Management of Test Oil: Recapture and Reuse

Philip Sontag, Joanne Letson, Tom Coolbaugh, and Grant Coolbaugh
Applied Research Associates, Inc. (ARA) | Ohmsett
Leonardo, New Jersey, USA
psontag@ohmsett.com

Abstract

The Bureau of Safety and Environmental Enforcement's (BSEE) Ohmsett test facility in Leonardo, New Jersey has a long history of performing numerous oil spill response-related tests. Many of these employ a range of test oils including crude, fuel, refined, etc. With an eye toward environmentally acceptable management of these fluids, a significant amount of effort is focused on the evaluation of oil characteristics before and after their use.

The Ohmsett staff routinely collects used test oils with skimming equipment and are aware of the stresses that may be imparted to materials during the collection process off the water's surface. A variety of equipment used to collect oil at the facility includes weir, disc, and drum-style skimmers. Recent efforts were directed toward establishing a method for evaluating specific oil characteristics following a test activity, including API gravity, viscosity, and water content. The intent is to be able to confidently provide materials of known specifications that meet test requirements in a reasonable and environmentally appropriate manner such that valuable resources may be used to their full capacity.

This paper addresses recent efforts at the Ohmsett facility to recover, treat (e.g., heat and decant), and evaluate used oils in a manner that provides potential customers with oil that has properties consistent with their test needs. Examples will be provided for recent tests with refined base oils Calsol 8240 and Hydrocal 300 of different viscosities and densities. In at least one case, the before and after measurements were nearly identical and functionally equivalent for consistency during testing. The result is added value to the customer, reduced waste, and ultimately, increased environmental acceptability.

1 Introduction

A primary focus of the Bureau of Safety and Environmental Enforcement's (BSEE) Ohmsett test facility is testing and training using a variety of crude and refined oils. To meet the needs of the client, the oils are routinely characterized for properties such as viscosity, density, and water content. This ensures consistency from test to test and provides inputs to the Ohmsett oil management processes so that oil samples may be used as efficiently as possible in support of a reduce, reuse, recycle philosophy. It is important to maximize the use of a particular volume of oil since it does represent a commodity with a significant intrinsic value and the more that it can be used in testing and/or training, the less oil is consumed lowering the overall environmental impact.

When considering the use of new vs. used oil, a variety of factors must be considered. First, the cost of new oil and shipment is expensive; second, used oil requires more man-hours and upfront costs for oil treatment. Weighing these factors is important before deciding to use new or fresh oils. Ultimately, client cost considerations and requirements for their specific test are the most important. Oil used for testing must be "fit-for-use."

With an eye toward environmental stewardship at the Ohmsett facility, efforts are being made to evaluate the properties of oil samples before and after use and identifying opportunities for reusing them, either as materials that are similar to fresh or materials that may have changed significantly but are still suitable for alternative uses, e.g., use during skimmer training vs. performance evaluation tests.

Test oils come in contact with the test tank water which increases water content thus increasing oil viscosity as emulsification progresses. Oil viscosity can be affected by a small amount of water content, especially when oil temperatures fluctuate (Wang et al., 2018; Du et al., 2017). In addition, physical collection methods apply forces on test oils which can also impact viscosity and subsequent flow during transport (Lyu & Huang, 2023). Oil type, temperature, and viscosity are all careful considerations when transporting and using oils at the Ohmsett facility.

Oil condition and characteristics must be fit for purpose for specific customer uses. Refined oils used at the Ohmsett facility include Hydrocal 300, Calsol 8240, and a very low sulfur fuel oil (VLFSO). Calsol 8240, formed from a multistage hydrogenation process, and Hydrocal 300, a naphthenic base oil (Calumet Specialty Products Partners, L.P.), have been chosen as representative refined oils that meet the requirements for a variety of tests when a specific crude oil is not needed. Initial applications of these refined oils began with testing needs that required high volumes of oil with limited crude oil availability at that time. Calsol 8240 and Hydrocal 300 are representative of high and medium-viscosity refined oils. Influence on viscosity by temperature, water content, and possible shear during use are factors that are oil and use-specific (Stoicescu & Cristescu, 2008), and the goal is to be able to characterize used oils so that they may be reused, even though their properties may have changed with time.

