

Each individual test required that a considerable number of steps be completed, in a relatively short period of time, to ensure a successful run. The following check-list was followed for each test.

1. Attach the nozzles required for test to the spray boom.
2. Clean or replace the dispersant feed line before the test, if required.
3. Clean the dispersant supply tank and fill it with the appropriate dispersant or dispersant and water mixture.
4. Pressurize the spray system to the required pressure for the test.
5. Turn on the underwater lights.
6. Place the spray boom in its start position.
7. Power-up the spray boom valve switch and spray boom drive motor.
8. Set the spray boom take-up speed to the required setting.
9. Establish the siphon in the water sampling lines.
10. Set up the video camera and test its alignment and operation.
11. Start the air curtain bubbler system.
12. Place a clean, weighed “cookie tray” in the spray path, at water level at the extremity of slick, to capture spray for an estimate of applied liquid volume.
13. Lay down the oil slick of required thickness.
14. Start video recording ... ensure the timer is also being recorded to capture event timing.
15. Start the spray boom take-up motor and adjust to the appropriate speed (motor should be warmed-up at high speed for a few minutes if a slow speed setting is used in the test)
16. Start the dispersant spray and charge the spray lines (contents captured by plastic sheet and trough).

17. Initiate the spray boom movement to apply dispersant (boom drive mechanism and spray automatically turn off).
18. Remove the cookie-tray and weigh for estimate of quantity of applied dispersant.
19. Start the wave paddle at the appropriate energy level.
20. Take water samples at 1, 5, 10, 15, 20 and 30 minutes (be sure to flush the sampling lines prior to each sample by at least 250 ml).
21. Stop the test after 30 minutes.
22. Pre-weigh a number of sorbent sheets and record their weight.
23. Sorb the surface oil remaining within the oil containment zone at the end of the test.
24. Shut down all systems.
25. Extract the oil from the collected water samples and measure the oil concentrations using the Horiba Oil Analyzer.
26. Weigh the air-dried sorbent after drip-drying overnight and determine the approximate quantity of oil remaining on the surface at the end of the test.
27. Record all results and any useful observations made during the test.

7. Test Results

A total of 12 tests were completed. The primary results of the testing are summarized in Table 1 and detailed data for all tests are presented in Appendix C. The dispersion efficiencies reported in Table 1 were calculated using the sorbent data collected at the end of each test and the measurement method outlined in section 5. It is evident from this table that the performance of Corexit 9527 is not affected when diluted with water at a ratio of 1:10. The thick oil tests resulted in complete dispersion and the “thin”, under-dosed, tests about 30% dispersion for both methods of application. The performance of Corexit 9500 was severely reduced when applied diluted with water at 1:10 and 3:10 ratios. For the thick oil tests, where the proper design dispersant dosages were achieved, Corexit 9500 dispersed only about 15 % of the oil when applied in a 1:10 dilution with water whereas complete dispersion was achieved when it was applied neat. The dispersion increased to about 40 % when the dilution was decreased to 3:10. It should be noted that even these low values are likely inflated by about 5 % due to evaporation losses that occur over the time period that the test oil is on the water surface.

The reasons for the ineffectiveness of Corexit 9500 when applied in a diluted form under these controlled conditions are not known. Anecdotal accounts from an actual field use of Corexit 9500 educted into a fire-monitor discharge appear to contradict these laboratory results. In a response to the Red Seagull spill in the Gulf of Mexico in January 1998, approximately one and one-half drums of Corexit 9500 were applied via eduction into a fire-nozzles's water flow, to approximately 20 barrels of fresh Arabian Medium crude oil. The surface oil was observed to disperse after the application and the coffee-colored clouds characteristic of a successful dispersant use were seen in the vicinity of the thick oil patches that were targeted (Henry, 2000). Several factors could have contributed to the contrary results seen in the field use and laboratory tests. The differnences in oil types, mixing energy levels, the contact time and mixing levels between the dispersant and water, and the final dispersant-to-oil dosage ratios could all have contributed to the different outcomes. It remains that when the results for Corexit 9527 and 9500 are compared under similar laboratory conditions, dilution reduced the performance of Corexit 9500 whereas it did not affect the performance of Corexit 9527.

