Feasibility of Using Ohmsett for Dispersant Testing and Research

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Abstract
The Minerals Management Service operates a wave tank facility in Leonardo, New Jersey, known as Ohmsett, which is used primarily for the testing of oil spill equipment. The objective of this study was to examine the feasibility of performing dispersant effectiveness testing at the facility. The study included (1) interfacial tension laboratory tests; (2) turbidity tests; (3) laboratory tests to determine efficacy of the current filtering material used at Ohmsett and alternative filtering materials for removing dispersant and chemically dispersed oil; and (4) full-scale testing at Ohmsett.

The study showed that (1) the presence of dispersant in Ohmsett water following dispersant tests will strongly affect the interfacial tension of oils used in subsequent boom or skimmer tests at Ohmsett, so that the tank will have be thoroughly cleaned following a dispersant testing program; (2) dispersant concentrations in the water can reach at least 400 ppm before having a noticeable effect on the dispersion of floating oil, so that many experiments could be done consecutively without concern that residual dispersant is in the tank; (3) a number of experiments per day could be run in sequence before having to filter the body of water to remove dispersed oil; (4) underwater viewing of dispersant testing will only be possible for the first test in a series; (5) it is possible to remove most dispersed oil from Ohmsett tank water using cellulose as the filter aid; (6) activated carbon is likely to remove dissolved dispersant with a high degree of effectiveness; and (7) overall, dispersant testing at Ohmsett could be done with good success if the testing program is carefully designed and implemented with regard for the limitations noted above.

1.0 Introduction
One difficulty in using oil spill dispersants in the field is predicting and measuring the effectiveness of the dispersant over a range of conditions. The main variables include oil type and weathered state, dispersant type, dispersant-to-oil ratio, application method, slick thickness, and sea state. Dispersant testing in small-scale laboratory tests has been shown to be of limited value in predicting dispersant effectiveness in actual spill situations. Dispersant testing in ocean field trials has yielded useful results, but these are only valid for the narrow range of conditions that were experienced in the trials. Testing a wide range of variables at sea in many trials is possible, but would be expensive and also difficult to get approved by regulators. The situation remains that little quantitative information is available on dispersant effectiveness under real spill conditions. What is needed is a facility that can be used to test a wide range of dispersant-use variables under conditions that simulate actual conditions much better than existing laboratory tests do. Ohmsett may be such a facility.

The problem is that Ohmsett may not be currently equipped to do dispersant
testing. The main concerns are that:

1. dispersant entering the tank water from one or more tests may affect the results of subsequent dispersant tests;
2. dispersant in the water may affect slick behavior in subsequent tests involving spill recovery or containment devices;
3. turbidity caused by dispersed oil from one or more tests may affect underwater viewing of subsequent tests; and
4. removal of dispersant and tiny dispersed oil droplets from the water might be difficult and expensive to accomplish.

Before Ohmsett can be used for routine dispersant testing and research, it is necessary to assess these technical concerns.

2.0 Study Goals

The study approach involved seven goals or tasks to reach the objective of the study. These are outlined below.

Task 1 – to review the current operations at Ohmsett that have relevance to dispersant testing and to review government regulations related to the discharge of contaminated water from the tank.

Task 2 – to determine the critical concentration of dispersed oil and dispersant that could affect subsequent tests involving dispersant or subsequent tests involving boom and skimmer work.

Task 3 – to determine the critical concentration of dispersed oil that would cause enough turbidity in the tank to prevent underwater viewing and photography of the dispersant tests.

Task 4 – to determine how many dispersant experiments could be done before the critical concentrations identified in Tasks 2 and 3 are realized. This would indicate how often the tank will have to be treated to remove dispersant products and dispersed oil. To accomplish this task properly, it was necessary to scope out a design for a dispersant program at Ohmsett.

Task 5 – to determine whether the current filtering material used at Ohmsett, namely, diatomaceous earth, is able to remove mechanically dispersed oil, chemically dispersed oil, and dispersant chemicals themselves.

Task 6 – in the event that the current filter system was found to be unable to filter dispersant and/or dispersed oil, the purpose of this task was to research and test other filtering materials and approaches.

Task 7 – to verify the results of the above laboratory work at full-scale at the Ohmsett facility itself.

The following sections present details of each of the tasks in the order presented above.

3.0 Current Operations at Ohmsett

3.1 Description of Ohmsett

The Minerals Management Service operates the National Oil Spill Response Test Facility known as Ohmsett (Oil and Hazardous Materials Simulated Environmental Test Tank) located in Leonardo, New Jersey. Ohmsett is used primarily for the testing and development of devices and techniques for the control and cleanup of oil spills. The main structure of the facility is a pile-supported concrete
tank with the following water dimensions: 203 metres (667 feet) long, 20 metres (66 feet) wide, and 2.4 metres (8 feet) deep (see Figure 1).

Figure 1. The Ohmsett Wave Basin as Viewed from the North End (Boom Under Test)

The tank is filled with brackish water from nearby Sandy Hook Bay. The salinity is maintained at a level of approximately 17 parts per thousand (ppt). (Note that Ohmsett is considering using water with a salinity of 30 ppt, starting in the year 2000, to more closely resemble ocean conditions.) The tank is spanned by three movable bridges. The main bridge is equipped with an oil distribution system capable of laying oil slicks on the surface several metres ahead of the devices being tested. Devices can be towed at speeds up to 6.5 knots. The tank includes a flap-type wave generator at the south end and a wave-absorbing beach at the north end which can be lowered to the bottom of the tank to allow waves to reflect from the north wall. The wave generator can produce regular (unidirectional sinusoidal) waves up to 61 centimetres (2 feet) high and up to 45 metres (100 feet) long. With the beach lowered a “confused condition” can be produced which resembles a “harbor chop” with heights of 70 centimetres (2.3 feet).

The clarity of the water in the Ohmsett tank is achieved by the use of a leaf-type filtration system containing diatomaceous earth (DE) as the filter aid. The filter can remove suspended particles between 1 to 100 microns (micron = 10^{-6} metre). Algae growth is controlled through chlorination with sodium hypochlorite.

3.2 Discharge Regulations

The operators of Ohmsett are allowed to discharge the tank contents into
nearby Sandy Hook Bay according to the conditions outlined in Permit No. NJ00057762 issued by the New Jersey Pollutant Discharge Elimination System (NJPDES) Regulations N.J. A.C. 7:14A-1 et seq. The facility has been classified as a minor facility by the New Jersey Department of Environmental Protection. On the understanding that the filtered water from the tank could be discharged up to twice per year, the NJPDES permit states, among other conditions not relevant to this study, that: (1) there shall be no discharge of floating solids or visible foam in other than trace amounts; (2) there shall be no visible sheen; (3) the daily maximum of total suspended solids shall not exceed 20 mg/L; (4) The daily maximum of petroleum hydrocarbons shall not exceed 15 mg/L (approximately 15 ppm by volume); and (5) the daily maximum pH shall not exceed 9.0.