2 Objectives

The following sections will highlight several examples of refined oils that have been used at Ohmsett and were suitable for subsequent uses. The goals of this study are to examine the impact of various factors on test oil properties and to examine the possibility of extending their periods of usefulness and minimizing the volumes sent for disposal over any given period of time. In particular, the properties before and after use, the methods used for characterization, and the potential for future uses are discussed. In this matter, clients can make informed decisions with respect to their specific testing and training needs and whether they require unused oil or if reclaimed/repurposed oil will meet their needs.

3 Methods

3.1 Oil Storage, Transport, and Reuse

A 5,700 L (1,500 gallon) storage tank on the facility’s main bridge is used to distribute oil for testing within the Ohmsett test tank. This tank is filled using oil stored in the facility’s 227,000 L (60,000 gallon) tank farm (Figure 1).

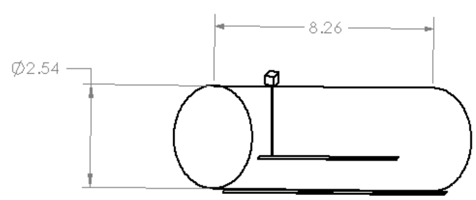

Figure 1 Horizontal tank within tank farm (meter) including belly heaters and inversion heaters

The type and condition of this oil vary and is distributed to the main bridge distribution tank using a complex series of pumps, valves, piping, and hoses. Depending on ambient conditions, ease of movement may differ, and heating may be used to lower viscosity if needed.

Once the oil has been used during testing or training, it is skimmed from the tank water's surface and transferred into an appropriate tank where it can be analyzed (Figure 2). Depending on how the oil was used, its properties can vary significantly from its initial state. In the case of the oil shown in Figure 2, it is evident that it has emulsified significantly, and dewatering will be needed to better understand suitability for further use.

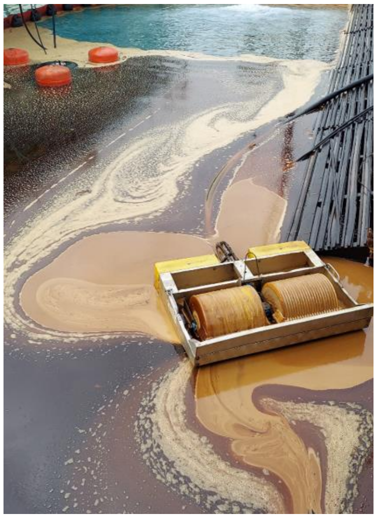

Figure 2 Used oil skimming for collection, decanting, analysis, and possible reuse

Flow rates to and from the tank farm appropriate to the oil type, temperature, and viscosity, are controlled by a positive displacement pump (Figure 3). Once oils are stored, they can be heated and decanted for re-use. Although oil used in testing will likely not return to initial oil characteristics (e.g., viscosity and density), it may be the case that they are quite close, especially if decanting processes are successful.

Figure 3 Flow rate and positive displacement pump operations between the test tank (left) and tank farm (right)

The primary method used to heat recaptured oil during cold weather conditions is a vertical oil heater located in the facility's tank farm (Figure 4). Oil circulated through the vertical tank of the heater can reach up to 90°C and is transported back into the tank farm storage tanks where continuous heating is applied to keep the oils fluid. The high temperatures of the vertical oil heater are paramount for oil-water separation in large volumes since heat transfer and overall circulation within the storage tanks become problematic during cold weather. Following this heating technique, oils are decanted and analyzed in the laboratory to evaluate the extent to which properties may have changed relative to fresh test oils, before use.