It again should be noted that the design oil thickness for the "thin" oil tests could not be achieved. The oil thickness for these tests was about 1.9 mm rather than the 0.75 mm design thickness. As was previously discussed, the oil would not spread any thinner. Dispersant was applied in these tests at a rate that would treat slicks that are 0.75 mm thick. This resulted in an under-dosing of the oil. The approximate dispersant to oil ratio achieved in the "thin" oil tests was about 1:190. This explains the lower efficiencies recorded for these runs. However, the results for the under-dosed tests follow the same trends as for the "thick" oil, properly dosed, tests. The 9527 results show no difference whether the dispersant is applied in a neat or diluted form and the 9500 results are obviously poorer in the dilute application case.

The results of Table 1 are supported by the in-water concentrations and video records taken during the testing. Tables C1 to C7 show the in-water concentrations measured for each run along with the efficiency estimates made using the sorbent data. The in-water oil concentration data is too limited to generate mass-balance estimates. Their primary value is to verify that little oil entered the water column during those runs where the dispersant was not effective and that large quantities were detected in the effective runs.

Table 1 : Test Results Summary

Dispersant Type	Thick Oil Results		"Thin" Oil Results	
	Neat	Dilute (1:10)	Neat	Dilute (1:10)
Corexit 9527	99	97	31	32
			40*	29
Corexit 9500	97	14	41	22
		17		
		41 (3:10)		

* dispersant dosage for this run was higher than other "thin" tests , approximately 1:125 vs 1:190

A composite VHS format video of all of the tests has been compiled and submitted with this report. The composite video shows the beginning 5 minutes of each test, including the dispersant application period, and the end of the test when the remaining oil is being sorbed. The video has been organized to show the neat application case followed by its companion dilute application result so direct comparisons of the oil slick behavior can easily be made for the two cases.

8. Conclusions and Recommendations

The test results indicate that the performance of Corexit 9527, when used on Alaska North Slope (ANS) crude oil, is not affected when diluted with water at a ratio of 1:10. However, the performance of Corexit 9500, on ANS crude, was severely reduced when applied diluted with water at both 1:10 and 3:10 ratios.

It is recommended that these preliminary results be considered before using 9500 in application systems where dilution of dispersant with water is used, such as in high capacity "fire-monitor" systems. Single-nozzle application systems should be considered for the efficient delivery of Corexit 9500 in neat form to eliminate the possibility of reduced effectiveness.

Additional testing should be completed to determine if the reduced efficiency of Corexit 9500, when applied dilute, is due to the type of oil, the method of mixing or delivery of the dispersant into the water stream or the contact time between the dispersant and the water carrier.

The reason for the reduced performance of Corexit 9500 when applied in a diluted form should be investigated in consultation with the manufacturer. This would assist in the future development of dispersants and provide a better understanding of the processes involved.

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Appendix A : Alaska North Slope Crude Oil Properties

OIL NAME: ALASKA NORTH SLOPE

		WEATHERING (Volume %)	
1.0 TYPE: Crude	Fresh	26.43%	34.18%
2.0 DENSITY (g/mL):			
1°C	0.888	0.936	0.946
15°C	0.875	0.927	0.940
3.0 VISCOSITY:			
3.1 DYNAMIC VISCOSITY (mPa·s):			
1°C	37.9	1655.0	105826.4*
15°C	15.4	301.9	1480.0
3.2 KINEMATIC VISCOSITY (mm²/sec):			
1°C	42.7	1768.2	111867.2*
15°C	17.6	325.7	1574.5
* Viscosity at the pour point.			
4.0 INTERFACIAL TENSIONS @ 20°C (mN/m):			
4.1 AIR-OIL:	29.8	33.3	35.2
4.2 OIL-SEAWATER:	5.1	10.0	22.1
5.0 POUR POINT (°C):	-30	-9	6
6.0 FLASH POINT - CLOSED CUP (°C):	<10	58	130
7.0 EMULSION FORMATION TENDENCY AND STABILITY:			
7.1 TENDENCY 1°C	1.00	1.00	1.00
7.2 STABILITY 1°C	0.00	1.00	1.00