There is no restriction on salinity, nor is there any apparent restriction on concentrations of detergent or other surfactants in the water, except, as noted above, that no visible foam must be evident in the discharge.

4.0 Effects of Dispersant in Ohmsett Water on Surface Slick Behavior

The main concern with performing dispersant testing at Ohmsett is that dispersant left in the tank’s water after a given test might affect the properties and behavior of floating oil in subsequent tests, either more dispersant tests using crude oils or conventional tests using the three Ohmsett test oils. The specific concern is that the interfacial tension of floating oil might be significantly lowered and thus produce premature slick entrainment (in conventional boom tests) or enhanced slick dispersibility (in dispersant effectiveness tests). To understand this issue, two sets of experiments were performed. First, laboratory tests were conducted to measure the surface tension and interfacial tensions of the water and oils involved, first using regular Ohmsett water and then using the same water dosed with dispersant. Second, a standard dispersant effectiveness test procedure was used in the laboratory to check the effects of dispersant-dosed water on the dispersibility of surface slicks.

4.1 Interfacial Tension Tests

Tests were performed to measure: (1) the surface tension of Ohmsett water and the surface tension of the test oils and crude oils; and (2) the interfacial tension between Ohmsett water and the test and crude oils, both as a function of dispersant concentration in Ohmsett water. The following describes the test materials, methods and results of the laboratory study.

4.1.1 Test Materials

The three test oils used at Ohmsett to test skimmers and boomers were selected for obvious reasons. These are called Calsol, Sundex, and Hydrocal. Also, two crude oils that are transported in large volumes in U.S. waters were selected. These are Alaska North slope crude oil and Arabian Light crude oil. Properties of the five oils are presented in the original report (SL Ross 2000).

Only two dispersants were selected for study: Corexit 9527 and Corexit 9500. These are the only dispersants that are widely available in the U.S.

Ohmsett water itself was used in all tests. This was shipped from the facility to the SL Ross Laboratory in a 55-gallon drum, which turned out to be somewhat rusty on the inside, so the water used in the tests required a coarse filtering to remove rust
particles. The salinity of the water was measured to be only 10 ppt. This is substantially less than the value of 17 ppt that is indicated in Ohmsett literature.

4.1.2 Test Apparatus and Procedure
All surface tension and interfacial measurements were made using the CSC DuNouy Ring Tensiometer, model 70545 in general accordance with the procedure outlined in ASTM D971-82.

4.1.3 Results of Interfacial Tension Tests

Surface Tension of Ohmsett Water
The addition of dispersant (both Corexit 9527 and 9500) in concentrations as low as 1 to 2 ppm (vol) had a noticeable effect on the surface tension of Ohmsett basin water. A concentration of 50 ppm dispersant approximately halved the surface tension of the water. During the testing it was noted that concentrations of dispersant as low as 10 ppm caused the water to foam when it was vigorously agitated, and a concentration of 50 ppm produced stable foam on the water surface that survived for a considerable time after the agitation ceased.

Surface Tension of Floating Oils
The addition of dispersant to Ohmsett basin water had no appreciable effect on the surface tension of any of the five oils tested. Surface tension of floating oil is measured by testing at the oil/air interface. The results suggest that the dispersant surfactants, otherwise located in the water and at the oil/water interface, are not present in appreciable concentrations in the body of the oil or at the oil/air interface.

Interfacial Tension of Hydrocal, Calsol and Sundex
The presence of very small concentrations of dispersant in Ohmsett water (in the range of 2 to 5 ppm) was enough to produce a measurable drop in interfacial tension of the Ohmsett test oils. A interfacial tension reduction of approximately 50% was found at concentrations of 50 ppm. Corexit 9527 appeared to reduce the interfacial tension slightly more than Corexit 9500. Reductions in interfacial tension to below 18 mN/m falls outside the range currently required for standard Ohmsett boom tow tests.

Effect of Interface Aging
In tests with Hydrocal, the interfacial tension decreased further over time, but not sharply, after the oil was placed on Ohmsett water containing concentrations of 10 ppm of either 9527 or 9500.

Interfacial Tension of Alaska North Slope Crude Oil
The presence of dispersant in Ohmsett water reduced the interfacial tension of fresh Alaska North Slope crude oil, but not by as much as with the Ohmsett test oils. The effect was measurable at 10 to 20 ppm and caused an approximately 40% reduction at 50 ppm.

Interfacial Tension of Arab Light Crude Oil
The addition of dispersant to Ohmsett water reduced the interfacial tension of fresh Arab Light crude oil, more so than with Alaska North Slope. The effect was measurable at 2 to 5 ppm and caused an approximately 50% reduction at 50 ppm. Corexit 9527 had a slightly greater effect than Corexit 9500.

In addition to the above, it was noted in the experiments that the presence of dispersant changed the spreading behavior of the two crude oils; neither produced a sheen on the water with dispersant concentrations as low as 1 ppm. As well, preliminary qualitative tests showed that, although the presence of Corexit 9527 in Ohmsett water did not appear to affect the oil sorption of a commercial sorbent pad at concentrations of 50 and 100 ppm, it did reduce the hydrophobic character of the sorbent considerably. The sorbent dipped in Ohmsett water containing 50 or 100 ppm of dispersant retained considerably more water than the one dipped in undosed Ohmsett water. Similar visual tests with an aluminum plate indicated that the addition of dispersant to the water at 50 and 100 ppm slightly reduced the amount of oil adhering to the plate.

4.1.4 Summary and Implications of Results

The results clearly indicate that the presence of dispersant in Ohmsett water strongly affects the interfacial tension of the three Ohmsett test oils and the two crude oils tested. Even concentrations as low as a few ppm are enough to cause dramatic effects. This does not necessarily mean that such small concentrations will affect the behavior of slicks during boom and skimmer performance tests, but there is a reasonable possibility of this for the following reason. During boom testing at Ohmsett one of the standard measurements is to note the minimum tow speed at which the slick becomes unstable and small droplets are broken off the main slick and swept under the boom. This first indication of oil entrainment is called “first loss”. It is possible that very small dispersant concentrations in the water, in reducing the interfacial tension between the oil and water, will cause slicks to become unstable and entrained before they normally would. Whether this will indeed happen is simple enough to confirm by tests at Ohmsett itself, but it is difficult to confirm in the laboratory because of scaling problems. Further, even if full-scale tests were to show a negligible effect with low dispersant concentrations, a negative perception could exist with clients of Ohmsett, which would be unacceptable. Therefore it must be assumed that even small concentrations of dispersant in the water are unacceptable for conventional equipment testing at Ohmsett, and that the tank will have to be thoroughly cleaned and cleared of dispersant following a dispersant testing program.

The question remains whether the results of a dispersant effectiveness test in the tank will be affected by low concentrations of dispersant in the tank caused by a previous dispersant test. If this were the case, the tank would have to be cleaned and cleared of dispersant after each experimental run, and this could prove to be expensive and unfeasible. This is discussed next.