Figure 4 Vertical heater operation to aid in heat transfer during decanting

3.2 Laboratory Analysis

Oil characteristics were determined for new and used oils. Properties are described and discussed in the following section. In the case of used oils, the materials had been subjected to a variety of test conditions, recovery methods, and additional treatment processes. These included exposure to salt water, sunlight, different ambient temperatures, subjected to shear during transfer via skimmers (e.g., disc, drum, or customer test equipment), and in-situ/emulsion forming and breaking.

The Ohmsett test laboratory is equipped with several instruments to characterize oil properties, with the main focus on water content (Figure 5), density (Figure 6), and viscosity (Figure 7). Viscosity and density measurements are typically performed at 20°C and 5°C while water content measurements were carried out at room temperature.

Figure 5 Water content measured with the Metrohm 917 Coulometer

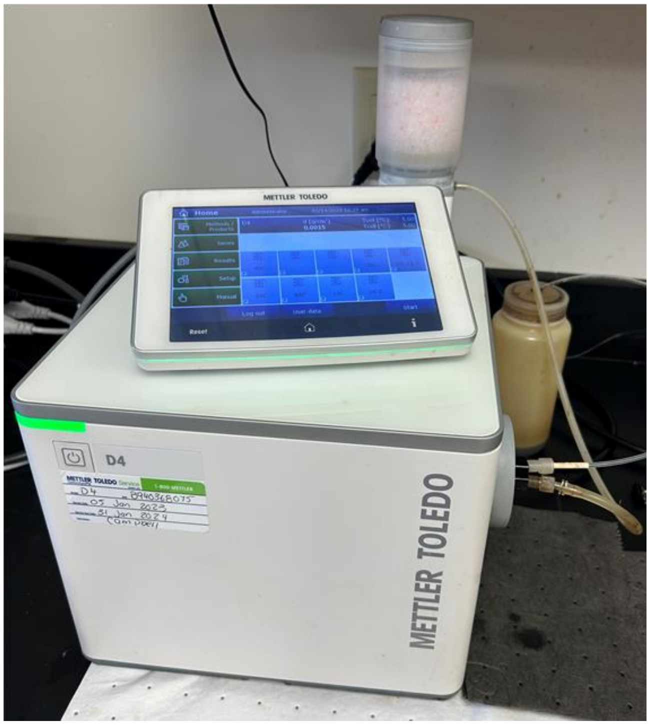

Figure 6 Oil density measured with the Mettler-Toledo D4 density meter

A HAAKE VTiQ Air bearing viscometer (Figure 7) was used to determine the viscosities of oil samples at 5°C and 20°C. Rheological parameters included 155 rotations per minute at a shear rate of 68 1/s.

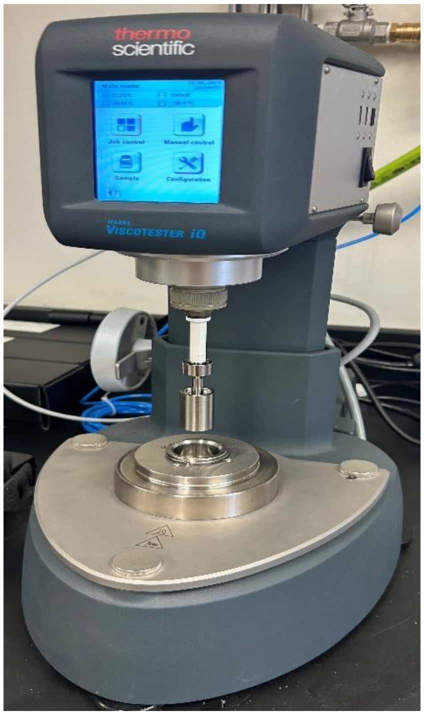

Figure 7 ThermoScientific HAAKE VTiQ Air bearing viscometer

Measurements were reported for the viscometer, density meter, and titrator with the respective units of millipascal-second (mPa-S), g/cm3, and percentage water. API Gravity was calculated using the measured densities and the standard equation (Equation 1):

$$\text{API Gravity} = (141.5 / \text{SG} (@ \text{T}^{o}\ \text{C})) - 131.5 \qquad (1)$$

