

## **Studies on Decanting Recovered Oil Spill Fluids**

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### **ABSTRACT**

Skimmers operating in waves often recover a large amount of water, both in the form of emulsions and free water. Recovered water dramatically reduces the temporary storage capacity available for oily fluids offshore. This paper<sup>1</sup> describes an ongoing, multi-year program to research decanting of water from recovered oil spill fluids.

The first series of tests studied the rate and amount of free water separation that can be expected in simple temporary storage containers. The results indicated that “primary break” occurred within a few minutes to one hour, depending on the physical characteristics of the oil. Rapidly decanting this free water layer produced immediate increases of 200 to 300% in available storage. Initial oil concentrations in the decanted water also depended on the physical properties of the oil; they ranged from 100 to 3000 mg/L. These declined by a factor of approximately 3 after one hour of settling, and by a factor of approximately 5 after one day.

The second series of tests was undertaken to better understand the effects of emulsion breakers injected into a recovery system. The experiments addressed the injection/mixing/settling regimes required for optimum water-removal from an emulsion using demulsifier. The ability of demulsifier addition to reduce pumping heads and the effects on the oil content of decanted

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<sup>1</sup> This paper has been reviewed by the U.S. Minerals Management Service staff for technical adequacy. The opinions, conclusions, and recommendations contained in this paper are those of the authors and do not necessarily reflect the views and policies of the U.S. Minerals Management Service. The mention of a trade name or any commercial product in this report does not constitute an endorsement or recommendation for use by the U.S. Minerals Management Service. Some of the research described in this report was also supported by the Alaska Department of Environmental Conservation. The findings and conclusions presented by the authors are their own and do not necessarily reflect the views or position of the Department.

water were also assessed. Various injection locations and mixing technologies were investigated. The use of a demulsifier, combined with decanting, substantially reduced the volume of water in storage.

A third series of tests was recently completed to research the partitioning of the surfactant between the oil and water phases in demulsifier-treated fluids in order to determine potential problems that may be associated with discharging the separated water into the ocean. Preliminary indications are that the separated water will contain a large percentage of the demulsifier at concentrations in the hundreds of parts per million, or greater.

## **INTRODUCTION**

The preferred approach to cleaning up an oil spill is to contain and thicken the oil slick(s) with booms and then place skimmers in the oil or emulsion to recover it. The recovered fluids are placed in temporary storage containers for transfer to larger storage vessels or for direct input into the waste recycling and disposal system. Offshore skimmers often recover a large amount of water, both in the form of water contained in emulsified oil and free water. In some cases, the transfer pump built into the skimming system can impart enough energy to cause additional emulsification of the recovered fluids. The problem is that the recovered water (both emulsified and free) dramatically reduces the temporary storage space available at the site of skimming operations. This can result in having to stop skimming prematurely when the storage capacity is reached and having to wait until empty temporary storage containers arrive at the response site. The treatment and separation of recovered water onsite is the largest area of neglected technology in mechanical response today (Schulze et al. 1995).

In the relatively low-energy environment within a temporary storage device, the recovered fluids will begin to separate into layers of oil, emulsion and water. Periodically discharging the separated water back into the containment boom can considerably extend the available storage space and increase the effective use of available resources to remove oil from the water surface.

There is an optimum time at which the separated water should be discharged, or decanted, from the temporary storage device. This optimum time maximizes the amount of water that can be removed from the container, minimizes the oil content of the discharged water, and minimizes the time that the storage is "out of service". The decision when to decant may also depend on whether or not sensitive resources could be affected by the dispersed oil or dissolved demulsifier concentrations in the discharged water.

The first test series (involving lab-scale tests in flasks in 1997 and large-scale tests at Ohmsett in 1998) investigated the decanting of mixtures of recovered oil and water and gave some quantitative insight into the oil/water separation processes occurring in simple temporary storage devices (SL Ross 1999). The objective of those tests was to determine the optimum time to decant the water and maximize the available on-site storage space during a skimming operation.

That many skimmer operations are, sooner or later, faced with recovering a water-in-oil emulsion was addressed in the second test series. These emulsions can easily contain 70 to 80% water that is tightly held and may not separate out, even after standing for days or months. This emulsion will quickly fill the available temporary storage space, even after decanting the free water layer, with a product that contains mostly water. The available temporary storage space could be further extended by using chemical emulsion breakers (also called demulsifiers) to cause the water-in-oil emulsion to break into oil and water phases, followed by decanting of the water separated from the emulsion.

Although some skimmer systems (notably the Framo Transrec 350) incorporate demulsifier delivery systems, the dynamics of the separation process are not well understood. Literature reviews of the demulsification of oil spill emulsions are presented by Payne and Phillips (1985) and SL Ross et al. (1992). Preliminary research into the process performed in the early-1990s (SL Ross 1991 and 1992, Strom-Kristiansen et al. 1993a and 1993b, Lewis et al. 1995a and 1995b) gives some guidance on the concentrations of demulsifier required for rapid breaking and the importance of mixing energy to the process; however, these preliminary studies were not pursued further. Readers interested in further details of past work on demulsifiers are encouraged to read the literature review in SL Ross 2002.

The second group of experiments, in both the lab using a scale-model piping network simulating an offshore recovery and transfer system, and again at Ohmsett, was designed to assess the effectiveness of an oil spill emulsion breaker on water-in-oil emulsions and the injection/mixing/settling regimes required for optimum water-removal performance. The ability of emulsion breaker addition to reduce pumping heads and the effects of demulsifier addition on the oil content of decanted water were also assessed. Various injection locations (skimmer head, discharge hose, tank inlet, etc.) and mixing technologies (static in-line, impeller, etc.) were investigated.