8.0 DISTILLATION DATA (°C):

VOLUME % EVAPORATED	LIQUID TEMPERATURE (°C)	VAPOUR TEMPERATURE (°C)
IBP	93.8	40.7
5	152.9	91.2
10	185.2	115.4
15	218.3	143.7
20	262.3	197.0
30	324.6	265.7
40	377.1	312.9
50	418.4	338.9

9.0 WEATHERING:

$$F_v = \frac{\ln(1+6023 * O \exp(4.5 - 3996.7/T_k)/T_k)}{(6023/T_k)}$$

where: F_v is fraction of oil lost by volume
ln is natural log
O is evaporative exposure
exp is exponential base e
T_k is environmental temperature (Kelvin, K = °C + 273)

Source: S.L.Ross Environmental Research Ltd. Analyses

Alaska North Slope (SOCSEX)

Origin: Alaska, USA

The oil analyzed by ESD was used in the 1994/95 Subsurface Oil in Coarse Sediments Experiment (SOCSEX). The evaporated oils were produced by Coastal and Ocean Resources, using air stripping. Data from OGJ 99 were originally published in 1992.

API Gravity

	Reference	ID
27.5	OGJ	99
25	ESD	96

Density (g/mL)

Temperature (°C)	Evaporation (volume %)		Reference	ID
0	0	0.8922	ESD	95
0	15	0.9087	ESD	95
15	0	0.8814	ESD	95
15	0	0.8899	OGJ	99
15	15	0.8976	ESD	95

Dynamic Viscosity (mPa·s or cP)

Temperature (°C)		Reference	ID
0	42	ESD	95
5	32	ESD	95
10	25	ESD	95
15	21	ESD	95

Kinematic Viscosity (mm²/s or cSt)

Temperature (°C)		Reference	ID
16	32	OGJ	99

Hydrocarbon Groups (weight %)

	Evaporation (volume %)		Reference	ID
Saturates	0	53	ESD	95
Saturates	15	52	ESD	95
Saturates	22	47	ESD	95
Aromatics	0	37	ESD	95
Aromatics	15	38	ESD	95
Aromatics	22	40	ESD	95
Resins	0	6	ESD	95
Resins	15	7	ESD	95
Resins	22	9	ESD	95
Asphaltenes	0	4	ESD	95
Asphaltenes	15	3	ESD	95
Asphaltenes	22	5	ESD	95

Source: Emergencies Science Division
Environment Canada
www.etcentre.org/main/e/db/db.html
A Catalogue of Crude Oil and Oil Product Properties