4.2 Dispersant Effectiveness Tests

In all standard dispersant effectiveness tests, the procedure involves creating a slick of oil on a contained amount of water, adding dispersant to the oil and then mixing the system in some way to create an oil-in-water dispersion. For the current
requirement this procedure is changed by adding dispersant to the water phase and not to the oil phase. In this way one can assess the extent to which the dispersant in the water from one test at Ohmsett might enhance oil-in-water dispersion in the next.

4.2.1 Test Materials

Fresh Alaska North Slope crude oil and Ohmsett water (after filtering small particles of rust) was used in all tests. The dispersant used was Corexit 9500. The salinity of the water was about 10 ppt, which was lower than expected.

4.2.2 Test Procedure

Tests were performed using the WSL Revolving Flask Test (also called the Labofina Test). This popular test is described in a number of sources (e.g., Nordvik et al. 1993). Briefly, the standard test works as follows. Dispersant in the amount of 0.2 mL is added dropwise to 5 mL of test oil on the surface of 250 mL of sea water in a conical separatory funnel. The funnel is rotated for 2 minutes, stopped and allowed to rest for 1 minute. Then 50 mL of the contents are drained, removed and analysed using a spectrophotometer for oil concentration to yield a dispersant effectiveness value, measured as the amount of oil in the water phase divided by the starting amount oil, expressed as a percentage.

As indicated above, the test was modified in one major way: the dispersant used in the test was added to the water phase and not to the oil phase. The oil was poured on the surface after dispersant was mixed with the water. Two series of tests were performed. The first series again involved a small change to the test in that 100 mL was withdrawn for oil extraction and spectrophotometric analysis and not 50 mL as outlined in the test procedure. This was done to make the test more sensitive to low concentrations of oil in the water phase, in anticipation of the dispersant effectiveness results being low. In the second series the standard 50 mL were withdrawn. Tests were conducted at room temperature, 19.5°C for the first series and 25°C for the second.

4.2.3 Results of Dispersant Effectiveness Tests

The results, shown in Table 1, indicate that there is virtually no difference between the control (natural dispersion with no dispersant) and the dispersant-in-oil cases up to at least 400 ppm. A noticeable effect occurs at 800 ppm where the dispersant effectiveness was measured to be 27.6 percent.

Table 1. Dispersant Effectiveness Using Modified WSL Test

<table>
<thead>
<tr>
<th>Dispersant Concentration</th>
<th>Dispersant Effectiveness, %</th>
<th>First Series (100 mL withdrawn)(^a)</th>
<th>Second Series (50 mL withdrawn)(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control, no dispersant</td>
<td>6</td>
<td>2.7 ± 1.9</td>
<td></td>
</tr>
<tr>
<td>20 ppm in water</td>
<td>2.1</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>80 ppm in water</td>
<td>4.9</td>
<td>5.0 ± 1.1</td>
<td></td>
</tr>
</tbody>
</table>
250 ppm in water | - | 6.0 ± 1.0
400 ppm in water | - | 6.1 ± 0.7
800 ppm in water | 27.6 | -
Dispersant-on-Oil Test | 41.6 | -

a. No replications
b. Three replications; results expressed as average ± one standard deviation

Note that when the same amount of dispersant used in the 800 ppm experiment was used in a standard test (but applied onto the floating oil), the dispersant effectiveness was much higher, namely 41.6 percent. This is not surprising because one of the dispersant surfactants (namely, sodium diiso-octyl sulphosuccinate (Aerosol OT, Alcopol O)) is known to be particularly effective only when added directly to the oil. Finally, it is interesting to note that the dispersant effectiveness values in Table 1 are somewhat lower than the values that would normally be expected with the WSL test using an oil like Alaska North Slope crude and Corexit 9500. The reason is that Corexit 9500 is designed for normal sea salinity situations (in the 30 ppt range). The product is relatively ineffective in fresh water and only moderately effective in brackish waters (the Ohmsett water used in the test had a salinity of only 10 ppt).

4.2.4 Summary and Implications of Results

The results show that dispersant concentrations in the water can reach at least 400 ppm before having a noticeable effect on the results of a standard dispersant effectiveness test. In the 2.6 million gallon tank at Ohmsett, 400 ppm of dispersant represents 1040 gallons of dispersant. If, for example, dispersant experiments at Ohmsett were to involve a drum of oil (55 gallons) each, and a dispersant-to-oil ratio of 1-to-25 is used, the amount of dispersant used in each experiment would be about 2 gallons. This means that hundreds of such experiments could be done consecutively, with increasing dispersant concentrations in the tank, without concern that the dispersant in the tank were having an effect on the dispersant effectiveness results.

The probable reason that no effects were found on dispersant effectiveness at the surface – even with in-water concentrations in the 100 ppm range – is that these concentrations are still orders of magnitude lower than dispersant concentrations at and near the water surface during a dispersant application. When dispersant is applied to an oil slick in a dispersant-to-oil ratio of 1-to-25, the concentration of dispersant in the floating oil is 40,000 ppm. This high concentration would tend to overwhelm any effect that the dispersant in the water might be having.

In summary, there should be no concern of performing a series of dispersant tests with a modest concentration of dispersant in the water. As will be shown later, the main problem is not the high dispersant concentration but the high oil concentration.

5.0 Turbidity/Visibility Study

One advantage of dispersant testing at Ohmsett compared to testing at sea is the ability to use the viewing panels on the tank’s side to observe the underwater plume of dispersed oil as it develops over time. The objective of this component of the study was to determine the likely visibility in the Ohmsett test tank after a
chemical dispersant effectiveness test. Depending on the amount of oil used in each test and the amount dispersed, oil concentrations generated in the tank could be as low as 10 ppm (for 26 gallons dispersed) and as high as 100 ppm for experiments involving 4 or 5 drums of oil. The question is: If the oil were to remain suspended in the tank, how would this affect one’s ability to see the formation of a dispersed oil cloud in subsequent tests?

Two sets of experiments were designed to answer the question. The goal of the first set of tests was to generate a calibration curve to relate the concentration of oil in water to the water turbidity, using a HF Scientific DRT 100B turbidimeter. This is the same device employed routinely at Ohmsett to monitor the tank’s water quality; when the turbidity reaches an unacceptable level the filtration system is put into service to clarify the water. The information generated in this set of tests provides a link between water clarity measured during routine Ohmsett tests and that measured after chemical dispersion tests. The second test was designed to provide an estimate of the distance that an observer could see into the test tank at different dispersed oil concentrations.

Details of the test methods and results for the two tests are available in the original report (SL Ross 2000). Presented here are the summarized results and a discussion of their implications.