The third (and ongoing) set of tests was designed to study the partitioning of the active ingredient in demulsifiers between the oil and water phases in recovered fluids. Four different demulsifiers were tested on different emulsions using both the bench-scale piping model and large-scale tests at Ohmsett. These tests were designed to measure the concentration of demulsifier in decanted water as a function of several operational variables.

## **1998 DECANTING TESTS AT OHMSETT**

Following an extensive series of tests in glass flasks in 1997 (SL Ross 1998), a series of tests was conducted at Ohmsett in November 1998 to investigate the decanting of oil/water mixtures recovered by weir skimmers (SL Ross 1999). The following parameters were varied during the tests:

- i) Two circular weir skimmers:
  - Desmi Terminator - nominal Oil Recovery Rate (ORR) in waves of 20 m<sup>3</sup>/hr (90 US gpm)
  - Pharos GT-185 - nominal ORR in waves of 10 m<sup>3</sup>/hr (45 US gpm)

- ii) Two slick thicknesses:
  - 20 mm and 100 mm (representing the thickness expected in a single vessel sweep system and a large, multi-vessel offshore boom system respectively)
- iii) Three oil types:
  - Hydrocal, Calsol and Sundex (with viscosities of 1100, 13,000 and 300,000 mm<sup>2</sup>/s [cSt] respectively at the test temperature)
- iv) Two wave conditions
  - Wave #1 (15 cm x 11.3 m with a period of 2.8 s) and wave #2 (15 cm x 4.6 m with a period of 1.7 s)

## Methods

A 15-m (50-ft.) section of 24-in. conventional containment boom was deployed in a square at the north end of the Ohmsett basin, between the main and auxiliary bridges (Fig. 1). Two recovery devices were deployed in the boomed area: a GT-185 skimmer and a Desmi Terminator skimmer (Fig. 2). Only one skimmer was operated for a given test.

The skimmer discharge was directed to the eight oil recovery tank cells located on the auxiliary bridge (Fig. 3). The separated water from the oil recovery tanks was either dumped back into the Ohmsett test basin, or directed to a temporary holding tank for water sampling. The time when the filling of each tank cell was started and finished was recorded. The depth of fluid in each cell was measured and recorded. Simultaneously with the filling operation, two minutes after tank cell #7 was filled, the separated water was decanted until the discharge from the bottom visibly contained oil. The remaining oil recovery tank cells were decanted in sequence at 5, 10, 15, 30, 45, and 60 minutes after the time they each reached full.

For selected cells in each test, the decanted water was directed to a temporary holding tank on the deck beside the auxiliary bridge (Fig. 4). When all water from a selected cell was transferred, the contents of the temporary holding tank were thoroughly mixed with a bladed impeller and allowed to settle for five minutes to allow large droplets of oil, from the end of the decanting process, to surface. The surface oil was removed with a sorbent pad and then the temporary holding tank was drained. A small water sample, for oil content analysis, was taken when half the water had been drained. The purpose of this was to estimate the average concentration of "permanently dispersed" oil in the decanted water - i.e., the droplets that would not rise out and re-coalesce with the slick if the decanted water was discharged back into a boomed area. During three of these tests (one for each of the three test oils) duplicate samples of the decanted water were placed in vertical columns for 24 hours (Fig. 5) and then drained. The water from the bottom, middle and top of the columns was sampled and was analysed for oil content.

The depth of oily fluid remaining in each cell was measured (these depths, combined with the initial depths, were used to calculate the volumes of recovered product, decanted water and oil remaining). The idea was to determine the time required for "primary break" of the skimmer discharge product. "Primary break" is the point at which the bulk of the lower density phase has

risen to the top and most of the higher density phase has settled to the bottom; both phases typically contain small droplets of the other phase at this point. At primary break, the interface between the two phases may not yet be distinct. Each oil recovery tank cell was mixed and sampled to determine the water content of the fluid remaining. The various samples collected were analysed using standard Ohmsett procedures for water content of oil (ASTM D1796), oil concentration in water (EPA 413.1), density (ASTM D1298), interfacial tension and surface tension (ASTM D971), and kinematic viscosity (ASTM D2983).

### **Summary of Results**

Complete details of the test results may be found in the project report (SL Ross 1999) which may be obtained using the MMS web site [www.mms.gov/tarprojects/](http://www.mms.gov/tarprojects/).

Fig. 6 shows typical water separation results for one of the test oils used (20 mm thick Calsol slicks). The four graphs show the results obtained with the GT-185 skimmer in wave No. 2 (Test 2) and wave No. 1 (Test 3), and with the Desmi skimmer in wave No. 2 (Test 4) and wave No. 1 (Test 5). Each plot shows:

- Percent Decanted -  $[\text{volume of water decanted}/\text{volume of fluid recovered}] \times 100\%$ ;
- Decanted Water Volume; and,
- Water Volume Remaining -  $[\text{volume of fluid recovered} - \text{volume of water decanted}] \times \text{water content of remaining fluid}$ .

plotted against elapsed time from when the tank cell was filled to when it was decanted.

All the plots clearly show that most of the water can be decanted from the recovered fluid with a delay of only 30 minutes or so. Skimmer type and wave period did not seem to greatly affect the decanting. For the thin slicks of the less-viscous oils the separation of the water from the recovered fluid was essentially complete in 15 to 30 minutes. Up to 60 minutes was required for primary break with the thicker, more-viscous slicks.

For the thin slicks, the trend appeared to be faster separation with increasing oil viscosity. This was probably because the recovered product consisted of oil droplets entrained in a continuous water phase. The more viscous the oil the larger the oil droplets in the water; larger oil droplets rise faster than smaller ones.

For the thick slicks, the situation appeared to be different. With these slicks, the skimmers recovered much less water, and it is likely that the recovered fluid stream consisted of water droplets suspended in a continuous oil phase. In this case oil viscosity controlled the settling rate: higher oil viscosities meant longer settling times. With the highest viscosity oil, the water was semi-permanently emulsified in the oil and did not settle appreciably over the 60-minute test.