Appendix B : Spray Boom Calibration Data

Figure B1 : Dispersant Spray Boom Calibration Curve

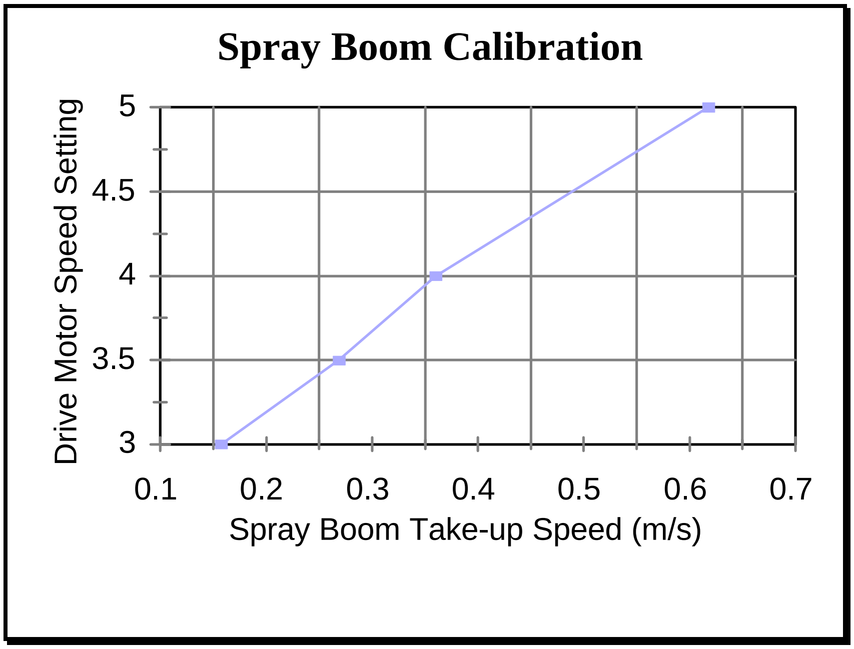

Table B1

Approximate Spray Arm Speed Requirements for Conditions Noted Below

Oil Thickness (mm)	0.75
Disp Dosage[1]	75
Disp Conc. % in water	100
Spray Width (m)	1
Boom Sp Factor	2.385
Number of Nozzles	2

	Flow and Calc Boom Speed (m/s) for Each Nozzle Type									
Pressure	1501		1502		1504		1508		1515	
	gpm/nozzle	Boom Sp	gpm/nozzle	Boom Sp	gpm/nozzle	Boom Sp	gpm/nozzle	Boom Sp	gpm/nozzle	Boom Sp
20.000	0.070	0.370	0.140	0.741	0.280	1.481	0.560	2.963	1.1	5.820
30.000	0.085	0.450	0.170	0.899	0.350	1.852	0.690	3.651	1.3	6.878
40.000	0.100	0.529	0.200	1.058	0.400	2.116	0.800	4.232	1.5	7.936
60.000	0.125	0.661	0.250	1.323	0.490	2.592	0.980	5.185	1.8	9.523
80.000	0.140	0.741	0.280	1.481	0.570	3.016	1.100	5.820	2.1	11.110
100.000	0.160	0.846	0.320	1.693	0.630	3.333	1.300	6.878	2.4	12.697

[1] This refers to 1 part of dispersant to 75 parts of oil.
The boom speed factor is an approximate adjustment factor to account for the difference in speed of the spray nozzle rotation and the dispersant spray sweep speed at the water surface.

Table B2

Approximate Spray Arm Speed Requirements for Conditions Noted Below										
Oil Thickness (mm)		3								
Disp Dosage[1]		75								
Disp Conc. % in water		100								
Spray Width (m)		1								
Boom Sp Factor		2.385								
Number of Nozzles		2								

	Flow and Calc Boom Speed (m/s) for Each Nozzle Type									
Pressure	1501		1502		1504		1508		1515	
	gpm/nozzle	Boom Sp	gpm/nozzle	Boom Sp	gpm/nozzle	Boom Sp	gpm/nozzle	Boom Sp	gpm/nozzle	Boom Sp
20.000	0.070	0.093	0.140	0.185	0.280	0.370	0.560	0.741	1.1	1.455
30.000	0.085	0.112	0.170	0.225	0.350	0.463	0.690	0.913	1.3	1.719
40.000	0.100	0.132	0.200	0.265	0.400	0.529	0.800	1.058	1.5	1.984
60.000	0.125	0.165	0.250	0.331	0.490	0.648	0.980	1.296	1.8	2.381
80.000	0.140	0.185	0.280	0.370	0.570	0.754	1.100	1.455	2.1	2.778
100.000	0.160	0.212	0.320	0.423	0.630	0.833	1.300	1.719	2.4	3.174

Table B3

Approximate Spray Arm Speed Requirements for Conditions Noted Below										
Oil Thickness (mm)		0.75								
Disp Dosage[1]		75								
Disp Conc. % in water		10								
Spray Width (m)		1								
Boom Sp Factor		2.385								
Number of Nozzles		2								