The results indicated that underwater oil behavior effects at Ohmsett will only be visible by keeping turbidity to very low levels. If dispersed oil concentration in the tank reaches a value of only a few ppm, it will be impossible to view underwater effects. As discussed in the next section, each dispersant experiment will certainly lead to these concentrations and higher. Therefore, in a series of dispersant experiments, only the first experiment will be visible underwater and be recordable by video or photography. For example, if three experimental runs are done per day and the tank is thoroughly cleaned in preparation for the next runs, then one in three experiments will be visible underwater. This is not ideal, but may be acceptable considering that the qualitative benefits of underwater viewing are much less important than the quantitative aspects of the experiments.

6.0 Scoping Out a Dispersant Testing Program at Ohmsett

6.1 Statement of Problem

The specific purpose of this task was to determine how many dispersant experiments at Ohmsett could be done consecutively before critical dispersant and oil concentrations in the tank are realized. This would indicate how often the tank would have to be treated to remove dispersant products and dispersed oil.

As discussed above, the results of the interfacial tension tests showed that very low concentrations of dispersant in Ohmsett water (as low as 5 ppm) are enough to cause a measurable drop in interfacial tension between floating oil and the water. It is assumed that this would be unacceptable with respect to the testing of booms and skimmers at Ohmsett, and that the tank would have to be thoroughly cleaned of dispersant before such testing.

This need to clear the tank of dispersants does not apply to dispersant testing, however. The results of the WSL dispersant testing program indicates that dispersant effectiveness testing of oils in the Ohmsett facility will likely not be affected until the concentration of dispersant in the water reaches 400 ppm or higher. In this case,
several dispersant tests could be done in sequence without concern that the dispersant in the tank water was having an influence on the effectiveness of dispersant applied to a test slick of oil. The amount of oil that could be spilled to yield 400 ppm of dispersant (at a DOR of 1-to-25) is 26,000 gallons.

This large number seemingly suggests that – aside from the problem of underwater viewing, which will only be possible in the first experiment of a series – many dispersant experiments could be done in sequence at Ohmsett without having to filter oil and dispersant from the water. However, the analysis does not take into account the fact that dispersant effectiveness at Ohmsett will likely be determined primarily by measuring oil concentrations in the water immediately beneath treated, dispersing slicks. The concentrations of interest could be as low as 100 ppm; therefore, background levels of oil in the tank must be significantly lower than the anticipated concentrations of dispersed oil. Clearly, allowing the background concentrations of oil to reach levels approaching this number are not acceptable.

There are two main conclusions that arise from this:

1. It is likely that a series of dispersant tests can proceed at Ohmsett, but without the capability of underwater viewing of all tests. A number of tests could be done in sequence, without concern that the dispersant in the tank were affecting dispersant effectiveness results, but the concentration of oil in the tank could not be allowed to build up to a level that interferes with the quantitative measurement of dispersed oil beneath the treated slicks; and

2. The tank would have to be thoroughly cleaned of dispersant (and oil) before starting a test series involving booms or skimmers.

In summary, the main problem in running a series of dispersant experiments is not the amount of dispersant that will be put into the tank, but the amount of oil. A high concentration of dispersed oil in the tank, say in the 100 ppm range, is likely to be too high a background concentration for measuring dispersed oil concentration in the next dispersant effectiveness test. To determine acceptable background levels, and to understand other important factors, it is useful to scope out how dispersant testing at Ohmsett could be done, as is done next.

6.2 Review of Variables That Could Be Investigated At Ohmsett

There are two clear advantages of doing dispersant testing at Ohmsett rather than at sea: (1) the ability to alter and control variables in a systematic way; and (2) the much lower costs of the testing. These are the same advantages that have justified the activity at Ohmsett in the area of boom and skimmer testing. As with boom or skimmer testing, the main idea with dispersants is to do testing with a view toward predicting product performance in actual spill conditions over a range of conditions. The main variables to consider for dispersant testing include: (1) oil type and weathered state; (2) dispersant type; (3) dispersant-to-oil ratio; (4) application method; (5) slick thickness; and (6) sea state.

The environmental variables of air/sea temperature and salinity are not easily altered at Ohmsett, but could be considered under special circumstances. Each of the variables listed above is considered in turn.

6.2.1 Oil Type and Weathered State

At least two different oil types should be part of the test program. These would
be carefully selected to show the potential differences in dispersant response. There is little point in using the three Ohmsett test oils (Sundex, Calsol and Hydrosol) as these are synthetic blends formulated for use in boom and skimmer testing. Of more relevance to dispersant testing would be one or more crude oils and/or a series of fuel oil blends that meet desired viscosity targets. Should crude oils be used they will need to be weathered prior to use to better reflect real-world conditions and provide a more stable test fluid. The current thinking is that weathering the crude oils in the Ohmsett tank itself will not be a good idea, at least in the beginning.

A second test oil to consider would be a series of IFO-380 residual fuel oils ‘cut-back’ to varying viscosities with heavy gas oil (MDO - Marine Diesel Oil). This would provide a standard set of test fluids that will be relatively easy to obtain and unvarying over time.

6.2.2 Dispersant Type and Dispersant- to-Oil Ratio

At this time the logical dispersant candidates for use at Ohmsett would be Corexit 9527 and Corexit 9500. Until the experimental protocols are fully developed, the usual dispersant-to-oil ratio (DOR) of 1:25 should be used. Later, DORs of 1:50 and 1:100 would be worth looking at. Again, the results of the work would need to be benchmarked against findings from lab studies, past and future.

6.2.3 Application Method

The main advantage of Ohmsett over laboratory systems in terms of dispersant application is that spray systems can be tested at full scale. This does not mean that aircraft need to be used to apply dispersant, but that the spray nozzles and pumps used in the full-scale systems can be used at Ohmsett. This is a major advantage because the drop size distribution of the dispersant spray is likely an important parameter.

6.2.4 Slick Thickness (and Spill Volumes to Consider at Ohmsett)

Slick thickness is a crucial variable. Thicknesses measured at recent field trials in Europe suggest that even small spills will have an emulsion thickness (of the thick portion of the slick) in the order of 1 to 5 mm, much of it due to windrowing. Using the moving bridge, a slick could be laid out that is 1 mm thick, and about 2 metres wide and 50 metres long. This would represent a volume of 0.1 m³ or 26 gallons. If dispersant is applied to this slick and the slick is completely and instantaneously dispersed into the top 1 metre of water, it would produce a dispersed oil concentration of 1000 ppm. Gradually, after some time the oil would mix in the whole tank and produce a maximum concentration of 10 ppm.

The above scenarios suggest that several dispersant tests could be done sequentially. In these the upper metre or so would be sampled in each test yielding concentrations perhaps in the 250 to 1000 ppm range, with background concentrations growing steadily from zero ppm oil to 7.5 to 30 ppm just before the fourth experiment. This signal-to-background ratio of 33.3 (1000/30 or 250/7.5) seems acceptable, but it would be lower in practice because the dispersion process would not be instantaneous (yielding lower initial concentrations in the upper layer of water) and because the dispersed oil would take some time to mix homogeneously to the 7.5 to 30 ppm levels noted above.