Doubling the volume of fluid placed in the tank cell [equivalent to doubling the height of the fluid in the tank cell] had no discernible effect on decanting times or the final percent water decanted. Agitating the receiving tank with wave action also had no discernible effect on water separation rate or amount.

Fig. 7 illustrates typical oil-in-water concentration data obtained from analysing the decanted water samples. The highest concentrations of oil in the decanted water occurred when skimming Calsol slicks. Initial concentrations were in the 1400 to 3000 mg/L range. These declined to 400 to 1000 mg/L after one hour of settling. The lowest concentrations of oil in the decanted water were for the Sundex oil. In these tests, the concentrations were initially in the 100 to 450 mg/L range, declining to about 50 to 150 mg/L after 60 minutes of settling. When skimming Hydrocal the concentrations of oil in the decanted water were initially about 1000 mg/L. These declined to approximately 200 mg/L after one hour. Allowing 24 hours settling further reduced oil concentrations in the decanted water to 30 to 70 mg/L for Calsol, 2 to 20 mg/L for Sundex and 30 to 100 mg/L for the Hydrocal test series. Doubling the volume of fluid recovered in each cell did not appreciably affect the oil-in-water concentrations.

### **2001 DECANTING TESTS WITH EMULSION BREAKER ADDITION**

In July 2001, a second series of tests was carried out to investigate the use of emulsion breakers injected into an oil spill recovery system at both lab-scale (at SL Ross) and mid-scale (at Ohmsett). The experiments were designed to assess the injection/mixing/settling regimes required for optimum water-removal performance from a meso-stable water-in-oil emulsion with an oil spill demulsifier. Various injection locations (skimmer head, discharge hose, tank inlet, etc.) and mixing technologies (static in-line, mechanical, etc.) were investigated.

The scaled laboratory tests involved pumping water-in-oil emulsion and free water through a scale-model piping loop consisting of ½-inch copper and plastic tubing of various lengths, an in-line mixer and eight settling tanks (Fig. 8). Three different types of pumps were used. Demulsifier was injected at various locations, and the fluid was decanted and measured to determine the efficiency of emulsion breaking achieved. These tests are not discussed in this paper. They may be found in SL Ross 2002 that can be obtained using the MMS web site [www.mms.gov/tarprojects/](http://www.mms.gov/tarprojects/).

At Ohmsett, a Desmi Terminator skimmer was used to recover the same emulsion as used in the laboratory tests, from the water surface, using different slick thicknesses, two wave heights and different recovery rates (to vary the turbulence in the recovery system). A static in-line mixer was used for some tests, and in others a bladed impeller was used to add extra mixing energy to the recovered fluids. Demulsifier was injected into the recovered fluid at various locations. The recovered fluid was allowed to separate in the recovery tanks and measured to determine the demulsifier efficiency.

### **Methods**

At the beginning of the Ohmsett tests, and subsequently as required, large batches of emulsion were prepared. A gear pump was used to prepare the emulsion, since large quantities of a consistent quality were required on a daily basis. The procedures are detailed in the report (SL Ross 2002). Based on a series of emulsion formation and stability tests and experience gained from the laboratory tests 2.5% Bunker C was added to the Hydrocal oil in order to create a

suitable parent oil for the preparation of a meso-stable water-in-oil emulsion. The function of the Bunker C was to provide asphaltenes to stabilize the small water droplets in suspension in the oil. A sample of the first batch of emulsion prepared was allowed to sit for 24 hours, and showed no signs of breaking. The target properties of the emulsion were: 50% (vol.) water content with a viscosity of approximately 1000 cP at a shear rate of  $1 \text{ s}^{-1}$  at 21°C. A 50% water content was chosen because it could be prepared reasonably quickly using the gear pump technique with little risk of inverting the emulsion, as can occur with higher water contents.

The same test setup and procedures used in the 1998 tests were employed for the 2001 tests, with some additions to accommodate the emulsion breaker. Pressure transducers were also installed, located at either end of a 13-m (42.5-foot) section of the skimmer discharge hose to measure pressure drop. For some tests, the skimmer discharge was directed through a Lightnin Series 45 Model 4 Type 12H in-line mixer. The separated water from the oil recovery tanks was directed to a temporary holding tank for water sampling, and then sent to a holding tank for eventual treatment and disposal to the sanitary sewer. This was to avoid adding dissolved emulsion breaker to the 10,000 m<sup>3</sup> of Ohmsett tank water, which may have negatively affected subsequent test programs.

Demulsifier (Alcolpol O 70% PG, aka Drimax 1235B a solution of sodium diisooctyl sulfosuccinate in propylene glycol/water) was injected using a fixed-rate (1 L/min = 0.25 US gpm) peristaltic pump into the recovered fluid in one of two locations: directly into the skimmer weir or into the discharge hose just before the wye upstream of the inline mixer (Fig. 9). As with the 1998 tests, for some runs the decanted water was sent to a sampling tank, where it was mixed thoroughly, and sampled for oil content analysis. As well, this tank and mixer was used to thoroughly mix the entire contents of some recovery tank cells, to assess the effects of additional mixing energy on emulsion breaking.

### **Summary of Results**

The efficiency of emulsion breaking chemicals in resolving water-in-oil emulsions is highly parent oil/surfactant specific and can be strongly affected by the dosage of the demulsifier and the weathering processes that an emulsified oil has undergone. The tests conducted for this part of the study investigated the effects of mixing energy and other physical parameters on the efficacy of one emulsion breaker with one water-in-oil emulsion specifically “engineered” for the project. The conclusions drawn below are only strictly valid for this combination of demulsifier and emulsion. The tests showed that use of a demulsifier injected into a recovery system, combined with decanting, can substantially reduce the volume of water in temporary storage tanks and the water content of emulsions for disposal/recycling. Table 1 is a summary of the results from these Ohmsett tests.