4 Results

4.1 Oil Properties – Fresh and Recyled

Hydrocal 300 results indicated relatively low water content (< 1.5%) in oil samples undergoing heating and decanting following use during on-water testing (Table 1). This is to be expected based on experience, i.e., the oil viscosity and ability to heat during the decanting process allow for effective emulsion breaking. Test oil viscosities were reasonably comparable to fresh, unused oil after undergoing heating and decanting at 20°C and deviated more at 5°C. As shown in Table 1, as the water content was reduced during the processes of heating and decanting, the test oil viscosity decreased from values of 235 mPA-S at 20 ºC and 949 mPA-S at 5 ºC.

Table 1 Hydrocal 300 viscosity and water properties in fresh and recycled samples

Samples	**Viscosity (mPa-S) @ 20°c**	**Viscosity (mPa-S) @ 5°C**	**Water Content (%)**
Fresh Oil	266.0	607	0.02
Heat + Decant – Top	202.2	688	0.18
Heat + Decant – Bottom	214.4	767	0.32
Used Test Oil	235.0	949	1.25

The 20 ºC oil density measurements were comparable to the fresh oil sample following heating and decanting (± 0.01 g/cm^3) and the bulk of the water had been removed (Table 2). The 5 ºC measurements fluctuated a bit more. This may be due to issues associated with the water content itself during the cooling process and non-homogeneous conditions within the samples.

Table 2 Hydrocal 300 density and API gravity in fresh and recycled samples

Samples	Density (g/cm^3) @ 20°C	Density (g/cm^3) @ 5°C	°API Gravity @ 20°C	°API Gravity @ 5°C
Fresh Oil	0.8989	0.9080	25.91	24.34
Heat + Decant – Top	0.8997	0.9095	25.77	24.08
Heat + Decant – Bottom	0.9031	0.9087	25.18	24.22
Used Test Oil	0.9034	0.9072	25.13	24.47

Calsol 8240, the higher viscosity test oil, after heat cycling and decanting, water content below 1% was obtained (Table 3). It is possible that with additional treatment, the water level could be reduced further, but the purpose of the described work was to understand the extent to which used test oils could be processed to a point where they could be useful for additional tests or training.

In the case of Calsol 8240, a more significant finding was the effect that usage and refurbishment had on bulk viscosity. A substantial decrease in viscosity was observed and this may be attributed to the shear forces that the higher molecular weight material experienced during transfer, use, skimming, and heat cycling.

Table 3 Calsol 8240 viscosity and water content properties in fresh and recycled samples after heating/decanting

Samples	Viscosity (mPA-S) @ 20°C	Viscosity (mPA-S) @ 5°C	Water Content (%)
Fresh Oil	3400	16,000	0.06
Heated/Decanted Oil	2450	6,880	0.3

As shown in Table 4, despite the changes in viscosity, density, and calculated API gravity are similar to initial oil properties following heating and decanting.

Table 4 Calsol 8240 density and API gravity in fresh and recycled samples

Samples	Density (g/cm^3) @ 20°C	Density (g/cm^3) @ 5°C	API Gravity @ 20°C	API Gravity @ 5°C
Fresh Oil	0.9362	0.9452	19.64	18.20
Heated/Decanted Oil	0.9287	0.9406	20.86	18.94

4.2 Test Oils

Clients selected a variety of new and used refined oils for testing in 2022 (Figure 8). Hydrocal 300, a medium-viscosity refined oil was chosen most frequently (new and used). Only new Calsol 8240, diesel and very low sulfur fuel oil (VLFSO) was selected for testing.