Pre-weathering the oil, with evaporation and emulsification, should render it
of high enough viscosity to remain as a coherent carpet if it were laid down from the moving bridge. The oil/emulsion viscosity would have to be in the order of several thousand cP and the bridge should be moving at about 2 knots (1 m/s) for this to happen. The oil/emulsion could be pumped out of a 2 metre long spreader bar (a tube with holes drilled every couple of inches) at a suitable rate to produced the required thickness over the 50-metre length of the experimental slick. In this way 0.5 mm, 1 mm and 2 mm slicks should be possible.

The dispersant should be applied after the discharged oil has had a chance to stabilize on the surface, but before the oil has had a chance to spread out. This could be achieved by mounting a dispersant spray bar (also 2 metres wide) on the same moving bridge. It could be positioned ‘aft’ of the moving bridge if the oil deposition bar is mounted ahead. If it were seen in this set-up that the slick was not stabilized before applying dispersant, the other moveable bridge could be brought into play to apply dispersant after a short delay, or the dispersant pass could wait until the bridge returned quickly to the starting position after the oil deposition run.

6.2.5 Sea State

The relationship between dispersant effectiveness and sea state is very important to understand, and yet, because of a lack of quantitative field data, it is also poorly understood. Because Ohmsett does well in simulating a range of sea state conditions, testing at the facility offers a large advantage over laboratory testing and even testing in the field where the weather and sea states are always an uncertainty.

6.2.6 Temperature and Salinity

Water and air temperatures at Ohmsett are obviously not easily controllable, but testing in the fall and early winter is possible, and the results of such testing can be compared to the results collected during the warmer months.

Salinity is difficult and expensive to control at Ohmsett because once a certain high salinity is achieved it is impossible to reduce the level without discharging a large amount of the salty water into the nearby bay and replacing it with fresh water. Ohmsett operators currently try to maintain a salinity of approximately 17 ppt which is that of the bay water. If dispersant testing at Ohmsett becomes a reality, it will be necessary to increase the salinity of the tank to sea water conditions. This is because the main interest is using dispersants on marine spills at sea where full salinity conditions exist, and the dispersant products of particular interest today are of the salt water type, namely Corexit 9527 and 9500.

6.3 Suggested Dispersant Test Program At Ohmsett

6.3.1 Experimental Variables

From the foregoing description the possible variables are:

(1) test oils: weathered heavy and medium crude oils, and “cut-back” IFO-380 residual fuel oil to resemble IFO-60, IFO-120, IFO-180 and IFO-380;
(2) test dispersants: Corexit 9527 and Corexit 9500;
(3) treatment rates: DORs of 1:25, 1:50, and 1:100;
(4) slick thickness: 2 mm, 1 mm and 0.5 mm;
(5) Simulated sea state: to be decided.
6.3.2 Measurements to Make

Visual observations, recorded on video, would probably be made useless by the turbidity of the dispersed oil in the water, except for the first and possible second experiment in a series. They might make interesting viewing and might be of educational or training value, but would not be of much quantitative use.

The dispersed oil in water concentration should be measured with Turner AU10 fluorometers with the ‘short’ oil filter set. The fluorometers use an excitation frequency of 254 nm and an emission frequency of 360 nm. They are regularly used (when fitted with other filter sets) to monitor water quality and should be available for short-term rental as needed. They would require data loggers. If six fluorometers are available, it is recommended that the submersible pumps, which are used to convey continuously sampled water to the fluorometers, be placed along the tank centerline at 1 and 2 metres depth and two to either side (also at two depths) to monitor the sideways dispersion of the plume.

With suitable filters and calibration these fluorometers could measure from well below 0.5 ppm up to 100 ppm dispersed oil. The readings would need to be calibrated with water samples that are taken and extracted with solvent.

An accurate mass balance will always be difficult. Initially there will be a very low level of dispersed oil due to natural dispersion. When the dispersant is added this will rapidly rise. Eventually, if allowed to, the dispersed oil will be evenly dispersed throughout the entire volume of the water in the tank; 53 gallons will give 20 ppm overall. However, before total mixing is achieved there will be much higher readings in the plume under the slick. It will not always be possible to measure this accurately because the scale of the ‘patchiness’ of oil concentration with distance would require an large number of fluorometers. Accordingly, one of the most important things to be measured would be the ‘average’ rate of increase in oil concentration in the water, with the transient excursions smoothed out.

One should try to use sorbent to collect and measure all of oil remaining on the surface after an experiment (to check or calculate dispersant effectiveness values), but this is known to be difficult to do.

6.3.3 Experimental Approach

The following are ideas on how testing might proceed. Under quiescent conditions and with the use of the moveable bridges, oil is discharged in the center of the tank to form a rectangular shape, 2 m x 50 m. The UVF underwater system takes a background reading of oil concentration in the “test zone” under the slick. The wave generator is started. Dispersion begins and is recorded on a continuous basis by the UVF system. After some time the experiment is stopped. This could be when the remaining slick on the surface reaches the sides of the tank (to avoid wall effects) or it could be when the rate of dispersion has leveled off to some low number, or could be based on some other criteria. In any case, say that this time is in the order of 1 hour.

After the experiment the wave generator is stopped and the dispersed oil is allowed to rise to the surface for a period of time. Say this is 1 or 2 hours. The oil on the surface would be carefully sorbed or skimmed, leaving some dispersed oil in the tank that is relatively low in concentration and inhomogeneously distributed. The wave generator is turned on for a certain amount of time (say ½ hr to 1 hr) to mix the contents of the tank as thoroughly as possible. The wave generator is turned off and
the tank is ready to proceed to the second experiment, this time with a higher background reading in the test zone. The entire experimental cycle takes 2 to 4 hours, depending mostly on the time allowed for the dispersed oil to rise to the surface after the waves are stopped. This would then allow two to four experiments per 8-hr working day.

During the remaining 16 hours of the day, the filter would continue to work removing as much oil and dispersant as possible. At the start of the next working day any surface oil would be skimmed, and then the wave generator (and air bubbler) would be started to mix the tank again as thoroughly as possible before the beginning of the next series of experiments.

This would continue every day until either the background concentration of dispersed oil becomes too high or the series of experiment is over. At this point the tank water would be thoroughly cleaned and filtered in preparation for other test programs.

6.5 Summary of Scoping Analysis
This scoping analysis suggests that a number of dispersant experiments could be run in sequence at Ohmsett before having to filter the body of water to remove dispersed oil. Perhaps two to four experiments could be run in a row involving about 26 to 53 gallons of oil each.

The main issue remains how, and how quickly, one can remove the dispersed oil from the system. This will affect the number of tests that can be accomplished per week, the overall costs of the testing program, and the days needed after the program to start a boom or skimmer program. This crucial issue – the capability of the filter in removing dispersant and dispersed oil – is discussed next.