	Flow and Calc Boom Speed (m/s) for Each Nozzle Type									
Pressure	1501		1502		1504		1508		1515	
	gpm/nozzle	Boom Sp	gpm/nozzle	Boom Sp	gpm/nozzle	Boom Sp	gpm/nozzle	Boom Sp	gpm/nozzle	Boom Sp
20.000	0.070	0.037	0.140	0.074	0.280	0.148	0.560	0.296	1.1	0.582
30.000	0.085	0.045	0.170	0.090	0.350	0.185	0.690	0.365	1.3	0.688
40.000	0.100	0.053	0.200	0.106	0.400	0.212	0.800	0.423	1.5	0.794
60.000	0.125	0.066	0.250	0.132	0.490	0.259	0.980	0.518	1.8	0.952
80.000	0.140	0.074	0.280	0.148	0.570	0.302	1.100	0.582	2.1	1.111
100.000	0.160	0.085	0.320	0.169	0.630	0.333	1.300	0.688	2.4	1.270

Table B4

Approximate Spray Arm Speed Requirements for Conditions Noted Below

Oil Thickness (mm)	3
Disp Dosage[1]	75
Disp Conc. % in water	10
Spray Width (m)	1
Boom Sp Factor	2.385
Number of Nozzles	2

	Flow and Calc Boom Speed (m/s) for Each Nozzle Type									
Pressure	1501		1502		1504		1508		1515	
	gpm/nozzle	Boom Sp	gpm/nozzle	Boom Sp	gpm/nozzle	Boom Sp	gpm/nozzle	Boom Sp	gpm/nozzle	Boom Sp
20.000	0.070	0.009	0.140	0.019	0.280	0.037	0.560	0.074	1.1	0.145
30.000	0.085	0.011	0.170	0.022	0.350	0.046	0.690	0.091	1.3	0.172
40.000	0.100	0.013	0.200	0.026	0.400	0.053	0.800	0.106	1.5	0.198
60.000	0.125	0.017	0.250	0.033	0.490	0.065	0.980	0.130	1.8	0.238
80.000	0.140	0.019	0.280	0.037	0.570	0.075	1.100	0.145	2.1	0.278
100.000	0.160	0.021	0.320	0.042	0.630	0.083	1.300	0.172	2.4	0.317

Table B5

Approximate Spray Arm Speed Requirements for Conditions Noted Below

Oil Thickness (mm)	3
Disp Dosage[1]	75
Disp Conc. % in water	30
Spray Width (m)	1
Boom Sp Factor	2.385
Number of Nozzles	2

	Flow and Calc Boom Speed (m/s) for Each Nozzle Type									
Pressure	1501		1502		1504		1508		1515	
	gpm/nozzle	Boom Sp	gpm/nozzle	Boom Sp	gpm/nozzle	Boom Sp	gpm/nozzle	Boom Sp	gpm/nozzle	Boom Sp
20.000	0.070	0.028	0.140	0.056	0.280	0.111	0.560	0.222	1.1	0.436
30.000	0.085	0.034	0.170	0.067	0.350	0.139	0.690	0.274	1.3	0.516
40.000	0.100	0.040	0.200	0.079	0.400	0.159	0.800	0.317	1.5	0.595
60.000	0.125	0.050	0.250	0.099	0.490	0.194	0.980	0.389	1.8	0.714
80.000	0.140	0.056	0.280	0.111	0.570	0.226	1.100	0.436	2.1	0.833
100.000	0.160	0.063	0.320	0.127	0.630	0.250	1.300	0.516	2.4	0.952

Appendix C : Detailed Test Results

Table C1

9500a Dispersant Applied to Thick Oil at 1:75 Dosage

Time (Min.)	In-Water Oil Concentrations (mg/l)					% Dispersed (as per Surface Sorbents)	
	Dec. 10		Dec. 9				
	Neat		Dilute 1:10			Neat	Dilute 1:10
	top	bot	top	bot		97.3	14
1	558	231	75	76			
5	489	471	32	27			
10	364	378	32	24			
15	301	290	1.5	0			
20	244	242	0	0			
30	178	158	0	0			