The efficacy of the demulsifier was a strong function of free water content, between an upper and a lower limit. In these tests, if the free water content exceeded about 60%, the effect of the surfactant was substantially reduced. If no free water was present, the level of turbulence generated by the flow was insufficient to promote emulsion breaking. Free water contents of

greater than about 33% was required to reduce the bulk viscosity of the fluid to the point where the flow regime was turbulent, and mixing energy was supplied to promote emulsion breaking. It is possible that this phenomenon is demulsifier-specific and would not be observed with a different demulsifier. It is also possible that this phenomenon is related to the solvent used in the demulsifier, and use of a different solvent would yield different results.

The degree of emulsion breaking achieved increased with increasing mixing energy applied to the fluid. Increasing the flow rate (and hence turbulence level) and increasing the length of the flow path both resulted in increased emulsion breaking. The use of in-line mixers further increased the removal of emulsion water. The application of mechanical mixing energy, using a bladed impeller, after placing the recovered fluid in a tank, also increased demulsification. The best location for injection of the demulsifier was at the skimmer pump for recovered fluids containing up to 50% free water to maximize the amount and time of the mixing applied. For recovered fluids containing more than 60% free water, decanting the free water followed by the application of mechanical energy worked best.

Primary break occurred in only a few minutes (2 to 5 in the lab tests, less than 15 for the Ohmsett tests). The application of demulsifier did not appear to affect this.

The Ohmsett results indicated that the use of a demulsifier increased oil-in-water concentrations by approximately a factor of two in the decanted water (Fig. 10). Although it is not known what portion of each oil-in-water reading was associated with dissolved demulsifier in the water, the decanted water did contain a significant amount, as evidenced by its tendency to foam when agitated.

As long as the recovered fluid contained at least 33% free water, the pressure drops due to skin friction in the tubing and hoses approximated those expected for flowing water. The use of an in-line mixer significantly increased backpressures.

### **2003 Tests to Study the Partitioning of the Demulsifier**

Demulsifiers are surface-active, or surfactant, chemicals that can be added to ‘break’ or ‘resolve’ the emulsion back into separate oil and water phases. Demulsifiers function by destabilizing or disrupting the film of precipitated asphaltenes and/or resins that are known to stabilize water-in-oil emulsions. For a demulsifier to function effectively, it must be able to come into intimate contact with the oil-water interface around the water droplets in emulsified oil. The surfactant chemicals within a demulsifier therefore need to be introduced into the emulsified oil and thoroughly mixed with it.

Being surfactants, the active ingredients of demulsifiers are not truly soluble in either water or oil; the minimum surface free energy is achieved when the surfactant molecules are orientated at an oil/water interface. This property results in their surface-active nature. The molecules of surfactants can orientate into “micelles” or “reverse micelles” to accommodate their solution in either water or oil. These are less preferred arrangements than orientation at an interface, but this

is critical to the behaviour of these chemicals. It is therefore possible for surfactants to be present in bulk in either the water or oil phases, as well as at the oil/water interface. This tendency is known as 'partitioning'. Of course, if a demulsifier is effective, it greatly reduces the amount of oil/water interface originally in a water-in-oil emulsion, and much of the surfactant would move back into the bulk liquid phases. The proportion of surfactant that will be present in the oil or water phases depends on the relative proportion of oil and water phases that are available for them to be dissolved in as well as the surface active properties of the demulsifier itself.

The use of surfactants in demulsifiers for breaking recovered emulsified oils is therefore quite complex. The surfactants in demulsifiers are normally in the form of a concentrated solution blended in a solvent. The solvent in the blend allows the surfactants to transfer into the emulsified oil. In the inevitable presence of free water during oil recovery operations some surfactant may move directly into the free water and will not perform its intended function of breaking the emulsion. This tendency can be minimised if the proportion of free water is kept to a minimum. The transfer of surfactants into the emulsified oil can be difficult because of the highly viscous nature of many emulsified oils. Once inside the bulk of the emulsified oil, the surfactants need to be able to contact the oil/water interface at the surface of the entrained water droplets. Some surfactant may orientate to form reverse micelles within the oil – this is effectively 'lost' from the emulsion-breaking process unless mechanical agitation introduces it to the oil/water interface.

The surfactants within demulsifiers can therefore partition into any of the phases that they may encounter during spilled oil recovery:

- Into the free water
- Into the oil phase
- Into the emulsified water phase that is subsequently separated by gravity

If the bulk of the surfactants in the demulsifier remain with the oil, there should be no problem with their use; the recovered oil will be collected and disposed of. However, if the majority of the surfactants partition into the separated water (either initially free or entrained water), they will be discharged into the environment if the separated water is decanted overboard. Some partitioning is an inevitable consequence of surfactant behaviour. The relative tendency to partition, either as individual molecules or as micelles and reverse micelles between oil and water is very dependent on molecular structure.

Some demulsifiers, such as sodium diisooctyl sulfosuccinate, are strong ionic surfactants that have a relatively high toxicity to some marine organisms. If a recovered fluid consists of 50% free water and 50% of an emulsion containing 75% water and all the emulsion breaker used to treat it (typically dosed at 1:400 demulsifier:emulsion) transfers into the water, the decanted water could contain some 1400 ppm of demulsifier. Discharge regulations in some jurisdictions would not permit the decanting of such water to the ocean in normal circumstances. Other demulsifiers, such as the EO/PO (ethylene oxide/propylene oxide) copolymers are non-ionic, and tend to be much less toxic.