7.0 Diatomaceous Earth and Cellulose as Filters for Oil and Dispersant
The main purpose of this laboratory study was to evaluate how effective the current filter system at Ohmsett might be in filtering both dispersed oil and dispersant materials. Before discussing the test program, the filter system and procedures at Ohmsett are described.

7.1 Filter Operation at Ohmsett
The filtration system at Ohmsett includes a U.S. Filter Co. Autojet 1000 leaf filter that has 28 five-foot diameter septum disks, commonly called “leaves”. Each leaf is porous and covered with a nylon mesh. When in use the nylon cloth holds a “pre-coat” which can be one of a variety of materials or combinations of materials, but currently the filter aid used at Ohmsett is diatomaceous earth (DE).

The filter operation is a complex batch process, involving eight steps in each filtration cycle (MAR 1997). Briefly stated, a slurry of DE is introduced into the filter prior to each filtration cycle so that a pre-coat layer of DE is deposited. This takes about 15 minutes. Once the filtering process begins, additional filter aid, called body feed, is added to the filter influent. As the DE-charged filter operates and removes contaminants from the Test Basin, water flow is continuously restricted and reduced, and the differential pressure between the filter inlet and outlet continues to increase. When the differential pressure reaches a certain level or when the operation cycle time reaches 24 hours, the operation is stopped, the filter is cleaned and the process
begins again.

7.2 Study Approach

The question here is whether the current filter aid, a particular grade of diatomaceous earth, is capable of removing oil and dispersant. A wide variety of DE grades are commercially available. The coarser grades have greater permeability and solids-handling capability than do the finer grades, but the finer grades will generally produce a cleaner effluent. Some grades of DE are pretreated to improve performance. According to the operations manual for the filter at Ohmsett (MAR 1997), other filter aids are required to sorb finely dispersed oil droplets.

It was recognized at the outset of the study that diatomaceous earth itself might not be adequate to filter fine particles of oil, as suggested in MAR 1997, but this could only be checked by experimentation. This was done, as reported below, and, indeed, the current filter aid proved to be inadequate. So, after some research and discussion with the supplier of filter aids to Ohmsett, a company that supplies a full range of products, another product was found and tested as well. The following is a report on this two-step testing process. For convenience, the test results of both filter aid products are reported together, even though the tests proceeded one after the other.

7.3 Test Materials

The oil used in the tests was fresh Alaska North Slope and the dispersant was Corexit 9500. Three kinds of water were used in the tests: filtered Ohmsett water, salt water with salinity of 10 ppt and distilled water. In terms of filter aids tested, the first task was to evaluate the product currently used at Ohmsett. This is a diatomaceous earth product called Celatom Diatomite FW-60, manufactured by Eagle-Picher Minerals, Inc. The other product selected and tested is a ball-milled cellulose fiber product called Celatom Pre-co-Floc PB-100M, also manufactured by Eagle-Picher. A specifications sheet for the Pre-co-Floc product series is provided in SL Ross 2000.

7.4 Test Apparatus and Choice of Solvents

The analytical instrument used to measure dispersed oil and dispersant in water was a Horiba OCMA-350 non-dispersive infrared oil content analyzer. This instrument measures the absorption of IR light by a sample in the 3.4 to 3.5 $\mu$m wavelength range. This is the wavelength of light absorbed by the C-H bond. In order to measure the oil content of a sample of water, the sample is shaken with a solvent that extracts the hydrocarbons. The solvent used for the extraction and analysis obviously cannot absorb light in the 3.4 to 3.5 $\mu$m wavelength range. Up until a few years ago the solvents of choice were carbon tetrachloride and Freon. The use of these solvents is becoming increasingly restricted because of their ozone-depleting properties. The Horiba OCMA-350 is supplied with a non-banned chlorofluorocarbon solvent, S-316, a polymer of chlorotrifluoroethylene. Although this solvent has the necessary property of having no C-H bonds to absorb IR light in the stated wavelength range, its solvating power with crude oil was found to be less than desirable and it is also very expensive. In any case, this is the solvent that was used to assess the effectiveness of the diatomaceous earth filter aid.

After the tests with DE, it was decided to research alternative solvents. A suitable substitute was found in IR-spectroscopy grade perchlorethylene (also known
as tetrachloroethylene). Perchlorethylene has a much better solvating power with crude oil and is much less expensive. It was this solvent that was used to evaluate for the test series with cellulose as the filter aid.

7.5 Test Procedure

The tests conducted in this phase were intended to simulate the operation of the Ohmsett leaf filter, but the loadings of filter aid (both the pre-coat and the body-coat) used were higher than those that are used at Ohmsett. The purpose of this was to ensure that any beneficial effects of the filter aids would be easily detected. The tests involved filtering samples of water contaminated with about 50 mg/L of either Alaska North Slope (ANS) crude oil, Corexit 9500 or ANS crude oil pre-mixed with 1:20 Corexit 9500. All sample were vigorously shaken with a wrist-action shaker to ensure good dispersion of the contaminant into the water prior to extraction and/or filtering.

The filter used was a ceramic-type Buchner funnel fitted with medium-to-fine Fisher brand P8 filter paper (5.5 cm diameter) and placed on a 1-L glass Kimax filter flask. Vacuum was provided by a water-tap aspirator. Prior to a filter test, a “pre-coat” of filter aid was placed on the filter paper. This involved mixing a slurry of 12 g of Diatomite (or 6 g of Pre-co-Floc) in 200 mL of tap water and filtering the slurry (as a comparison, this is about four-times as much pre-coat as would be normally used on the Ohmsett leaf filter). For a test, 12 g of Diatomite (or 6 g of Pre-co-Floc) was mixed with the contaminated water and filtered (this is about a 50-times greater concentration of filter aid in the body-coat slurry than would be used with the Ohmsett leaf filter).

7.6 Results of Filter Tests

Figure 2 shows the results obtained with the tests involving the diatomaceous earth filter aid, Diatomite FW-20. It is clear that the diatomaceous earth does not remove much Corexit 9500 dissolved in water. Also, it appears that the product only removes about 50% of dispersed oil from water. The figure shows the poor solvating power of the S-316 solvent with crude oil - each of the three ANS-contaminated samples was prepared with a concentration of 50 mg/L. These results led to the conclusion that the diatomaceous earth was not a suitable filter aid for dispersed oil or dissolved dispersant.

Figure 3 shows the much better results obtained with the cellulose filter aid, Pre-co-Floc PB-100. These tests were conducted with distilled water to reduce the problems found in the first test series when extracting salty water with the S-316 solvent. The Pre-co-Floc PB-100M was able to remove virtually all of the dispersed ANS (either crude oil alone or crude oil pre-mixed with 1:20 dispersant). For the oil-in-water samples that were filtered twice (through the same filter cake), additional oil removal was detected in each case.