Table C2

9527 Dispersant Applied to "Thick" Oil at 1:75 Dosage

Time (Min.)	In-Water Oil Concentrations (mg/l)					% Dispersed (as per Surface Sorbents)	
	Dec. 1		Dec. 2				
	Neat		Dilute 1:10			Neat	Dilute 1:10
	top	bot	top	bot		98.7	97.2
1	120	372	1652	1269			
5	683	792	568	598			
10	393	423	320	353			
15	321	301	276	284			
20	n/t	176	212	177			
30	n/t	195	167	165			

Table C3

9500a Dispersant Applied to Thick Oil at 1:75 Dosage

Time (Min.)	In-Water Oil Concentrations (mg/l)					% Dispersed (as per Surface Sorbents)	
			Dec 14				
	Neat		Dilute 1:10			Neat	Dilute 1:10
	top	bot	top	bot			17
1			138	88.3			
5			69.1	48.9			
10			29.7	58			
15			30.8	26.6			
20			n/t	26.5			
30			n/t	40.3			

Note: Table C4 results are for dispersant applied diluted 3 parts dispersant to 10 parts of water

Table C4

9500a Dispersant Applied to Thick Oil at 1:75 Dosage							
Time (Min.)	In-Water Oil Concentrations (mg/l)					% Dispersed (as per Surface Sorbents)	
			Dec 15				
	Neat		Dilute 3:10			Neat	Dilute 3:10
	top	bot	top	bot			41
1			280	260			
5			250	256			
10			183	178			
15			112	129			
20			83.9	96.1			
30			66.7	62.2			

“Thin” Slick Results

Notes:

These slicks were about 1.9 mm thick or 2.5 times thicker than the design thickness of 0.75 mm and they were often patchy in coverage. Dispersant was applied assuming an average 0.75 mm thickness. This resulted in an actual dispersant application ratio of about 1:190 instead of the design 1:75. This explains the lower dispersant efficiencies.

The Dec. 1 neat 9527 results in Table C5 are high due to a higher application of dispersant .. the dose in this instance was estimated to be about 1:150.

Table C5

9527 Dispersant Applied to "Thin" Oil at 1:75 Dosage

Time (Min.)	In-Water Oil Concentrations (mg/l)					% Dispersed (as per Surface Sorbents)	
	Nov. 30		Nov 26				
	Neat		Dilute 1:10			Neat	Dilute 1:10
	top	bot	top	bot		30.6	32
1	126	108	105	17.5			
5	12.3	9.3	28.4	20.3			
10	0	0	24.6	3.8			
15	0	0	6.3	0			
20	0	0	0	0			
30	0	0	0	0			

Table C6

9527 Dispersant Applied to "Thin" Oil at 1:75 Dosage

Time (Min.)	In-Water Oil Concentrations (mg/l)					% Dispersed (as per Surface Sorbents)	
	Dec. 1		Nov 26				
	Neat		Dilute 1:10			Neat	Dilute 1:10
	top	bot.	top	bot.		40*	29
1	182	91	158	18.7			
5	37.5	19	59.9	51.9			
10	36.2	9.8	0	0			
15	7.7	10.6	0	0			
20	9.1	5.9	0	0			
30	5.7	7.6	0	0			

Table C7

9500a Dispersant Applied to "Thin" Oil at 1:75 Dosage							
Time (Min.)	In-Water Oil Concentrations (mg/l)					% Dispersed (as per Surface Sorbents)	
	Dec 9 -b		Dec. 9 -a				
	Neat		Dilute 1:10			Neat	Dilute 1:10
	top	bot	top	bot		41	22
1	123	109	27.1	21.1			
5	23.1	42.2	9.4	2			
10	22.3	20.5	3.7	0			
15	20.4	17.3	0	0			
20	n/t	15.2	0	0			
30	n/t	17.5	0	0			