Some emulsions are easier to break with ionic surfactants, and some are easier to break with non-ionic surfactants. The environmental consequences of demulsifier use will depend on:

- Their effectiveness in breaking emulsions
- Their partitioning behaviour into the different water and oil phases
- Their toxicity to marine organisms
- The potential for dilution of the decanted water in the receiving water body

The purpose of the final series of tests reported here was to study the partitioning of different emulsion breakers injected into a recovery system at both lab-scale (at SL Ross) and mid-scale (at Ohmsett). At the time of writing, the lab tests using the scale-model piping network had been completed. A preliminary review of the lab-scale analytical data showed that the surfactants from all three demulsifiers were present in the decanted water at concentrations of hundreds of parts per million or higher. The tests at Ohmsett were carried out in the same manner as the two previous series. The analysis of the samples taken during the Ohmsett tests was not yet available.

## **Summary**

A series of lab-scale and mid-scale tests with and without the use of emulsion breakers were completed recently that give some quantitative insight into the oil/water separation processes occurring in temporary storage devices (SL Ross 1998, 1999 and 2002). The objective of these tests was to determine the optimum time to decant the water and maximize the available on-site storage space during a skimming operation as well as the efficacy of adding emulsion breakers into the recovery stream to allow decanting of emulsified water. The results indicate that “primary break” (the initial separation of the recovered fluid into a layer containing most of the oil and a layer containing most of the free water) occurs within a few minutes to one hour, depending on the physical characteristics of the oil. Rapidly decanting this free water layer, in appropriate situations, may offer immediate increases of 200 to 300% in available temporary storage space. Initial oil concentrations in the decanted water also depended on the physical properties of the oil; they ranged from 100 to 3000 mg/L. These declined by a factor of approximately 3 after one hour of settling, and by a factor of approximately 5 after one day. The addition of emulsion breakers can increase the amount of water that could be decanted, in the same time frame. Addition of the emulsion breaker seemed to increase the oil content of the separated water significantly, by factor of approximately two. Tests were recently completed to assess the partitioning of the surfactant between the oil and water phases in demulsifier-treated fluids in order to determine the potential problems that may be associated with discharging the separated water into the ocean. Preliminary indications are that the separated water will contain a large percentage of the demulsifier at concentrations in the hundreds of parts per million range, or greater.

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Test Number	Demulsifier Injection Point	Demulsifier Doseage (Fluid:Demulsifier)	Wave Type	Inline Mixer	Initial Slick Thickness (mm)	Final Slick Thickness (mm)	Fluid Recovery Rate (gpm)	Estimated Free Water (%)	Recovered Emulsion Water Content (avg %)	Extra Mix Water Content (%)		Oil Content of Decanted Water (ppm)			Back Pressure (psig)	Pressure Drop (psi/ft)
										Tank 4 Lab/Vol	Tank 1 Lab/Vol	2 min	30 min	60 min		
1	No	none	1	No	19	104	140	48	51	-	-	214	72	337	6.4	0.011
2	No	none	2	No	21	26	106	60	57	-	-	490	220	327	7.1	0.020
3	Skimmer	992	1	No	62	90	144	68	52	-	-	543	574	343	7.1	0.025
4	Skimmer	732	2	No	90	70	152	66	57	-	-	1086	514	404	7.1	0.020
5	Discharge	732	1	No	70	57	139	69	70	-	-	1079	629	479	7.0	0.019
6	Discharge	676	2	No	64	27	137	64	71	-	-	1376	606	543	7.0	0.022
7	Before Mixer	990	1	Yes	27	18	144	72	71	-	-	1113	433	432	10.2	0.031
8	Before Mixer	826	2	Yes	18	8	142	69	66	-	-	871	560	176	9.9	0.022
9 (DUP 8)	Before Mixer	787	2	Yes	20	5	135	66	67	-	-	1052	304	305	9.6	0.020
10	No	none	1	No	105	62	157	47	52	-	-	-	294	181	8.7	0.034
11	No	none	2	No	89	25	147	45	61	-	-	-	1110	301	8.1	0.028
12	Skimmer	1669	1	No	88	14	287	37	44	-	-	-	357	233	18.5	0.134
12A	Skimmer	624	1	No	100	28	135	8	54	-	-	-	-	-	10.4	0.050
13	Skimmer	646	2	No	53	18	134	44	55	-	-	2543	655	618	6.9	0.015
37	Skimmer	650	2	Yes	47	0	134	58	46	-	-	882	136	104	9.3	0.015
38 (DUP 37)	Skimmer	605	2	Yes	15	36	125	54	43	-	-	763	530	570	8.8	0.016
39	Skimmer	670	1	Yes	36	39	139	56	45	39/36	38/37	-	-	-	na	na
40	Skimmer	2397	1	Yes	87	130	323	54	33	36/23	42/32	-	-	-	37.6	0.142
41	Skimmer	2750	2	Yes	130	109	371	47	35	45/27	34/27	-	-	-	37.4	0.133
42	No	none	2	Yes	159	115	377	39	39	45/48	48/42	-	-	-	38.5	0.150
43	Skimmer	582	2	Yes	171	85	78	43	52	36/31	33/??	-	-	-	3.6	-0.035
44	Discharge	2854	2	No	86	73	385	75	43	57/27	39/42	-	-	-	20.8	0.159
45	Discharge	2800	1	No	172	68	377	32	50	45/41	40/37	-	-	-	23.2	0.192

Table 1. Summary of Ohmsett Demulsifier Test Results



Figure 1. Boomed test area between main and auxiliary bridges.