Although the results with dissolved dispersant were not as spectacular, there is an indication that the cellulose product can remove 50 to 66% of the Corexit 9500 from water as well. As with the S-316 it is noted that the perchlorethylene solvent could not extract all of the dispersant from the water samples - the readings of about 15 mg/L of 9500 on Figure 13 result from extracting 50 mg/L samples. Thus, the readings of approximately 7 mg/L for the filtered water represent something like 23 mg/L (7 x 50 / 15) remaining in the water.
The dispersant removal results are somewhat supported by a series of surface tension measurements made of filtered water. These were:

Surface tension reading for distilled water = 73.6 dynes/cm
Surface tension reading for distilled water containing 50 mg/L of Corexit 9500 = 55.2 dynes/cm
Surface tension reading for filtered water = 61.3 dynes/cm
Figure 2. Removal of Oil, Oil/Dispersant Mix and Dispersant from Water by Celatom Diatomite FW-60

Figure 3. Removal of Oil, Oil/Dispersant Mix and Dispersant from Water by Celatom Pre-Co-Floc Pb-100m
7.7 Additional Bench-Scale Tests at Ohmsett

At this point of the study it was not possible to state definitively that the cellulose would be effective in removing dispersed oil or dissolved dispersant from Ohmsett tank water. Follow-up work was necessary, and was carried out in the lab at Ohmsett. This work had the purpose of determining the best grade and loading of cellulose filter aid. The test plan and results can be found in SL Ross 2000. The conclusions from the tests are summarized below.

(1) The tests conducted in Ottawa were repeated at the Ohmsett lab with two grades of cellulose filter aid (PB-100M and PB-200M) recommended as suitable by the manufacturer. The results indicated no significant difference in performance between the two in removing dispersed oil from Ohmsett tank water. PB-100M was selected for use in the full-scale tests described in the next section because there was more laboratory data on its performance.

(2) Tests with different thicknesses of cellulose on the filter paper indicated that a loading on the Ohmsett leaf filter of 15 to 30 lb/100 ft² would be appropriate for the full-scale tests.

(3) Several one-hour tests with larger batches of Ohmsett water filtered through a thickness of cellulose filter aid equivalent to a loading of 30 lb/100 ft² indicated that it would continue to remove dispersed oil droplets over this time frame without significant decline in removal efficiency. Measurements of the surface tension of the filtered water to determine whether or not the cellulose removed dissolved dispersant were not conclusive, but indicated that the filter aid was not an effective removal agent for the dissolved surfactants over the one-hour time span.

8.0 Full-Scale Verification Testing at Ohmsett

The goal of this final task in the study was to verify the findings of the lab-scale work by running a series of tests using the Ohmsett filtering system at full scale. Based on the lab-scale testing described in the previous section, it was decided to perform the full-scale tests using cellulose rather than DE as the filter aid, and that a pre-coat of 15 lb/100 ft² would be used.

8.1 Methodology of Full-scale Tests

8.1.1 Test Set-up

In designing the verification tests, it was desirable to operate the filter system at as close to typical design conditions as possible. This meant that, for a one-hour test and a design flow rate of 1800 gpm, as much as 108,000 gallons of water would be passed through the system. This could have been achieved by simply running the filter system in its normal mode of operation and injecting chemically-dispersed oil to the influent upstream of the filter. However, there was uncertainty over whether the filter could remove the dissolved dispersant, and operating the filter system in this manner could lead to a measurable concentration of dispersant in the water in the Ohmsett test tank. Using portable tankage for the required volume of test fluid – influent and effluent – did not seem to be a reasonable solution given that the planned series of tests would require up to 1,000,000 gallons of contaminated fluid. Therefore, the full-scale tests were designed to be carried out with the filter system in a closed loop, comprising the filter and pump, and the piping and fittings connecting the two.
Chemically dispersed oil to contaminate the influent water was prepared by first mixing dispersant into a volume of crude oil. For all tests, a dispersant-to-oil ratio of 1:20 was used. A measured amount of this doped oil was then poured into a tank containing a pre-determined volume of clean Ohmsett water. While the oil/dispersant mixture was being added and throughout the test, the tank contents were vigorously mixed with a bladed electric mixer to create and maintain small oil droplets in suspension. During each test, a slurry of this dispersed oil was pumped from the tank into the recirculating water in the closed loop.

Influent samples were taken just upstream of the leaf filter to determine the actual oil-in-water concentration entering the filter. As the influent samples were taken, an effluent sample was also taken from an existing tap in the line just downstream of the filter.

For each test, the water in the test loop was disposed of and replaced with fresh water from the Ohmsett test basin. Salinity in the Ohmsett test basin was measured to be approximately 15 ppt. There are plans to increase the tank salinity to 35 ppt to better represent offshore conditions. Therefore, at the start of each test, salt was added to the water in the test loop to increase the salinity to approximately 35 ppt.

8.1.2 Test Materials
The oil used in the tests was fresh Alaska North Slope and the dispersant was Corexit 9500. Based on the results of the lab-scale tests, the filter aid selected for use in these full-scale tests was Celatom Pre-co-Floc PB-100M. A specifications sheet for the Pre-co-Floc product series is provided in SL Ross 2000.

8.1.3 Test Variables
Based on the suggested dispersant tests and limiting background concentrations of dispersed oil, the main influent concentration of interest is on the order of 50 mg/L. Additional runs were done at half and double this concentration to determine the range of effectiveness.

Although it was planned to use a flow rate at or close to the design flow rate of 1800 gpm throughout the tests, due to the air infiltration problems that were experienced during the dry-run testing of the closed loop it was decided to use a lesser flow rate of 1500 gpm.

The majority of the tests were run with a precoat of 15 lbs / 100 ft², with several tests run with a precoat of 30 lbs / 100 ft².

8.1.4 Sampling and Analysis
The concentration of oil in the water samples was determined using solvent extraction/IR. The concentration of dissolved dispersant in the effluent samples was determined using surface tension measurements. Influent and effluent samples were drawn at five and 10 minutes into each test, and every 10 minutes thereafter.

8.2 Results
Of primary concern in these tests was determining the ability of the Ohmsett filter system to remove dispersed oil from the water. If the filter were effective it would be possible to reduce the oil concentrations in the tank to acceptable levels and
thus be able to carry out a series of dispersant tests over a period of a week or more.

The entire results, with figures showing the influent and effluent oil concentrations for the eight tests are presented in SL Ross 2000. Table 2 is a summary of the average removal efficiencies for each test. As seen there is no significant difference in the results for the three tests which covered “standard” conditions of 30 mg/L influent and 15 lbs / 100 ft² precoat (test #7), the case of the same influent with double the precoat (#6), and the case of double the influent concentration and double the precoat.