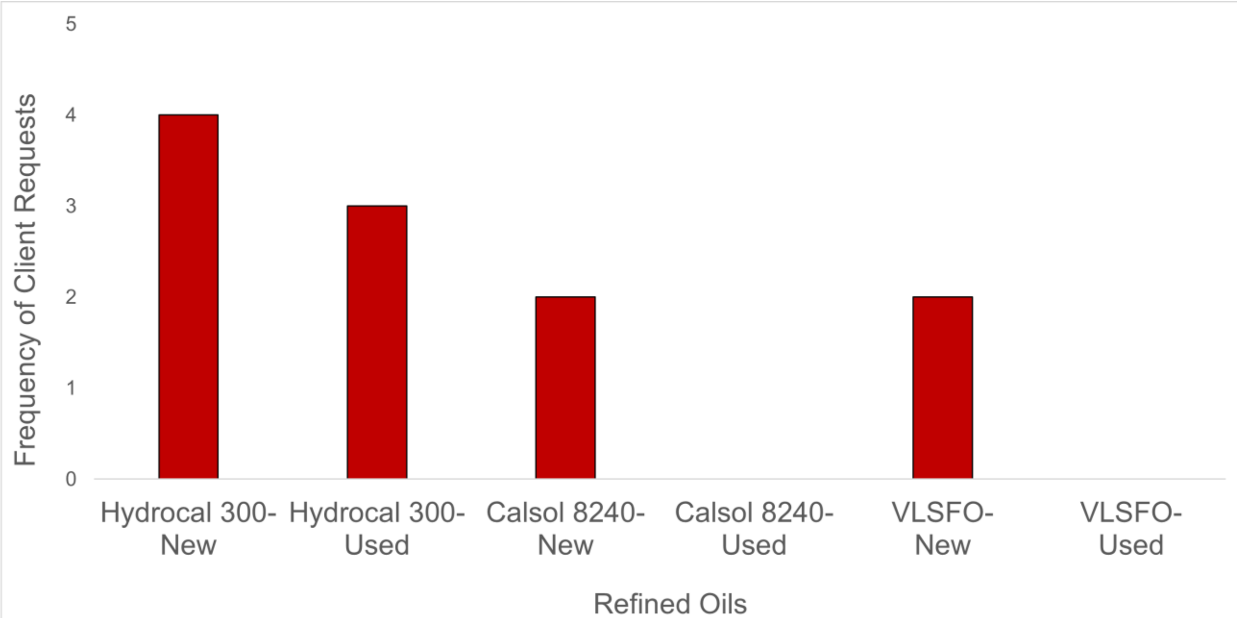

Figure 8 Client requests for new and used refined test oils in 2022 (very low sulfur fuel oil (VLSFO)

5 Discussion

A key focus of the work described has been to understand the extent to which oils used during spill response testing and training may be used multiple times. Traditionally, oils have been viewed as new and used with the latter possessing much less intrinsic value and generally suitable for relatively simple training or testing events that do not rely on a high level of defined characteristics. However, if it is possible to measure specific properties and compare them to known product specifications, it is entirely likely that a significant percentage of the initial value may be retained at 20°C, and the oils can be used multiple times with good effect. At lower temperatures (~5°C), viscosities were shown to deviate slightly from original values. These seasonal considerations should be taken into account when considering the application of used refined oils at low temperatures, particularly Calsol. New high-viscosity crude oil could be considered when performing low-temperature tests requiring mechanical equipment. Clients indeed chose to utilize used Hydrocal 300 for multiple tests in 2002 as it has the ability to retain similar viscosity values to fresh oil following heating and decanting. Effective product/raw material stewardship is essential in many business operations, especially with respect to minimizing waste generation and disposal; the Ohmsett facility is no different.

Findings from this brief study show that the use and reuse of refined oil products can be optimized for enhanced value. In particular, we have shown that despite the challenges of using test oils under conditions that generate significant amounts of emulsion production during various tests, i.e., incorporation of water into the oil phase, it is possible to recycle the oils on a useful scale by heating and decanting to recover materials that can be characterized and used again.