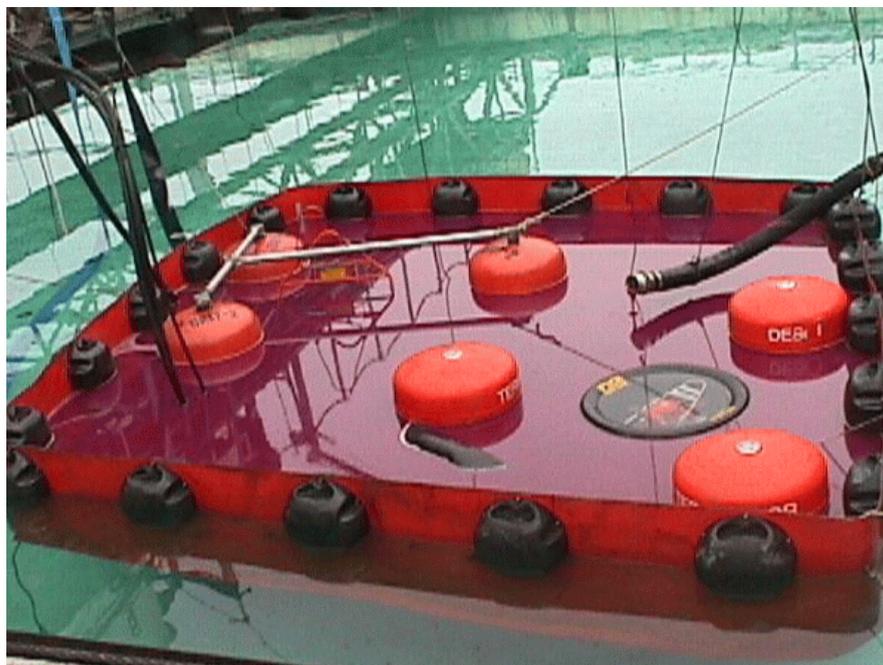


Figure 2. Skimmers in boomed test area with Calsol oil. Desmi Terminator at front right, Pharos GT-185 at back left.



Figure 3. Recovery tank on auxiliary bridge.



Figure 4. Mixing tank for decanted water sampling.



Figure 5. Steel columns used to hold 24-hour water samples (plastic buckets are to prevent rain entering tops)

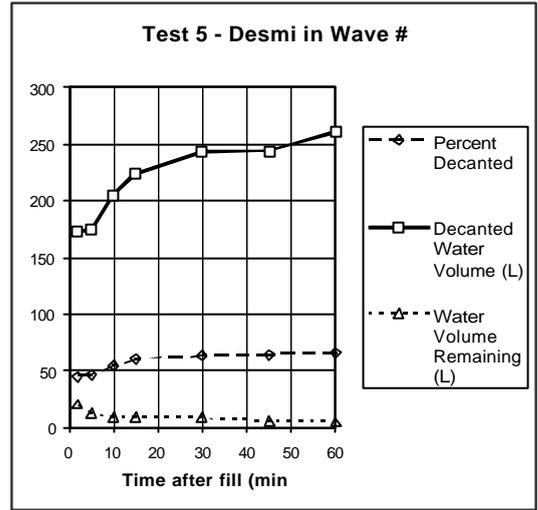
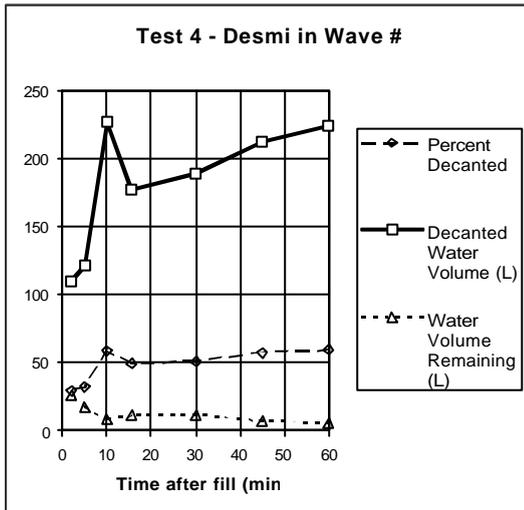
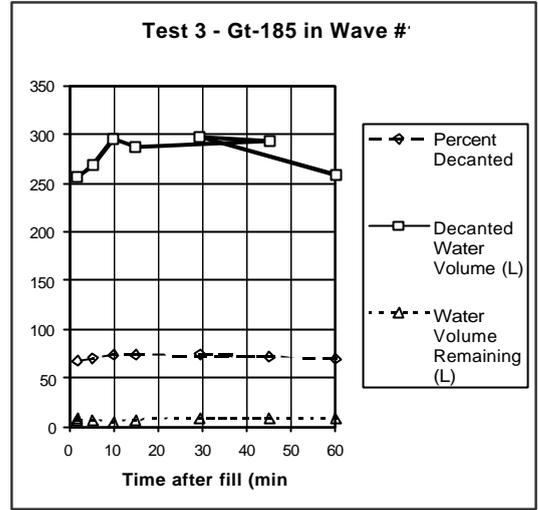
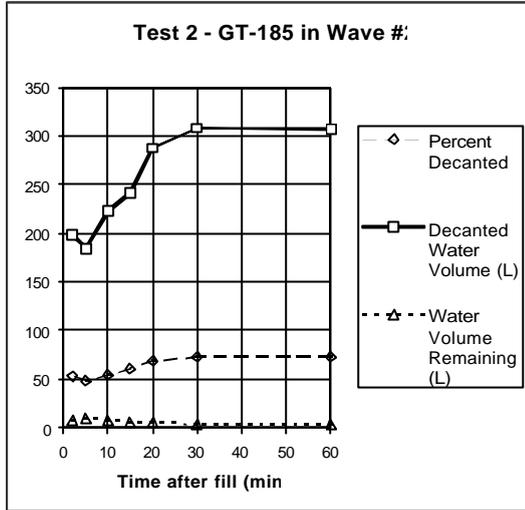