Table 2. Summary of results - removal of dispersed oil

<table>
<thead>
<tr>
<th>Test #</th>
<th>Precoat, lbs / 100 ft²</th>
<th>Avg. influent conc., mg/L</th>
<th>Avg. effluent conc., mg/L</th>
<th>Removal Efficiency, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closed-loop tests</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>15</td>
<td>105</td>
<td>44</td>
<td>58</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>33</td>
<td>13</td>
<td>61</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>44</td>
<td>20</td>
<td>54</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>4.5</td>
<td>2.9</td>
<td>35</td>
</tr>
<tr>
<td>5</td>
<td>30</td>
<td>47</td>
<td>22</td>
<td>53</td>
</tr>
<tr>
<td>average</td>
<td></td>
<td></td>
<td></td>
<td>52</td>
</tr>
<tr>
<td>On-stream tests</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>30</td>
<td>28</td>
<td>4.3</td>
<td>85</td>
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<td>7</td>
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<tr>
<td>average</td>
<td></td>
<td></td>
<td></td>
<td>81</td>
</tr>
</tbody>
</table>

A second concern in these tests was whether or not the cellulose would effectively remove dispersant from the influent water. The lab-scale results were ambiguous, but it was suspected that there would be a limited effectiveness if any. This was confirmed in the full-scale testing.

8.3 Conclusions

(1) A leak in the closed loop allowed air to enter the system during the first five tests, reducing the effectiveness of the filter. This was a problem related solely to running the system in a closed loop and should not present a problem in actual running of the filter system in its normal mode of operation. In fact, in subsequent tests with the filter “on-stream” in its normal operating mode, no such problem occurred.

(2) Using cellulose as the filter aid as opposed to diatomaceous earth
presented no particular difficulties in handling, slurry preparation, or in the pre-coating procedure.

(3) Cellulose appears to be effective in removing dispersed oil from the Ohmsett tank water. In the on-stream tests, an average of 81% of the dispersed oil was removed from an influent stream that had an oil-in-water concentration ranging from 23 to 87 mg/L.

(4) Cellulose does not appear to be effective in removing dispersant from the water. Measurements of the surface tension of the effluent water indicate dispersant concentrations of at least 1 to 2 mg/L, which corresponds to the influent concentration of dispersant calculated by a mass balance. This will not limit the ability to carry out a series of dispersant tests, but following those tests, treatment of the tank water will be required prior to containment boom or skimmer testing.

9.0 Bench-Scale Testing of Activated Carbon

A small series of tests with activated carbon was performed to determine its efficacy to remove dispersant. The work was done in the Ohmsett lab following the procedure outlined in ASTM D 3860-98. In this test, samples containing a known concentration of dispersant are prepared, various measured amounts of pulverized activated carbon are added to the samples, and after a contact period of two hours, the mixture is filtered through a specified membrane filter. The results are reported as the amount of contaminant adsorbed per unit weight of the carbon.

The results, shown in Table 3, clearly indicate that activated carbon will remove dispersant from Ohmsett tank water. Comparing the influent to effluent concentrations of dispersant it is seen that 90 to 100% of the Corexit is removed. Further testing is required with lower volumes of activated carbon to determine the optimum volume of carbon, and to allow a determination of the amount required for filtering Ohmsett water over a range of dispersant concentrations.

<table>
<thead>
<tr>
<th>Corexit conc., mg/L</th>
<th>Carbon weight, g</th>
<th>Surface tension, dynes/cm</th>
<th>Corexit remaining, mg/L</th>
<th>Corexit adsorbed per unit carbon, mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>pre-filter</td>
<td>post-filter</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.01</td>
<td>48</td>
<td>70.7</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
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</tr>
<tr>
<td>20</td>
<td>0.02</td>
<td>40</td>
<td>73.3</td>
<td>0</td>
</tr>
</tbody>
</table>
10.0 Conclusions

(1) Dispersant testing at Ohmsett offers two distinct advantages over testing at sea: (1) the ability to alter and control variables in a systematic way; and (2) the much lower costs of testing. These are the same advantages that have justified the activity at Ohmsett in the area of boom and skimmer testing.

(2) Laboratory tests indicate that the presence of dispersant in Ohmsett water following dispersant tests will strongly affect the interfacial tension of oils used in subsequent boom or skimmer tests. Even concentrations as low as a few ppm may be enough to cause dramatic effects. Therefore it must be assumed that even small concentrations of dispersant in the water are unacceptable for conventional equipment testing at Ohmsett, and that the tank will have be thoroughly cleaned of dispersant following a dispersant testing program.

(3) The results of dispersant effectiveness testing, with dispersant added to the water rather than to the oil, show that dispersant concentrations in the water can reach at least 400 ppm before having a noticeable effect on the dispersion of floating oil. This means that many dispersant experiments could be done consecutively, with increasing dispersant concentrations in the tank, without concern that the dispersant in the tank were having an effect on the dispersant effectiveness results.

(4) Turbidity studies and analysis indicate that underwater oil behavior effects from dispersant testing at Ohmsett will only be visible by keeping turbidity to very low levels. If dispersed oil concentration in the tank reaches a value of only a few ppm, it will be impossible to view underwater effects. Because each dispersant experiment will certainly lead to these concentrations and higher, only the first experiment in a series of dispersant experiments will be visible underwater and be recordable by video or photography.

(5) An analysis scoping out the experimental possibilities of testing dispersants at Ohmsett suggests that a number of dispersant experiments could be run in sequence at Ohmsett before having to filter the body of water to remove dispersed oil. Perhaps two to four experiments could be run in a row involving about 100 L to 200 L of oil each.

(6) A series of bench-scale tests followed by a full-scale test using the existing filter system at Ohmsett showed that it is possible to remove dispersed oil from Ohmsett tank water. An average of 81% of the dispersed oil was removed using cellulose as the filter aid.

(7) It was found that cellulose was not effective in removing dissolved dispersant from the water. A preliminary series of bench-scale tests were performed and these indicate that activated carbon will remove dissolved dispersant with a high degree of effectiveness. Further testing with activated carbon will be required to determine the amounts of material required for a range of dispersant concentrations and tank-water volumes.

(8) Overall, the study concludes that there are several restraints to dispersant testing at Ohmsett, but that such testing could be done with good success if the testing program is carefully designed and implemented with due regard for the limitations
noted above.

11.0 Epilogue
On the basis of the promising results of this work, funds have been provided to move the project to the next stage, namely the design and validation of an experimental protocol for dispersant effectiveness testing at Ohmsett. Full-scale tank work is planned for April 2000.

12.0 Acknowledgements
The work was funded by MAR, Inc., operator of the Ohmsett facility on behalf of the U.S. Minerals Management Service (MMS). We acknowledge the support of MAR technical staff during all phases of the work especially the work done at the facility itself. We also acknowledge the advice and support provided by Mr. James Lane, who was the MMS scientific authority for the project. We especially wish to thank Mr. Alun Lewis who volunteered much time to the project, mostly to provide preliminary design ideas on dispersant testing at Ohmsett. At the time of writing Mr. Lewis and the authors are working on the next phase of the project.

12.0 References