Even though the higher viscosity test oil, Calsol 8240, decreased in viscosity following its use, it still retained enough viscosity to continue to be characterized as high viscosity and could be used for oil spill response training purposes. Its water content was somewhat higher than the starting value, but the potential to use it for other tests requiring high viscosity is of value. Oftentimes, a test does not require a viscosity of a particular value, but rather one of known value.

The lower viscosity material, Hydrocal 300, had properties that were substantially like the starting values after use, the main difference being the water content that was 0.2-0.3% rather than the starting value of 0.02%. For several testing and training purposes, this difference may be inconsequential.

As a final example, during a test performed previously with Hydrocal 300, the oil was used during the evaluation of an oil recovery system, collected, and decanted. Because of the relatively low viscosity of the Hydrocal 300, it was not heated before decanting in this case. As shown in Figure 9, the properties before and after use, i.e., fresh vs. used, are quite similar. The density/API gravity, viscosity, appearance, and color are almost identical. The used sample had a small amount of water, but for potential future use on a wave tank during oil spill response technology testing the amount is most likely inconsequential, and from a physicochemical perspective, the materials would be expected to behave similarly.

	Fresh Hydrocal 300	Used Hydrocal 300
Density (g/cm^3)	0.9006	0.9008
Viscosity $_\eta$ in mPA-S	206	177
Water Content %	0.0	0.2
API Gravity	25.6	25.6
Appearance	Clear/Bright	Clear/Bright
ASTM Color Scale	~6	~6

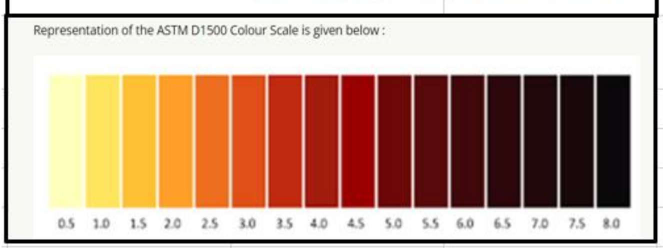

Figure 9 Comparison of Hydrocal 300 properties before and after use

6 Conclusion

It has been shown that it is possible and should be encouraged to maximize the use of potentially constrained and valuable resources during oil spill response testing and training. By characterizing oils before and after use, including any post-use recovery treatments, the characteristics of particular oils may be documented in support of their use in a variety of manners. In the worst case, even though an oil may have changed due to shear stresses during transfer and use, i.e., weathering processes including emulsification and evaporation, or other factors, by knowing its end-state properties it is most likely that it could be used again depending on the needs of the client. In the best case, a used oil may appear similar to its original state in the spring, summer, and fall and although it could not be called "fresh," it could be used for multiple testing purposes. In any event, the value of the oil resource could be retained at least in part before it is finally disposed of.

7 Acknowledgements

The authors gratefully acknowledge the staff of Applied Research Associates, Inc., who operate Ohmsett under contract to the Bureau of Safety and Environmental Enforcement (BSEE) with specific thanks to Alan Guarino, Pete Reno, Tom Schmidt, Allen Cannone, and James Price for their expert input and technical assistance before, during, and after oil use and data collection. A special thank you to Ohmsett Technical Writer Jane-Ellen Delgado for her assistance in the preparation of this paper.

8 References

Du, Y., Wu, T.H., & Gong, R. J., "Properties of Water-Contaminated Lubricating Oil: Variation with Temperature and Small Water Content", *Tribology Materials Surfaces & Interfaces*, 11(1):1-6, 2017.

Lyu, Y., & Huang, Q. Y., "Flow Characteristics of Heavy Oil-Water Flow During High Water-Content Cold Transportation", *Energy*, 262:15, 2023.

Stoicescu, M., & Cristescu, T., "Influence of Temperature and Water Content on the Viscosity of Some Oil Types", *Revista De Chimie*, 59(8): 906-910, 2008.

Wang, S.L., & Li, A.F., "Effect of Water Content and Temperature on the Rheological Behavior of Caoqiao Heavy Oil", *Petroleum Science and Technology*, 36(11): 739-743.