Figure 6. Water Removal from Fluid Skimmed from 20 mm Calsol Slicks

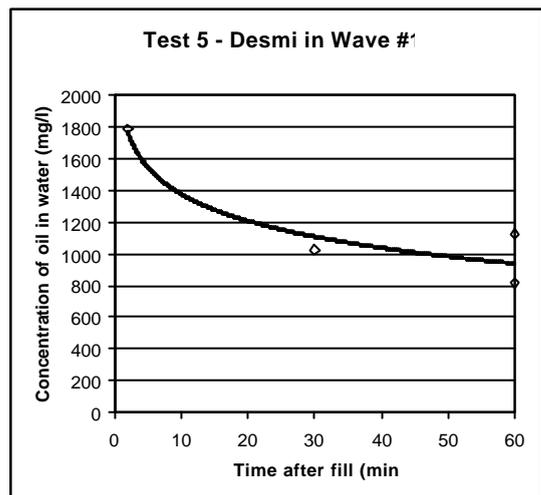
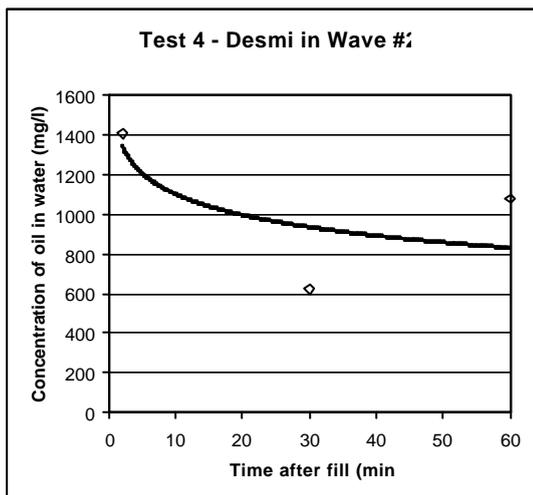
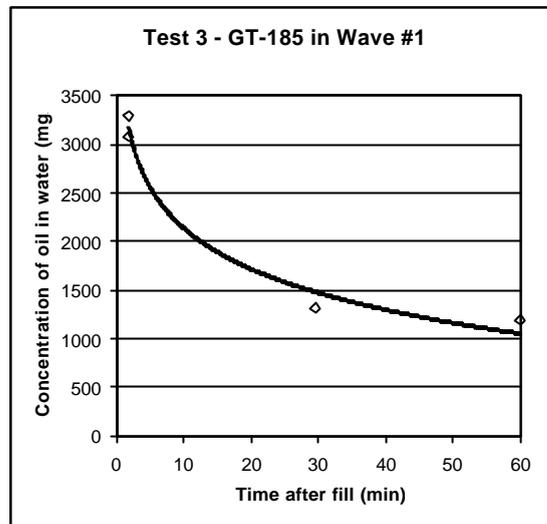
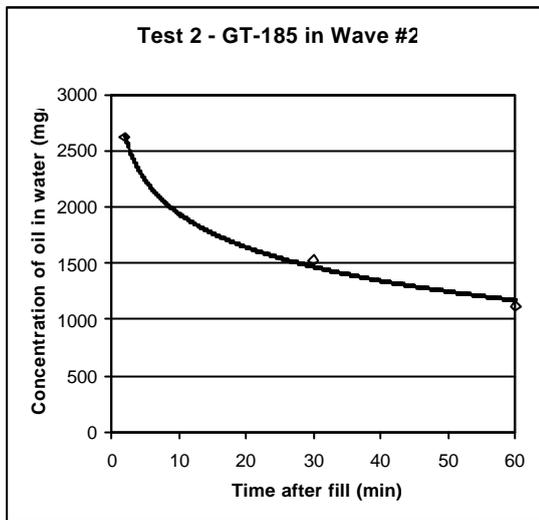


Figure 7. Oil Content of Decanted Water from 20 mm Calsol Slick



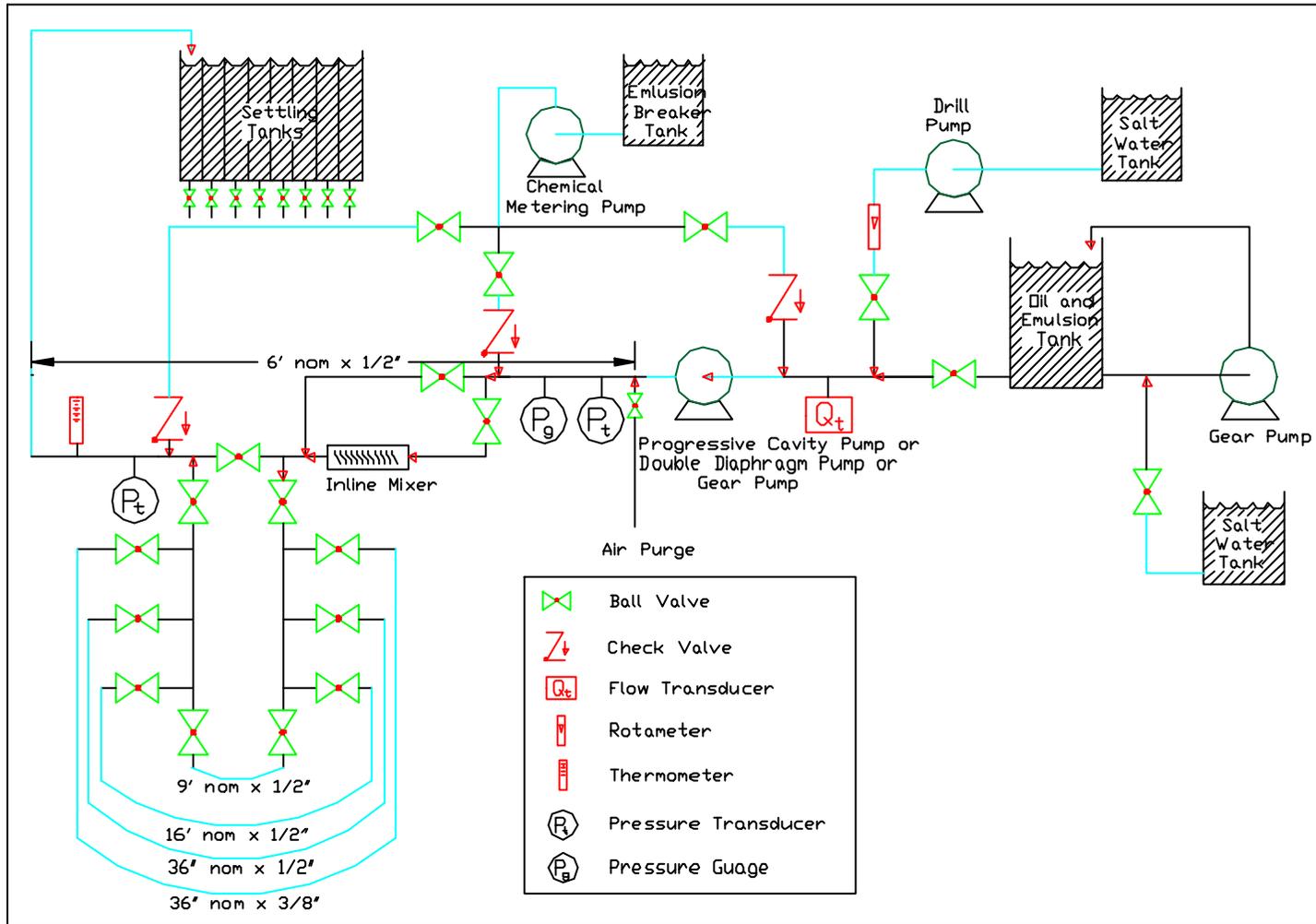


Figure 8. Schematic of Laboratory Scale-model Piping Network Setup



Figure 9. In-line mixer on deck connected to discharge hose just before recovery tanks.

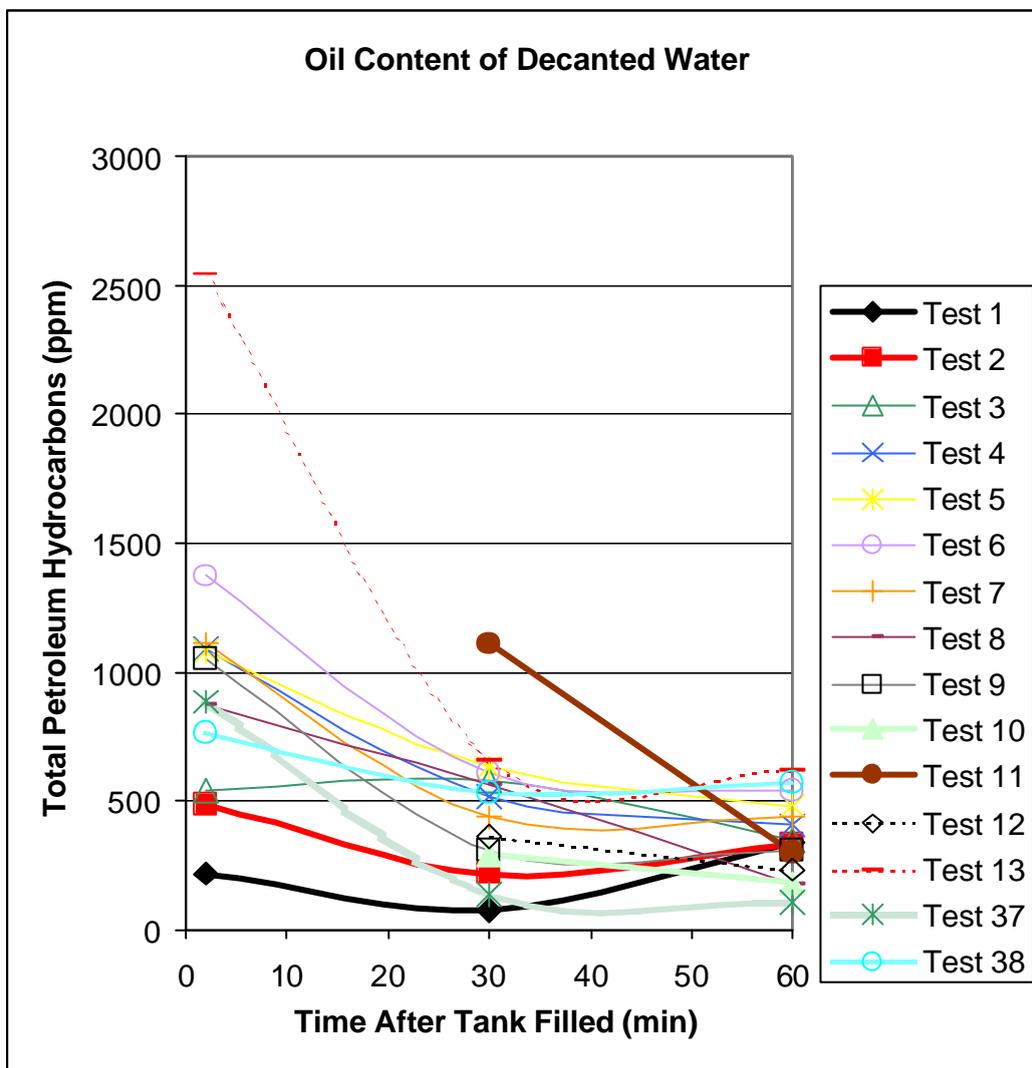


Figure 10. TPH Concentrations in Decanted Water from Emulsions Treated with Demulsifier (Baseline tests, i.e., no demulsifier, are #'s 1,2, 10 and 11)